Development of Affordable Tools for Brass Metal Handicraft Products in Assam

Thesis submitted in partial fulfilment of the requirement for the award of the Degree of

Doctor of Philosophy

By

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29th Feb 2024

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CERTIFICATE

This is to certify that the work contained in this thesis entitled 'Development of Affordable Tools for Brass Metal Handicraft Products in Assam' submitted by Mrs. Kiran Kumari Mahato to the Indian Institute of Technology Guwahati, Assam (India) for the award of the degree of Doctor of Philosophy has been carried out under my supervision. This work has not been submitted elsewhere for the award of any other degree or diploma.

Place: Guwahati
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DECLARATION

I hereby declare that the work contained in this thesis entitled 'Development of Affordable Tools for Brass Metal Handicraft Products in Assam' is my own work done under the supervision Prof. Pratul Chandra Kalita, at the Department of Design, Indian Institute of Technology Guwahati (IITG), Assam. I hereby declare that to the best of my knowledge, it contains no materials previously published or written by another person, or substantial proportion of material which have been accepted for the award of any other degree or diploma at IITG or any other educational institute, except where due acknowledgement is made in this thesis. Any contribution made to the research made by others, with whom I have worked at IITG or elsewhere, is explicitly acknowledged in the thesis. I also hereby declare that the intellectual content of the thesis is the product of my work, and as per general norms of the reporting research findings, due acknowledgements have been made wherever the research findings of other researchers have been cited in the thesis.

Place: Guwahati

Date:29th Feb 2024

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DEDICATION

I would like to dedicate this thesis to my family members and people who are working in metal handicraft clusters across India.

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Many people have contributed directly or indirectly to the accomplishment of this research. Before sharing my work in the conscious circle, I'd like to gratefully thank everyone of them for their unwavering support and guidance. First and foremost, I would like to express my gratitude to my supervisor, Prof. Pratul Chandra Kalita, Department of Design, Indian Institute of Technology Guwahati, for his direction and intellectual contributions throughout the completion of this research. He had incredible faith in me and was really patient, for which I will be eternally grateful. I appreciated all his contributions of time, and ideas to make my doctoral experience productive and stimulating. I also thank the other members of my doctoral committee: Prof. Amarendra Kumar Das, Dr. Urmi Ravindra Salve from Department of Design, and Prof. Sukhomay Pal from Department of Mechanical Engineering for their time, interest, and helpful comments. They had provided their valuable advice, guidance, and suggestions which helped me to undertake the research during the entire research period successfully.

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ABSTRACT

Design is a creative human activity that promotes social, economic, and environmental well-being. In India, handicrafts have artistic excellence and economic importance and utilitarian characteristics which make them popular. Handicrafts are also environment friendly because in their crafting process they often use natural, eco-friendly, recyclable materials. The history of brass metal handicraft manufacturing in India is very old. Over the period, handicrafts emerged with more creativity, new designs, new interventions, and process innovations. Craftsman from cottage industry are major player in handicrafts development. During Mughal period India was the largest supplier of the brass metal handicrafts in the world. After Industrial revolution, the handicrafts sector has begun to decline because of the popularity of machine-made products with low prices and quality compared to handmade items.

Existing handicraft sectors are studied through online and on field to know the state of art. Study involve literature review and field survey. A background research analysis for Indian handicraft is conducted in order to comprehend the significance of Indian handcrafts making in the progress of the country. Government initiated various programs to improve craftsmen education and job conditions. Also, to understand the evolution and collapse of Indian handicrafts, production by artisan over three distinct time periods: before the advent of the British in India, during British rule, and post-independence. In this research, our focus of study is about brass sheet metal handicraft. Existing brass sheet metal cottage handicraft sectors face low production affects the sustainable livelihood of respective artisans. There is great potential of Indian sheet metal brass handicraft's market due to its unique look and artistic qualities. Artisan's inherent technical skills and expertise can be helpful to develop new product by entrepreneur with less investment cost.

Aim of initial study is to know the reason behind the low production of brass sheet metal handicraft cottage industries. Initial literature reviews and field study was conducted to identity and priorities the scope of design intervention in brass sheet metal handicraft sector to increase the production. Technical, production, organizational, personal, finance, management, government, and location factors are reviewed systematically, which influence the productivity of any product. Manufacturing method involve in production of brass metal handicraft play crucial role on production and also impact the supply chain. Affordability, less flexibility of technology to manufacture variety of crafts, dependency on electricity, space constraint, educational skills requirements, etc. are the factors which effect the decision making of artisans to adopt advance technology. The research is carried out to intervene tool design and

development for bottleneck processes to ease the crafting process of brass sheet metal handicraft. It comprised of study of existing manufacturing process, tools and machinery involved and finding problems associated with existing process specially the bottleneck processes for suitable solutions. Concepts of tool were design and developed based on appropriate technology through design by research for bottleneck processes i.e. roll forming (surface bending), shaping and hemming. Process time improvement through shaping and hemming tool is 75% Process time improvement by surface bending tool is 65%. For refinement of concepts, CAD model and prototype have been used. The porotypes are validated and tested with technical person of IIT Guwahati workshop and craftsman from Hajo village of Assam.

The research established that newly designed tool is affordable and easy to use for higher productivity and quality. All the parts of tools are developed using mild steel material

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CHAPTER 1

Role of Indian Handicraft for the Growth of the Country

1.1 Handicraft

1.2 A Chronicle of Indian Handicrafts Through Pre-Colonial, Colonial, and Post-Independence Eras

1.3 Metal Handicraft

1.4 Field Study for Brass Metal Handicraft at Hajo, Assam

1.5 SWOT Analysis of metal handicraft sector

1.6 Scope of Design Intervention / Innovation

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1.8 Aim and Objective

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CHAPTER 1

Role of Indian Handicraft for the Growth of the Country

The Indian government is actively pursuing a range of initiatives to foster industrialization and enhance self-sufficiency within the country. The "Make in India" initiative launched by the Government of India has been a significant push towards boosting the manufacturing sector in the country. This initiative aims to encourage both domestic and international companies to manufacture their products in India, promoting economic growth, job creation, and technological advancement. The attention garnered from the industry highlights the importance of revitalizing and strengthening the manufacturing sector. The initiative has brought the spotlight back on manufacturing, emphasizing its pivotal role in economic development and self-sufficiency [1].

Notably, traditional Indian cottage handicraft industries have historically played a pivotal role in meeting the diverse demands of local communities, thus contributing to the self-reliance of villages. This form of cottage handicraft manufacturing, often characterised by small-scale, home-based, or artisanal production, makes a significant and noteworthy contribution to both society and the economy. Handicraft production and development have a versatile role, impacting various aspects such as generating employment opportunities and income, fostering sustainable development, and promoting village self-sufficiency. Therefore, in a developing nation, handicrafts serve as a fundamental catalyst for grassroots-level industrialization. Additionally, they serve as a vital source of livelihood through employment opportunities [2]–[4]. The research aims to comprehend the role of Indian handicraft manufacturing in contributing to the overall growth of the country. This is pursued through a descriptive study, which typically involves a detailed and comprehensive exploration of the subject in the context of the role of Indian handicraft manufacturing. The study involves an industry overview, economic impact, cultural significance, market dynamics, artistic communities, government initiatives, challenges and future prospects, sustainability, and innovation.

1.1 Handicraft

Manufacturing is a production method that transforms primary sector raw materials into finished products through a specific process. The transformation of goods is done through creative work such as defining and determining forms and features. It refers to a range of human activities, from handicrafts to high-tech mechanical processes.

Handicrafts are items made by hand, often with the use of simple tools. According to the United Nations Educational, Scientific, and Cultural Organization/Information Technology Community (UNESCO/ITC) definition of handicraft in the Global Market Assessment 2006 report:

"Products which are produced either completely by hand or with the help of tools. Mechanical tools may be used as long as the direct manual contribution of the artisan remains the most substantial component of the finished product. Handicrafts are made of sustainably produced raw materials and can be produced in unlimited numbers. Such products can be utilitarian, aesthetic, artistic, creative, culturally attached, decorative, functional, traditional, religiously and socially symbolic and significant".[5]

Indian handicrafts are celebrated worldwide for their profound artistic and traditional essence, exemplifying a rich tapestry of skills and techniques. Rooted in indigenous knowledge and graced with remarkable flexibility, the handicrafts sector has consistently fostered a breeding ground for innovative designs and transformative interventions.

Within this vibrant tapestry, artisans occupy multifaceted roles, ranging from the creation of bespoke items tailored to the unique needs and preferences of consumers to the marketing and sale of these exquisite goods. As time has unfolded, the realm of handicrafts has witnessed an ever-increasing potency, evolving with the infusion of fresh designs, ground-breaking interventions, and a spirit of relentless innovation. It continues to be a testament to the enduring legacy of human creativity and craftsmanship.

Indian handicrafts ascended to global acclaim during the illustrious reign of the Mughals. This pivotal era saw India emerge as the preeminent supplier of exquisite metalwork and textiles on the world stage. However, the roots of India's handicraft proficiency extend far beyond the Mughal dynasty, tracing back to the indomitable spirit of creativity that thrived from the ancient Indus Valley Civilization to the opulent times of Mughal rule.

India stands as a unique beacon in the world, having maintained an unbroken tradition of handicraft manufacturing since time immemorial, a testament to the enduring legacy of artistry and skill.

To comprehensively grasp the evolution and tribulations of Indian handicrafts, a three-fold examination is imperative: first, the era predating the British colonial presence in India; second, the challenging times under British rule; and third, the post-independence period when India reclaimed its sovereignty. These distinct epochs illuminate the ever-shifting landscape of artisanal production, providing valuable insights into the past, present, and future of this cherished craft tradition.

1.2 A Chronicle of Indian Handicrafts Through Pre-Colonial, Colonial, and Post-Independence Eras

Pre-Colonial Era:

The history of handicraft manufacturing in India boasts an ancient lineage, with roots stretching back to the remarkable Indus Valley Civilization. Archaeological findings from this era reveal the existence of pottery and intricate metal objects crafted from materials like copper, bronze, and tin.

The Vedic texts provide further testament to the early craftsmanship of Indian artisans, showcasing their adept use of metals, clay, and wood for pottery. While these historical records offer tantalizing glimpses into the past, the precise techniques employed in these creative processes remain shrouded in mystery.

One compelling artefacts from the Indus Valley Civilization, the captivating bronze dancing girl, hints at the sophisticated casting processes known to the people of that time. The presence of tools and weaponry such as axes, swords, knives, daggers, spearheads, razors, gouges, helmets, cauldrons, and buckets during the Bronze Age underscores the multifaceted skill sets possessed by the craftsmen of ancient India. As time advanced into the Iron Age, evidence of iron tools emerged, including implements like axes and ploughs that played pivotal roles in enhancing agricultural production.

Among the technological discoveries of the Iron Age, the potter's wheel and the wood pole lathe emerged as two paramount innovations. These inventions not only revolutionized the craftsmanship landscape but also paved the way for more efficient and refined production methods.

Throughout these early periods, a unique feature of the Indian handicraft landscape was the development of the "trade guild" system. These guilds were professional bodies comprised of various skilled craft makers who banded together to oversee the quality of production, maintain equitable pricing, and ensure fair wages. In addition, they actively engaged with traders within the "Nigam" (corporation) to foster the growth and expansion of trade and exports.

Before the advent of the "Jajmani System," handicraft production thrived in small-scale units, requiring minimal capital investment. However, the introduction of the "Jajmani System" marked a significant shift in the dynamics of the craft industry. Under this system, individuals from the upper caste imposed restrictions on certain occupations, leading to a dependence on lower-caste artisans for essential goods and services. In exchange for their contributions, artisans received rent-free land for their craft practice, access to food and credit facilities, and residential accommodations, among other benefits. Additionally, artisans were honoured with bonuses and increased salaries, cementing their vital role in the socioeconomic fabric of ancient India [6].

Under the Jajmani system, traditional trade relationships between skilled artisans, Nawabs, and higher-caste individuals began to erode. This marked a significant departure from the intricate web of economic transactions that had sustained Indian handicrafts for generations. The system of patronage and trade that had supported artisans was gradually dismantled. The lasting influence of the Jajmani system is particularly evident within cottage industries, where it has firmly entrenched itself. This historical framework has consigned the artisans within these industries to the lower strata of both the social and economic hierarchy, continuing a cycle of disenfranchisement and disadvantage[7], [8].

Colonial Era:

Handicrafts, once the life force of India's economy, faced a stark transformation that led to their decline. The introduction of the Jajmani system and the increasing influence of the British Empire played pivotal roles in reshaping the landscape of Indian craftsmanship.

The British Empire exerted complete control over the "trade guild" which had been established to boost the business of Indian handicrafts. This control further marginalized Indian artisans and their crafts. Industrialization gained significant momentum during the colonial period as a direct result of British colonial policies. These policies significantly transformed rural India into a key source of raw materials for British industrialization and created a profitable market for British machine-made products[9].

The real blow to Indian handicrafts came with the influx of machine-made British goods into the Indian market. These products were often sold at lower prices, making them more accessible to consumers. The influx of British mass-produced goods posed a big challenge to the struggling Indian handicraft sector, putting artisans in a difficult position[10], [11]. Their craft, once a source of livelihood, faced declining sales and wages. Many were compelled to abandon their traditional crafts in pursuit of alternative means of sustenance.

The British Empire, recognizing the skilled craftsmanship of Indians, started to harness this talent for their own construction projects. The use of Indian craftsmanship for British projects worsened the already struggling handicraft sector.

These sweeping changes wrought havoc on the once-thriving handicraft industry in India, causing a severe and lasting decline in this vital aspect of the country's cultural and economic heritage [12], [13].

An economic change in which employment in the crafting sector declined due to various economic or political reasons is called the “process of de-industrialization”

Based on early nationalist views, critics, their studies, and cases, Daniel Thorner's theory predicts a major reduction in the workforce in the nineteenth century but not in the twentieth century. The census data from 1881 to 1931, based on Daniel Thorner's theory, did not support de-industrialization. But A. K. Bagchi concluded support for de-industrialization through evidence from Bhuchan-Hamilton's population survey of 1809–13 and the 1909 census survey. He found that in Bihar, the population of five districts, that was dependent on manufacturing industries declined from 18.6% to 8.5%. There are several arguments made for A. K. Bagchi's method of data collection[14]. Krishnamurthy agreed that there was a decline in the number of people engaged in industrial activities. Krishnamurthy emphasized that to understand de-industrialization, one must have a clear grasp of industrialization. He defined industrialization as an increase in the proportion of manufacturing output per capita. In this context, Thorner's theory alone is not sufficient to determine de-industrialization. To assess de-industrialization, it's important to examine data on manufacturing output and overall economic output.

R. Chattopadhyay engaged in a debate over Daniel's theory and introduced specific criteria for studying economic changes related to industrialization. According to his theory, industrialization is characterized by three factors: first, a change in national income (NNP); second, the ratio of the change in manufacturing output to the change in national income; and third, a change in the manufacturing workforce as a percentage of the total population. A decrease in these factors indicates de-industrialization[15].

Post-Independence Era:

Despite economic growth, the decline in the workforce affects the total growth of the country. Prior to independence, Mahatma Gandhi aimed to achieve self-reliance for the country. He initiated rural development programmes with the goal of uplifting rural communities and ensuring equal opportunities, particularly for women and girls. Gandhiji's Charkha (spinning wheel) intervention aimed to boost employment opportunities and enhance the quality of products produced[16].The Khadi and Village Industries Commission (KVIC) was established in 1957 with the mission to generate employment, manufacture marketable products, and promote self-sufficiency in rural areas. The Khadi industry is a significant contributor to employment, having employed around 1.5 million people, both full-time and part-time, in Khadi spinning in 1994[17].

After India gained independence, the government became actively involved in formulating policies to revive the country's rich craft traditions and support small and cottage industries.

Various organizations were established to address and improve different aspects of the handicraft sector. In the early 1990s, India initiated economic liberalization, which provided craft exporters with the opportunity to participate in international exhibitions abroad at a reasonable cost.

During the initial five-year plans, the primary focus was on addressing the fundamental needs and challenges faced by the handicraft sector through financial assistance. Subsequently, between 1984 and 1986, two export promotion councils were established: The Carpet Export Promotion Council and the Export Promotion Council of Handicrafts. Their aim was to boost exports from the country.

To support smaller and emerging exporters, the International Carpet Fair in Varanasi and the Indian Handicrafts and Gifts Fair in New Delhi were inaugurated in 1989 and 1994, respectively. These events provide overseas buyers from around the world with the opportunity to access a wide range of products in one convenient location. [9]. The various strategies adopted by the government in export and the impact of globalisation are seen in the export of the handicraft industry. It is observed that the export of Indian handicrafts increased from 92.11 million dollars in 1990-91 to 1875.5 million dollars in 2005-06. Due to the 2008 financial crisis, there was a decline in export figures for 2010-2011, as shown in figure 1.1. This economic crisis has had a profound effect on the country's GDP. It was also discovered through analysis that the development of rural areas is significant for GDP growth and tackling this competitive globe. [10].

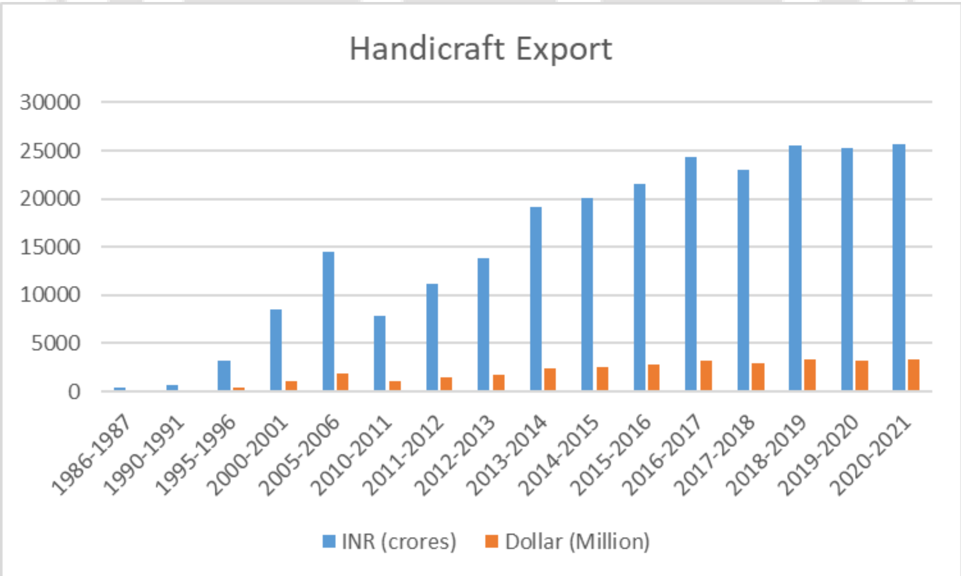

Figure 1.1: Handicraft export chart other than hand-knotted carpets (source: EPCH export data 2022)
https://www.epch.in/index.php?option=com_content&view=article&id=76&Itemid=181
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Indian handmade products have a suitable position on the world market. Its distinctive designs, expertise, finesse, colors, raw materials, etc. create a distinct conception of how people look for handicraft. According to Export Promotion Council for Handicraft **(**EPCH) data, Australia, Canada, France, Germany, Italy, Japan, the Netherlands, UAE, Switzerland, the USA, the UK, LAC, and Other Countries are the main supplying countries. They contribute 2.71%, 1.88%, 3.85%, 5.93%, 1.44%, 0.62%, 5.58%, 6.11%, 0.28%, 38.38%, 6.4%, 1.82%, and 25%, respectively, in export sales.

The current status of crafts in India is deeply rooted in rich traditions from the past. Many traditional crafts continue to flourish because they serve practical purposes, are accessible to the general public, and remain popular in both local and international markets.

Items such as bedcovers, sheets, cushions, curtains, tablemats, bags, metal and wooden furniture, mats, boxes, cabinets, toys, utensils, garden pots, terracotta items, brass and silverware, leather products, cane, jute, and coir goods, carpets, rugs, and more have a substantial domestic market. Most of the units producing these utilitarian craft items fall under the category of small-scale cottage industries. Moreover, traditional crafts like wall hangings, silver cutlery, brass pots, embellished wooden sculptures, marble and wood inlay work, silk carpets, wrought iron furniture and decorative pieces, traditional paintings, enamelled furniture, stone and wood carvings, as well as metal, wood, and stone sculptures are highly sought after in India and abroad. India is known for its rich tradition of crafts, and these crafts often cluster in specific regions of the country. These craft clusters are characterized by a concentration of artisans and craftspeople specializing in particular traditional crafts. Here are some notable craft clusters in India: Table 1.1, presents various craft products and the number of clusters involved in crafting. Table 1.2, presents clusters and artisans involved in handcraft work.

Table 1.1: Crafts and number of clusters involved in crafts work (source: Ministry of Textile) http://www.craftclustersofindia.in/site/Cluster_Directory.aspx?mu_id=3 February2024

S.N.	Crafts	No. of Cluster(s)	S.N.	Crafts	No. of Cluster(s)
1	Ari-work	2	21	Metal Ware	40
2	Bidri	1	22	Miscellaneous Crafts	9
3	Cane & Bamboo	125	23	Musical Instrument	4
4	Carpet	15	24	Natural Fiber Bag	2
5	Coir Twisting	2	25	Patch work	1
6	Conch-Shell	3	26	Pottery and Clay Objects	14
7	Doll & Toys	15	27	Rugs & Durries	11
8	Filigree & Silverware	2	28	Shawl Embroidery	1
9	Folk Painting	10	29	Stone (Carving)	19
10	Furniture	9	30	Stone (Inlay)	6
11	Grass, Leaf, Read & Fiber	85	31	Terracotta	32
12	Horn & Bone	1	32	Textile (Hand Embroidery)	307
13	Jewelry	37	33	Textile (Hand Printed)	54
14	Jute	6	34	Textile (Handloom)	55
15	Leather (Footwear)	9	35	Theatre, Costumes & Puppet	1
16	Leather (Other Articles)	11	36	Wood (Carving)	41
17	Leather Craft	1	37	Wood (Inlay)	4
18	Meenakari	5	38	Wood (Turning and Lacquer Ware)	10
19	Metal Images (Classical)	5	39	Zari	45
20	Metal Images (Folk)	5			

Table 1.2: Clusters and Artisans involved in handcraft work (source: Ministry of Textile) http://www.craftclustersofindia.in/site/Cluster_Directory.aspx?mu_id=3 February2024

States	Total Clusters	Total Artisans	SHGs
Andhra Pradesh	29	18405	741
Arunachal Pradesh	6	1141	65
Assam	46	14914	946
Bihar	6	1447	104
Chhattisgarh	8	4185	375
Delhi	13	9364	416
Goa	1	233	13
Gujarat	121	35183	2336
Haryana	21	1586	139
Himachal Pradesh	23	929	178
Jammu & Kashmir	51	10933	877
Jharkhand	18	6809	490
Karnataka	19	12218	1081
Kerala	11	10979	5253
Madhya Pradesh	67	5784	430
Maharashtra	18	2142	152
Manipur	32	9107	580
Meghalaya	4	648	45
Mizoram	2	435	33
Nagaland	6	2409	132
Orissa	35	10572	735
Punjab	11	5892	256
Rajasthan	18	2485	192
Sikkim	2	531	32
Tamil Nadu	14	4042	175
Tripura	17	6270	514
Uttar Pradesh	96	20256	1441
Uttrakhand	20	2488	202
West Bengal	29	10306	655
Total	**744**	**211694**	**18588**

In the 18th century, the British set up the Moradabad craft cluster, which later gained global recognition for its artefacts [18]. People are familiar with clusters connected to urban areas or tourism. Most cottage industries lacked efficient market connections. The Indian government has improved infrastructure to support craftsmen, helping them compete globally and promoting cottage industries.[19].

Handicrafts play a vital role in preserving cultural heritage and traditions. They often reflect the history, values, and artistic expressions of a particular region or community. Handicraft industries often empower marginalized or disadvantaged communities by providing them with opportunities for economic participation. Handicrafts provide equal opportunities for women and girls. The cottage industry, which typically involves handicrafts, has been a significant part of rural industrialization. Modern technology is advancing, yet all these technical skills are enhanced by craft skills acquired through experience as tacit knowledge[20].

Handicraft industries provide livelihoods for a significant number of artisans and craftsmen, particularly in rural areas, thereby reducing unemployment and promoting economic stability[21], [22]**.** Handicrafts empower rural communities through income, tourism, jobs, sustainability, and poverty reduction**.** Exceptional technical skill, creativity, and innovation in handicrafts: a pivotal driver of economic growth and employment. Handicrafts are often created using sustainable and eco-friendly materials, contributing to environmentally responsible practices [23]–[26]. In many developing nations, handicraft production is a major form of employment and, in some countries, constitutes a significant part of the overall exports in the economy. Handicraft is identified as the second-largest sector of rural employment after agriculture in many regions of the world[27]. In the European country of Lithuania, a national heritage law was enacted in 2007, recognizing handicraft heritage as a significant alternative source of employment. Also, legislation approved policies for the protection of heritage products, including their development and market, in 2008 and 2011. Apart from this, government institutions have implemented measures to improve the education level of artisans and the workplace[28]. Similarly, industrialized countries such as Italy, Colombia, Tunisia, Thailand, and Morocco, have seen a significant contribution of handicrafts to employment and exports in the economy[29].

Handicraft promotes creativity and artistic expression, encouraging artisans to continually innovate and develop new techniques and designs. The rich history and significance of metal handicrafts in ancient India, emphasizing the continuous innovation and artistic expression of craftsmen.

1.3 Metal Handicraft

Metal handicrafts have a long history in the country, dating back to ancient civilizations like the Indus Valley and Harappan cultures. These crafts are favoured for their practicality, distinctive beauty, and antique appeal. Overcoming historical challenges, Indian handicraft artisans adapted by crafting new designs in tune with consumer trends and utilizing their expertise in diverse metalwork [30].

Based on the preliminary information provided by the Export Promotion Council of Handicrafts (EPCH) in tables 1.3 and 1.4, the metalcraft sector has emerged as a substantial contributor to the worldwide market, specifically in the realm of handicraft exports. The substantial influence of this industry on the global market is apparent from the data at hand, underscoring its lasting impact on the international stage.

Table1.3: Review exports during 2023-24 (April-October)

Items	**Rs. in cr.**		**Increase/ Decrease in % over 2022-2023**	**US$ in millions**		**Increase/ Decrease in % over 2022-2023**
	2022-23	**2023-24**		**2022-23**	**2023-24**	
	(April-September)			**(April-September)**		
Artmetal ware	2182.06	2205.73	1.08	279.01	267.58	-4.09
Woodware	4087.42	3508.21	-14.17	522.64	425.59	-18.57
Handicraft textiles & scarves	1651.83	729.46	-55.84	211.21	88.49	-58.1
Embroidered & crochetted goods	1995.51	2054.02	2.93	255.16	249.18	-2.34
Shawls as artwares	5.74	0.41	-92.86	0.73	0.05	-93.23
Zari & zari goods	32.41	19.46	-39.96	4.14	2.36	-43.03
Imitation jewellery	785.62	811.22	3.26	100.45	98.41	-2.03
Agarbatties & attars	626.23	695.09	11	80.07	84.32	5.31
Misc handicrafts	4943.2	4767.58	-3.55	632.06	578.37	-8.49
Total	**16310.02**	**14791.18**	**-9.31**	**2085.48**	**1794.36**	**-13.96**

Table1.4: Review exports during 2022-23 (April-March)

Items	Rs. in cr.		Increase/ Decrease in % over 2021-2022	US$ in millions		Increase/ Decrease in % over 2021-2022
	2021-22	2022-23		2021-22	2022-23	
	(April-March)			(April-March)		
Artmetal ware	4152.56	4349.37	4.74	556.92	540.20	-3.00
Woodware	9080.88	7622.98	-16.05	1217.89	946.79	-22.26
Handicraft textiles & scarves	3089.97	2524.61	-18.30	414.41	313.56	-24.34
Embroidered & crochetted goods	5340.72	3825.43	-28.37	716.28	475.13	-33.67
Shawls as artwares	5.18	6.08	17.37	0.70	0.76	8.57
Zari & zari goods	69.40	71.25	-39.96	9.31	8.85	-4.94
Imitation jewellery	1539.02	1553.37	2.67	206.41	192.93	-6.53
Agarbatties & attars	1427.42	1329.97	0.37	191.44	165.19	-13.71
Misc handicrafts	8547.85	8736.18	2.20	1146.40	1085.06	-5.35
Total	**33253.00**	**30019.24**	**-9.72**	**4459.76**	**3728.47**	**-16.40**

Globally, China holds the largest share of the handicraft export market in the world. China produces cheap machine-made products in a very efficient manner. After China, Vietnamese metal handicrafts have great demand in the international market. In the Chinese market, consumer trends are changing. Consumers are found to be inclined mostly toward the uniqueness, origin, and quality of the product. The Indian metal handicrafts market has great potential due to its unique look and artistic qualities, like Vietnam. India lags in quality and branding, such as packaging[5]. Brass is growing in demand because of its antique qualities and ability to be mixed with various creative materials.

Brass, bronze, and copper metals have been used in India for many years. The country produces more brass than any other on the globe. Decorative ornaments and practical implements are both made of brass. Examples of decorative metal crafts include windchimes, chandeliers, lampshades, statues of God, humans, animals, birds, and birds of prey. Utility metal crafts include, for instance, cutlery, jugs, vases, planters, furniture, and ashtrays. Both domestic and foreign markets have a need for brass metal handicrafts. Brass is revered as pure and sacred in India. Brass is used by Hindus for religious purposes to make Diya, or lamps, God idols, and

Pooja thalis (plates). Different types of brass products and their manufacturing techniques are mentioned in Chapter 2. Different metalware and metal image crafting centres are given below in tables 1.5, 1.6, and 1.7.

Table 1.5 Part1: Metal Ware crafting centers **(**source: Ministry of Textile) http://www.craftclustersofindia.in/site/Cluster_Directory.aspx?mu_id=3 February2024

S.N.	Cluster Name	State	District
1	Behut	Uttar Pradesh	Saharanpur
2	Kharai Tamta	Uttarkhand	Bageshwar
3	Khongnang Pheidekpi	Manipur	Imphal
4	Heirangoithong	Manipur	Imphal
5	Khurai	Manipur	Imphal East
6	Bamon Kambu	Manipur	Imphal East
7	Palwal Hodal	Haryana	Faridabad
8	Sanjay Place	Chhattisgarh	Raipur
9	Bhainchua	Orissa	Bhubneshwar
10	Bishnugarh	Jharkhand	Hazaribag
11	Dhokra	Andhra Pradesh	Adilabad
12	Sheopur Kalan	Madhya Pradesh	Bhopal
13	Sadeibereni	Orissa	Bhubneshwar
14	Navsari	Gujarat	Ahmedabad
15	Kharai	Uttarkhand	Bageshwar
16	Reamal	Orissa	Dhenkanal
17	Varanasi	Uttar Pradesh	Varanasi
18	Dungarpali	Orissa	Sonepur
19	Baipariguda	Orissa	Koraput
20	Cuttack	Orissa	Cuttak
21	Khunta	Orissa	Mayurbhanj
22	Rangali	Orissa	Sambalpur
23	Adhoc	Assam	Guwahati
24	Kakarwada	Chhattisgarh	Bastar
25	Amravati	Maharashtra	Nagpur
26	Salekasa	Maharashtra	Gondia
27	Nutan Vasahat	Maharashtra	Jalna
28	Chandan hira	Maharashtra	Jalna
29	Moradabad	Uttar Pradesh	Moradabad
30	Payyannoor	Kerala	Thrissur
31	Kuharpara	Chhattisgarh	Bastar
32	Natchiarkoil	Tamil Nadu	Madurai
33	Ghatotand	Jharkhand	Hazaribag
34	Dariapur	West Bengal	Madinipur East
35	Ichhawer block	Madhya Pradesh	Bhopal

Table 1.5 Part2: Metal Ware crafting centers (source: Ministry of Textile)

36	Forum for Literacy and Development	Jammu & Kashmir	Srinagar
37	Vishwanath Charili	Assam	Sonitpur
38	Bhopal	Madhya Pradesh	Bhopal
39	Tikamgarh	Madhya Pradesh	Bhopal
40	Bastar	Chhattisgarh	Raipur

Table 1.6: Metal Images (Folk) crafting centers (source: Ministry of Textile) http://www.craftclustersofindia.in/site/Cluster_Directory.aspx?mu_id=3 February2024

S.N.	Cluster Name	State	District
1	Khurai	Manipur	Imphal East
2	Bishnugarh	Jharkhand	Hazaribag
3	Varanasi	Uttar Pradesh	Varanasi
4	Adhoc	Assam	Guwahati
5	Ujjain	Madhya Pradesh	Bhopal

Table 1.7: Metal Images (classical) crafting centers (source: Ministry of Textile) http://www.craftclustersofindia.in/site/Cluster_Directory.aspx?mu_id=3 February2024

S.N.	Cluster Name	State	District
1	Bhainchua	Orissa	Bhubneshwar
2	Dhokra	Andhra Pradesh	Adilabad
3	Sheopur Kalan	Madhya Pradesh	Bhopal
4	Rangali	Orissa	Sambalpur
5	Rangashaipet	Andhra Pradesh	Warangal

In the metal handicraft sector, most of the artisans work in the house or cottage industries. These industries are unorganized and traditional in nature. Production is seasonal and based on local demand. It is difficult to maintain the minimum standard of living due to low production, and middlemen take the maximum share of profit[31][32]. The planning commission recognises that the unorganised sector, which accounts for around 93% of the workforce, lacks a systematic framework for skill upkeep or acquisition.

While artisans are highly esteemed for their craftsmanship, they frequently face challenges in adapting to evolving market demands and shifting fashion trends. These difficulties can be attributed to factors such as lower levels of formal education and financial constraints[33]. Nevertheless, it's essential to acknowledge the pivotal role played by supply chain management in enabling artisans to stay attuned to changing market preferences and fashion trends. A supply chain typically involves a forward flow of materials and a backward flow of information. As a result, the core objective of supply chain management is not limited to creating value solely for the company but extends to optimizing the entire supply chain network, including the ultimate satisfaction of end customers[34].

The metal handcraft cottage sector grapples with persistently low production, leading to reduced income for artisans. Consequently, the younger generation is increasingly turning to alternative livelihoods for sustainable economic prospects rather than perpetuating traditional cultural crafts. Figure 1.2 illustrates the multitude of factors contributing to the challenges faced by the metal handicraft industry[18], [35]–[39].

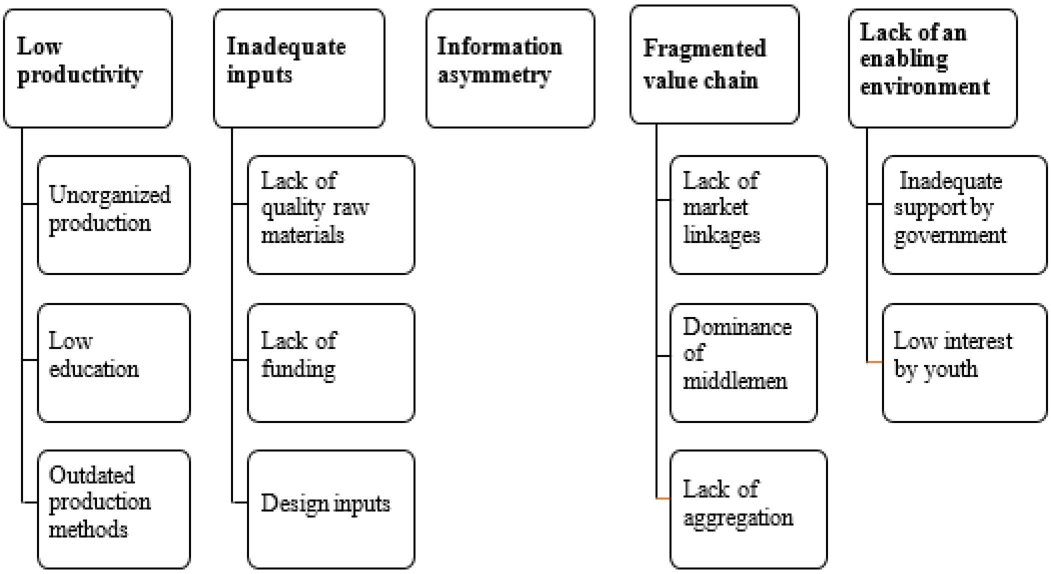


Figure 1.2: Challenges faced by metal handicraft

The government has launched a variety of schemes and programs aimed at delivering comprehensive assistance for the development of handicraft clusters and enterprises. The handicrafts sector faces inefficiencies due to a multitude of institutions overseeing various aspects of crafts without sufficient coordination in terms of schemes and strategies. The division and separation of administrative structures among related sectors, such as handlooms, handicrafts, Khadi, and micro-industries, hinder the optimal utilization of resources. This issue was highlighted in the 2012 12th plan report, which emphasized the need to unify and streamline the approach to conceptualizing programs, allocating budgets, and promoting and branding Indian crafts across all these sectors for holistic development[40].

At present, the office of the Development Commissioner (Handicraft) is implementing the following schemes for the promotion and development of the handicraft sector:

A. National Handicrafts Development Programme (NHDP)

The NHDP scheme provides support to handicraft artisans, creating a conducive environment. The schemes aim to strengthen the handicrafts sector and empower artisans by providing marketing platforms, resilient infrastructure support, and design and skill training programmes. Schemes also provide social security coverage and pensions to artisans to empower them.

1. Marketing Support & Services
2. Design & Skill Development in Handicraft Sector
3. Ambedkar Hastshilp Vikas Yojana
4. Direct Benefit to Artisans [Welfare]
5. Infrastructure and Technology Support
6. Research & Development

The NHDP scheme promotes premium handicraft products, expands the production base, empowers artisans, and preserves heritage.

B. Comprehensive Handicrafts Cluster Development Scheme (CHCDS)

The infrastructure and production chains at handicraft clusters are expected to be scaled up through mega-cluster developments under CHCDS. The proposed initiative will aid in the development of new or upgraded infrastructure, market connections, product innovation, and diversification [41]

The National handicraft policy aims to address the sector's crucial needs and gaps effectively. The policy's vision is to create a supportive environment for the growth of the handicrafts sector, ultimately ensuring sustainable livelihoods for artisans across the country.

People worldwide take pleasure in appreciating and collecting antiques from bygone eras, often recognizing the unique cultural traditions of a particular place through its distinctive handicrafts. India stands as the world's largest market for brass handicrafts, encompassing a wide array of brass antiques, utility items, and more. As one of the foremost brass producers globally, India holds the top position in brass handicraft production, with the majority of metal handicraft enterprises specializing in the creation of brass products.

1.4 Field Study for Brass Metal Handicraft at Hajo, Assam

Field surveys are a common method for researchers to initiate new investigations. In the current study, multiple field surveys were conducted to gather various types of data. This process began with selecting the study location and was followed by data collection and reporting.

1.4.1 Selection of Study Location

We've opted for field surveys in Assam's brass metal handicraft industry because we have easy access to institutional resources, enabling us to gather comprehensive information and insights about the metal handicraft sector.

In Assam, articles made of brass metal have a rich tradition as utilitarian items. Historically, production centres for brass metal were located in Titabar, Raha, and Dhekiajuli in eastern and central Assam. However, during the colonial period, these centres disintegrated and became primarily focused in the Sarthebari region of western Assam. There are also smaller-scale brass metal industries in various areas of western Assam, including Kartimari, Asharkandi, Sapatgram, Bilasipara, and Gauripur. Notably, Hajo in Kamrup district and the Sarthebari cluster in Barpeta district remain prominent centres for the brass metal industry[42]

The stack holders were personally questioned to better understand the issues with the current procedure. Detail analysis of the craft-making process is done to determine where improvements might be made.

1.4.2 Data Collection

The field survey aims to collect information about various aspects of the brass metal handicraft industry. This includes details on the current sources of raw materials, the types of raw materials used, the range of products manufactured, production time, daily activities, the number of artisans involved, the presence of working clusters, the working environment, the level of effort required for various tasks, and the available infrastructure facilities. The field survey collected data using videos, photos, observations, and personal interviews. The sample size was determined to be 30, taking into account the point of data saturation.

1.4.3 Field Survey Report

In Hajo, the brass metal handicraft sector primarily uses brass metal sheets as raw materials. There are more than 300 families directly involved in this craft. Brass is a metallic alloy that is made of copper and zinc (14 - 16% zinc). The thickness of sheet varies from 24 gauge (0.5mm) to 10 gauge (2.5mm). These sheets are often supplied by local vendors or middlemen who provide the sheets and pay minimal labour costs or share a small profit. Additional materials like lacquer, borax powder, brass metal powder, zinc powder, and sometimes used brass metal objects are required.

Brass sheets are sometimes imported from Bangladesh and Kolkata, and the raw materials are broken into small pieces. These pieces are then placed in an iron vessel and heated over a fire vent, sometimes with the use of machines. Wood or coal is the primary fuel used to melt the brass.

In Hajo, the most prevalent brass metal handicraft products include Xorai (offering dishes on stands used for religious purposes), Kalah (vases), Ban-bati (meal dishes with stands), and more. Additionally, Assam produces other significant brass metal utensils like the Tow (a wash bowl for edibles), the Korahi (similar to the Tow but with multiple holes), Gamla (a utility pot), and the Kahi (a cooking vessel).

Artisans in the brass metal industry work in household clusters, with each cluster typically consisting of 4-5 artisans who are involved in the entire manufacturing process. The artisans work for 8 hours each day. Clusters are operating by fulfilling small orders, engaging in batch production, and creating customized items without disrupting their existing infrastructure. The traditional methods used in this industry include manual processes such as cutting, shaping, joining, polishing, filing, and designing, among others.

Step 1: As seen in Figures. 1.3 and 1.4, the brass sheets are cut and formed over the die.

Figure 1.3: Shearing operation

Figure 1.4: Forming operation

Step 2: As depicted in Figures 1.5 and 1.6, a technique is used to create nicks along one edge of two brass sheets when joining them together. Subsequently, the nicks are overlapped, and both sheets are meticulously hammered flat to achieve a secure join.

Figure 1.5: Nick formation process

Figure 1.6: Joining process

Step 3: Borax and payan are combined to make a rough paste, which is applied to the joint. When the paste is heated, it melts and joins the parts.

Figure 1.7: Soldering process

Step 4: Cleaning is accomplished by submerging the craft in sulfuric acid-infused water. Brushing and water cleansing come after dipping.

Step 5: Polishing

Step 6: In the brass metal craft, artisans employ different techniques for ornamentation of surfaces. They may carve forms on the surface for ornamentation, or they may use hammers to create impressions. Interestingly, the same method is used for crafting all kitchenware and utility items. The tools of their trade include a variety of hammers (ranging from small to large), pincers, chisels, lathe-based surface-finishing tools, and polishing instruments. You can see these tools in Figures 1.8, 1.10, and 1.11.

Figure 1.8: Hammers, pincers, and chisels of various sizes are used as tools in the manufacturing process

In addition to the mentioned tools, a wooden die is utilized to forge the sheet into the desired size and shape.

Figure 1.9 Wooden Die

Figure 1.10: Lathe-based surface finishing tool

Figure: 1.11 Polishing tools

A 5 HP motor powers these lathe-based surface finishing and polishing devices.

Figure 1.12. Unused tools

Most artisans in the Hajo brass metal industry work in the traditional, unorganized sector, and production is seasonal. The entire crafting process happens on a small scale, and artisans are paid based on their production rates. The use of traditional equipment can limit output rates, resulting in lower per capita income.

1.4.4 Summary of Field Survey

All the production units pointed out the problems of the high cost of raw materials and energy. In 1957-58, the Industries Department, Govt. of Assam, established a rolling mill with five-ton capacity at Sarthebari. However, due to a lack of skilled manpower to run that rolling mill as well as the high running cost of the rolling mill, the mill remained unutilized.

The artisans' working posture often involves awkward positions, resulting in ergonomic-related drudgery. This has led to various issues, including crack formation and product failures, when traditional machinery and tools are employed in the crafting process. Conducting a study on designing tools and techniques can help reduce the production failure rate in the production process. There have been design interventions in the manufacturing tools, but some tools remain unused. The main challenges in balancing modern and traditional technologies used in crafting are related to ease of use, reliability, cost, and the maintenance of technology. Surface finishes and other problems with quality Such fracture creation causes the product to be rejected.

Artisans' wages are tied to their overall production output, which can be challenging for them as low productivity makes it difficult to earn a sustainable income.

The production of crafts is seasonal and cultural based. The "Pitoloi Chair" is a product designed as part of an initiative to revive an ancient skill and improve production through product diversification.

Artisans have limited market awareness and are connected to the market through middlemen, resulting in reduced direct market access. Middlemen, despite their limited education, play a significant role in providing livelihood opportunities to artisans through their market connections. The Pitoloi chair case study demonstrates that these middlemen can be instrumental in marketing if they are young entrepreneurs or designers capable of connecting artisans and users on a global scale through various e-commerce platforms. They can also contribute to increasing product demand through product diversification.

Moradabad's affordable and high-quality machine-made products have introduced strong competition in the market for Assam's brass handicrafts.

1.5 SWOT Analysis of Metal Handicraft Sector

Strengths

- Abundant skilled labour with cost advantages and a rich heritage of indigenous knowledge, foster innovation and creativity.
- Flexibility in production, allows for small orders, batch production, and customized items without disrupting existing infrastructure.
- High-quality production with minimal capital investment.
- Vintage characteristics that seamlessly complement other artisan products.
- A wide range of distinctive goods offered by the metal handicraft industry.
- Significant contributions to employment and overall economic growth in the country.

Weaknesses

- Quality vs. Quantity Dilemma: Artisans are often paid based on the quantity of crafts they produce, which can lead to a sacrifice in product quality due to time constraints.
- Time-Consuming Quality Assurance: Prioritizing quality can extend the production time, potentially affecting timely delivery to customers.
- Limited Knowledge and Market Access: Many artisans lack knowledge about government resources and market dynamics, which can hinder their ability to access available support and opportunities.
- Communication and Infrastructure Challenges: Inadequate communication and infrastructure facilities can pose hurdles for artisans in the metal handicraft industry.
- The lack of quality and branding, including packaging, can be a significant weakness in the metal handicraft industry in India. This can hinder the industry's ability to compete effectively in the global market and command higher prices for its products. Strengthening quality control and investing in branding and packaging can help address this weakness and enhance the industry's overall competitiveness and appeal to customers

These weaknesses, point the need for addressing issues related to reward structures, skill development, market access, and infrastructure improvements in the industry.

Opportunities

- Self-Sufficiency and Economic Growth: The growth of the handicraft sector can significantly contribute to India's self-sufficiency and overall economic development.

- Product Diversification and Global Markets: Product diversification opens up opportunities in developing nations by combining antique qualities with other craft goods, facilitating entry into global markets.
- Affordable Development through Collaboration: Collaboration among businesses in the handicraft and product design industries can make the development process more cost-effective, leading to substantial contributions to the country's economic growth.
- Market Understanding through Entrepreneurial Collaboration: Collaboration between entrepreneurs in the handcraft and product design industries can help artisans better understand the market and consumer preferences.
- Strengthening Local Knowledge and Global Presence: Involving new business owners and artisans strengthens local knowledge of handicraft entrepreneurship, enhancing the industry's visibility on the global stage.

These opportunities highlight the potential for growth, sustainability, and increased global recognition for the metal handicraft industry.

Threats

- Traditional brass metal artisan cottage industries face challenges due to competition from machine-made goods in places like Moradabad and higher-quality products from rival nations. This competition is causing artisans to seek alternative livelihoods.

The literature highlights the multifaceted role of handicrafts in fostering economic growth, preserving cultural heritage, creating employment, and contributing to sustainable development. While India's handicrafts have a rich cultural heritage and global demand, challenges persist in quality, branding, production, and administrative coordination. Government initiatives aim to address these issues and empower artisans.

1.6 Scope of Design Intervention / Innovation

Six states West Bengal, Uttar Pradesh, Odisha, Andhra Pradesh, Rajasthan, and Assam - play a significant role in India's rural handloom and handicraft industry. They collectively represent 65% of all rural handloom and handicraft establishments, 46% of the rural population, and 45% of the rural poor in India. Handicrafts are a vital part of India's rural economy, and if supported and nurtured, they can help reduce rural-urban migration[40]. The required support details are shown in Table 1.8 by All India Artisans and Craft Workers Welfare Association (AIACA), National Handicraft Policy Report 2017.

There are many areas where intervention is required to improve the handicraft cottage industries. <u>The main goal of this study is to revive the ancient tradition of brass metal</u>

craftsmanship by enhancing the capacity of handicraft artisans. This is done by introducing technology to improve production efficiency and reduce the drudgery involved in the craft-making process. The research area is chosen based on the expertise and facilities available.

Table 1.8: Framework of Policy objectives and key areas of intervention

Objective 1: Improve livelihood and socio-economic conditions of handicrafts artisans by developing their capacities. **Desired Outcomes:** Traditional skills professionalized through necessary inputs leading to increased competitiveness for markets and readiness for enterprise development **Interventions/ Action Areas** 1. Skill upgradation 2. Design education and training 3. Efficiency and quality in inputs supply 4. Access to finance 5. Technology inputs for production efficiency and reducing drudgery 6. Market intelligence 7. Market access
Objective 2: Provide an enabling environment for growth of crafts sector by supporting establishment and growth of artisan based enterprises **Desired Outcomes:** Informal crafts sector mainstreamed into formal creative industry **Interventions/ Action Areas** 1. Mobilizing and organizing artisans 2. Incubation and formalization of crafts enterprises 3. Common infrastructure 4. Regulatory environment (taxes, raw material policy, compliance, etc) 5. Access to credit and finance 6. Labour, quality and environmental standards 7. Investment in public goods 8. Investment in R&D
Objective 3: Create a differentiation for hand crafted products leading to higher and larger profit and market share by supporting and facilitating effective marketing and branding for the sector. **Desired Outcomes:** Indian handicrafts having a comprehensive brand for genuine excellent handicrafts with increased brand value, demand and sale in national and export markets.

Interventions/ Action Areas 1. Certification and GIs 2. "Handmade in India" campaign 3. Market and trade facilitation
Objective 4: Enhance artisan well-being by designing and facilitating effective schemes **Desired Outcomes:** Improvement of artisan livelihood and greater opportunities created for their welfare and growth **Interventions/ Action Areas** 1. Develop a comprehensive database of artisans and crafts 2. Review and revamp existing schemes 3. Effective convergence with social security and other social welfare schemes 4. Institutional partnerships for effective uptake and utilization of schemes 5. Institutional strengthening for effective implementation of schemes
Objective 5: Preservation of traditional crafts heritage by ensuring continuity of traditional handicrafts traditions across generations and promoting awareness among the wider public. **Desired Outcomes:** Revival and revitalization of traditional knowledge and creative skills **Interventions/ Action Areas 2** 1. Transmission of traditional knowledge and skills to next generation 2. Documentation of handicrafts skills, especially in endangered crafts 3. Making comprehensive information on handicrafts and artisans accessible to all

1.7 Research Questions

1 What are the opportunities for innovation and design intervention in the brass metal handicrafts manufacturing process?

2 What are the challenges for adapting advanced tools, machinery, and technology in the brass metal handicraft sector?

3 How to formulate a sustainable tool design intervention in brass metal handicraft sector?

4 How strategic design interventions can improve productivity and quality in brass metal handicrafts?

1.8 Aim and Objectives

Aim: Design and development of affordable and acceptable tools for enhanced productivity and quality of brass metal handicrafts.

Objectives:

- To explore possible areas of design intervention in the field of the brass metal handicrafts sector.
- To study the challenges of stakeholders of the brass metal industry in Assam.
- To study the challenges of adaptation of advance tools, machinery and technology in brass metal handicraft sector.
- To study the manufacturing process, tools and equipment used in brass metal handicraft sector in Assam.
- To design and develop appropriate and sustainable tools to improve productivity and quality in brass metal handicrafts.

1.9 Research Gap

The handicraft sector is suffering from low productivity, causes law income, and is full of drudgery due to age-old technology and equipment. The vision for the handicrafts sector for the 12th FYP (Five Year Plan) is: "To create a globally competitive handicrafts sector and provide sustainable livelihood opportunities to the artisans through innovative product designs, improvement in product quality, the introduction of modern technology, and preserving traditions"[43], [44]. The following strategies are the center of focus to achieve the above vision:

i. Product development and production,
ii. Marketing and compliance,
iii. Infrastructure Development,
iv. Livelihood and working environment.

Technical, production, organizational, personal, finance, management, government, and location are various factors that influence the production of any product[45].

An analysis of handicraft through literature and field surveys reveals that one of the reasons for the migration of artisans is the local competition with the Moradabad handicraft sector. The Moradabad cluster has integrated various design innovations into its manufacturing process, such as electroplating, moulding tools, carving, and polishing[46], [47]. These innovations enhance the quality of craftsmanship while also reducing craft prices. This price gap and good quality reduces the demand for products from local regional clusters and is a reason for low production, impacting the economically sustainable livelihood of artisans. The survey results indicate that a mill in Hajo, Assam, primarily producing raw brass as its main raw material, was established to fulfil the need for affordable raw materials. However, the government-owned mill remained closed due to a disparity between the rapid material output it generated and the slow demand for manual craft products. This misalignment between material production and market demand may have contributed to the mill's closure.

Handicraft production and development have a broad impact, spanning various aspects such as generating employment opportunities, increasing income, promoting sustainable development, and fostering village independence. To achieve these objectives, there is a pressing need to seamlessly blend traditional craftsmanship with effective product management. This integration should encompass considerations like customer preferences, choice of materials, skill development, stakeholder engagement, retail strategies, and market positioning. In doing so, an essential component is the formulation of sustainable plans to ensure the long-term viability of handicraft industries and their positive impact on communities and economies[40]. To promote micro agricultural enterprises and entrepreneurship for rural development The study focuses on the potential of handicraft production as a means to provide sustainable employment in rural areas of the Philippines. It explores how micro - handicraft firms adapt to the challenges and opportunities brought about by the Regional Comprehensive Economic Partnership (RCEP), which has opened doors to larger international markets. The analysis identified three fundamental characteristics of adaptive capability: value creation, organizational agility, and resourcefulness [48].

1.10 Methodology

The study's methodology, outlined in Table 1.9, involves referencing information from various sources and mediums. The initial phase focuses on clarifying and defining the problem, incorporating both primary and secondary data collection methods.

Table1.9: Methodology Outline

Sr. No.	Method	Material
1.	Descriptive method,	Sources of Reference: Books, Journals, Conference Papers, and various Literature. The research illuminates the varied role of handicrafts, underscoring their multifaceted nature. Despite the rich cultural heritage and global demand for India's handicrafts, challenges endure. Government initiatives are directed at addressing these issues and promoting empowerment. The study also integrates a field survey for comprehensive insights.
2.	Sample Selection	In the age group of 30-60 years, there are 300 families engaged in brass handicrafts. The working principles are similar across a diverse range of products. Consequently, the 30 artisans and the Mahajan, under whose supervision the industry operates, are actively engaged in designing solutions.
3.	Data collection	Data collection relied on targeted investigations through semi-structured interviews, observations, study findings, and insights.
4.	Analysis	A thorough perspective analysis is conducted for the brass metal handicraft industry, encompassing planning, handicraft product development, and sales analysis, with consumers at the centre of focus. It provides insights into the industry's evolution, covering various aspects like social impact, socio-economic factors, community involvement, accessibility, affordability, cultural preservation, long-term sustainability, and policy implications.
5.	Tests	Value stream mapping is a lean management technique used for analysis purposes. It involves a lean analysis of the production process and time analysis. Ergonomic analysis is applied to address user-related aspects in the development of hand tools. The development of tool involves a quality or value analysis assessing utility, reliability, safety, maintenance, lifetime, and pollution aspects. Additionally, value analysis using an engineering value approach emphasizes cost reduction through guidelines such as elimination, reduction, simplification, modification, and standardization In the final stages, hand tools are methodically designed and developed. They are subjected to rough testing with the active participation of artisans, and necessary modifications are made at various stages to address challenges and issues encountered during the testing process.
7.	Analysis Type	Qualitative analysis
8.	Approach	Top down Approach

Descriptive Study: Data is collected through field survey, observation, personal interview, governmental publication, journal, and articles.

Perspective Study: The preliminary findings from the literature study and field survey of the brass metal handicraft sector lead to certain conclusions.

Experimental Study: Value stream analysis is a lean analysis of manufacturing processes, the study of existing tool techniques and processes, human factors, quality or value analysis, and cost reduction.

Human Factors: The aesthetics and functionality of a product must balance the human factor, or ergonomics. A product should have the basic principle of human compatibility through a user friendly relationship.

Quality or Value Analysis:

Table1.10 Attributes which commonly contribute to the quality or value of the product are as follows.

Utility	Performance on aspects such as capacity, power, speed, accuracy or versatility
Reliability	Freedom from breakdown or malfunction , function under varying environmental conditions
Safety	Secure, hazard-free operation
Maintenance	Simple, infrequent or no maintenance requirements
Lifetime	Except for disposable products, a long time which offers good value for initial purchase price.
Pollution	Little or no unpleasant or unwanted by products, including noise and heat

Cost Reduction:

Table 1.11: A Checklist of cost-reduction guideline as follows

Eliminate	Can any function, and therefore its components, be eliminated altogether? Are any components redundant?
Reduce	Can number of components be reduced? Can several components be combined into one?
Simplify	Is there a simpler alternative? is there an easier assembly sequence? Is there a simpler shape?
Modify	Is there a satisfactory cheaper material? Can the method of manufacture be improved?
Standardize	Can parts be standards rather than special? can dimensions be standardized or modularized? Can components be duplicated

Manufacturability Interaction Matrix: Manufacturing processes are complex and impacted by many design factors. As a result, there are potential concerns that have the ability to disrupt manufacturing operations. In order to assess the manufacturability of the design, it was necessary to develop an interaction matrix between stakeholders and the development process.

Taking into account the diverse needs of consumers (artisans) and analysing various design aspects related to manufacturing, a manufacturing interaction matrix is prepared to guide the development of hand tools.

Concept Development: By considering insights from qualitative studies, lean analysis, and various aspects of value and cost analysis, an interaction matrix has been developed. Subsequently, concepts were generated and modified based on this matrix.

Testing: Hand tools are designed and developed and tested with participated artisans.

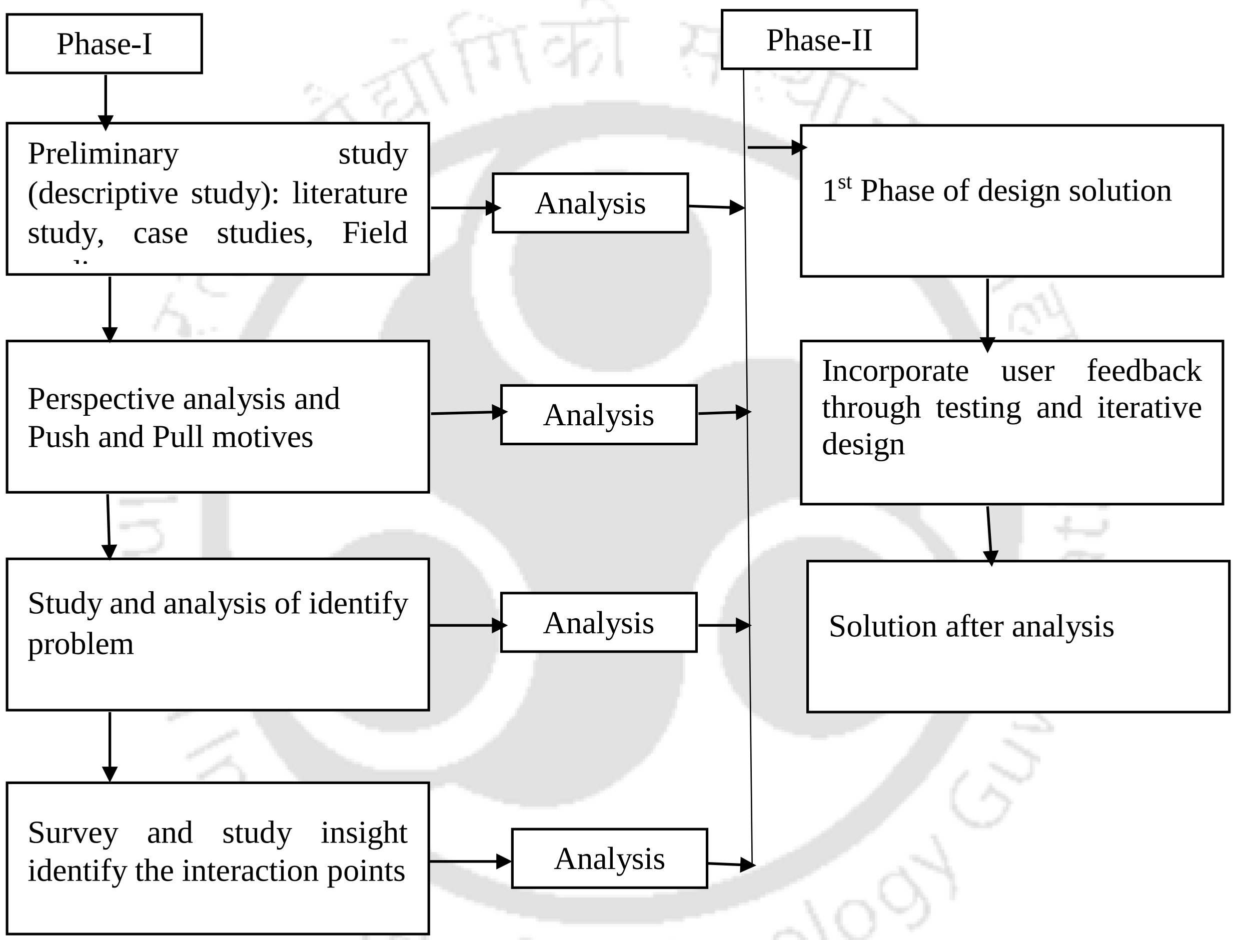


Figure 1.13: A flow chart to describe the design methodology

1.11 Expected Outcome from the Research

To enhance the competitiveness of the handicraft sector in the market, there is a crucial need to design and develop efficient hand tools. This initiative aims to reduce the costs associated with traditional brass metal handicrafts, ultimately contributing to improved output and quality, thereby making it a financially viable profession. Technological advancement and intervention in handicraft emerge as pivotal factors demanding attention from the scientific community.

The focus lies on elevating the productivity and comfort of artisans, tapping into the potential for scalable business. The envisioned hand tools should possess the capacity for higher production, enhance the quality of craftsmanship, offer cost-effectiveness, facilitate easy assembly and disassembly, ensure reliability, and require straightforward maintenance. Additionally, these tools should be user-friendly, establishing a harmonious synchronization between artisans, hand tools, and their working environment.

1.12 Validation

The validation of the hand tool design in terms of the previously described objectives will be carried out through lab and field testing with the participation of artisans, and production time will be compared with traditional hand tools.

1.13 Conclusion

Based on a field survey, there is a declining interest in Assam metal handicrafts due to their high prices and subpar quality. To ensure the profitability of the Assam brass metal handicraft sector, efficient production processes and quality enhancements are imperative. This study addresses these challenges by incorporating design interventions into manufacturing tools, aiming to accelerate craft production rates and increase overall capacity.

Design involvement in manufacturing tools is seen as essential for Assam's brass metal handicrafts to bridge the price gap between handcrafted and machine-made items, thereby supporting small enterprises. The study meticulously analyzes the pros and cons of tools, equipment, and apparatus used in contemporary practices. It also delves into the technology, equipment, and tools employed in rural brass metal handicraft enterprises.

When designing and developing hand tools, special consideration is given to their flexibility across various crafts and product ranges. The intervened tools are designed for easy adaptation and utilization across a variety of crafts and products, ensuring ergonomic suitability for artisans.

The process involves deforming brass metal sheets using intervened tools to create 3D forms in both 2D and 3D planes. For bending the sharp edges of crafts or products, a hemming tool is employed. Shaping tools are used to create the necessary curved surface in the 3D plane, while surface bending tools contribute to forming cylindrical shapes in the 2D plane. The intervened tools significantly enhance productivity in batch production, simultaneously improving the health of artisans by eliminating the manual hammering process for hemming against an anvil.

The scalability of these tools is evident, with improved productivity in larger batch sizes leading to reduced costs. Importantly, the newly designed metal sheet forming hand tools apply uniform pressure, mitigating quality issues such as crack formation. Ultimately, these tools are poised to benefit both individual artisans and small entrepreneurs associated with the brass metal craft sector.

1.14 Outline of the Thesis

Chapter 1 introduces handicraft production, the significance of brass metal handicraft production, and its SWOT analysis. The aims and objectives of the doctoral research are also covered here based on the various research questions raised.

Chapter 2 covers details of the literature review process with field survey of the brass metal handicraft sector in Hajo, Assam. Various challenges faced by artisans, and various challenges for the adaptation of new technology, tools and equipment are studied, and research gap is identified.

Chapter 3 describes the methodology adopted for complete research work.

Chapter4 consist of the design and development of tools, includes findings from the design and testing. Also discussed all success and failure steps of each design.

Chapter 5 is the concluding chapter of the research work, and moreover, justification of the findings and results of the research, considering the research questions framed for the research aims and objectives. Contributions of the research, limitations of the research, and possible future research work is also mentioned in this chapter to further improve.

CHAPTER 2

Analysis of the Brass Metal Handicraft Industry: A Comprehensive Perspective

2.1 Introduction

2.2 Strategizing the Brass Metal Handicraft Industry

2.3 Brass Metal Handicraft Development

2.4 Brass Metal Handicraft Sales

2.5 Push and Pull Motives

2.6 Problems Identification

2.7 Discussion

CHAPTER 2

Analysis of the Brass Metal Handicraft Industry: A Comprehensive Perspective

The ancient Indian handicraft industry has a rich history of employing consumer-centric strategies throughout various time periods, eras, and dynasties. These strategies were evident in the innovative approaches and interventions that extended from the selection of raw materials to the final product design. Additionally, the guild system played a pivotal role in promoting and upholding these consumer-centric strategies.

The history of Indian handicrafts exemplifies a continuous dedication to serving the consumer. Artisans and craftsmen of different periods exhibited a remarkable ability to adapt to the shifting preferences of consumers, while the guild system provided the necessary structure to support and reinforce these consumer-centric practices. This long-standing tradition of consumer-focused strategies has contributed to the enduring success and appeal of Indian handicrafts[49]–[51].

The study aims to identify areas for design improvement in Assam's brass metal handicraft sector and understand the challenges faced by stakeholders. This is achieved through a perspective study that involves comparative research between contemporary brass metal handicraft and historical traditional brass metal handicraft. The comparative analysis seeks to provide insights into the evolution of brass metal handicraft, highlighting changes, challenges, and potential areas for enhancement in the present context.

2.1 Introduction

Brass is an alloy of copper. Copper appears in Shukla Yajurveda during the Vedic Age (Circa 2000 B.C.- 1000 B.C.). Copper it recognized as "Lohityas" (red metal). Further words "Tamra" appear for copper as per evidence of Charka Samhita, Sushruta Samhita, and Kautilya Arthashastra. During this period, various products were found, including flat Celts (tools), long objects from the United Provinces, harpoon (weapon) or spearheads, a barbed harpoon head, rings, a human figure, and swords. Various ancient copper specimens from different time periods in ancient India include the following: copper Bolt in the Anoka Pillar, colossal copper statues of Buddha, copper coins, copper plates, copper utensils, copper casket. These artifacts provide insights into the historical use of copper in India.

Ancient India had a rich tradition of brass work, as evidenced by various brass artifacts, statues, and weaponry dating back to the 1st century B.C. or A.D. Brass was used for artistic and utilitarian purposes, and the craftsmanship of ancient Indian brass workers was remarkable. The knowledge of brass as an alloy and its preparation was advanced in India, as metallic zinc was prepared in India several centuries earlier than in Europe. Brass artefacts from this period include a brass casket and urn discovered in stupas. One of the most remarkable examples of ancient Indian brass work was a Vihara (monastery) made of brass. Brass work was also prevalent in crafting idols for worship. The use of brass extended to weaponry during the Moghul period in India[52].

In ancient India, the people of the Indus Civilization created a variety of articles and ornaments using materials like gold, silver, copper, and brass. Among these, copper and brass were more commonly used, with the Indus people being the first to use silver, which was more prevalent than gold. This period is often referred to as the "Brass Age" because of the significance of brass. They crafted various tools like axes, knives, spears, arrows, saws, and blades, typically by melting and shaping metals. Brass was initially less common than copper, suggesting that awareness and use of brass came later.

In the Harappan region, high-quality brass and copper utensils were discovered, mainly created through metal casting. Small metal statues were made through a process known as "closed melting" or "lost-wax casting." Notably, it's mentioned that the absence of a stylus in spears made them less sturdy[53].

India is the largest brass-making country in the world. But when it comes to the recognition of metal art by society, some special regions are famous for their regional metal crafts in India.

Kamrupi

Kamrupi Metal Craft, with its brass and bell metal products, stands as a testament to the artistic and cultural richness of Assam. These crafts not only serve practical purposes but also reflect the cultural identity of the region and its people. They continue to be celebrated and cherished for their beauty and cultural significance, making them a unique and enduring part of Assam's heritage. Brass and bell metal products are known for their beauty, utility, and form. Brass is an extremely important cottage industry, with the highest concentration of artisans in Hajo. Utensils and daily-use items such as Xorai (dishes mounted on a stand used to hold offerings to deities), Kalah (vase), Ban-bati (meal dish with a stand), Bota (flat circular tray with a stand to offer sweets), etc. are produced in Hajo, an Assam brass metal cluster. While Sarthebari is well known for its bell metal craft [54][55].

Figure 2.1: Kamrupi brass metal products, Xorai, Kalah, Ban-bati, and Bota respectively

Bidri Ware

Bidri pottery is a highly acclaimed traditional art form that originates from Bidar, a city located in the state of Karnataka, India. Bidriware is known for its distinctive inlaid designs, dark or smoky appearance, and the use of precious metals such as silver, brass, and sometimes gold. This craft has a rich history and has found its way into various artistic creations and functional items. Here are some key details about Bidri pottery:

Inlay Technique: Bidriware is distinguished by its intricate inlay work, where silver, brass, or gold (and sometimes a combination of these metals) are meticulously inlaid into the surface of the metal, typically blackened with a special process. This inlay work often features intricate and ornate patterns, adding to the beauty and allure of the products.

Product Range: Bidriware artisans create a wide range of artifacts, including containers, boxes, plates, bowls, trays, and other functional as well as decorative items. These products are not only aesthetically pleasing but also serve practical purposes.

Bidar, Karnataka: Bidar is the primary and most renowned centre for Bidri pottery. It has a long history of producing exquisite bidriware, and the craft is deeply embedded in the local culture and tradition.

Hyderabad, Telangana: Hyderabad is another significant hub for the production of bidriware. Artisans in this region have also contributed to the preservation and development of this craft.

Other Regions: While Bidar and Hyderabad are the most active centers, Bidriware is also practiced in a few other regions across India, including Purnia in Bihar, Lucknow in Uttar Pradesh, and Murshidabad in West Bengal. However, the products from Bidar and Hyderabad are often considered the most authentic and of the highest quality.

Bidri pottery is not only a craft but a reflection of the rich artistic and cultural heritage of India. The skilled artisans who create Bidriware continue to produce exquisite pieces that are appreciated for their artistic beauty and craftsmanship. This craft has also earned geographical indication (GI) status, further highlighting its significance and uniqueness. [56].

Fig 2.2 a: A cup with lid Bidri ware **Fig 2.2 b**: Bidri ware vase and decanter

Figure 2.2: Bidri ware

Pembarti

Pembarti metalwork, a renowned Indian craft with a history of over 5000 years, hails from the village of Pembarti, situated around 60 kilometres from Warangal in Telangana. This craft is celebrated for its intricate brass sheet metal artwork. Artisans use traditional techniques like embossing and engraving to create a variety of items, including decorative pieces, utensils, lamps, and religious artifacts. Pembarti's rich artistic heritage has made it a significant centre for this craft, preserving cultural traditions and historical significance [42].

Figure 2.3: Pembarti Metal Craft

source:https://www.dsource.in/resource/sheet-embossing-pembarthi/introduction ,February 2024

Dhokra

Dhokra crafts are created by hand-casting bronze and brass metal using the vanishing wax method. The history of this art form dates back to ancient times, with the famous "Dancing Girl" from Mohenjo Daro being one of its earliest known examples. Dhokra metalwork is currently most commonly produced in states such as Andhra Pradesh, Orissa, Madhya Pradesh, Jharkhand, and West Bengal. This versatile metal craft is used to craft a wide range of items, including religious motifs, tribal characters, and animals like horses, elephants, owls, and peacocks, showcasing its rich artistic and cultural significance [57].

Figure 2.4: Dhokra craft

source:http://handicrafts.nic.in/pdf/list_of_craft_registred_under_geographical_indication_handicraftsnew.pdf, February 2024

Moradabad Metal Craft

Moradabad, a city in the northern Indian state of Uttar Pradesh, is renowned for its brass craftsmanship. It is often referred to as the "Brass City" or "Peetal Nagri" due to its significant contribution to the production of brass items. Brass craft in Moradabad is primarily created using sand casting techniques, although metal sheet - forming methods are also employed. The city is famous for its wide range of brass home goods, which include items such as utensils, decor, and other practical items. These brass crafts are often adorned with intricate natural motifs, showcasing the artistry and attention to detail of Moradabad's artisans.

Figure 2.5: Moradabad brass craft
source:https://dsource.in/sites/default/files/resource/brass-work-moradabad/downloads/file/brass-work.pdf February 2024

Jaipur Metal Craft

Jaipur, the capital of Rajasthan, has a long history as a centre for artisans and crafts. Metal containers have been essential household items in the region for centuries. Skilled artisans in Jaipur create these containers with intricate designs and traditional techniques, reflecting the city's rich artistic heritage. Today, Jaipur remains a prominent hub for both traditional and contemporary metalwork, offering a wide range of metal products for practical and decorative use.

Figure 2.6: Utensil product (Jaipur metal craft)
source:https://dsource.in/sites/default/files/resource/thathera-jaipur/downloads/file/thathera-jaipur.pdf February 2024

Budithi Brass Craft

Budithi metalcraft, a traditional craft in the Indian state of Andhra Pradesh, primarily employs brass as its key material. Brass is widely used to create a range of items, including traditional cooking utensils, flower pots, and planters. These brass products are known for their characteristic geometric patterns, which feature a combination of straight lines and curves. These designs result in simple yet visually striking presentations, adding to the aesthetic appeal and utility of the crafted items.

Figure 2.7: Different Range of Flower Vase (Budithi Brass Craft)

Source: https://lepakshihandicrafts.gov.in/budithi-brassware.html February 2024

Metalcraft's product line is wonderfully diverse, offering a wide range of handcrafted items.

2.2 Strategizing the Brass Metal Handicraft Industry

To effectively tailor products and marketing strategies in the brass metal handicraft industry, it is essential to understand the current market conditions, encompassing demand, competition, and industry trends. This understanding should be complemented by a thorough analysis of consumer preferences, behavior, and demographics. These insights will inform the strategies needed to cater to the specific needs and desires of the target audience, ultimately enhancing the industry's competitiveness and relevance in the market.

Product development, distribution, price, advertising, personal selling, sales promotion, packaging, and branding are all included in the market study. All of these initiatives are created to fulfil consumer demands and achieve organizational objectives[58].

2.2.1 Consumer Insights

Metal handicrafts possess distinctive features and carry profound artistic and cultural values. From ancient India to the present day, it is evident that consumer purchasing behaviour significantly shapes the dynamics of the market.

According to Export Promotion Council for Handicrafts (EPCH) data, a wide variety of Indian handicrafts are well-liked throughout the world for their patterns, hues, and primary materials.

The Global Handicraft Assessment Report highlights the rich cultural diversity across different regions of India. This diversity translates into a wide array of unique and visually distinct handicraft items. These distinct visual characteristics, stemming from ethnic diversity, contribute to heightened demand for these items in the global market. The varied cultural influences and craftsmanship techniques result in a remarkable tapestry of handicrafts that attract global attention and appreciation.

The case study examines traditional Batik handicrafts in south-western China and identifies a key challenge: the existing design methods do not adequately meet the evolving visual preferences of consumers. To address this issue, the study introduces a generative design approach for Batik patterns using shape grammar and artificial neural networks (ANN). This innovative method bridges the gap by creating diverse and personalized Batik designs, optimizing the relationship between design parameters and visual cognitive image (VCI) values. It also efficiently produces Batik patterns that align with VCI values. Notably, the research focuses on the generative design of bronze drum patterns, which carry rich ethnic and religious significance, highlighting the cultural importance of this approach. Overall, the study's objective is to better cater to the ever-changing and personalized visual cognitive needs of consumers, ensuring that batik patterns align more effectively with market demands[59].

The historical and contemporary brass handicrafts, such as Kamrupi brass, Bidri ware, Pembart, Dokra, Moradabad brass handicrafts, Jaipur brass handicrafts, and Budhiti brass handicrafts, highlight that the appeal of handicraft items in rural markets is strongly influenced by local culture, traditions, and ambiance. These factors collectively give these brass metal handicrafts a unique value, encompassing both functional and decorative pieces. India's diverse regions further enrich this diversity, each contributing distinct cultural influences and crafting traditions to the world of brass handicrafts.

The urbanized handicraft sector in Moradabad and Jaipur, particularly focusing on brass handicrafts, is illustrative of a broader trend observed in various case studies. These studies highlight that handicraft industries located in proximity to urban areas, characterized by robust supply chains and tourism connections, tend to prioritize product diversification. The strategic positioning of these industries enables them to capitalize on urban-centric advantages, including efficient supply chain logistics and access to a diverse consumer base. This strategic approach helps enhance the value of their products, enabling them to meet changing market demands and benefit from their advantageous geographical locations for ongoing growth and added value[57], [60]–[62]. The continuous improvement in the intrinsic value of these handcrafted pieces is primarily driven by factors like ongoing product innovation and a strong commitment to enhancing quality.

Figure 2.8: Value added brass products through design and finish (Source: Gupta 2012)

The findings from the field survey reveal a noteworthy initiative by an emerging young entrepreneur aimed at revitalizing a fading ancient craft. Collaborating with brass metal handicraft entrepreneurs in Assam, he has innovatively designed the "Pitoloi chair" (shown in Figure 2.9). This endeavour showcases a proactive approach to preserving and rejuvenating traditional crafts through entrepreneurial vision and collaboration within the local artisan community.

The paper introduces a framework for aiding experts in crafting high-quality products. They focus on developing knowledge tools for handling functional, procedural, and experiential knowledge. The GUITAR HERO project serves as a case study, aiming to create a knowledge-based system for craftsmen designing electric guitars with aluminium bodies—a departure from the usual wooden guitars. The project dives into innovative territory, and they've implemented an ontological representation of the electric guitar using NavEditOW, an internet-based framework for encoding, navigating, and querying ontologies in the OWL language. Figure 2.10 provides a detailed depiction of the metal guitar with specific part callouts.

These examples underscore the remarkable advancements and diversification within the realm of brass metal arts. They include innovative creations like metal guitars and brass tea sets, which not only showcase the enduring appeal of brass craftsmanship but also demonstrate the fusion of tradition and contemporary creativity in this craft[63], [64].

Figure 2.9: Collection of Pitoloi chairs (Source: Field survey)

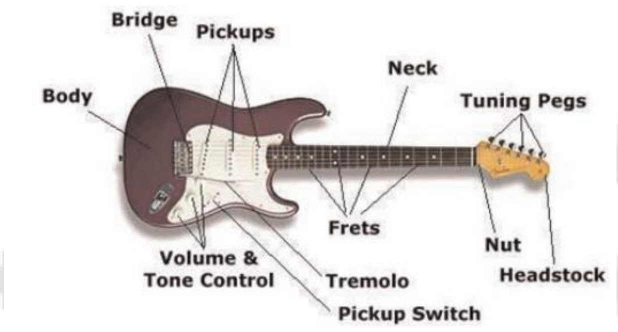


Figure 2.10: Metal electric guitar with main components (Source: S. Bandini and F. Sartori 2010)

The transformative process of translating traditional handicraft values into contemporary utensils, guided by visual references, not only addresses consumer needs but also plays a pivotal role in fostering the sustainable development of handicraft. This dynamic approach not only ensures the preservation of cultural heritage but also aligns with evolving consumer preferences, creating a harmonious synergy between tradition and modernity. By bridging the gap between heritage craftsmanship and present-day demands, this strategy contributes significantly to the longevity and relevance of traditional crafts in the context of sustainable development[65], [66].

2.2.2 Market

Export play a significant role in the economy of a country. Post-Maurya Empire, India emerged as the primary exporter of luxury items to the Roman Empire, resulting in substantial profits. The discovery of a significant number of coins from various rulers, including the Indo-Greeks, Sakas, Parthians, Kushanas, indigenous rulers, tribal republics, cities, and guilds, suggests a robust money economy and advancements in trade and commerce. This archaeological evidence indicates the pivotal role played by guilds in facilitating trade and contributing to the economic prosperity of the region. Guilds were established to

- Urbanize the infrastructure of rural handicrafts.
- Association with the King suggests a level of recognition and support from the ruling authority.
- The organization of crafts into guilds led to a higher degree of specialization within various industries. This specialization contributed to the growth and refinement of crafts, enhancing the expertise of individual artisans in their respective domains.
- Under the Mauryan Empire period demonstrated a balance of state regulations and facilitation of economic activities, with infrastructure development, financial support for guilds, and a nuanced taxation system. The Mauryan state played a pivotal role in shaping the economic landscape, and the 'Arthashastra' provided a comprehensive guide for governance and economic administration.

It is identified that the urbanization of rural handicrafts plays a significant role in enhancing global connectivity. The market categories are: the global market, the urban market, and the rural market. Each of these categories likely represents distinct consumer segments with specific characteristics and preferences. Understanding and targeting these markets can be crucial for developing effective marketing strategies and tailoring products or services to meet the needs of each market segment[67].

Today, the Export Promotion Council for Handicrafts (EPCH) of India plays a pivotal role by furnishing crucial export data that unveils a panoramic view of the global handicraft market. This comprehensive dataset not only signifies the international demand for Indian handicrafts but also illuminates the diverse preferences and trends observed in different countries. Anticipating the global demand trends for 2025, Table 2.1 outlines the import patterns of metal handicrafts across different global regions [68].

Table 2.1: Global Regional Import Trends of metal handicraft

Countries	HS Code	Product
USA	970500	Animal figures - 97050010
	741999	Articles of brass - 74199930
	392310	Boxes - gift - 39231020
	970300	Sculptures - 97030010
	940510	Chandliers - 94051010
EU	741999	Articles of brass - 74199930
	970500	Animal figures - 97050010
	420231	Jewellery boxes - 42023110
Japan	741999	Articles of brass - 74199930
	960899	Holders - 96089910
	970500	Animal figures - 97050010
	392310	Boxes - gift - 39231020
	940510	Chandliers - 94051010
Latin America	741999	Articles of brass - 74199930
	392310	Boxes - gift - 39231020
CIS	741999	Articles of brass - 74199930
	940510	Chandliers - 94051010
	392310	Boxes - gift - 39231020
Australia	392310	Boxes - gift - 39231020
	420231	Jewellery boxes - 42023110
ASEAN	741999	Articles of brass - 74199930
	392310	Boxes - gift - 39231020
	940510	Chandliers - 94051010
	420231	Jewellery boxes - 42023110

Table 2.2: Global Import Trends of Metal-Based Household Articles by Region and Country

Region	Country(ies)	Import Trends
USA	-	High demand for aluminum-made table and kitchen articles, pot scourers, polishing pads, gloves (HS code 761510).
EU	Germany, Netherlands	Increasing interest in copper-based kitchenware and tableware articles (HS code 741810).
France	-	Growing preference for copper-based items in modern kitchens; Increasing demand for metal photograph frames and mirrors (HS code 830630).
Germany	-	Usage of manual doorbells in major shops.
LAC Region	Ecuador, Chile, Mexico, Brazil	Growing demand for copper kitchenware and metal photograph frames/mirrors (HS code 741810, 830630). Brazilian culture favors large utensils for communal cooking.
CIS Region	Kazakhstan, Russia, Azerbaijan	Increasing demand for copper kitchenware and metal photograph frames/mirrors (HS code 741810, 830630). Promotion of copper utensils for cardiovascular health benefits.
Japan	-	Gong is integral to Japanese culture, symbolizing good luck.
Africa	Nigeria, Mauritius, South Africa, Uganda	Rising demand for copper kitchenware and metal photograph frames/mirrors (HS code 741810, 830630). Potential for animal-shaped cutlery due to a preference for animal designs.
ASEAN Region	Thailand, Philippines, Indonesia	Increasing demand for copper kitchenware and metal photograph frames/mirrors (HS code 741810, 830630) in Thailand.

The provided information offers valuable insights into the market dynamics of copper-based brass metal articles, highlighting not only the existing demand but also the potential market opportunities in diverse regions. This analysis takes into account the influence of cultural preferences, providing a comprehensive understanding of the global landscape for these metal articles and revealing prospects for market expansion.

Domestic and international fairs serve as pivotal platforms that facilitate the seamless connection of businesses to the global market. These events play a crucial role in fostering economic growth, promoting cross-border trade, and creating opportunities for businesses to expand their reach beyond national boundaries.

Tourism also serves as a significant catalyst for global market connectivity by revitalizing local artisan handicrafts through a harmonious blend of tradition and innovation. Beyond the realm of domestic and international fairs, the tourism industry plays a crucial role in promoting economic growth and cultural exchange. Travellers explore diverse destinations, they often seek authentic, locally crafted souvenirs, providing a unique market for traditional artisan products. This demand not only preserves cultural heritage but also encourages artisans to infuse innovation into their craft, creating products that resonate with both tradition and contemporary tastes. In essence, tourism emerges as a powerful force, fostering global market connections and supporting the sustainability of local artisan economies. This fusion has given rise to a diverse array of high-quality, culturally significant products that appeal to tourists and uplift local communities[56], [69].

The artisan sector thrives on a high degree of decentralization, with most artisans choosing independent work over formal collectives. While this autonomy allows for creative freedom, it also poses challenges in terms of efficiency and production capacity. The absence of formal structures impacts individual costs, leading to challenges in managing raw materials, transportation, and ancillary activities. In essence, the sector's decentralized nature fosters creativity but presents hurdles to optimizing operations and costs[43]. The poor infrastructure make it challenging for rural craftsmen to sell their products to consumers worldwide. Moradabad (Uttar Pradesh), Bidar (Karnataka), Jaipur (Rajasthan), and Balakati (Odisha) boast well-established tourism supply chains, vital for their economies. These regions leverage cultural, historical, or artisanal attractions to attract tourists, with robust supply chains ensuring the promotion and export of local products. Moradabad's brassware, Bidar's historical sites, Jaipur's traditional crafts, and Balakati's cultural and natural assets contribute significantly to their respective exports through thriving tourism industries. Sustainable development and ontology-based multi-agent systems have been implemented to enhance the supply chain of the handicraft sectors[70]–[72]. Tourism integration in villages creates opportunities for rural handicraft retailing, but limited resources hinder village artisans from reaching global consumers. Research conducted in Kerala, India, focuses on understanding the challenges faced by rural craft cooperatives in selecting retail channels. The findings emphasize that cooperatives with exclusive retail channels can establish sustainable market relationships for rural artisans[73].

The study in rural Iran shows that with the right support and infrastructure, e-marketing can succeed in less developed rural areas, benefiting smallholder villagers. By combining the Theory of Planned Behavior with Rural Economy Geography, the Geographic Model of Planned Behavior (GeoTPB) was developed. Notably, this model accurately predicted the intention of 76% of villagers to adopt e-marketing. There is a significant opportunity to promote e-marketing in rural area [74].

In India, the lack of education among artisans in cottage industries contributes to a limited awareness of market dynamics and available resources. These industries typically rely on seasonal demand orders initiated by middlemen (Mahajans), often tied to customs and rituals. The continued existence of traditional handicrafts relies on their capacity to balance the preservation of heritage with adaptation to contemporary market dynamics[75]–[77]. A significant number of Indian villagers depend on cottage industries as their main livelihood source. While craftspersons possess valuable skills and creativity, the handicrafts sector requires strategic planning to overcome challenges, tap into opportunities, and ensure sustainable growth [78], [79].

The study focuses on Cappadocia, Turkey, to understand how tourism integration affects rural livelihoods. Using the Sustainable Livelihoods Approach (SLA) framework, the research delves into the perspectives of those incorporating tourism into their livelihoods, revealing substantial impacts on local communities. To foster sustainability, the recommendations emphasize supporting small local businesses, increasing overnight stays by promoting Cappadocia as a premier tourist destination, preventing fraud in local crafts and souvenir shops, and implementing protective legislation to address environmental concerns related to traffic, shops, balloons, and hydroelectric power plants [80]. The PRA (Participatory Rural Appraisal) tool is suggested for tourism research and is not confined to rural or small-sized communities. Researchers are encouraged to explore the potential application of the PRA tool in larger, urban, and complex communities as well [81]. C. Chanjief et al. propose a methodology for conducting a Technical Need Assessment (TNA) targeted at the traditional brass sector with the aim of enhancing production. The primary objective of the TNA is to provide a comprehensive overview of the entire supply chain. While the assessment predominantly concentrates on the design and production processes, its broader scope encompasses gaining insights into the intricacies of the complete supply chain[82].

2.2.3 Key Insights

Here's a summary (Table2.3), provides a concise and rephrased overview of the key insights from the passage on strategizing the brass metal handicraft industry.

Table2.3: Strategic Insights in Brass Metal Handicraft Industry

Insights	Key Points
Market Understanding	- Understanding current market conditions is crucial for effective product and marketing strategies. - Consumer insights, including preferences, behaviour, and demographics, inform strategies for industry competitiveness.
Consumer Insights	- Metal handicrafts, especially brass items, have distinctive features and cultural values. - Diverse cultural influences in India contribute to a wide array of unique handicraft items.
Innovation in Design	- Case study on Batik handicrafts highlights the importance of adapting design methods to meet evolving consumer preferences. - Generative design approaches, using shape grammar and artificial neural networks, showcase innovation in creating diverse and personalized designs.
Diversity in Brass Handicrafts	- Various brass handicrafts from different regions in India reflect local culture, traditions, and ambiance. - Items like Kamrupi brass, Bidri ware, Pembart, Dokra, Moradabad Brass handicrafts, Jaipur brass Handicraft, and Budhiti brass handicrafts contribute to unique values as both functional and decorative pieces.
Urbanization and Product Diversification	- Urbanized handicraft sectors, particularly in Moradabad and Jaipur, prioritize product diversification. - Proximity to urban areas enables efficient supply chains, tourism connections, and access to diverse consumer bases for ongoing growth and added value.
Entrepreneurial Initiatives	- Collaboration between a young entrepreneur and brass metal handicraft entrepreneurs in Assam to design the "Pitoloi chair" showcases a proactive approach to preserving and rejuvenating traditional crafts.

Table2.3 Part2: Strategic Insights in Brass Metal Handicraft Industry

Integration of Technology	- Projects like the GUITAR HERO project highlight the integration of technology in traditional craftsmanship. - Use of ontological representation and innovative approaches contributes to advancements and diversification within the brass metal arts.
Global Market Trends	- Analysis of global import trends provide insights into the demand for metal-based household articles in different regions. - Cultural preferences influence the demand for specific items, crucial for market expansion.
Tourism and Market Connectivity	- Domestic and international fairs, as well as tourism, play crucial roles in connecting businesses to the global market. - Tourism serves as a catalyst for revitalizing local artisan handicrafts and creating opportunities for market expansion through the sale of authentic souvenirs.
Challenges and Opportunities in Rural Areas	- Challenges faced by rural artisans include limited awareness of market dynamics and the absence of formal structures. - Opportunities exist for promoting e-marketing in less developed rural areas, benefiting smallholder villagers.
Sustainable Development	- The fusion of traditional handicraft values into contemporary utensils, guided by visual references, contributes to sustainable development. - Balancing the preservation of cultural heritage with the adaptation to evolving consumer preferences is emphasized.
Market Categories	- Introduction of market categories, including the global market, urban market, and rural market. - Understanding and targeting these markets are crucial for developing effective marketing strategies.
Role of Guilds in History	- Historical evidence suggests the pivotal role played by guilds in facilitating trade and contributing to the economic prosperity of regions. - Guilds were established to urbanize the infrastructure of rural handicrafts, leading to specialization, growth, and refinement of crafts.

These insights collectively provide a comprehensive overview of the brass metal handicraft industry, addressing market dynamics, consumer behavior, innovation, and the role of various factors in shaping the industry's present and future.

2.3 Brass Metal Handicraft Development

Indian Metal Handicrafts are often deeply rooted in cultural traditions and heritage. The preservation and promotion of cultural identity can be a significant factor in handicraft product development. The tradition of using brass, bronze, and copper metals in India dates back centuries, positioning the country as the world's largest producer of brass. The antique qualities and the versatile nature of brass, blending seamlessly with other craft products, contribute to its high demand. Brass is utilized in crafting both functional utensils and ornamental items, showcasing its adaptability and significance in Indian craftsmanship.

Examining rural decorative brass handicraft products reveals a diverse range, including statues depicting gods, people, animals, birds, and other culturally significant items. This showcases the intricate world of miniature art, emphasizing its potential to play a significant role in the design of souvenirs. The richness and variety of these brass handicrafts offer ample opportunities for creating unique and culturally resonant souvenir designs. Tables 1.2, 1.3, and 1.4 in Chapter 1 mention that India has metal craft production centres for brass metalware, metal image folk, and metal image classic. The process of creating brass products involves shaping, molding, and finishing the alloy into the desired form, whether it be utensils, decorative items, or other crafted products.

2.3.1 Raw Material

The raw material for brass products is primarily brass, which is an alloy of copper and zinc. The proportions of copper and zinc can vary, resulting in different types of brass with varying properties. The alloying process involves melting copper and adding the appropriate amount of zinc to achieve the desired composition. Other elements may also be added to enhance specific characteristics, such as lead for improved machinability or tin for added corrosion resistance.

In the realm of brass handicraft, it is notable that artisans employ casting and cold working processes to bring their creations to life. The brass varieties suitable for both casting and cold-forming processes are provided in Table2.4.

Table 2.4: Brasses for Cold Working [83]

Compositional Designation and EN number	Nearest Equivalent Old British Standard Alloy	Relevant Properties
CuZn30 CW505L	CZ106	Excellent cold ductility. In sheet form can be used for deep drawing. As wire, suitable for the most severe cold deformation.
CuZn37 CW508L	CZ108	Known as 'Common Brass', this is a good general purpose alloy suitable for simple forming.
CuZn10 CW501L	CZ101	Gilding metal with highest copper content. Very good corrosion resistance. Can be brazed and enamelled.
CuZn15 CW502L	CZ102	Similar to CW501L with slightly superior mechanical properties.
CuZn20 CW503L	CZ103	Further improvement in mechanical properties. Corrosion resistance not quite so good as CW501L. Good for deep drawing.
CuZn20Al2As CW703R	CZ110	Aluminium brass, common in tube form. Has excellent corrosion resistance. Used particularly for applications in clean seawater.

The cold-working brasses are used to produce sheet metal, strips, foils, wires, and tubes. Highly ductile single-phase alpha alloys like CW505L (Cartridge Brass) with their high copper content are preferred for deep drawing. For simpler forming needs, economical options include CW507L or CW508L.

Gilding metals such as CW501L, CW502L, and CW503L are known for their excellent ductility, strength, and corrosion resistance. They find frequent use in decorative architectural applications and costume jewelry. Specialized aluminium or arsenical brasses are available for enhanced corrosion resistance, with applications including condenser tubes for brackish or seawater environments. The diverse range of brass alloys caters to a variety of applications, considering factors such as ductility, strength, and corrosion resistance.

Table2.5: Brasses for Casting [83]

Compositional Designation and EN number	**Nearest Equivalent Old British Standard Alloy**	**Relevant Properties**
CuZn33Pb2-C CC750S	SCB3	General purpose sand castings. Moderate strength and good corrosion resistance.
CuZn39Pb1Al-C CC754S	DCB3	This is the most commonly supplied die casting brass. A fine grained version is available.
CuZn35Pb2Al-C CC752S	DZR1	This and CC751S (DZR2) have properties similar to CC754S (DCB3) but can be heat-treated to give resistance to dezincification.
CuZn33Pb2Si-C CC751S	DZR2	See remarks for CC752S (DZR1).
CuZn35Mn2Al1Fe1-C CC765S	HTB1	Alloy has good strength and toughness and good corrosion resistance. Sand casting is employed for most purposes, but die castings can also be produced and these will have superior mechanical properties.
CuZn25Al5Mn4Fe3-C CC762S	HTB3	This alloy is the nearest equivalent to the British Standard CC762S (HTB3) but there are many differences. Neither alloy should be used for marine conditions. They have higher strength than CC765S (HTB1).

The casting process excels in producing complex shapes, serving diverse needs from critical components like pipeline valves to ornamental applications, emphasizing superior surface finish and extended service life.

Tailored alloys for different casting processes offer a balanced combination of fluidity during pouring and hot strength to prevent hot tearing during solidification. Manganese is a useful deoxidant, and die-casting often utilizes 60/40 type alloys for lower casting temperatures and essential hot ductility. Small additions of silicon or tin improve fluidity and corrosion resistance. Aluminum is added to form a protective oxide film, keeping the molten metal clean. Controlled compositions, including aluminum, are used for dezincification-resistant castings. High - tensile brasses, like CC7655 (HTB1), find application in both sand casting and gravity die-casting for increased strength [83].

Assam brass handicraft utilizes CuZn15, specifically CW502L, as a primary raw material. CW502L is a brass alloy with a copper content of approximately 85%, providing a well-balanced combination of copper and zinc suitable for various brass handicraft applications. The specific composition of CW502L makes it a favoured choice, likely due to its desirable properties such as ductility, corrosion resistance, and suitability for crafting intricate designs. Also, in brass manufacturing, artisans strategically utilize brass alongside main alloy components, emphasizing sustainability through the incorporation of recycled brass scrap. This practice not only reduces environmental impact but also signifies a commitment to responsible resource management. Figure 2.11 illustrates brass raw material producers in India. The primary energy source used in the manufacturing of brass parts in the mentioned brass cluster is coal. Coal is a traditional and widely used energy source in various industrial processes, including metal manufacturing. It is often employed for its affordability and the high energy content it provides during combustion [84].

Figure 2.11: Brass (as raw material) manufacturer in India

2.3.2 Manufacturing Process

In brass metal manufacturing, forming and casting are indeed two major processes that play a crucial role in shaping the final products. Both forming and casting processes are integral to the versatility and variety of brass products in industries ranging from art and crafts to engineering and construction. The choice between these processes depends on factors such as the desired product, complexity, and the characteristics required for the final brass component. Forming is typically used for producing sheet metal, wires, and other shapes without melting the brass entirely. Casting is employed when intricate and complex shapes are required, allowing for the creation of detailed and precise components.

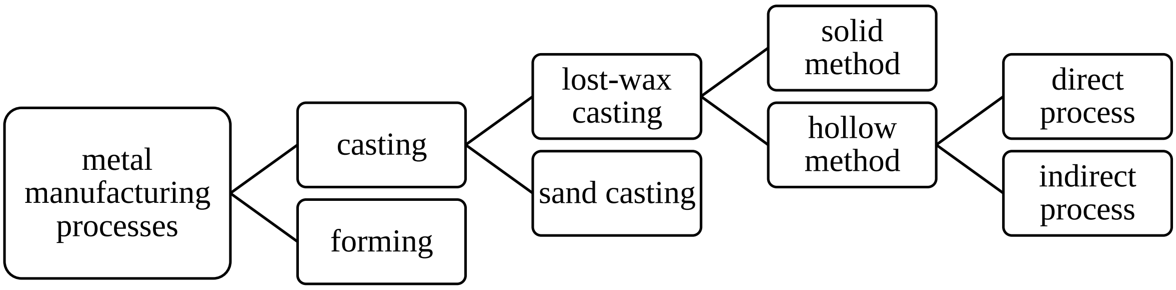


Figure 2.12: Manufacturing process involve in Metal handicraft industries

The casting production process, where a liquid substance, typically molten metal such as brass, is poured into a mould with a hollow chamber. Once poured, the molten metal fills the mold's cavity and takes on its shape. The next step involves allowing the molten metal to cool and solidify, eventually hardening into the desired form within the mold.

Lost-wax casting solid method

A wax model, which is a copy of the final result, is made in the first step. The mould is then created around the wax model. The wax figure is painted with a white clay solution to highlight its sheer features. Air that was released during the casting process has a path provided for it. The mould is then covered in clay, sand, and rice husk. It completely encircles the artwork. The mould becomes thicker as a result. For the purpose of pouring the metal without spilling it, tiny cup-like reservoirs have created. The casting procedure comes next. After melting, the metal is put into the mould. The product's finishing process is the last step.

Lost-wax hollow Casting Method

In this technique, casting in a mould is done by coating the mold's walls with layers of sculpting material rather than by completely filling the mould as in solid casting. As shown in Figures 2.13 and 2.14, there are two hollow casting techniques: the direct process and the indirect procedure.

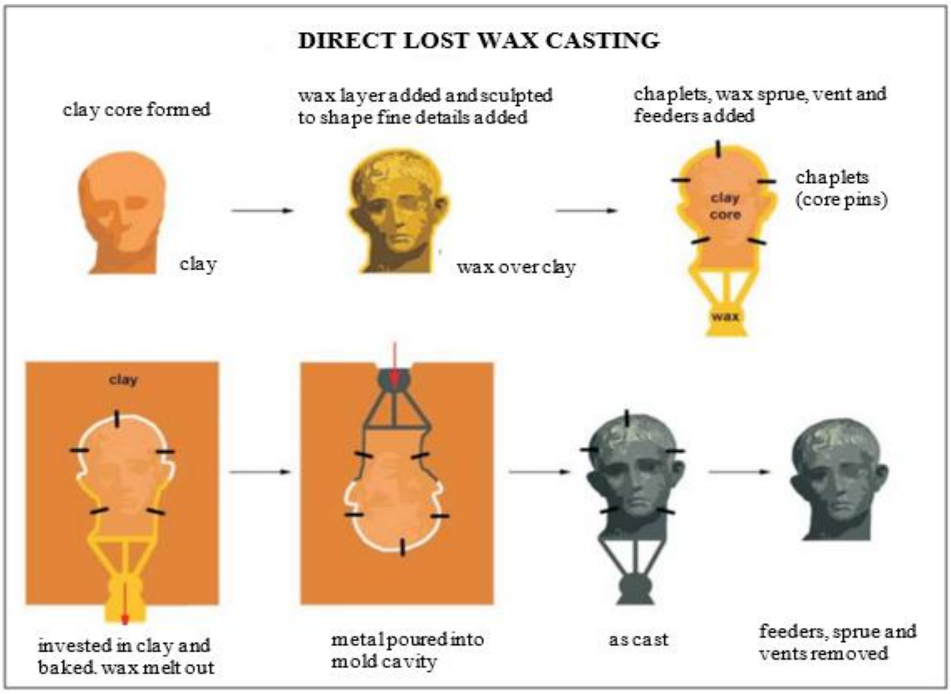


Figure 2.13: Direct hollow lost wax casting process (Source: P. Craddock, 2015)

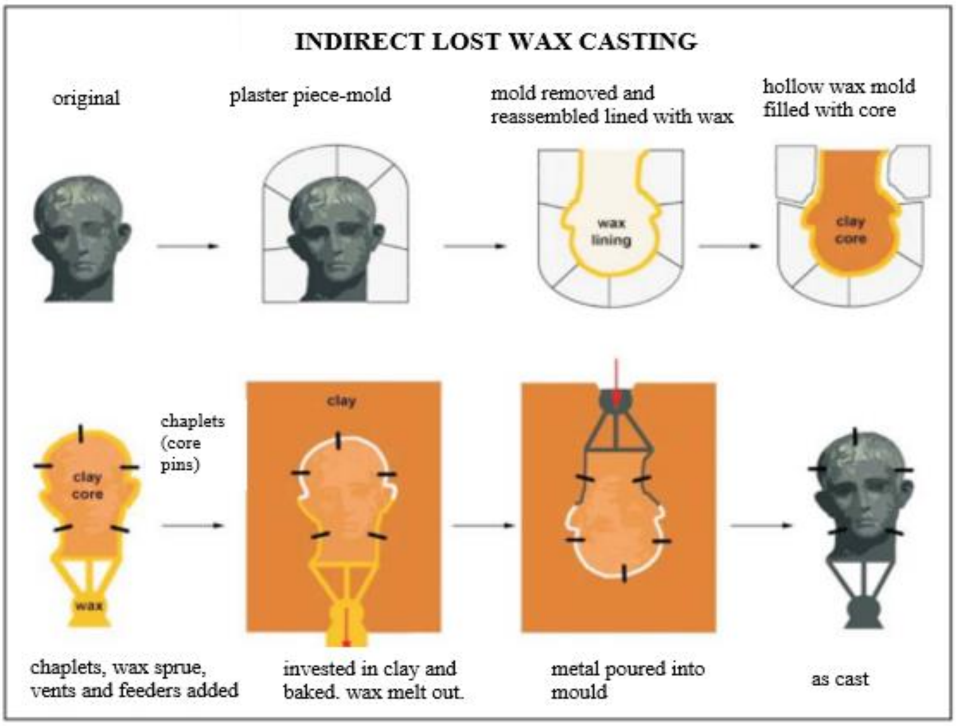


Figure 2.14: Indirect hollow lost wax casting process (source: P. Craddock, 2015)

Sand Casting

A mould cavity is first created using a plaster mould template. Very thin, cohesive sand with a small amount of clay is used to create the mould cavity. Then take the mould design out of the sand. It's time to pour the molten metal into the cavity of the mould now. Remove the casting by separating the sand mould [62], [85].

Forming

The material is deformed plastically throughout the production process of forming to adopt the geometry of the die. To achieve the form, the shape of brass metal sheets is pounded over a die with a variety of hammers. Tools for surface polishing and finishing are employed in addition to these [42].

2.3.3 Tools and Technology

The list of tools provided indicates a comprehensive set of instruments used in the traditional handicraft process for making metal crafts, particularly those involving brass. Here's a breakdown of the tools mentioned and their respective roles:

Hammer and Wooden Mallet: Used for shaping and forming the brass sheets by applying controlled force.

Metal Ring, Solid Metal Stand, Chisel: Chisels are employed for carving, cutting, or detailing the brass material. The metal ring and stand provide support during these processes.

Metal Scissors, Files: Utilized for cutting and shaping brass sheets with precision. Files are essential for refining the edges, surfaces, and details of the brass components.

Compass: Helps in measuring and marking accurate dimensions on the brass sheets.

Saw: Used for cutting brass sheets into specific shapes or sizes.

Grinding Machine: A grinding machine is employed for smoothing and shaping the surfaces of the brass components.

Buffing Machine: Buffing equipment is crucial for achieving a polished and finished appearance on the brass surface.

Welding Machine: Used for joining or assembling multiple brass pieces through welding.

Iron Pincers: Pincers assist in holding and manipulating the brass material during various stages of the crafting process.

Gas Torch Burners: Gas torch burners are employed for heating specific areas of the brass sheets, facilitating shaping and forming. These tools collectively contribute to the intricate and skilled process of forming, shaping, and finishing brass sheets to create beautifully crafted metal objects in the traditional handicraft style. Cottage industries are found all over the world and rely on conventional technologies. Aside from preserving traditional technology, technological intervention could indirectly lead to a more productive production process and varied design techniques [86]–[88].

2.3.4 Innovations and Contemporary Practices

The ancient lost wax and sand casting techniques continue to serve as the foundational methods for contemporary metal handcraft creation. Despite the advancement of technology, these traditional techniques persist due to their historical significance, versatility, and unique characteristics they impart to metalwork. It introduces the modern technology of investment casting, a refined version of lost wax casting, as depicted in Figure 2.15. In this advanced method, state-of-the-art waxes, refractory materials, and specialty alloys are utilized to ensure the production of high-quality components. The process offers key benefits such as accuracy, reproducibility, flexibility, and integrity. This integration of traditional foundations with modern technologies illustrates the evolution and adaptability of metal crafting techniques over time.

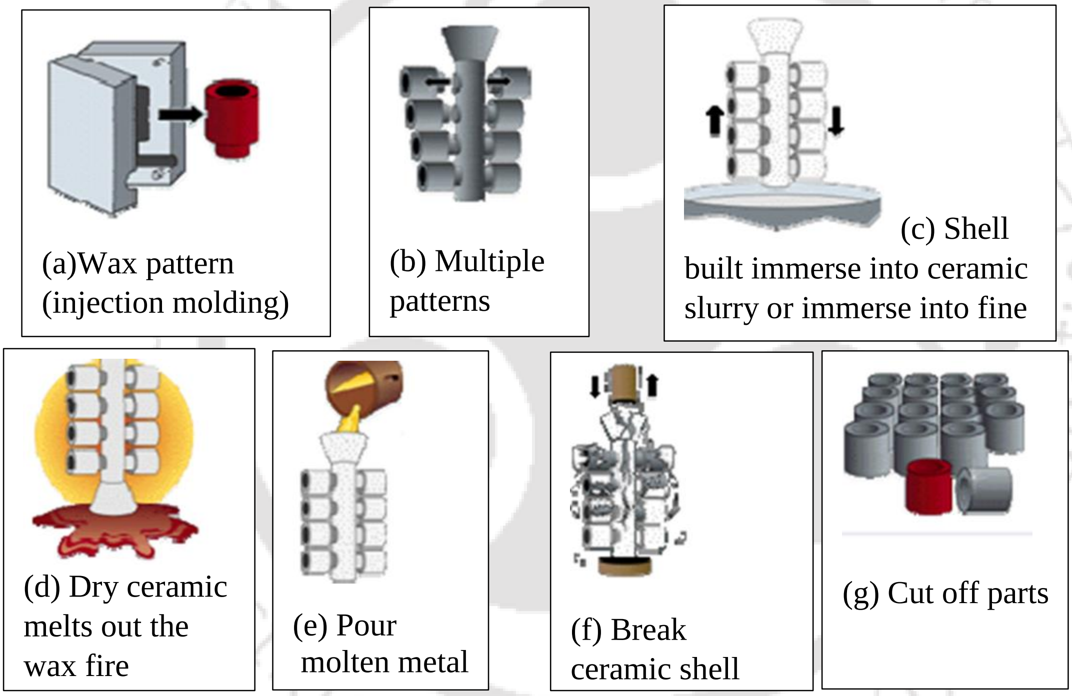


Figure 2.15: Investment casting (lost wax casting) used in industrial manufacturing (source: https://www.iitism.ac.in/~vivek/courses/MP/castings.pdf)

Iron Age technologies, such as the potter's wheel and the wood pole lathe, laid the foundation for advancements in craftsmanship. The link between the ancient wood pole lathe and its modern counterpart exemplifies the continuity and development of technology across different historical periods.

Potter's Wheel: The potter's wheel revolutionized pottery-making during the Iron Age. It allowed artisans to efficiently shape and form clay into vessels. The rotational movement enabled the creation of symmetrical and finely crafted pottery, showcasing advancements in precision and design for that era [89].

Wood Pole Lathe: The wood pole lathe, another notable Iron Age technology, was used for woodworking. It involved a reciprocating motion driven by a flexible pole, providing a method for turning wood. Craftsmen could use this lathe for various woodworking tasks, including shaping, carving, and creating cylindrical objects. The connection between ancient and modern technology is particularly evident in the evolution of the lathe.

Wood Pole Lathe and Modern Lathe Machine: The wood pole lathe served as a precursor to the modern lathe machine used in manufacturing and machining today. The fundamental principle of rotational motion and cutting remains, but modern lathes are powered by electricity or other energy sources, offering increased speed, precision, and efficiency [90].

Lathe is part of the broader category of machining processes, which entail removing material from a workpiece to attain the desired shape. These processes include milling, turning, and drilling. CNC (Computer Numerical Control) machining is a sophisticated form of automated machining, where computer programmes precisely control the manufacturing of intricate parts. Additionally, additive manufacturing (3D Printing) constructs objects layer by layer from digital models, enabling the creation of complex and customized designs.

Numerous clusters focus on metal forming procedures, utilizing force, often applied with a hammer, to shape metal sheets under specific conditions. Through these processes, the metal sheet undergoes alterations in both shape and size.

Additionally, the industry employs a variety of advanced metal sheet forming techniques, as illustrated in Figure 2.16. This depiction highlights the diverse options available, showcasing variations in geometry (shape and size) as well as surface finish achieved through these advanced methods. Also, the significance of carefully choosing the right metal forming method to attain desired outcomes, encompasses both the physical attributes and surface quality of the metal product.

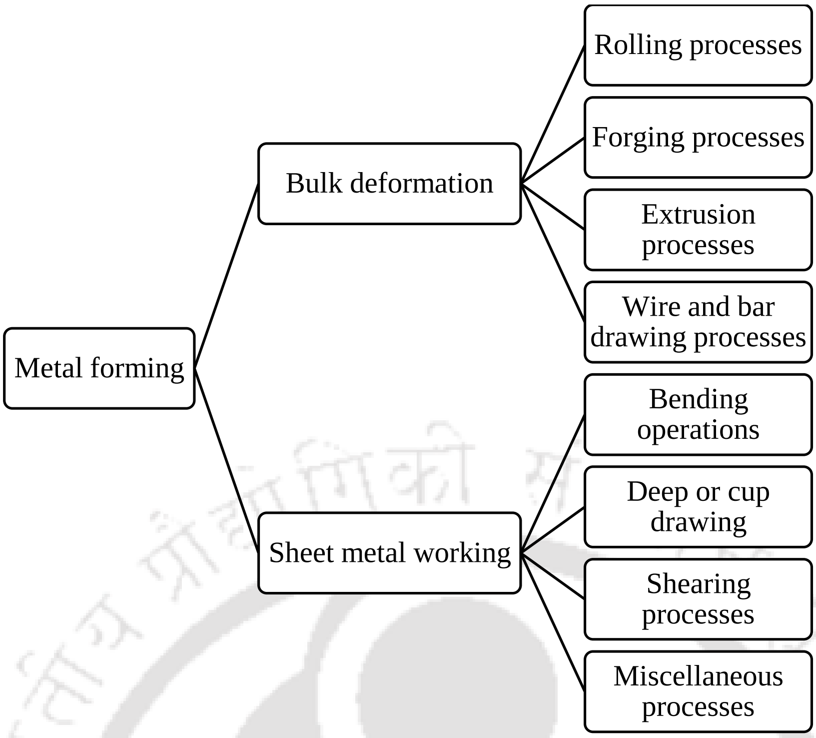


Figure 2.16: Classification of metal forming process

The Moradabad cluster has integrated a multitude of design innovations into its manufacturing process, incorporating techniques such as electroplating, moulding tools, carving, and polishing [46][47].

Handmade practices are crucial for cultural diversity and technological tradition. However, the influence of mechanical design and development ideas can guide craftsmen in enhancing production technology. The study centres on the Japanese traditional 'Kana-ami' technique, a handmade metal wire network. Similar to other traditional handmade industries, 'Kana-ami' workshops have dwindled due to social industrialization. The research, featuring an expert and a non-expert, employs industry-computed tomography to measure their products. The analysis highlights the expert's superior skill, particularly in minimizing damage to the metal wires' surface. This underscores the study's emphasis on preserving traditional craftsmanship in the context of industrial changes [91].The key factors influencing the production section include fundamental support, manufacturing prospects, information diffusion, procurement procedures, and additional obstructions. Together, these factors contribute to establishing a foundational framework for crafting products and enhancing their competitiveness in the market [92].

Beyond manufacturing tools and techniques, the effectiveness of 3D visualization technology is utilized to faithfully recreate real-life package designs seamlessly incorporated into handicraft. This integration yields a comprehensive and visually captivating virtual package experience, emphasizing the intersection of technology and craftsmanship [93]. AI is recognized for providing diverse avenues to express creativity in the realm of arts and crafts, contributing to the development of new cultural forms and fostering innovative methods and thinking [94].

Handicrafts, rooted in manual techniques reflecting cultural aesthetics, have undergone a dynamic transformation in contemporary practices. Artisans seamlessly blend traditional craftsmanship with innovative designs, materials, and techniques, creating unique and marketable products (Section 2.1). The shift from the traditional hand-pitcher method to the adoption of the pottery wheel and casting processes in pottery represents a tangible evolution [88]. Historical evidence, including artefacts and records, demonstrates how artisans seamlessly incorporated these modern techniques while preserving the essence of their craft. This transition highlights the adaptability of artisanal traditions to contemporary opportunities, offering a harmonious blend of traditional craftsmanship and innovative methods. The integration of the pottery wheel and casting processes serves as a testament to artisans' willingness to embrace new tools, ensuring the continued relevance and vitality of pottery in both traditional and modern contexts.

2.3.5 Skills and Trainings

The strategic importance lies in adapting handicraft production to meet global export demands by providing training that cultivates knowledgeable entrepreneurs in the sector. This approach ensures that individuals are equipped with the skills and understanding of international markets, facilitating the growth and success of handicraft businesses on a global scale. The training includes the manufacture of new products, branding, displays, pricing, negotiations, delivery methods, the completeness of export documents, and promoting handicraft products at the International Craft Exhibition [95].

The skilled artisans in the village demonstrate a tradition of creating numerous useful and unique handicrafts. This expertise is not only valuable in itself but is also passed down through generations. The artisans ensure the continuity of their craft by imparting their knowledge to their children, who, in turn, become the successors in the craft. This intergenerational transmission ensures the preservation and perpetuation of the handicraft tradition, highlighting the cultural and familial significance of the artisanal skills within the community.

Training is portrayed as a catalyst for positive development across various dimensions, contributing significantly to an individual's professional growth. The evaluation of an individual's performance involves assessing the impact on their skills, economic contributions, and overall effectiveness in the workplace over a specific timeframe[96]. The tourism market significantly contributes to the economy. Also, a positive inclination towards incorporating online marketing strategies into handicraft business management in the future There is a growing interest in acquiring digital marketing skills and training to improve tourism market access, both domestically and internationally [97].

2.3.6 Key Insights

Below are essential findings regarding the development of brass metal handicrafts as presented in Table2.6.

Table 2.6 Part1: Key insights of brass metal handicrafts development

Aspect	**Key Insights**
Cultural Significance	Metal handicrafts in India are deeply rooted in cultural traditions and heritage. The preservation and promotion of cultural identity play a significant role in the development of handicraft products.
Material and Production	Brass, being a versatile material, is widely used in metal handicrafts. India is the world's largest producer of brass. The manufacturing process involves shaping, molding, and finishing brass alloy into various forms, such as utensils, decorative items, and more.
Raw Materials	Brass products primarily use an alloy of copper and zinc. The proportions of these elements can vary, resulting in different types of brass with varying properties. Other elements like lead or tin may be added for specific characteristics.
Brass Alloys	Different brass alloys are used for various applications. Some are suitable for cold working processes, while others are used for casting. The choice of alloy depends on factors such as ductility, strength, and corrosion resistance.
Manufacturing Processes	The manufacturing process involves forming and casting. Forming is used for producing sheet metal and wires without melting the brass entirely, while casting is employed for intricate and complex shapes.
Traditional Techniques	Traditional techniques such as lost-wax casting and sand casting continue to be foundational methods for metal handicraft creation. The industry incorporates modern technologies, such as investment casting, highlighting its evolution.

Table 2.6 Part2: Key insights of brass metal handicrafts development

Tools and Technology	Various tools are used in the traditional handicraft process, including hammers, chisels, scissors, files, and machines for grinding and buffing. These tools contribute to the intricate and skilled process of forming and finishing brass sheets.
Innovations and Contemporary Practices	The industry combines traditional methods with contemporary innovations, such as electroplating, molding tools, carving, and polishing. The integration of 3D visualization technology and AI showcases a blend of technology and craftsmanship.
Skills and Training	Training artisans in the sector is crucial for meeting global export demands. This involves imparting knowledge about international markets, manufacturing new products, branding, pricing, and other aspects.
Cultural Transmission	Skills and expertise in metal handicrafts are often passed down through generations, ensuring the continuity of the craft. This intergenerational transmission highlights the cultural and familial significance of artisanal skills within the community.

Overall, the findings highlight the rich cultural heritage, the intricate craftsmanship involved, and the dynamic integration of traditional and modern elements in the metal handicraft industry in India.

2.4 Brass Metal Handicraft Sales

Throughout the years, exhibitions and trade fairs have emerged as significant attractions for tourists, playing a pivotal role in fostering folk migration across different territories. The public showcasing of products and services through exhibitions and trade fairs is widely acknowledged for attracting substantial investments and business opportunities. Additionally, these events serve as prominent avenues for sales promotion, offering a platform where businesses can effectively engage with potential customers and showcase their offerings to a diverse audience. The Indian Government launched the Indian Handicrafts & Gifts Fair in 1994 to promote Indian handicrafts globally and facilitate international market connections. Since its initiation, Figure 2.17 depicts a year-by-year increase in handicraft purchasing. Additionally, a graph illustrating the participation of overseas buyers consistently exhibits an upward trend, both seasonally and annually. This demonstrates the fair's success in fostering global interest in Indian handicrafts and facilitating market growth.

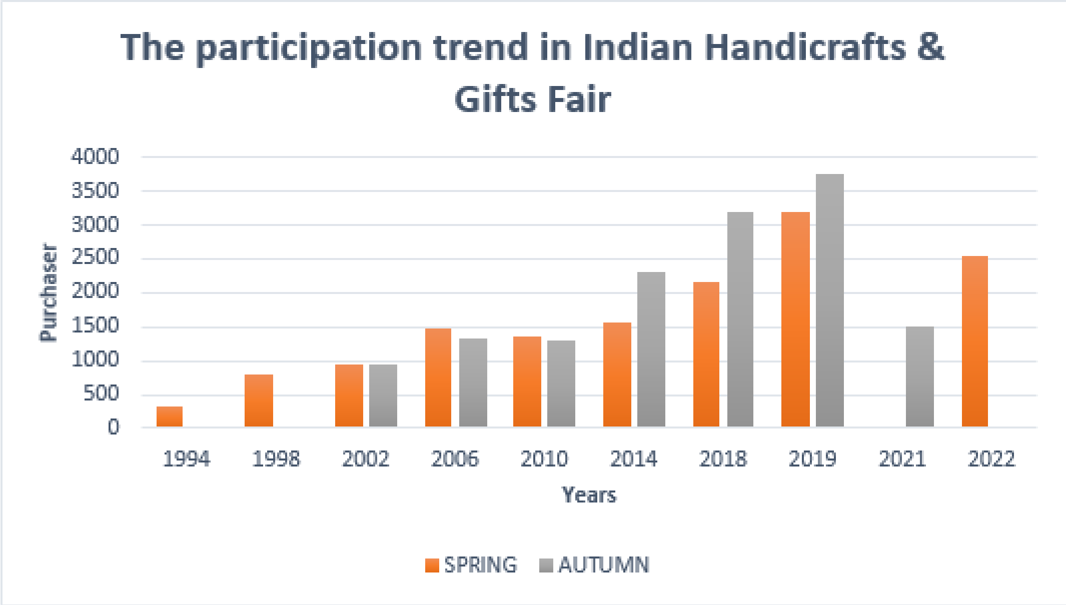


Figure 2.17 : Global buyers participation trend in Indian Handicrafts & Gifts Fair (source: Export promotion Council for Handicraft https://www.epch.in/policies/exportsofhandicrafts.htm)

The research conducted in Uttarakhand indicates that participation in handicraft exhibitions is motivated by a variety of factors, with four key elements identified: learning, maintaining awareness, purchasing, and attraction. The study goes on to classify attendees into three distinct clusters: shoppers, casual visitors, and knowledge-seekers, depending on the common characteristics observed within each group. This segmentation enhances our comprehension of the diverse motivations and preferences displayed by individuals attending handicraft exhibitions in Uttrakhand.

Souvenirs play a pervasive role in travel experiences, contributing billions of dollars annually to the global tourism economy through their production and consumption. Also, promote the handicraft. Souvenirs play a significant role in promoting handicrafts. These unique and often culturally rich items serve as tangible reminders of a particular place or experience, making them popular among tourists and visitors. Handicraft souvenirs, reflecting the local artistry and craftsmanship, contribute to the promotion of the region's cultural identity. They serve as a connection between the artisans and a global audience, showcasing the diversity and skill of local craftspeople [98].

Collaborative efforts play a crucial role in the commoditization of handicrafts, contributing to the promotion and growth of the handicraft sector. By working together, various stakeholders, such as artisans, designers, marketers, and other relevant entities, can join forces to enhance the production, marketing, and distribution of handicraft products. This collaborative approach aids in creating a market presence, increasing accessibility, and potentially boosting economic opportunities for artisans involved in the handicraft sector. It aligns with the broader goal of expanding the reach of traditional crafts and ensuring their sustainability in the market. The study focuses on the impact of Portugal's traditional costumes on the reinvention of fashion, highlighting collaborative efforts that integrate traditional craft techniques into innovative projects. This approach not only promotes Portugal's cultural identity but also aligns with the dual objectives of economic and social sustainability across diverse regions[99].

The Government of India initiated the One Station One Product (OSOP) scheme to boost the sale of handicrafts and promote "Vocal for Local." This scheme aims to support local manufacturers, providing them with a platform to sell their products and creating additional income opportunities, especially for marginalized sections of society. The focus on brass metal handicrafts presents significant potential, and the proposal is to design and promote the sale of these handicrafts through the One Station One Product scheme.

Promoting handicraft exhibitions through e-commerce media is crucial for bolstering local marketing efforts and ensuring their success. Indian handicrafts, known for their ethnic qualities, have been a significant draw for tourists. The purchase of these handicrafts as mementos not only reflects cultural appreciation but also contributes significantly to the economic landscape of India, forming a substantial part of the tourism-driven economy. E-commerce and information technology wield substantial influence in the advancement of handicrafts. These technologies play a pivotal role in shaping the interests of young students, significantly impacting their inclination to pursue entrepreneurship, particularly through online sales[100], [101].

Cost is a multifaceted factor that influences various aspects of a business's interaction with the market. It shapes pricing strategies, profitability, market positioning, and the overall ability of a business to navigate and succeed in a dynamic marketplace. The study on new product development in Small and Medium Enterprises (SMEs) emphasizes the vital importance of grasping the relationship between good/ service costs and production costs. The ultimate aim is profit optimization, and this is pursued through a comprehensive consideration of various factors that impact both costs and revenue in the process of developing new products[102].

2.4.1 Key Insights

Table 2.7 provides essential insights into the marketing and sales strategies of brass metal handicrafts.

Table 2.7: Key Insights of brass metal handicrafts sales

Insight	**Summary**
Exhibitions and Trade Fairs	Significant attractions for tourists, playing a pivotal role in fostering folk migration and attracting investments. Platforms for sales promotion and engaging with potential customers.
Indian Handicrafts & Gifts Fair Impact	Launched in 1994 by the Indian Government, showing a consistent increase in handicraft purchases and overseas buyer participation, fostering global interest in Indian handicrafts.
Motivations for Exhibition Participation	Uttrakhand research highlights four key elements motivating participation: learning, awareness, purchasing, and attraction, with attendees categorized into shoppers, casual visitors, and knowledge-seekers.
Souvenirs as Handicraft Promoters	Souvenirs contribute billions to the global tourism economy, serving as tangible reminders of a place or experience. Handicraft souvenirs reflect local artistry, connecting artisans with a global audience.
Collaborative Efforts in Handicraft Sector	Collaboration among stakeholders is crucial for the commoditization and growth of the handicraft sector, enhancing production, marketing, and distribution.
One Station One Product (OSOP) Scheme	Indian government initiative to boost handicraft sales, supporting local manufacturers and creating additional income opportunities, particularly for marginalized sections. Focus on brass metal handicrafts.
Promotion of Handicrafts through E-commerce	Leveraging e-commerce is crucial for promoting handicraft exhibitions locally. Indian handicrafts, known for ethnic qualities, significantly impact the tourism-driven economy. E-commerce and IT play pivotal roles in shaping young entrepreneurs' interests.
Cost as a Multifaceted Factor	Understanding the relationship between goods/services costs and production costs is crucial for profit optimization, especially in SMEs' new product development.

2.5 Push and Pull Motives

Tailoring survey questions based on these push and pull motives will help gather insights into the motivations and challenges faced by artisans involved in brass handicraft.

In the context of a survey on brass handicraft, "push" and "pull" motives refer to factors that either drive individuals or artisans toward engaging in brass handicraft activities (pull) or factors that might compel or push them away from such activities (push).

Pull Motives for Brass Handicraft:

a) To what extent does the artistic potential of brass motivate artisan's involvement in brass handicraft?

The artistic potential of brass can serve as a powerful motivator for involvement in brass handicraft, influencing artisans in terms of creativity, cultural expression, commercial success, personal satisfaction, innovation, and skill development. The degree to which this motivation plays a role depends on the individual artisan's values, aspirations, and the significance they attach to the artistic elements of their craft

b) How important is the preservation of cultural heritage in influencing artisan's engagement with brass handicraft?

The preservation of cultural heritage holds immense importance in influencing engagement with brass handicraft. It is not just a craft but a means of keeping traditions alive, fostering community connections, contributing to economic sustainability, and sharing the cultural richness of a community with the broader world.

c) To what extent does the potential for economic gains influence artisan's involvement in brass handicraft?

The potential for economic gains serves as a significant motivating factor for artisans' involvement in brass handicraft. While cultural and artistic considerations are often integral, the economic dimension plays a crucial role in sustaining the craft, supporting livelihoods, and contributing to the overall economic well-being of artisans and their communities.

d) How much does personal satisfaction contribute to Artisans commitment to brass handicraft?

Personal satisfaction is a powerful contributor to artisans' commitment to brass handicraft. Beyond economic considerations, the intrinsic rewards derived from the creative process, skill development, cultural connection, and positive feedback play a crucial role in sustaining an artisan's passion and dedication to their craft.

Push Motives for Brass Handicraft:

a) To what extent do economic challenges discourage artisan's involvement in brass handicraft?

Economic challenges can have a multifaceted impact on artisans involved in brass handicraft, affecting their income, market access, and overall sustainability. Addressing these challenges may require a combination of supportive policies, market interventions, and community-level initiatives to ensure the continued involvement and success of artisans in this traditional craft.

b) Does the lack of recognition for brass handicraft skills affect your enthusiasm for this craft?

Addressing the lack of recognition may involve efforts at both individual and community levels, including initiatives to raise awareness, promote cultural appreciation, and create platforms for artisans to showcase their skills. Recognition not only boosts the enthusiasm of artisans but also plays a vital role in preserving and promoting traditional crafts like brass handicraft.

c) To what degree does the fear of technological displacement influence artisan's engagement in brass handicraft?

The fear of technological displacement can have a profound impact on artisans engaged in brass handicraft, influencing their willingness to adopt modern tools, preserve traditional skills, and navigate the evolving landscape of the craft. Addressing these fears may require a thoughtful approach that considers both the preservation of cultural heritage and the potential benefits of responsible technological integration.

d) How does limited market access impact artisan's willingness to continue brass handicraft activities?

Addressing limited market access may involve initiatives such as market development, e-commerce platforms, marketing support, and community engagement. Providing artisans with opportunities to showcase their work in diverse markets can contribute to the sustained growth and continuation of brass handicraft activities.

2.6 Problems Identification

Handicraft artisans face significant hurdles stemming from an unorganized structure, educational limitations, financial constraints, technological gaps, insufficient market insights, and a deficient institutional framework. Addressing these issues is crucial for enhancing the overall well-being and success of artisans in the handicraft sector. Table 2.8 presents a comprehensive analysis highlighting various challenges identified in the brass metal handicrafts industry.

Table 2.8 Part1: Challenges in the brass metal handicrafts cottage industry

Challenges	**Impact**
Limited Market Understanding	Ineffective tailoring of products and strategies, potentially leading to reduced competitiveness.
Complex Consumer Insights	Difficulty predicting and meeting varied consumer needs, hindering the industry's ability to create targeted products.
Slow Design Innovation Adoption	Missed opportunities to align with evolving consumer preferences, risking outdated product offerings.
Limited Product Diversification in Rural Areas	Limited growth opportunities for rural artisans, hindering overall industry development.
Resistance to Technology Integration	Missed opportunities for advancements, limiting market appeal and innovation.
Limited Market Connectivity and Awareness	Reduced exposure and market access, limiting growth potential for smallholder villagers.
Struggling Sustainable Development Balance	Risk of decline in cultural significance or loss of consumer appeal.
Balancing Traditional Craftsmanship with Modern Demand	Need for adaptation without compromising the authenticity of the craft.
Resource Management and Environmental Impact	Environmental concerns and resource sustainability pose challenges to responsible manufacturing practices.
Global Market Access and Competition	Limited market access and competition hindering global growth.
Technological Integration and Skill Upgradation	Balancing traditional craftsmanship with technological innovations for industry advancement.

Table 2.8 Part2: Challenges in the brass metal handicrafts cottage industry

Cultural Preservation and Intergenerational Transmission	Risk of losing traditional skills eroding the cultural significance of handicrafts.
Tourism Market Access and Online Marketing	Limited exposure to potential customers and markets hindering industry growth.
Training Programs for Global Competence	Lack of global competence limiting the industry's ability to explore and succeed in international markets.

Artisans necessitate skills, credit, raw materials, technology, and access to markets concurrently to enhance the production of brass metal handicrafts. The interrelation of these requirements has been examined through literature reviews and field surveys, and the framework is depicted in Figure 2.18.

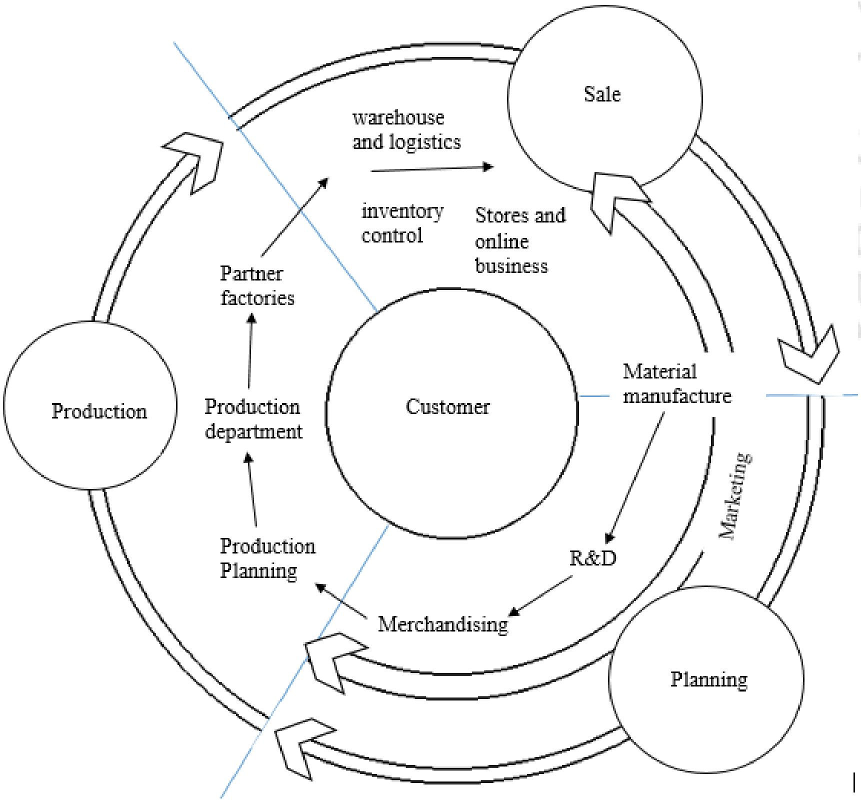


Figure 2.18: Frame work for product flow from the manufacturer to sale (source: UNIQLO Business model) https://www.fastretailing.com/eng/group/strategy/uniqlobusiness.html

2.6.1 Market Accessibility Challenges in the Handicraft Sector

Encouraging urbanization in rural handicraft sectors serves as a key driver for improving market connectivity, economic viability, and sustainable livelihoods. This can be achieved by leveraging tourism and well-established supply chain infrastructure. Handicraft enterprises, according to analysis, primarily connect to the market in two ways: direct sales through established supply chains and indirect sales facilitated by middlemen.

Direct sales through established supply chains: It involves comprehensive marketing strategies, including advertising, in-person selling, and packaging. Companies utilize exhibits, brochure distribution, and active participation in trade shows to promote their products. Sales promotion tools such as samples, premiums, coupons, displays, and effective packaging are integral to this approach. This strategy is crucial for enhancing connectivity between consumers and the handicraft industry. Cities like Delhi, Moradabad (Uttar Pradesh), Jaipur (Rajasthan), Ahmedabad (Gujarat), and Bengaluru (Karnataka) play a substantial role in contributing to market sales through well-established supply chains. The key characteristics of such successful supply chains include a commitment to good quality, product diversification, proximity to tourist centers, easy access to raw materials (as indicated in Figure 2.11), and efficient transportation facilities. These elements collectively contribute to the robustness of the supply chain and its positive impact on market dynamics.

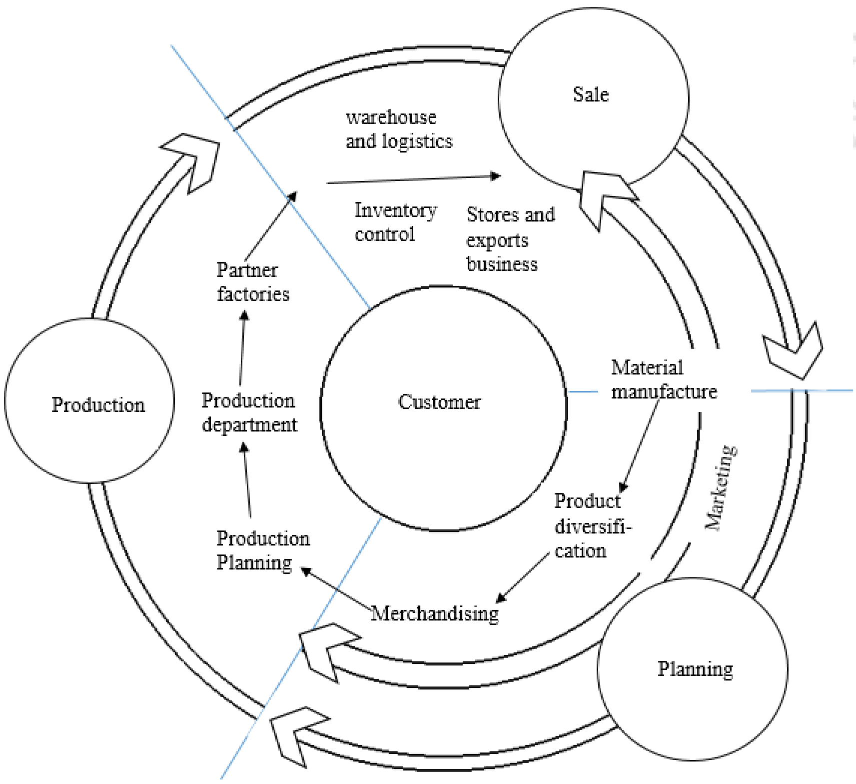


Figure2.19. Direct sale through established supply Chain

Indirect sales facilitated by middlemen

Indirect sales facilitated by middlemen involve a mediator who acts as a bridge between consumers and the handicraft sector. Typically, this intermediary is a financially sound member of the same community. Many cottage industries rely on middlemen, known as Mahajans, to facilitate sales. These middlemen play a crucial role in managing orders and providing artisans with essential resources. However, the main challenge faced by cottage industries in this context is the issue of market connectivity.

The presence of middlemen is often essential for cottage industries, especially when dealing with low-cost, well-crafted handicrafts from regions like Moradabad, Punjab, and Haryana. However, there is a notable concern that these external products are gradually infiltrating the local market. The domestic market for brass metal handicrafts is facing challenges in various states due to the absence of an effective marketing plan, underscoring the need for strategic initiatives to address this issue.

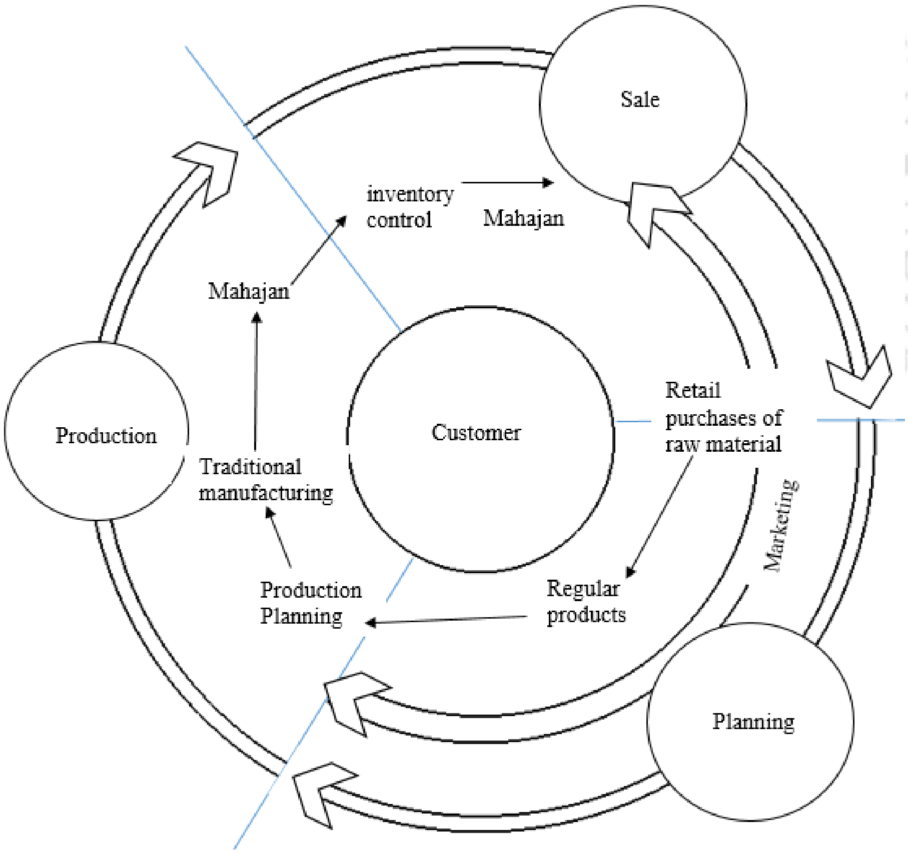


Figure2.20. Indirect sales facilitated by middlemen

2.6.2 Challenges in Expanding Product Offerings: The Issue of Product Diversification

Challenged by inadequate market connectivity, cottage industries have confined their product range to meet local demands. The nature of these demands, often rooted in cultural preferences, further restricts production to seasonal cycles. This confluence of limited market access and cultural specificity has shaped a production landscape characterized by a constrained product range and a seasonal production rhythm.

2.6.3 Challenges in Pricing Disparities: Addressing the Price Gap Issue

While well-crafted handicrafts from Moradabad, Punjab, and Haryana enjoy recognition, there's a growing concern over the gradual infiltration of these external products into the local market. The handicraft industries situated near raw material sources enjoy reduced raw material costs due to economical transportation. Production costs are further influenced by industries acquiring raw materials at retail prices rather than directly from manufacturers. Cottage industry artisans contribute to this supply chain by purchasing basic materials from middlemen, which increases the cost of raw materials.

The competitiveness of a business in the market is intricately linked to the cost of its crafts or products. Establishing manufacturing tools or processes involves considering various factors, including the cost of raw materials, crafting processes, as well as the expenses associated with order management and delivery. The examination of challenges in Assam brass handicraft sectors through comparative analysis is outlined in Table 2.9.

Table 2.9 Part1: Challenges in Assam brass handicraft sector

Challenge	**Impact**
Limited Market Connectivity and Awareness	Reduced exposure and market access, limiting growth potential for smallholder villagers.
Limited Product Diversification in Rural Areas	Limited growth opportunities for rural artisans, hindering overall industry development.
Resistance to Technology Integration	Missed opportunities for advancements, limiting market appeal and innovation.
Resource Management and Environmental Impact	Environmental concerns and resource sustainability pose challenges to responsible manufacturing practices.

Table 2.9 Part2: Challenges in Assam brass handicraft sector

Technological Integration and Skill Upgradation	The industry must strike a balance between preserving traditional craftsmanship and embracing technological innovations.
Market Accessibility Challenges in the Handicraft Sector	Lack of urbanization hinders market connectivity, economic viability, and sustainable livelihoods.
Challenges in Expanding Product Offerings	Limited market connectivity results in a confined product range, influenced by seasonal and cultural demands.
Challenges in Pricing Disparities	Infiltration of external products into the local market leads to pricing disparities and increased production costs.

These insights highlight the crucial need for the brass metal handicraft industry to overcome resistance to technology integration, address environmental considerations in resource management, and find a delicate balance between traditional craftsmanship and modern technological advancements. Embracing technology can lead to innovation and increased market appeal, but this must be done mindfully to preserve the industry's cultural authenticity and sustainability.

2.7 Discussion

Keep in touch with clients by offering affordable rates and high-quality goods, which will aid in preserving market competition. A technological intervention is required to enhance the creation of procedures and satisfy consumer demand. In this context, design intervention is viewed as a bridge between traditional craft and contemporary tools and techniques to enhance the quality of life of those working in the handicraft industry. Collaborative innovation between the designer and the artisans can contribute to the revival of the dying craft. It links social, economic, ecological, and cultural aspects to achieve sustainability. Innovations are needed to increase craft diversification through suitable modifications to existing products. It requires significant intervention and practical efforts to reach the market[103].

To enhance the livelihoods and socio-economic conditions of handicraft artisans by developing their capacities. The desired outcomes include the professionalization of traditional skills through necessary inputs, leading to increased competitiveness in markets and readiness for enterprise development. Additionally, there is a focus on incorporating technology to improve production efficiency and reduce labor-intensive tasks[40]. To enhance the efficiency and quality of handicraft, an imperative communication process between information technology specialists and handicraft experts is proposed. This collaborative initiative, involving principals as well, aims to investigate the obstacles and potentials associated with integrating technology. The goal is to leverage technological advancements for the improvement of manufacturing processes and to ensure the sustainable integration of traditional handicraft methods with modern technology [104]. The assessment of technology acceptance and usage identified several factors influencing the impact, including cost, training, time, perceived benefits, perceived ease of use, and the nature of business. These elements were found to significantly affect the adoption of technology[105]. Also, the adoption of production technology among craftsmen varies, resulting in differences in the quality of products. Some align their designs with market trends, maintaining feasible pricing, while others produce semi-finished items at lower prices. The economic feasibility of craftsmen is closely linked to their rates of adoption of production technology[106]. The adoption of technology can indeed be restricted by different backgrounds in education and experience. Several factors contribute to this phenomenon: access to education, digital literacy, cultural and social norms, work experience, fear of Changes, economic factor, age and generational differences, training opportunities[107][108].

The integration of product diversification into the Assam brass handicraft cottage industry has emerged as a significant contributor to elevating value within the handicraft sector. Particularly advantageous for young entrepreneurs during the product development phase, the feasibility and value added by handicraft skills and techniques are evident. However, it is crucial to note that the interplay of quality and pricing dynamics affects both traditional handicraft artisans and emerging young entrepreneurs in this industry. A field inquiry has brought to light the government's venture into producing raw materials for the brass metal handicrafts in Hajo, Assam. However, challenges have surfaced as the government mill experienced losses due to an imbalance between the high rate of material production and the low demand for manual labor. To address this, there is a recognized need for design involvement in manufacturing tools to enhance production efficiency and align it with demand dynamics. To address this challenge, there is a pressing need for effective manufacturing tools that can simultaneously enhance both quality and production efficiency within the sector.

Challenges hindering the adoption of advanced tools and technology in the brass metal handicraft sector include a shortage of skilled labor, high initial investment costs, resistance to change, difficulties in customization, market acceptance concerns, infrastructure and connectivity limitations, challenges in training and education, and obstacles in supply chain integration.

There is a notable scarcity of studies focusing on adaptations in manufacturing tool design to enhance the efficiency and quality of brass metal handicraft. In H.M.M.M. Jayawickramaa et al. 2016, research is done to look into the adaptation of relevant technology to replace conventional sand-casting methods and hand sheet metal carving procedures. Regarding cost, resource consumption, process efficiency, environmental concerns, and safety concerns, permanent mould designing and die pressing procedures meet the technological needs of the conventional brass sector [109].

All the research underscores the necessity for design interventions in manufacturing tools that are versatile across various handicrafts, cost-effective, user-friendly, and substantially enhance quality and productivity. This is aimed at improving the livelihoods and socio-economic conditions of cottage handicraft artisans.

CHAPTER 3

Research Methodology

3.1 Research Methodology

3.2 Research Design/ Design Methodology

3.3 Design Concept Development Methodology

CHAPTER 3

Research Methodology

3.1 Research Methodology

Initially, research is carried out to clarify and define the problem. It involves primary and secondary data collection. Primary data is collected through field surveys, observations, and personal interviews; secondary data is collected through literature reviews, government publication, journals, and articles.

In the Assam brass handicraft cottage industry, about 300 families are actively involved in the manufacturing process. Recognizing the similarities in the manufacturing process, a research sample of approximately 30 artisans has been selected to offer a representative insight into the diverse craft practices and manufacturing methodologies employed within the community.

The research strategies involved in data collection are descriptive studies, perspective studies, and experimental studies.

3.2 Research Design/ Design Methodology

There are the following stages involved in the research design framework to undertake the study and obtain valid, objective, and accurate answers to the research questions:

3.2.1 Descriptive Study

The research is conducted through a descriptive study, characterized by a detailed and comprehensive exploration of the subject, specifically focusing on the role of Indian handicraft manufacturing in Chapter 1. This study encompasses several key aspects, including an industry overview, economic impact, cultural significance, market dynamics, artisan communities, government initiatives, challenges and future prospects, as well as an examination of sustainability and innovation within the context of the Indian handicraft sector.

3.2.2 Perspective Study

The research aims to achieve its objectives through a multifaceted approach.

- Explore design intervention areas
- Study stakeholder challenges
- Conduct a comprehensive perspective study

In summary, to explore innovative design interventions, understand stakeholder challenges in the brass metal industry, and provide insights into the evolution of brass metal handicraft through a comprehensive perspective study, which is discussed in chapter 2.

The research identifies a critical gap in the need for design interventions in manufacturing tools within the handicraft industry. The existing literature falls short in comprehensively addressing tools that meet key criteria, including adaptability for diverse handicrafts, cost-effectiveness, user-friendliness, and a substantial impact on both quality and productivity. This research gap emphasizes the necessity for in-depth exploration and studies to inform the development of accessible and practical design interventions that can genuinely enhance the handicraft production process.

The adaptive capability of micro - handicraft firms is characterized by a commitment to value creation, organizational agility and flexibility, and resourcefulness in utilizing both institutional services and online platforms for product placement and promotion [48].Adaptive capability is achieved through value creation, focusing on both product and process improvement. This is complemented by a strong emphasis on customer service, indicating a proactive approach to meet evolving market demand.

3.2.3 Experimental Study

Handicraft repositioning is significantly influenced by the strategic implementation of tools, small technologies, and design[110]**.** The effectiveness of technology adoption is contingent on the presence of dynamic capabilities in resource management. Without a dynamic capability framework, the impact of technology adoption is likely to be less effective[111], [112].

The new design and manufacturing technique involves the identification of opportunity areas through a theoretical framework that analyzes key relationships among different domains such as crafts, industrial concepts, emerging technologies, design, and manufacturing [113].

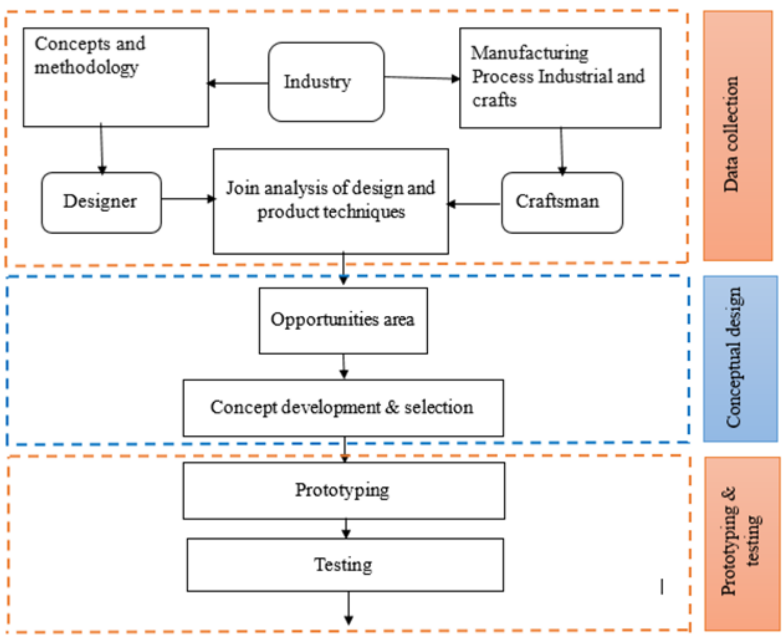


Figure3.1: Flow chart to describe the design technique for concept development

The "Kano Model" is employed to analyze the requirements of customers (artisans) and formulate a strategy for the design of tools. Figure 3.2 illustrates the process of the Kano Model.

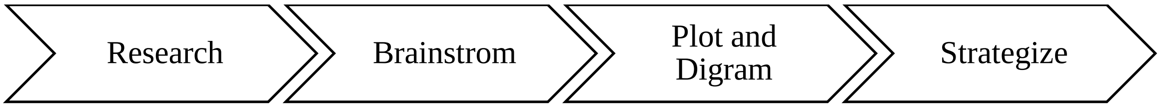


Figure 3.2: Process of the KANO MODEL

a) Development Selection Through Lean Six Sigma Involves

Applying Lean Six Sigma principles to hand tools involves streamlining processes, reducing waste, and improving overall efficiency. Here's a general analysis framework:

Define:

Project Scope: Clearly define the scope of the analysis, specifying which hand tools or processes will be addressed.

Customer Requirements: Identify and understand the key requirements of the end-users for the specific hand tools under consideration.

Measure:

Process Metrics: Establish relevant metrics to measure the current performance of hand tool-related processes, such as production time, defect rates, or lead times.

Data Collection: Gather data on the current state of hand tool processes, identifying areas of inefficiency or waste.

Analyze:

Root Cause Analysis: Use Six Sigma tools like Fishbone diagrams or 5 Whys to identify the root causes of inefficiencies or defects in hand tool manufacturing or usage.

Value Stream Mapping: Map the entire value stream for hand tools, from raw material acquisition to the end-user, identifying non-value-added activities.

Improve: Process Optimization: Implement Lean principles to eliminate waste and streamline processes. For example, optimize the hand tool assembly line to reduce unnecessary movements or waiting times.

Standardization: Develop standardized work procedures for hand tool manufacturing to ensure consistency and reduce variability.

Control:

Statistical Process Control (SPC): Implement SPC techniques to monitor and control hand tool manufacturing processes, ensuring that they remain within specified limits.

Training Programs: Establish training programs for workers to ensure they are well-equipped to use and maintain hand tools correctly.

Lean Six Sigma Tools for Hand Tools:

5S (Sort, Set in order, Shine, Standardize, Sustain): Apply 5S principles to organize the workspace and enhance the efficiency of hand tool usage.

Kanban: Implement Kanban systems for inventory management of hand tool components, ensuring that materials are replenished only when needed.

Poka-Yoke (Error Proofing): Introduce features in hand tool design or manufacturing processes that prevent errors or misuse.

Customer Satisfaction:

Voice of the Customer (VOC): Continuously gather feedback from end-users to ensure that hand tools meet their expectations and requirements.

Continuous Improvement: Establish a culture of continuous improvement to adapt hand tool designs and processes based on evolving customer needs and feedback.

Applying Lean Six Sigma to hand tools can lead to more efficient manufacturing processes, reduced defects, and increased customer satisfaction. It involves a holistic approach, addressing both the manufacturing processes and the end-user experience.

b) Other Feature Involves in Development

Basic Features

Excitement Features

Performance Features

These processes are employed in the development of concepts. A more in-depth analysis of these elements plays a role in formulating an interaction matrix, as illustrated in Table 3.2.

3.3 Design Concept Development Methodology

3.3.1 Statement and Analysis of the Problem

Value stream mapping as lean analysis, encompassing product, process flow, and time analysis, is conducted to pinpoint bottleneck processes. The investigation includes a comprehensive examination of distinct manufacturing techniques, tools, and equipment, regardless of whether they are employed in metal handicraft or advanced metal production. Through a meticulous comparison, only those tools and equipment compatible with the current manufacturing process in the handicraft industry are adopted, incorporating necessary design input, explained in Chapter 4.

3.3.2 Analysis of The Requirements

- Hand tool design requirements: perform specific functions; meet certain minimum precision requirements for each stage; low cost; safe to operate;[114]
- Meet various other requirements such as adaptability by artisans;
- Ergonomically designed working condition.

3.3.3 Human Factors

Human factors are researched to enhance human-machine interaction and boost system performance. The aesthetic and functionality of a product maintain a balance with the human factor, or ergonomics. A product should ensure the basic principle of human compatibility through a user friendly relationship.

- An anthropometric and behavioural match between the user and the product
- Ease of handling, ease of decoding messages
- Proper semantic application, Product reliability and safety
- Designing the overall form, shape, size of the product and layout of the parts for operational ease.
- Removing unnecessary bad parts and guarding unsafe things
- Training with specific instructions on how to use the system efficiently

Ergonomic analysis is applied to address user-related. aspects in the development of Hand tools.

3.3.4 Quality or Value Analysis

The development of hand tools involves a thorough analysis of utility, reliability, safety, maintenance, lifetime, and pollution aspects, with a focus on cost reduction through engineering value analysis and necessary modifications.

Table 3.1: Illustrates a method of applying these criteria to the process of choosing a tool design [114].

Possible alternatives	**Tool Design**				
	Function	**Productivity**	**Quality**	**Cost**	**Schedule time**
Concept A	*	*	*	*	*
Concept B	*	*	*	*	*
Concept C	*	*	*	*	*

3.3.5 Manufacturability Interaction Matrix

Taking into account the diverse needs of consumers (artisans) and analysing various design aspects related to manufacturing, a manufacturing interaction matrix is prepared to guide the development of hand tools.

Manufacturing processes are complex and impacted by many design factors. As a result, there are potential concerns that have the ability to disrupt manufacturing operations. In order to assess the manufacturability of the design, it was necessary to develop an organized listing of these potential concerns [115].

Table 3.2: Interaction matrix for manufacturability (source: Walden 2020)

Aspect of Design / Aspect of manufacturing	Design	Material	Product Dimensioning	Special Tool	Past Geometry	Special Skills	Ease of assembly	Reliability	Process capability	Capacity and scalability	Ergonomics	Material handling	Strategic sourcing	Quality testing and equipment	Maintainability
Process	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Supply chain	*	*		*	*	*				*	*	*		*	*
Equipment/ tools	*	*	*		*	*	*	*	*	*	*	*	*	*	*
Facility	*			*	*					*	*	*	*	*	*
Labour	*						*		*	*	*	*	*		
Quality	*		*	*	*	*	*	*	*	*	*	*	*	*	*
Cost	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Environment Safety & Health	*	*		*	*	*	*			*		*	*	*	
Sustainability	*	*		*	*		*				*		*	*	

CHAPTER 4

Design and Development of Hand Tools for Brass Metal Handicraft

4.1 Identify customers' needs through analysis of brass metal handicraft industry

4.2 Interpretation of data collection

4.3 Hand tools design and development

4.4 Conceptual design and development for hemming/ beading tool

4.5 Conceptual design and development for shaping tool

4.6 Conceptual design and development for surface bending tool

4.7 Human factors considered for design the hand tools

4.8 Results and discussion

CHAPTER 4

Design and Development of Hand Tools for Brass Metal Handicraft

A product is designed through an ongoing process of problem-solving and concept realization that takes into account the user's traits and constraints, art and aesthetics, material and process, and emerging technologies.

The main objective of tool design is to increase production while maintaining quality and lowering costs. To this end, the tool designer must:

1. Reduce the overall cost of manufacturing a product by making acceptable parts at the lowest cost.
2. Increase the productivity rate by designing tools to produce parts as quickly as possible.
3. Maintain quality by designing tools to consistently produce parts with the required accuracy.
4. Reduce the cost of special tooling by making every design as cost-effective and efficient as possible.
5. Design tools that safe and easy to operate.

4.1 Identify Customer's Needs Through Analysis of Brass Metal Handicraft Industry

Value stream mapping (mapping of material and information flow) was employed in this analysis as a lean management technique to comprehend the product value chain. A value stream map displays process activities, product and information flow, the connections between suppliers and the value chain, and customer requirements [116][117].

4.1.1 Product Analysis

The majority of the artisans are working in their homes. The products they make are the end products of traders and users. They transform raw materials into finished products. Brass sheet is used for making different brass metal handicrafts.

Range of Material thickness = Thickness of sheet varies from 24 gauge (.536mm) to 10 gauge (2.588mm).

Range of part dia varies from 120mm-250mm

Range of sheet width according to part varies 50mm-120mm

A variety of items are manufactured in the brass metal handicraft industry in Hajo, Assam. The product categories that were taken into consideration for the analysis and which were most frequently manufactured are listed below.

(a) Kalshi (water pot) (b) Tow (a wash- bowl for edibles)

(c) Gamla (utility pot) d) Kahi (cooking ware)

(e) Korahi (wash bowl with holes)

Figure 4.1: Product selected for analysis (source: field survey)

Table 4.1: Lean Analysis for brass metal handicraft at Hajo, Assam

Parameters	Traditional Manufacturing	Lean Analysis	Remark on current condition at Hajo, Assam
Raw material (Brass sheet) cost	High cost due to retail purchase	Institutional support is needed to produce raw materials in large quantities.	Due to losses incurred by a mismatch between speedier material production and low demand for manual crafting, government mills stayed closed.
Product range	Regular use product	Customized product	Customization seen, but quality improvement will require more time
Defects	Crack formations	Improved crafting process	It takes time and boosts overall manufacturing costs to suit consumer needs.
Quality	Price First	Quality first	Less emphasis is placed on quality because wages are based on output rate.
used Technology	Traditional technology,	Technology use to improve productivity	A lack of consistent electricity supply and dependence on electricity cause manufacturing to halt, therefore few automated tools are employed.
Market	Seasonal domestic market,	Improve connectivity with market in online and offline mode	Productivity and quality must be increased in order to diversify the product line and create new products. Competition from high-quality and affordable Moradabad metal ware.
Product price	High	Competitive price	Need improvement in quality and productivity

4.1.2 Process Analysis

Process analysis is used to locate and enhance system bottlenecks. The process analysis of handcrafted goods is displayed in Figure. 4.3 below. The brass sheet metal handicraft has six main steps: sharing, forming, joining, filling, scarping, edge bending, and polishing. The process is described in full in Chapter 1, Section 1.4, and the creation of the handicraft Kalshi (water pot) using the current method is shown in Figures 4.2 and 4.3.

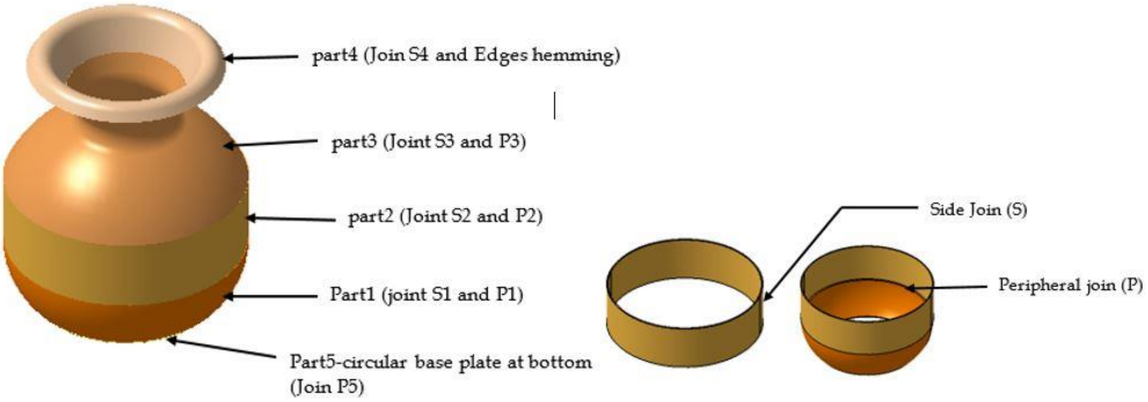


Figure 4.2 : Assembly of different parts to form a kalshi (water pot)

Table 4.2 : Operations details of kalshi

Operation	**Activity Description**	**Duration (min)**
Process 1	Shearing process (Part1+Part2+Part3+Part4 + Part5) (including measuring)	40
Process 2	Surface bending Part1,Part2, Part3, Part4 with side joinning S1, S2, S3 and S4 respectivly	15 (bending) + 20 (joinning)
Process 3	Shaping Process	
	Part1	15
	Part2	-
	Part3	18
	Part4 with hemming	45
	Part5	8
Process 4	Joinning process	
	Joint P3	12
	Joint P2	12
	Joint P1	12
	Joint P5	12
Process 5	Polishing	8

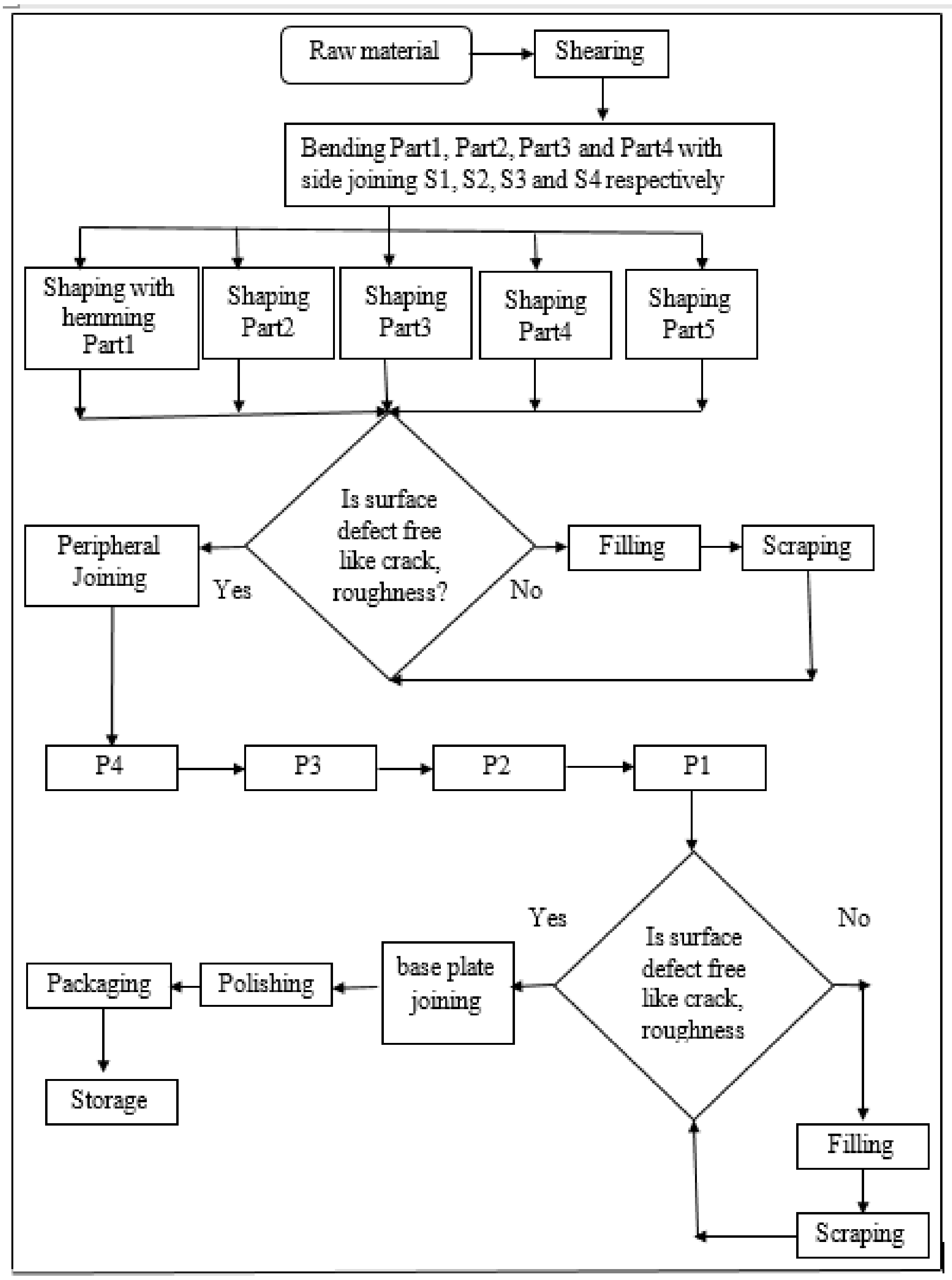


Figure 4.3: Process flow diagram of handicrafts product Kalshi

4.1.3 Measuring Process Performance

It is also known as time study analysis. Here, the main objective for measuring process performance is to determine the standard time for various operations for planning and scheduling so that work efficiency can improve.

Table 4.3: Time study analysis of Kalshi crafting process

S. No.	**Details**	**Current method**
1	Number of operation involved	12
2	Workforce involve in operation	4
4	Bottleneck operations	Joining process, Shaping and Hemming,
5	Cycle time for bottleneck operations	10 min average * 10 cycle =100 min
6	Lead time per person per day	180 min
7	Average cycle time (CT) per operation	15 min
7	Nominal Time (NT) per operation	15 min
8	Standard time (ST) per operation	18 min
9	Standard time per product per person	216 min (3hr 30min)

Time for appropriate number of cycle

Average cycle time (CT) = $\frac{\sum \text{time}}{\text{No.Of Cycle}}$

= 180/12 =15 min

Nominal Time (NT) = CT* (PR)

=15*1 =15 min

PR= Performance rating (lets considered performance rating for artisan is 100%)

Standard time (ST) = NT* (AF) =15* 1.18 = 18 min

where AF= ($\frac{1}{1-\%\text{Allowance}}$) =1.18

Standard time = Nominal Time/ (1- allowance factor) =16.6

Here 15% average allowanced factor have been considered based on average cycle time for all products field survey

Table 4.4: Time study analysis of selected cases

Product	Current Method	
	Standard time (min) / product	Work output (unit)/ 8hrs
Kalshi	216	2
Tow	128	4
Gamla	113	4
Kahi	70	7
Korai	142	3

4.1.4 Hand Tool Used

Various hand tools are employed by brass metal artisans, including pointed cutting tools, hammers, brazing pots, brass sheet cutters, single-headed hammers, tongs, and different anvils. However, it's noteworthy that these hand tools, crafted using conventional technology, often lack careful consideration for comfort and safety. Issues such as inappropriate grip diameter and unevenly textured grip surfaces have been identified. Additionally, certain types of hammers exhibit unnecessary heaviness, causing perceived discomfort in specific body regions when operated for extended durations, as expressed by artisans.

Particularly during activities like shape-making and polishing, artisans have reported extreme deviations in forearm, elbow, and wrist joints. The artisans have also expressed a need for modifications to certain tools and work machines to enhance overall performance and productivity. These insights underscore the importance of refining tool design to prioritize ergonomic considerations, ensuring not only the efficiency of the tools but also the well-being and comfort of the artisans who utilize them.

4.1.5 Working Posture

The working posture is a crucial consideration in tool design, especially when it comes to using specific tools or machines. The posture adopted by individuals during work significantly influences their performance, productivity, comfort, and safety.

In an organized industrial workplace, it's noted that industrial practices often confine individuals to specific work positions and postures for prolonged durations while performing specific tasks. This restriction is particularly evident in environments where tasks demand a consistent and specific posture.

In unorganized crafts and cottage settings, a variety of floor-sitting postures is commonly observed, allowing individuals to freely change their positions according to personal preference. Consideration for the various postures adopted by artisans has resulted in a gap in understanding their implications on performance and productivity. In such cases user-friendly hand tools is crucial to ensure efficient and safe use. Here are some principles and considerations are as follows:

- A user-friendly interface for hand tools is crucial to ensuring efficient and safe use.
- Design the tool with easily accessible components for maintenance and cleaning purposes, promoting tool longevity.
- If applicable, facilitate easy disassembly for maintenance or replacement of parts.
- Incorporate user feedback through testing and iterative design processes to refine the tool's interface based on actual user experiences.
- Develop prototypes to allow users to interact with the tool in a real-world setting, gathering valuable insights for improvement, etc.

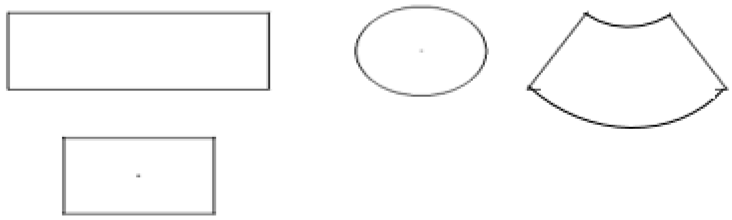
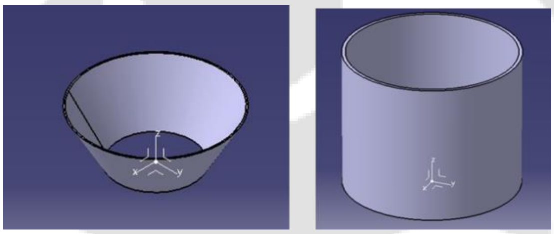
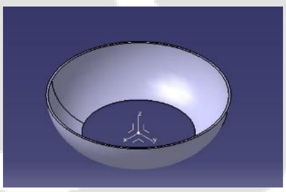
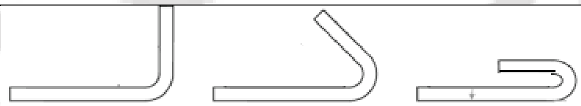
4.1.6 Established Target Specification

Specifications give a detailed explanation of what a product must do. They translate the needs of the client into technical language. Form, function, and human requirements are all considered together while creating a new product. Gestalt concepts of similarity are applied to identify the fundamental design solution or release the notion while taking functionality and user friendliness into consideration.

Form Follows Function

The initial stage of concept generation involves studying the fundamental forms and shapes created during craft labour, as indicated in Table 4.5. Additionally, be aware of the fundamental specifications for crafting with brass sheet metal, as these must be followed in order to achieve the intended craft shape and function.

Table 4.5: Basic geometric shapes observed during survey

Operations \ **Shape/ Forms**	**2D Shapes / 3D Forms**
Cutting or shearing operation	
Surface Bending operation	
Shaping operation	
Hemming or Sharp edge bending operation	

Function Follows Form

Before developing a concept, a field survey was conducted to uncover the critical connections between different production processes, such as crafts, industrial concepts, new technologies, design, and manufacturing, to pinpoint potential growth areas. Roller forming is suitable for the forming operations of brass metal crafts, according to an analysis of the various instruments used for manufacturing processes in the metal sector.

4.2 Interpretation of Data Collection:

Bottlenecks in the processes are discovered based on the design technique used and the thorough PFA (process flow analysis) and TSA (time study analysis). Potential concepts for the creation of tools were produced, taking the process bottleneck into consideration. The following are these:

A. Beading (hemming) tool
B. Shaping tool
C. Surface-Bending tool

The viability of the aforementioned principles was thoroughly examined. To increase efficiency and handicraft quality, tools are designed based on roller forming for small batch production. Below are some details about it.

4.2.1 Concept A: Hemming (Beading) Tool

Hemming is one bottleneck step that requires more time to execute, according to a field survey. Hemming is also necessary for handling the goods in a safe manner. Metal sheet edges are bent or folded during the hemming process to create a clean aesthetic appearance and to protect people from cutting edges.

Currently in brass metal handicraft sector, manual hemming as shown in Figure 4.4, is effected by

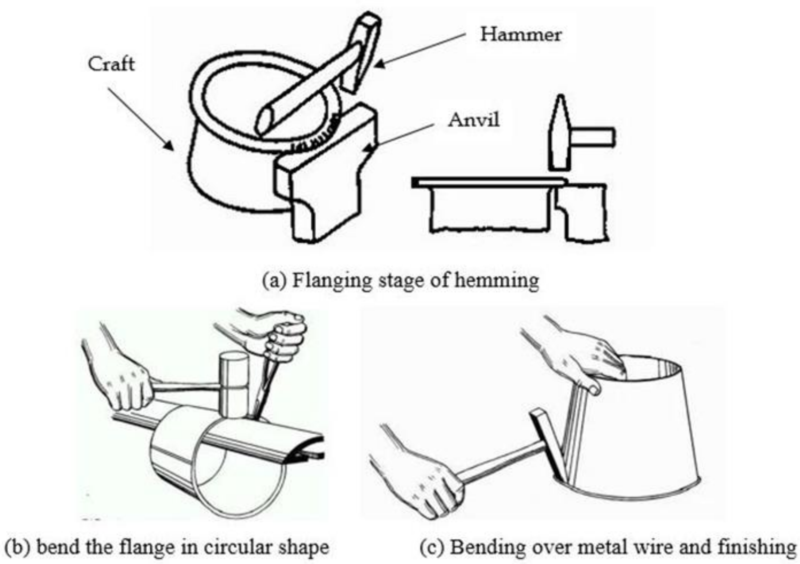


Figure 4.4: Traditional manual hemming technique

the hammering technique. The sheet rims are being turned up with hammers on their respective striking bases (anvils). Initially, the edge of the metal sheet is formed as "preliminary flanging" and "finish flanging". After flanging, the necessary size of wire is placed at the edge of the flange, and the metal sheet is bent in a circular motion over the metal wire. The flange is double the diameter of the wire. The following stage involves completing the edge bending. The hemming operation is finished with this.

In the manufacture of cookware, containers, and mass-produced vehicle parts, hemming tools are frequently used as a sheet-forming procedure. Hemming for kitchenware and other handcrafted items is another task required of artisans in cottage enterprises that manufacture sheet metal. There are two different hemming methods: classical hemming methods and hemming through roll forming methods.

The classical hemming procedure, as depicted in Figure 4.5, involves the use of standard punches. Hemming occasionally involves the use of hot press dies. In hot press die forming, material is quickly heated and cooled while still inside the tool. Using a mixture of heating, holding, developing, and quick cooling, a material was given remarkable strength qualities [118].

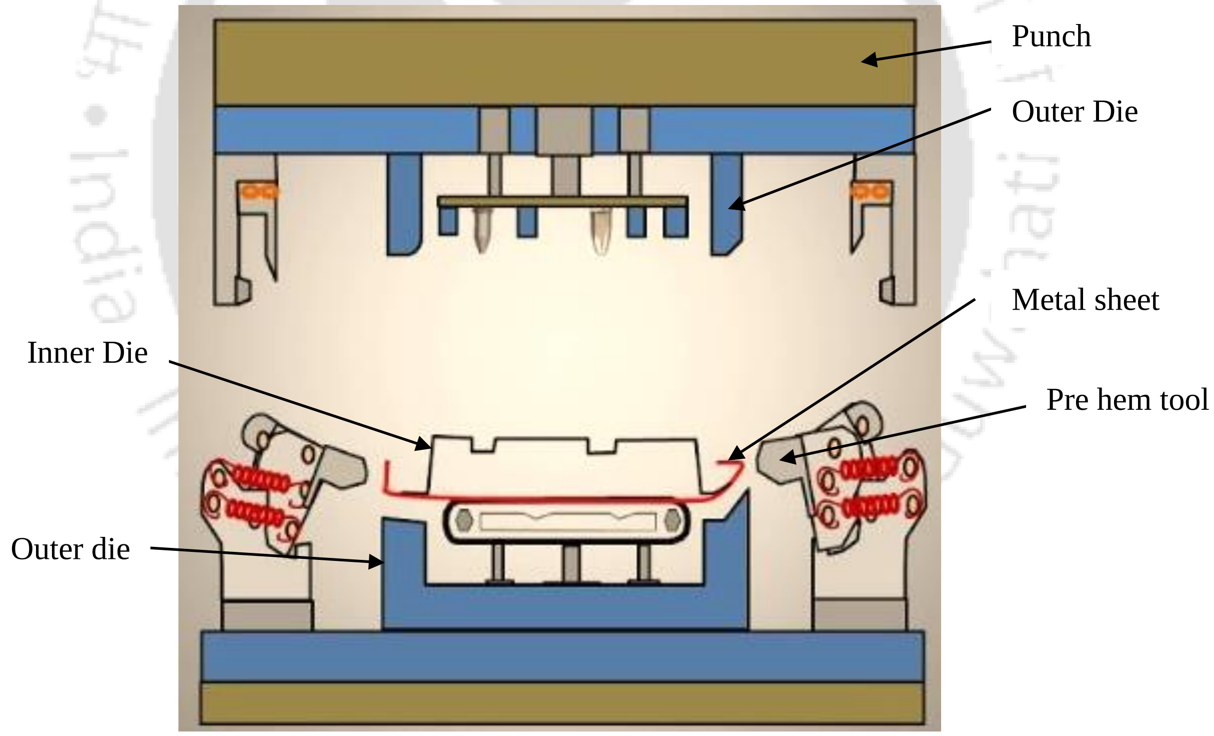


Figure 4.5: Concept of die working principle Outer Die

A long sheet metal strip is continuously or gradually bent into the necessary cross-section using the roll-forming technique, as seen in Figure 4.6. Hemming is done using roll forming as well. Hemming techniques include manual roller hemming, robot-assisted roller hemming, laser-assisted roller hemming, and electromagnetic shaping [119].

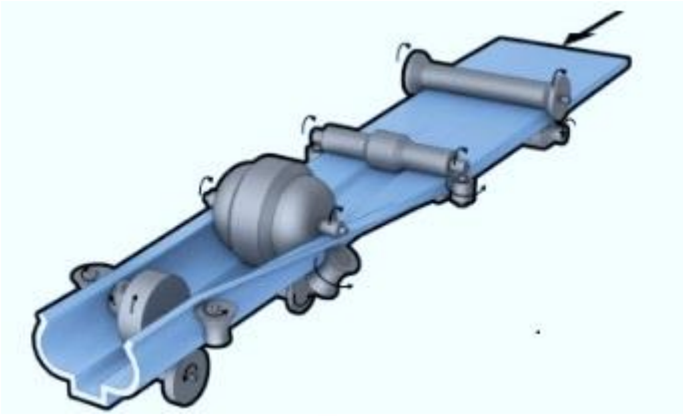


Figure 4.6: Roll forming process principle (source: https://www.manufacturingguide.com/en/roll-forming)

Manufacturers are concentrating on lowering manufacturing costs to compete with globalization. In these situations, roll hemming is done with rollers. It has been determined that using one or a few numerically controlled rollers is an effective way to satisfy relevant market and customer demand with little investment. [120].

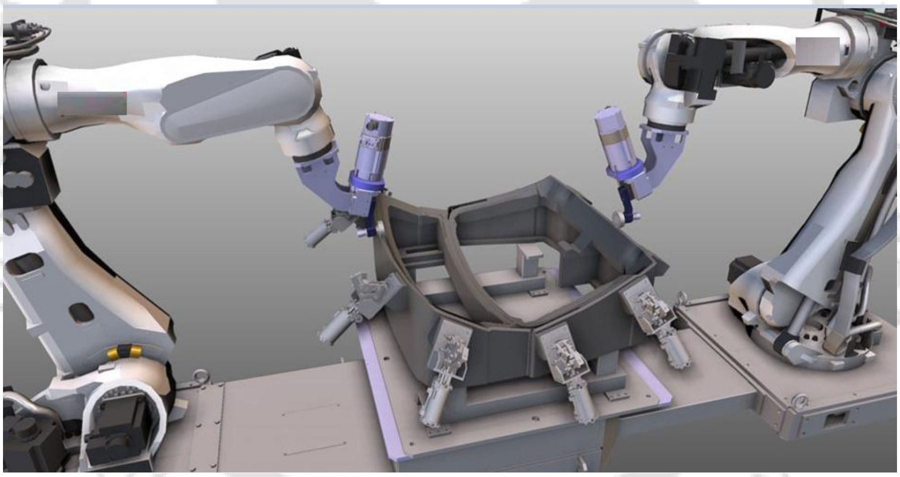


Figure 4.7: Numerically controlled roller hemming

The traditional hemming procedure is swapped out for a robotic base roll hemming procedure in the Saab Automobile AB industry case study. The closure panels are loaded and unloaded by one robot, while the tools are loaded and unloaded by another robot. Quick and simple tool changes cut down on hemming time and increase output [121]. Manual adjustment of hemming routes, resulting in higher die costs, higher time consumption, and excessive labour efforts. To eliminate all potential tolerances, positional mistakes, and orientational errors from the robot arm, a hand-eye sensor module is introduced. [122].

4.2.2 Concept B: Shaping Tool

Metal shaping involves converting a flat metal sheet into a curved component. Metal can be stretched by applying pressure when hammering or rolling it.

Another bottleneck process is the plastic deformation of the sheet metal to conform to the geometry of the die. Deep drawing is a technique used in industry to produce metal sheet shapes in three dimensions. A sheet blank (hot or cold) is often forced into a die by the mechanical action of a punch during deep drawing, as shown in Figure 4.8. Deep and shallow cups, ammo sheets, cartridge cases, beverage cans, sinks, cooling pots, and the drawing of irregularly curved forms, such as in automotive body panels, are examples of objects for which deep drawing is used.

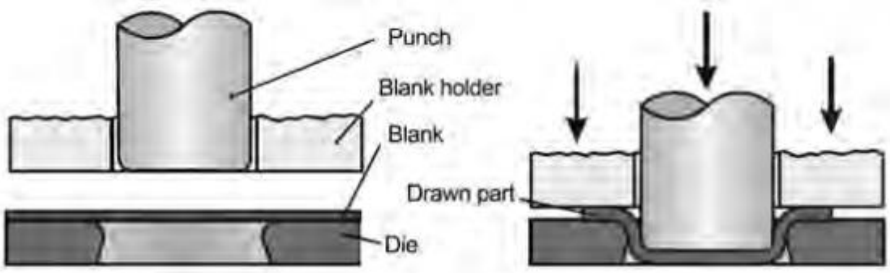


Figure 4.8: Deep drawing

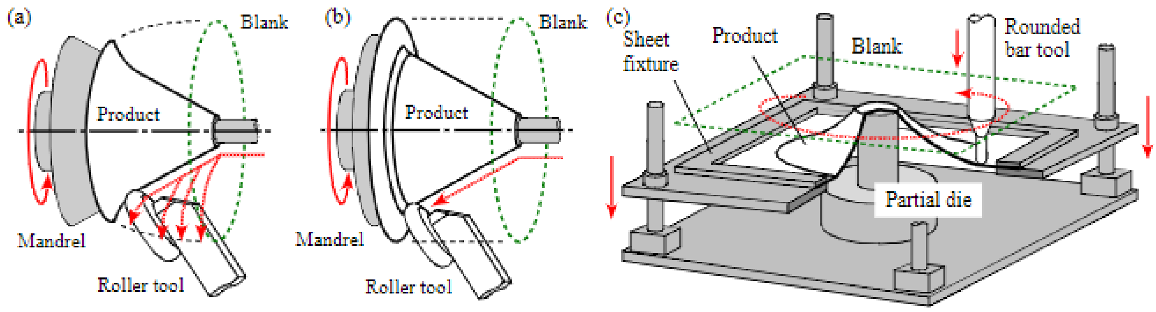


Figure 4.9 Schematic comparison between (a) conventional spinning, (b) shear spinning and (c) two-point incremental forming methods.

Additionally, three-dimensional shell construction techniques include standard spinning, shear spinning, and increment sheeting. The die (mandrel) with the necessary 3D shape is mounted on a blank sheet in this spinning technique. To create the dice's three-dimensional shape, a force is imparted to the sheet using a roller-based instrument [123].

4.2.3 Concept C: Surface Bending Tool

A hydraulically powered roller sheet bending machine is used in industry to distort sheets into hollow shapes with fixed or variable cross sections. To produce cylinders with different curves, rolling machines with three and four rolls are required. Three rollers typically perform the rolling procedure. The sheet is fed into two side rollers in the initial step of a three-roll bending operation. The sheet is bent or deformed in the second step using a third roller. Two side rollers rotate once again in the last phase, causing the sheet to constantly bend [124].

Figure 4.10: Hydraulic numerical controlled sheet bending machine

4.2.4 Findings:

- Advanced hemming, shaping, and surface bending tools are not suitable for use because of their cost and flexibility limitations with a wide range of products.
- Affordability and cost-effectiveness, usability, volume flexibility, and space are the primary challenges mentioned for design consideration.
- Considering that sheet metal forming is similar to the existing handcrafted manufacturing technique. The adaptability of such roller-based design adjustments can help artisans increase crafting output.

4.3 Hand Tools Design and Development

The design of a hand tool continues through the deployment of a roller base forming technique. The design exercise has the following features:

4.3.1 Basic Features

<u>Ergonomics:</u> Hand tools are designed with user comfort and efficiency in mind, often featuring ergonomic handles and grips to reduce strain and fatigue during use.

<u>Durability:</u> Hand tools are typically constructed from robust materials such as steel or alloy to ensure durability and longevity under various working conditions.

Versatility: Hand tools are designed to perform specific tasks and are often versatile, allowing users to apply them to a range of applications within their intended category.

Portability: Hand tools are generally compact and portable, making them easy to carry and use in different locations or work settings.

Precision: Many hand tools are crafted to provide precision in their functions, allowing for accurate and controlled work in various applications.

Safety Features: Hand tools often incorporate safety features such as non-slip grips, blade guards, or other mechanisms to reduce the risk of accidents and injuries.

Ease of Maintenance: Hand tools are typically designed for easy maintenance, allowing users to clean, sharpen, or replace parts as needed, contributing to their long-term usability.

Manual Operation: As the name implies, hand tools are operated manually, requiring physical effort from the user rather than relying on external power sources.

Common Types: Hand tools encompass a wide range, including hammers, saws, and more, each with specific features tailored to their intended use.

Cost-Effectiveness: Hand tools are often more cost-effective than their power tool counterparts, making them accessible to a broad range of users for various applications.

4.3.2 Excitement Features

Innovative Designs: Hand tools with unique and innovative designs can spark excitement among users. Unconventional shapes or multi-functional features can add an element of interest.

Colourful Finishes: Hand tools with vibrant or aesthetically pleasing finishes can bring a sense of excitement, especially for users who appreciate visually appealing tools.

Customization Options: Hand tools that allow for customization, such as personalized grips or engraved markings, can create a sense of ownership and excitement for users.

Compact and Portable Design: Tools that are designed compact, lightweight, and easily portable can make them more exciting for users who value convenience and mobility.

Interchangeable Parts: Hand tools with interchangeable parts or modular designs can add excitement, offering users versatility and the ability to adapt the tool for different tasks.

Incorporation of Technology: Some modern hand tools may integrate technology, such as digital measurement displays or smart features, which can add an exciting and futuristic element to traditional tools.

Limited Editions or Special Releases: Hand tools released as limited editions or special versions can create excitement among tool enthusiasts, collectors, or those looking for something unique.

Enhanced Performance: Hand tools that boast improved performance features, such as increased cutting precision or faster operation, can generate excitement among users seeking top-tier functionality.

Ergonomic Innovations: Hand tools with advanced ergonomic designs that prioritize user comfort and reduce fatigue can be exciting for those who value both form and function.

Educational Features: Hand tools designed for learning or educational purposes, such as those with interactive guides or instructional elements, can make the learning process more exciting for users.

4.3.3 Operational Features

Material Quality: High-quality materials, such as hardened steel or alloys, ensure durability and longevity, contributing to the overall performance of the hand tool.

Precision: Hand tools with precision engineering and accurate measurements allow for controlled and exact work, reducing errors in various applications.

Ergonomics: Ergonomically designed handles and grips enhance user comfort, reduce fatigue, and improve overall control during prolonged use.

Anti-Slip Grip: Textured or rubberized grips prevent slippage, providing a secure hold and enhancing user safety, especially when working in challenging conditions.

Adjustability: Tools with adjustable components or settings offer versatility, allowing users to adapt the tool to different tasks and materials.

Cutting Efficiency: Cutting tools, such as saws or shears, benefit from sharp blades and efficient cutting mechanisms for clean and effective performance.

Torque and Force: Wrenches, pliers, and similar tools designed to apply torque or force benefit from features that optimize the application of pressure, ensuring effective results.

Fastener Compatibility: Screwdrivers and wrenches with various tips or interchangeable heads accommodate different types and sizes of fasteners, enhancing versatility.

Quick Release Mechanisms: Tools with quick-release mechanisms, such as ratchets, facilitate rapid changes or adjustments, saving time and effort.

Dust and Debris Resistance: Sealed or protected mechanisms prevent the ingress of dust and debris, ensuring smooth operation and prolonging the tool's life.

Anti-Corrosion Coatings: Tools with coatings that resist corrosion are more durable and suitable for use in diverse environments, adding to their overall performance.

Measurement Accuracy: Tools with built-in measurement features, such as rulers or scales, contribute to accuracy in tasks that require precise measurements.

Gearing Systems: Hand tools with well-designed gearing systems, such as in socket wrenches, ensure efficient power transfer and ease of use.

Spring-Loaded Mechanisms: Tools with spring-loaded mechanisms, like pliers or clamps, enhance ease of operation and reduce hand fatigue.

Shock Absorption: Tools designed with shock-absorbing features, such as impact-resistant handles, mitigate vibrations and reduce user discomfort during use.

4.3.4 Highlight Key Point Associated with Product Design and Manufacturing

A condensed version can be crafted by highlighting key points across the aspects associated with product design and manufacturing, as well as those linked to the supply chain, equipment and tools, facility, labor, quality, cost, environment safety and health, and sustainability as illustrated in Table 3.2 interaction matrix.

The summary captures the main points across the various aspects, highlighting considerations, priorities, and key factors for each category as follows:

Design:

- The tools are crafted using mild steel as the primary raw material in the manufacturing process. This choice of material holds several advantages, contributing to the overall quality, durability, and practicality of the tools.
- The tools are designed to be manufactured by keeping all designs simple, functional, and easy to use. Preformed commercial materials and standard items are used, e.g., standard MS roller bars, rectangular MS bars, bearings, lead screws, screws for assembly, etc.
- different dimension ranges are studied Product dimensioning,
- Special tools, all screw used are standard L-N type screw LN keys are provided past geometry, No Special skills are required only initial training are introducing to understand the interaction.
- Ease of assembly.
- Parts are cut, welded, and drilled for fasteners. It needs only simple tool room machines like a power saw, lathe, arc welding machine, grinding machine, and drilling machine.

Gears are to be manufactured using a laser cut machine. Based on all these, it is evident that the tools can be easily manufactured in a moderately equipped workshop.

Manufacturing Process:

- Design tools that excel in their ability to consistently produce high-quality outputs within specified tolerances.
- Incorporate features that enhance precision, accuracy, and control in the manufacturing process.
- Optimize the tool's capacity to handle varying workloads and production demands.
- Consider factors such as cycle time, throughput, and efficiency to maximize overall productivity.
- Design tools that can seamlessly adapt and expand to accommodate changes in production volume or requirements.
- Incorporate modular or flexible features to enhance scalability without compromising performance.
- Prioritize rigorous quality testing procedures to ensure that the tools meet or exceed defined quality standards.
- Implement comprehensive testing protocols throughout the design and manufacturing phases.
- Emphasize the selection of high-quality materials and components for tool construction.
- Consider advanced or specialized equipment that enhances the efficiency and precision of the manufacturing process.
- Design tools with features that facilitate easy maintenance, repairs, and replacements.
- Prioritize accessibility to critical components and straightforward procedures for maintenance tasks.

Supply Chain:

- The design incorporates mild steel as the primary raw material for tool construction, utilizing readily available standard parts in the market. The manufacturing process involves cutting, drilling, and welding operations, which can be efficiently carried out in local workshops.
- The design is characterized by its compact nature, facilitating easy assembly and disassembly. This not only streamlines transportation but also simplifies storage and distribution processes, contributing to overall convenience and logistical efficiency.

Equipments and Tools:

- The tool's form, features, and functions align with the tasks it is designed to perform.
- Compatibility with other tools or equipment within the user's toolkit.
- Design integrates well with existing workflows or processes.
- High-quality materials and components to enhance durability and longevity.
- Conducted field testing during the design and manufacturing phases to identify and address potential reliability issues.
- Design controls and interfaces are straightforward and easy to understand.
- Incorporated ergonomic principles to enhance user comfort and reduce fatigue.
- The tool needs no regular servicing except the lubrication of its very few moving parts. In cases of wear and tear, all parts can be readily manufactured or repaired in any small workshop.

Facility:

- Design tools accommodate varying levels of workload to prevent bottlenecks.
- Optimized tool features to enhance productivity without sacrificing quality.
- Considered mechanization to increase overall production capacity.
- Designed modular tools that can be easily upgraded or expanded.
- Considered flexible manufacturing systems that can adapt to changes in production volume.
- Ensure that the tool design allows for seamless integration with additional units if needed.

Labour:

- The tool design takes into account the limited educational background of artisans, ensuring that the operation and use of the tool require minimal specialized skills. The goal is to create tools that are intuitive and easy to grasp, reducing the need for extensive training.
- Recognizing the lack of formal education, the tool design incorporates user-friendly features that minimize the need for extensive training. Clear and simple instructions are provided, and the design aims to be easily understandable, facilitating quicker adaptation for artisans without formal education.
- Maintain Straight Wrists: Wrist flexion promotes carpal tunnel syndrome. Repetitive actions or strong forces exacerbate any wrist deviation further. Use the instrument in a neutral grip at all times.

- Avoid Static Muscle Loading: To prevent undue tiredness, the work should be performed with the arm and shoulder in a natural position. This is particularly true when heavy tool weights or prolonged tool use are involved. Counterbalancing devices are a typical remedy.
- Avoid Stress Concentrations Over the Soft Tissue of the Hand: Pressure on these tissues can obstruct blood flow and nerve function. Reduce grip force requirements. Grip forces can pressure the hands or result in tool slippage. A special note is made of the distribution of force on the hand, which results in the same problems mentioned in avoiding stress concentrations. Maintain optimal grip span: The optimal power grip with the fingers, palm, and thumb should span 2.5–3.5 in. (63.5–88.9 mm). For circular tool handles, such as screwdrivers, the optimum power grip is 1.25–2 in. (31.75–50.8 mm). For fingertip use, the optimum precision grip is 0.3–0.6 in. (7.62–15.24 mm).
- Avoid Sharp Edges, Pinch points, and Awkward Movements: Sharp edges cause blisters and pressure points. Pinch points can make a tool almost unusable. Awkward movements are easily found through observation or use. The movement required to open a tool is a common problem, especially when used repetitively.

Quality:

- The tool is meticulously crafted by incorporating readily available standard parts from the market. The selection of dimensions is methodically determined, aligning with the requisite force needed to achieve a specific shape and size.
- Standard products typically have predefined and consistent dimensions, ensuring uniformity and compatibility in various applications.
- Standard products are expected to meet specified performance criteria without unexpected failures, ensuring users can rely on them for their intended purposes.
- Standard products are subjected to thorough quality testing procedures to verify compliance with industry standards and regulatory requirements. These assessments encompass a range of tests and inspections conducted both during and after the manufacturing process, ensuring that the product aligns with the predetermined quality benchmarks.

Cost:

- The tool design uses minimum material; these materials are readily available and can be manufactured in the nearby fabricator or workshop. These tools are designed to be easily manufactured and maintained at an affordable cost.

Environment Safety & Health:

- The tools are crafted using mild steel as the primary raw material in the manufacturing process. Tools are developed with mild steel as a raw material. Iron, the main component of mild steel, is one of the most abundant elements on Earth, reducing the environmental impact associated with raw material extraction.
- Mild steel is predominantly composed of iron, making it highly recyclable. The recycling process involves melting down scrap steel to produce new steel products without significant loss of quality.
- Mild steel can undergo closed-loop recycling, where the material can be recycled repeatedly without a loss in its inherent properties.
- Applying corrosion-resistant coatings or treatments to mild steel can further enhance its longevity, reducing the need for premature replacements and lowering the environmental impact.
- Mild steel itself has low toxicity, posing minimal health risks during its use and manufacturing.

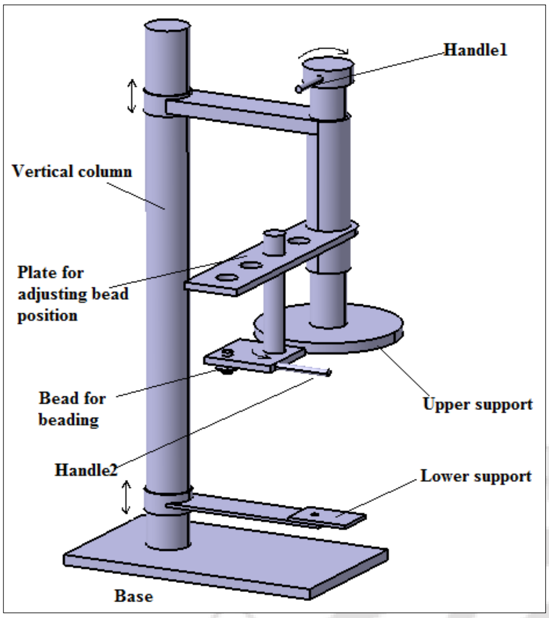
Sustainability:

- Design tools with components that are easy to recycle at the end of their life cycle.
- Low environmental impact, as easy to recycled.
- In the design process, a predominant use of standard parts is implemented to minimize waste during manufacturing. This is achieved by optimizing material usage and incorporating recycling practices for scrap materials. This approach not only ensures efficiency but also aligns with sustainable manufacturing principles.

4.4 Conceptual Design and Development for Hemming/ Beading Tool

4.4.1 1st Phase of Development

A flattened hemming tool is developed for brass sheet metal handicrafts to replace the existing complete manual hemming process by means of a hammer and anvil in the overall handcrafted utensil manufacturing process. This tool is conceptualized based on roller forming for small production quantities in batches to improve productivity and quality of crafts with multiple variants of utensils and other handcrafted products.



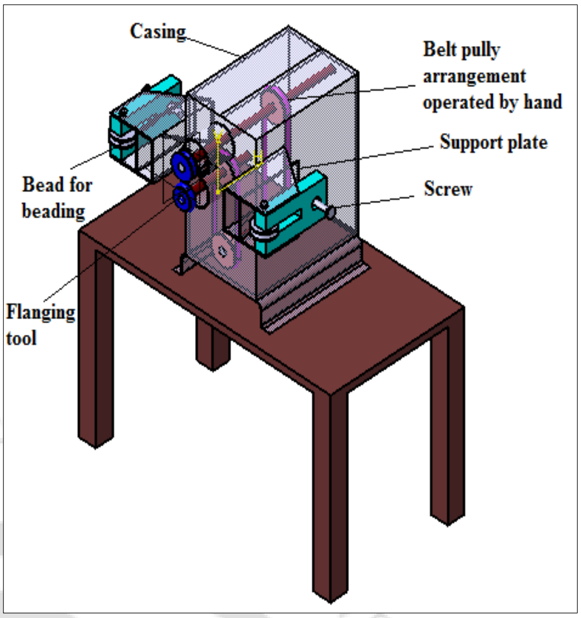


Figure 4.11: Conceptual CAD design for hemming tool

The design is further improved for the compactness of the tool. Figure 4.12 and 4.13 shows the developed concept of hemming tool.

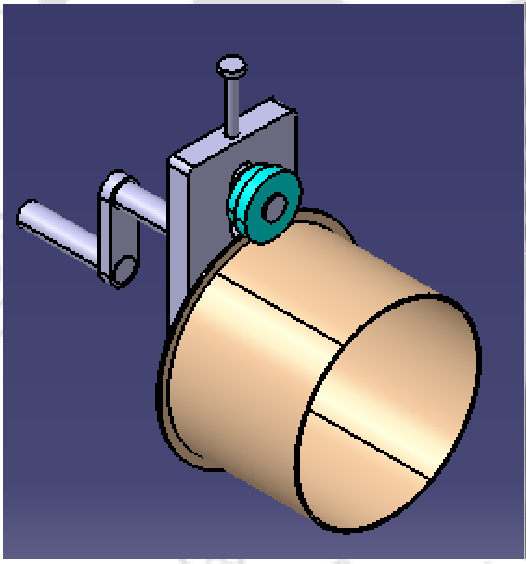
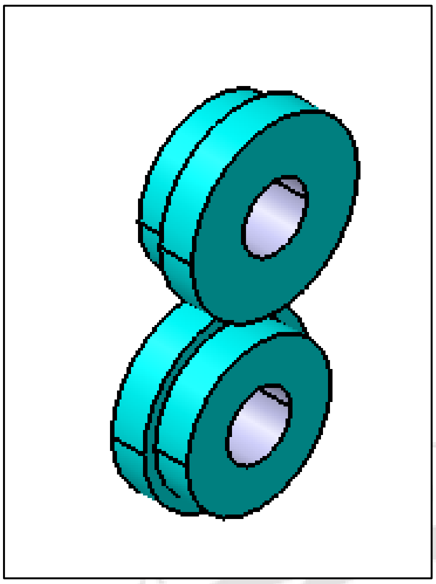


Figure 4.12: Hemming tool CAD Model concept1

Figure 4.13: Prototype of hemming tool concept 1



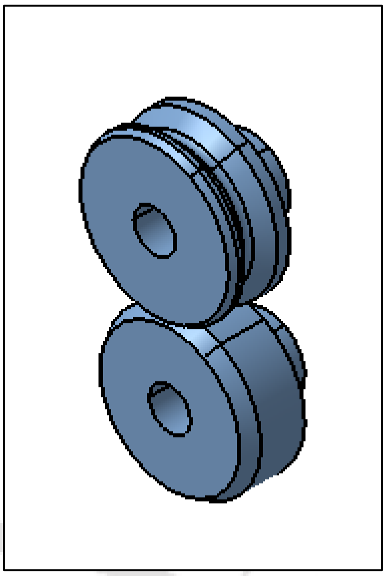


Figure 4.14: First set of roller dies **Figure 4.15:** Second set of roller dies

Developed concept1 follows the following steps for complete the operation:

Step 1: With the assistance of the initial set of roller dies, create a 90-degree flange on the sheet's outer edge (as seen in Figure 4.12).

Step 2: After that, place a metallic wire on the flange's surface and bend it around the wire to create a rough circular edge. It is a comparable procedure that is also use in traditional metalworking techniques.

Step 3: To complete the hemming operation, the profile generated from step 2 is further passed through a second set of roller dies (as shown in Figure 4.13).

Outcomes of Test1

- Roller dies are not fastened to the rotating shaft, as is evident. As a result, there is a slide between them, which disrupts the process's flow.
- With a given set of dies, obtaining a flange angle is challenging.
- There is design adjustment required with the variation in sheet thickness.
- There is a need for design constraints and ergonomic improvements.

4.4.2 2nd Phase of Development

The first phase of concept development's results are taken into account to further improve the concept. Additionally, we introduce the three sets of roller dies in this phase to eliminate the metal wire that was used for hemming/beading in the first phase.Therefore, .

Dimensions and Functional Characteristics

The following instructions will ensure that no extra tooling is needed when adding a curl (hem or bead) to the edge of a sheet.

- The outside radius of curl (R_o) can be no smaller than 2 times the material thickness (T).

  $R_o \geq 2T$

  $R_o \geq 2\times 2.59$

  $R_o \geq 5.1mm$

  R_i (inside radius of curl) = R_o –T = 5.1 - 2.59 = 2.51mm

- A hole should be at least the radius of the curl plus material thickness from the curl feature.

curl hole = R_i + thickness from curl features = 5mm

- A bend should be at least the radius of the curl plus 6 times material thickness from curl feature.

  bend= R_i + 6 × material thickness

  bend=2.5 + 6 × 2.59 =18mm (approx.)

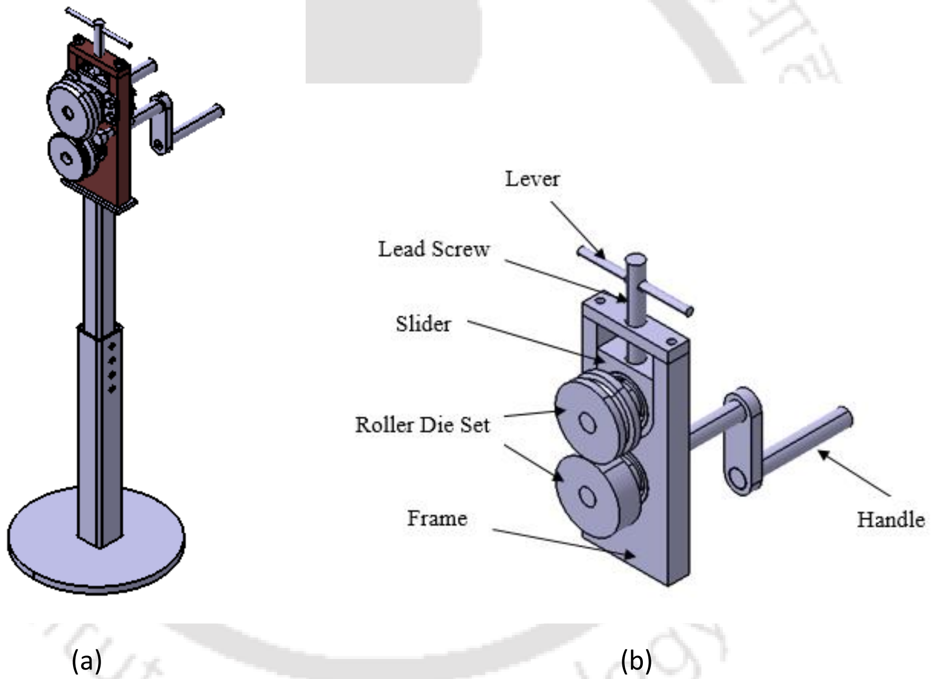


Figure 4.16: Hemming tool CAD Model 2 (a) with stand and (b) without stand

Figure 4.17: Physical model Hemming tool as concept2 view1

Figure 4.18: Physical model Hemming tool view2

Working of Tool

The complete hemming operation is done in 3 stages, and varied a range of products are covered through tools shown in the Figures 4.19 to 4.21

- The sheet edge bends up to 90 degrees during the initial stage of the hemming process. Between the die sets, the component is inserted. With the lead screw moving up and down, the dies are loosened and tightened. The lead screw is moved with the help of a lever. Rotate the roller with the aid of the handle to move the job between the dies.
- In the second stage, the edge of the sheet is further bent more than 90 degrees by introducing the second die set. The hemming is completed by a third set of dies.

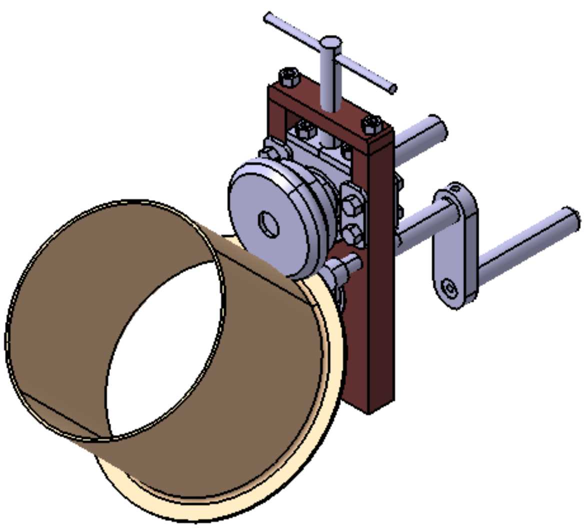


Figure 4.19: First stage 90 degree edge bend

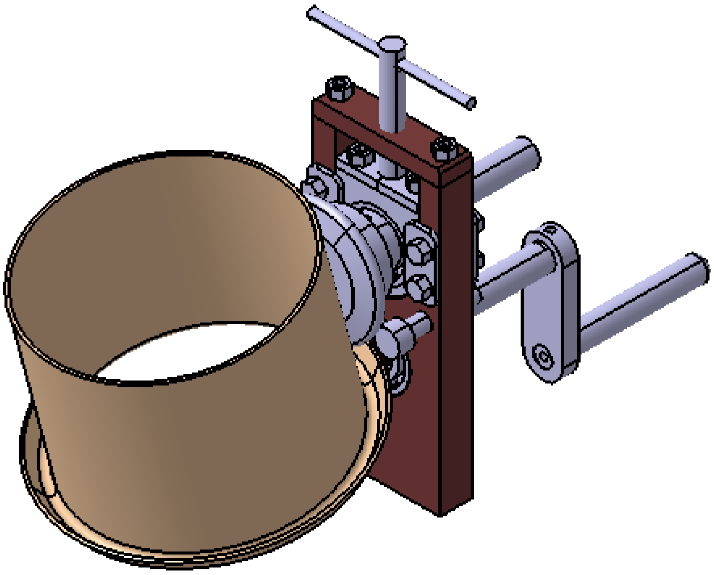


Figure 4.20: Second stage edge further bended more than 90 degree

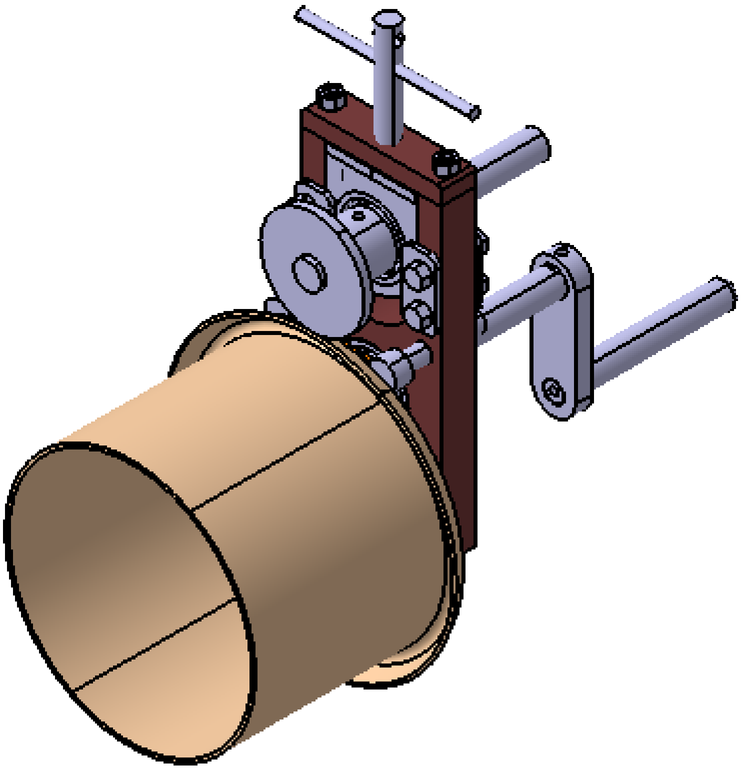


Figure 4.21: Final stage of hemming

Outcomes of Test 2

- During the loading of the panel, the slider slipped outside the frame. The slider guide is introduced (shown in Figure 4.22) to overcome this problem.

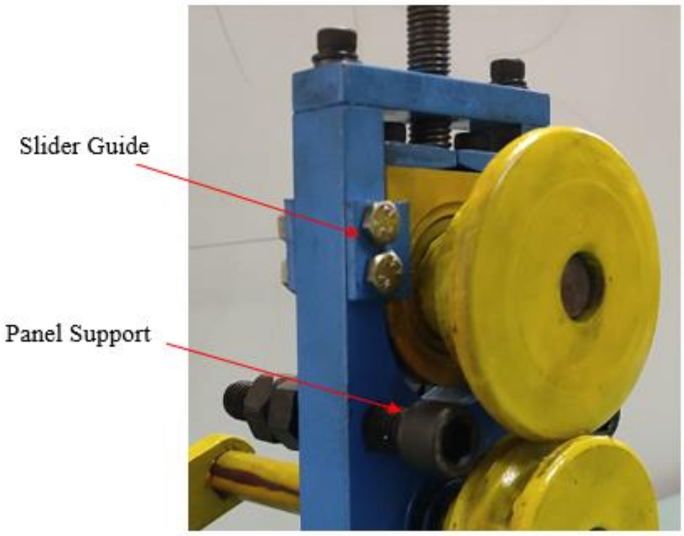


Figure 4.22: Tool with slider guide and panel support

- When hemming, the lack of panel support results in an uneven profile (as seen in Figure 4.23). As a result, panel support is included in the design. It prevents interruptions to the panel's flow.

Figure 4.23: Hemming in aluminium sheet panel

- When hemming, the lack of panel support results in an uneven profile (as seen in Figure 4.23). As a result, panel support is included in the design. It prevents interruptions to the panel's flow.

4.4.3 3rd Phase of Development

The tool is further enhanced by the addition of the gear drive illustrated in Figure 4.24, which helps to increase operational flow and minimise physical effort. Gears are created with a variety of sheet thicknesses in mind. Additionally, the handle mounting lever's length is lengthened for more torque.

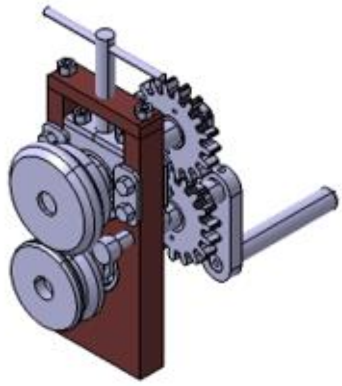


Figure 4.24: CAD model of Hemming with gears

Figure 4.25: Prototype of Hemming tool with gears

Figure 4.26: Hemming in brass sheet. metal

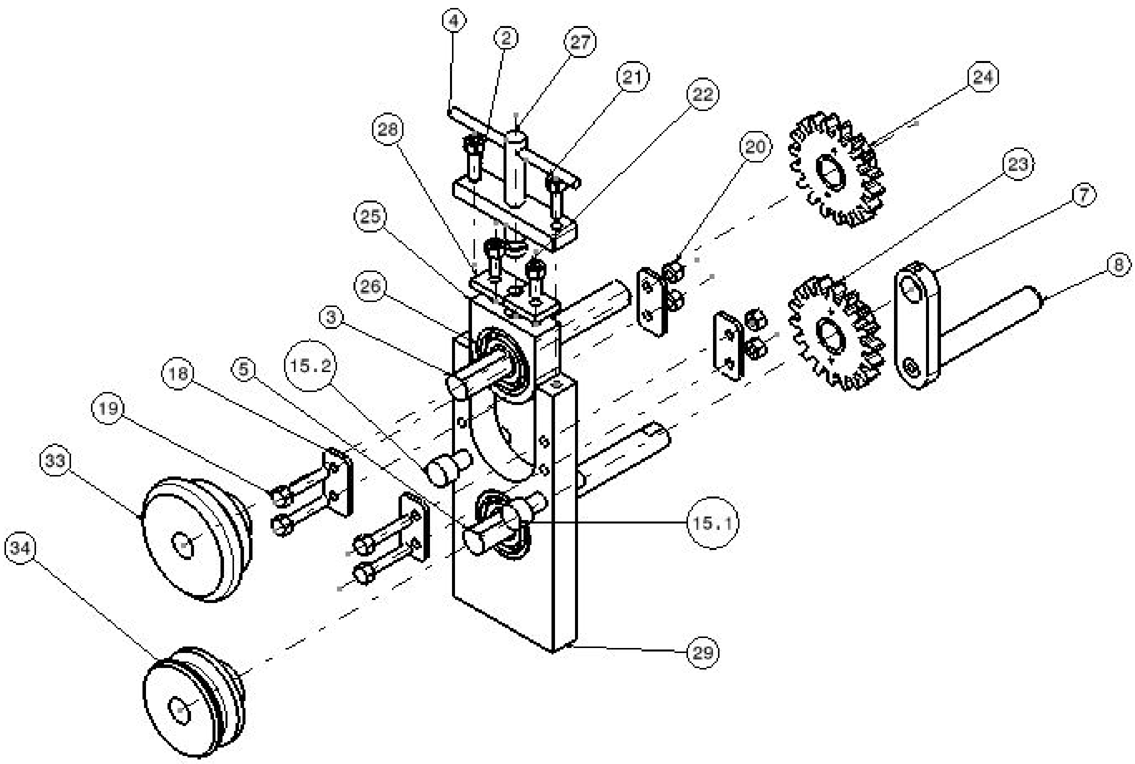
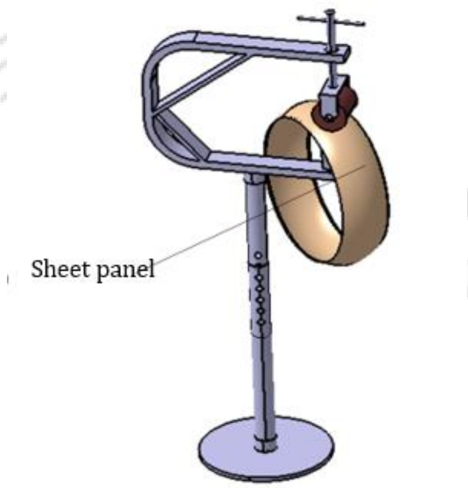


Figure 4.27: Exploded View of Hemming Tool (details are mentioned in Annexure IV)

4.5 Conceptual Design and Development for Shaping Tool

4.5.1 1st Phase of Development

The initially concept is generated by considering the form follow function and deploying roller dies to achieve the form.



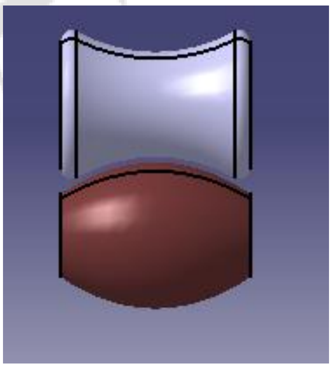


Figure 4.28: CAD model of shaping tool concept1 **Figure 4.29:** Roller Die set with forming gap

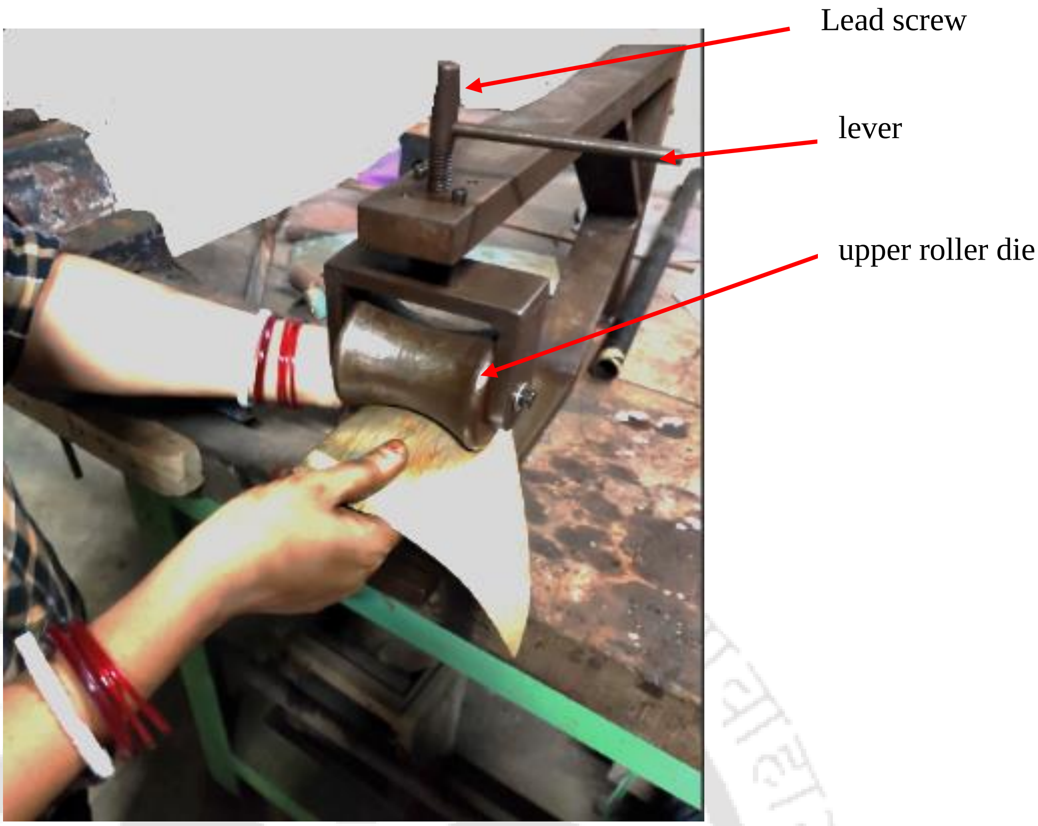


Figure 4.30 Prototype of shaping tool concept1

Working of Tool

Put a metal sheet between the dies first, then bend the surface by adjusting the upper roller. The upper roller dies can be raised and lowered using a lead screw and lever. The force required to stretch the sheet and change it into a curved surface increases with the downward movement of the dies, while the force decreases with upward movement. Metal is simultaneously pushed back and forth by the force of the worker.

Output of Shaping Tool Test 1

- The tool is tested on an aluminium sheet during a workshop test. It is noted that the twisting of the roller sub-assembly side by side, as shown in Figure 4.31, disturbs the flow of operation.

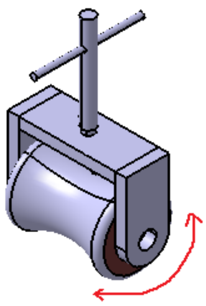


Figure 4.31 Upper roller die sub assembly

- The tool took more time to use and was uncomfortable to hold during the test.

4.5.2 2nd Phase of Development

By reducing extra elements and adding a handle for easy handling, the concept is further refined. Adding a guiding bush, as depicted in Figure 4.32, will prevent the upper roller from twisting and will allow the roller to freely move up and down.

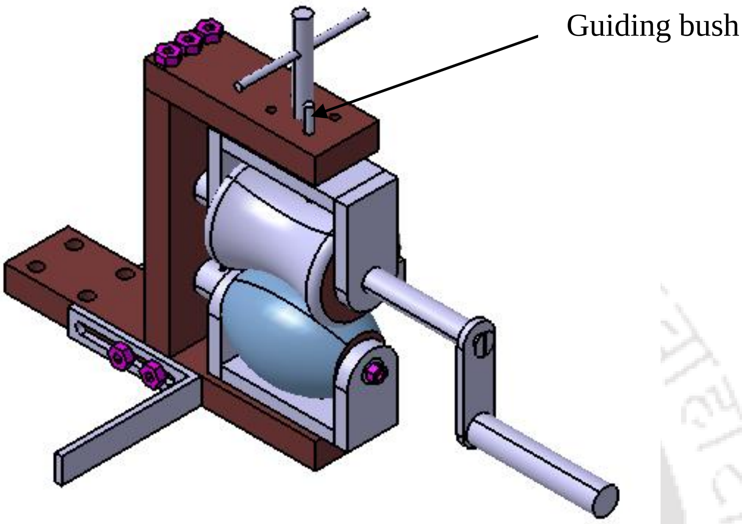


Figure 4.32: CAD model of shaping tool concept2

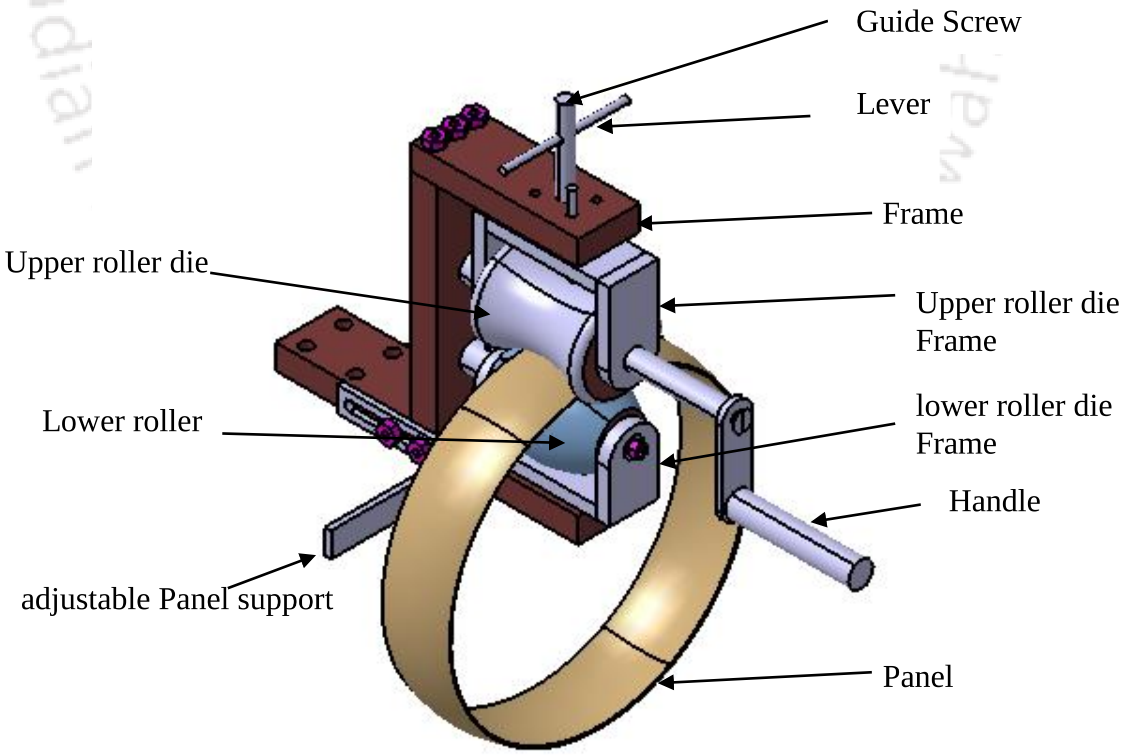


Figure 4.33: CAD model of shaping tool concept2 with panel loading condition

Working of Tool

- The top roller die frame can be moved. The upper roller's up-and-down action is facilitated by a guiding screw. It also applies force to the panel. The lower roller die frame is secured to the assembly frame's base.
- Between the upper and lower die sets, a cylindrical panel was inserted. Through the lead screw's adjustment, the higher roller applies pressure to the panel.
- The panel is then rotated using the handle to create a 3D-curved shape. The panel is guided by an adjustable support panel. It prevents any disruption to the flow's direction and course.
- The panel is unloaded by losing the guide screw.

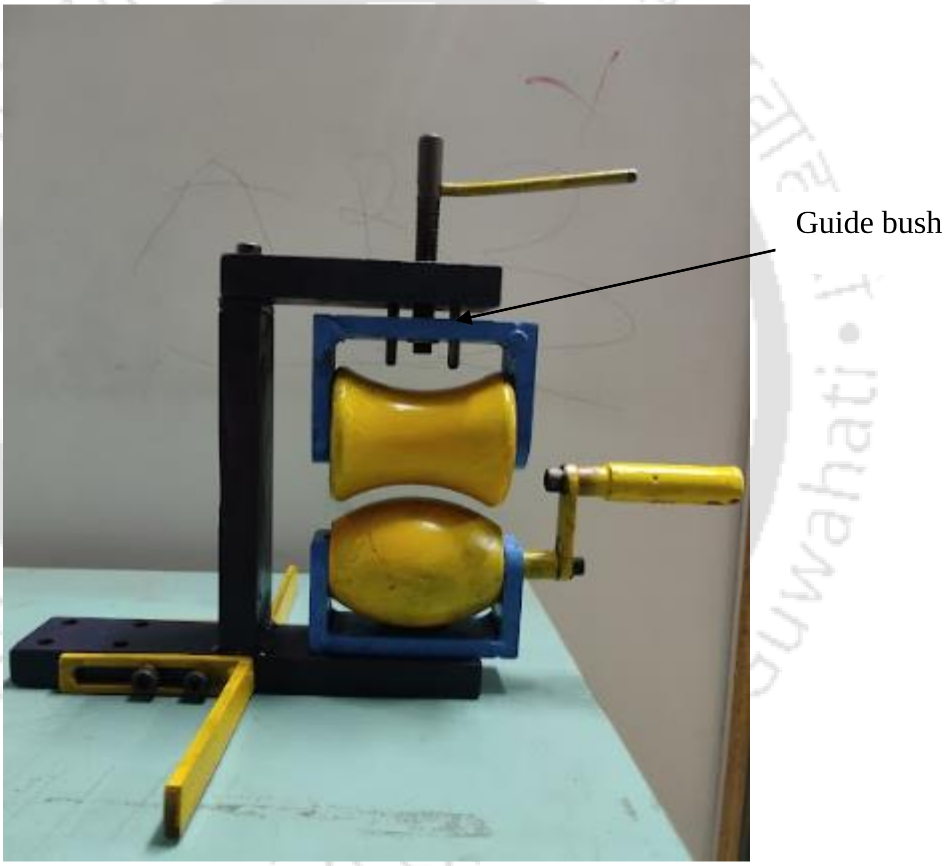


Figure 4.34: Prototype of concept 2

Outcomes of Shaping Tool Test2

- The tool is tested successfully using aluminium sheet. There were complications, such as the need for higher force while loading the brass sheet panel to construct the 3D form.
- There is a need for gear to reduce physical force and improve the rotation of the roller.

4.5.3 3rd Phase of Development

Gears are introduced to reduce muscular force and improve working. Gears are designed considering the variation in sheet thickness.

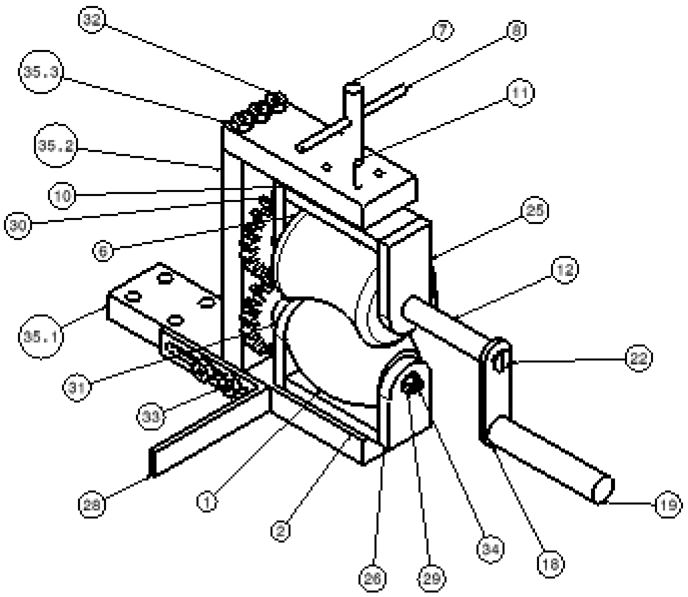


Figure 4.35: Isometric view of shaping tool with gears, concept3 (details are mentioned in Annexure V)

Figure 4.36: Prototype of Shaping tool with gear

Outcomes of Shaping Tool Test 3

- Figure 4.36 illustrates how an open-ended flat brass sheet was effectively transformed into a 3D curving form.
- In order to generate a 3D curved surface, a closed cylindrical brass panel is first tested in between a set of roller dies while taking into account the traditional handicraft approach. As seen in Figure 4.37, it causes the panel surface to take on an uneven form. The panel tries to stretch in both the lateral and longitudinal dimensions when force is applied to a closed cylindrical panel to achieve a curvature surface. Since the panel is closed, it is challenging to release the stretched force, which leads to shape abnormalities.

Figure 4.37: Brass panel with irregular shape

- This issue is fixed in a subsequent test on an open-ended, flat brass panel by adding side support. Upper and lower rollers assist in creating the final 3D curved surface, while side support aids in creating the round cylindrical form (illustrated in Figure 4.38).
- To deform plastically simultaneously in the lateral and longitudinal directions, a significant amount of force is required.
- For panel shaping, a pre-shaping process is necessary. The panel must be hammered in the middle area around its full flat surface over a die in order to deform it plastically.
- Then the panel is passed through the tool to get the final output in the form of 3D curve surface.

Figure 4.38: Modified shaping tool with gears

Figure 4.39: Output of Shaping tool

4.6 Conceptual Design and Development for Surface Bending Tool

4.6.1 1st Phase of Development

This concept is designed to increase productivity and craft quality in small batches of production using the three roller forming technique. Additionally, when sheets are bent, various ranges of sheet thickness and the radius of cylindrical forms are taken into consideration.

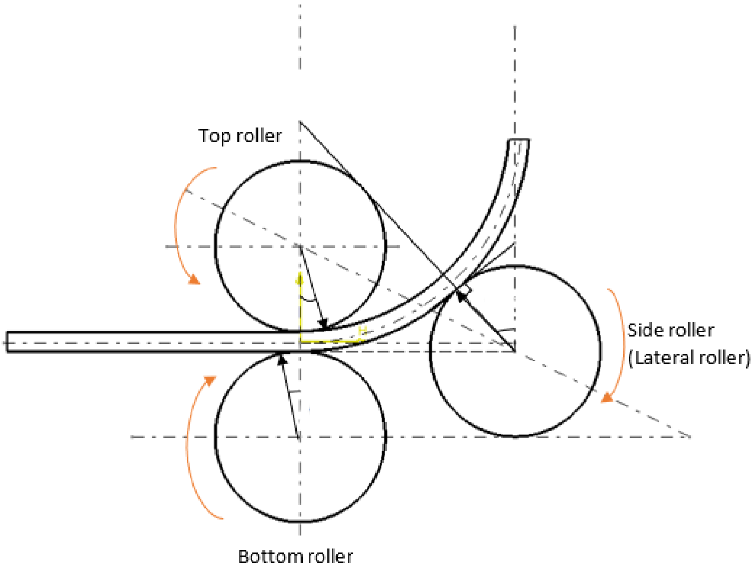


Figure 4.40: Working Principle of 3-Rollers surface bending

To create the form required for surface bending, the basic concept is generated through a conceptual process. Additionally, it integrates edge hemming, surface bending, and cutting metal sheets into one tool.

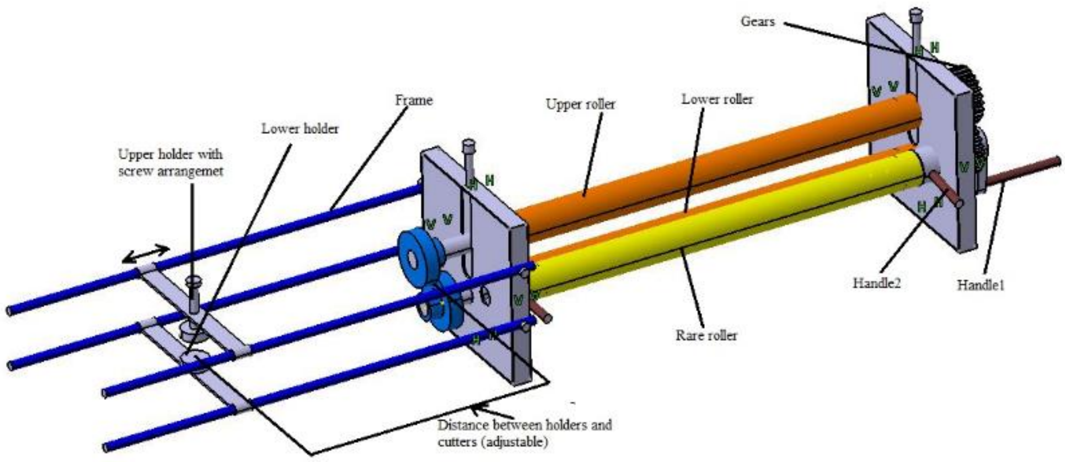


Figure 4.41: Initial Conceptual CAD design for surface bending tool

Design restrictions include the thickness variation of the metal sheet used for construction, the need for speed, and an anthropometric and behavioural fit between the user and the product, all of which serve to modify the original concept. As a result, the idea was changed to just apply to surface bending procedures.

Dimensions and Functional characteristics

Material: low lead yellow brass (65.0 cu, 35.0 Zn)

Ultimate tensile strength (UTS) = 317 Mpa

Yield strength = 447 Mpa

Elongation in 50mm = 0.65

Poisson ratio = 0.34

Young's modulus = 110 Gpa

Bend allowance

B = α (R +Kt) ……………….1

where α = Bend angles, radians

R = Inside radius of the bend, mm

K = location of neutral axis from bottom surface

= 0.33 when R< 2t

= 0.50 when R > 2t

t = Thickness of Sheet, mm

The particular radius at which cracks appears on the bend sheet is called minimum bend radius. It is always given in terms of sheet thickness.

Table 4.6: Minimum radius for bending [125]

Material	**Soft**	**Hardened**
Aluminum Alloy	0	6t
Low carbon steel	0.5t	4t
Titanium alloy	2.5t	4t
Beryllium copper	0	4t
Brass , low lead	0	2t

The calculation of load and stress acting on the sheet 2

W= $\frac{4EI}{RL}$ ……………….2

where W= load

I = Moment of inertia

R = Radius of curvature

L = length of sheet

Length of sheet = bend part sheet length + bend allowance

= 2πr + α (R +Kt) (Considered the dia of bend part 40mm, found as min dia from field survey)

=135mm

From equation 2

$W = \frac{4*110*1000*51.75}{23*135}$

= 7333.33 N

shaft subjected to twisting and bending moment

With load W of 7333.33 N considering factor of safety= 2

working load =7333.33*2 =14,666.66 N

considering shaft length =350mm (max width of sheet used)

Bending moment (M) = Force * horizontal distance

= 14,666.66 *.35

= 5133.33 N-m ………………3

Twisting moment (T) = Force * perpendicular distance

= 7333.33d N-m………………4

Te $=\sqrt{M^2 + T^2} = \frac{\pi}{4}\tau\, d^3$ (putting value of equation 3 and 4)

d = 38 mm (approximately)

Therefore, minimum dia of roller d= 38 mm

Length of Shaft = 350mm

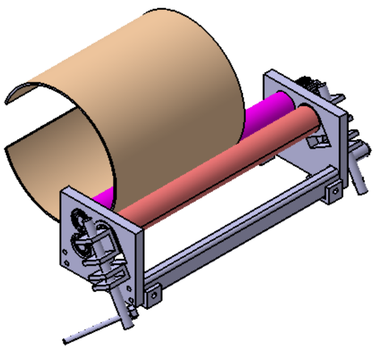


Figure 4.42: Surface bending tool without stand, concept1

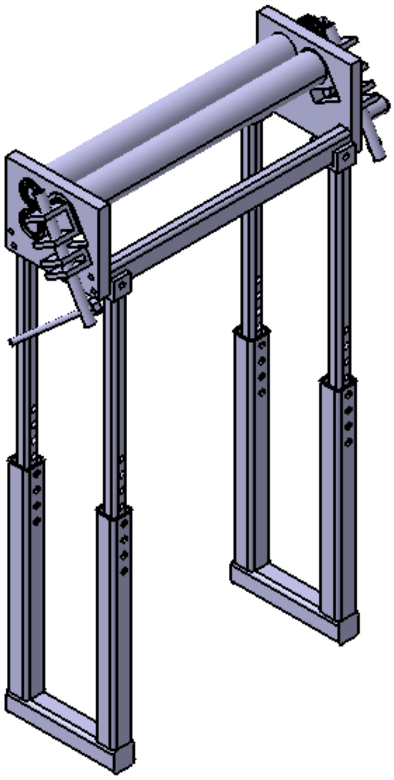


Figure 4.43: Surface bending tool with adjustable stand as Concept1

4.6.2 2nd phase of development

- The tool is further altered so that it can be used at the workbench. To accommodate for variations in metal sheet thickness and how simple the tool is to use by the craftspeople, the tool's design is changed.

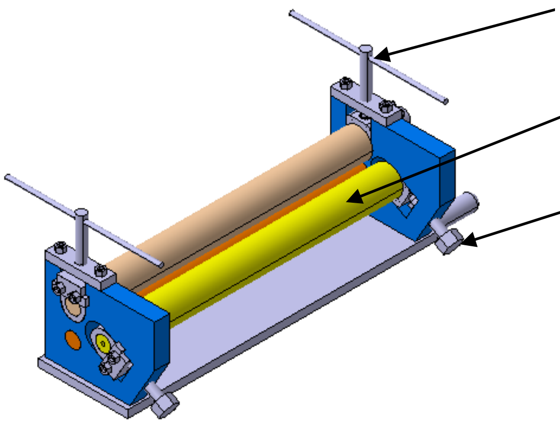


Figure 4.44: Isometric view of surface bending tool

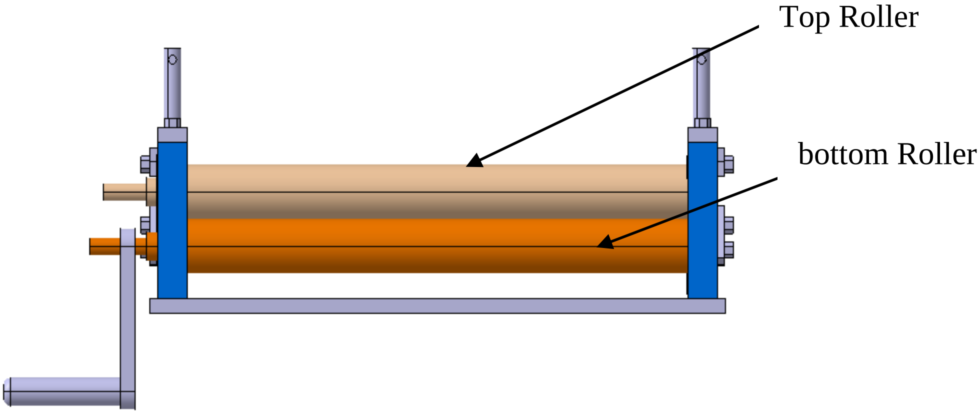


Figure 4.45: Side view of surface bending tool

Working of Tool

- First, the brass sheet panel is inserted between the upper and lower rollers. With the aid of the guide screw included in the tool, the top roller can be altered for different sheet thicknesses. Guide screws also exert force on the sheet.
- The sheet panel put between the top and bottom rollers is given push and support when the side roller is adjusted upward. With the aid of the handle, the panel is then turned between the higher and lower rollers to create a cylindrical shape.

Outcomes from Field Test 1

- Tool is successfully tested with aluminium sheet.

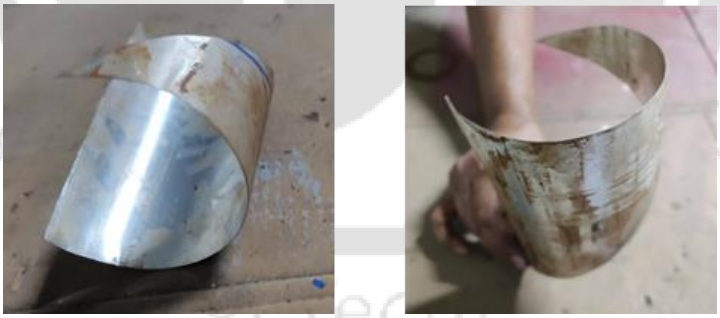


Figure 4.46: Outcomes of 1st test on aluminium sheet panel

- The panel made out of brass sheet is challenging to bend. Gear drive is required to lessen physical force and enhance working.

4.6.3 3rd phase of development

Figure 4.47: Side View of surface bending tool with gear

Figure 4.48: Bend part

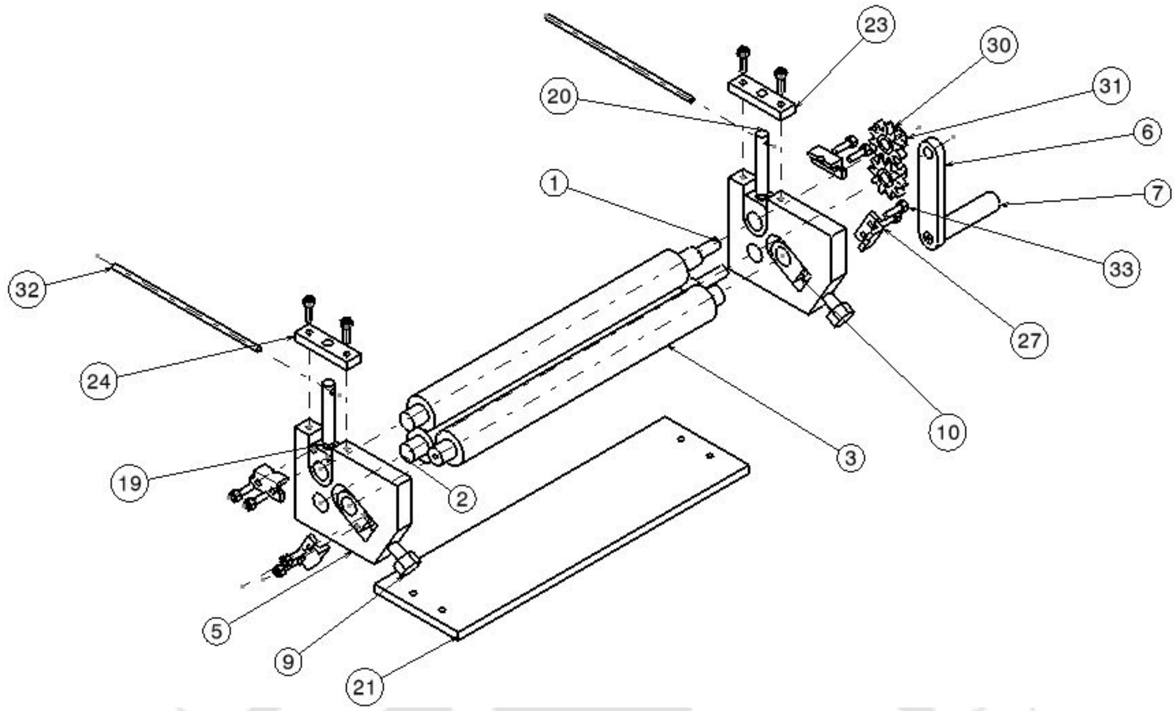


Figure 4.49: Exploded view of surface bending tool (details are mentioned in Annexure VI)

4.7 Ergonomic Study of Work Station

Workplaces often prioritize tools and setups that minimize strain on the body over extended periods. Standing workstations can help maintain better posture and reduce the risk of musculoskeletal issues associated with prolonged sitting.

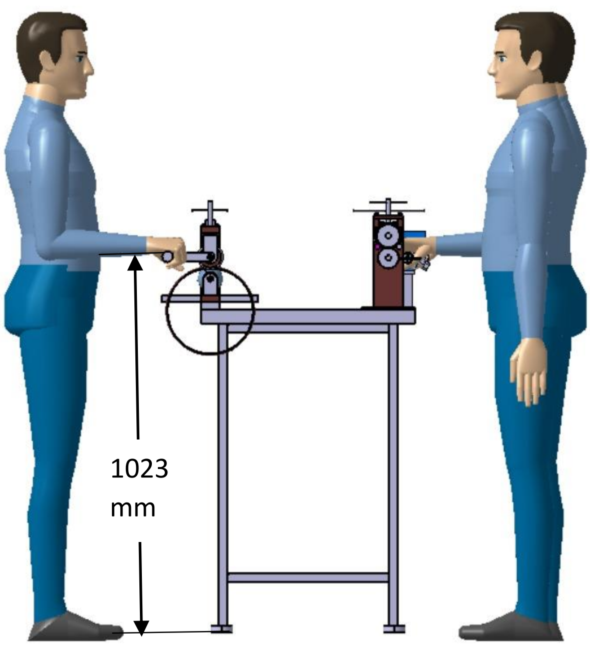


Figure 4.50: Front View of Work Station

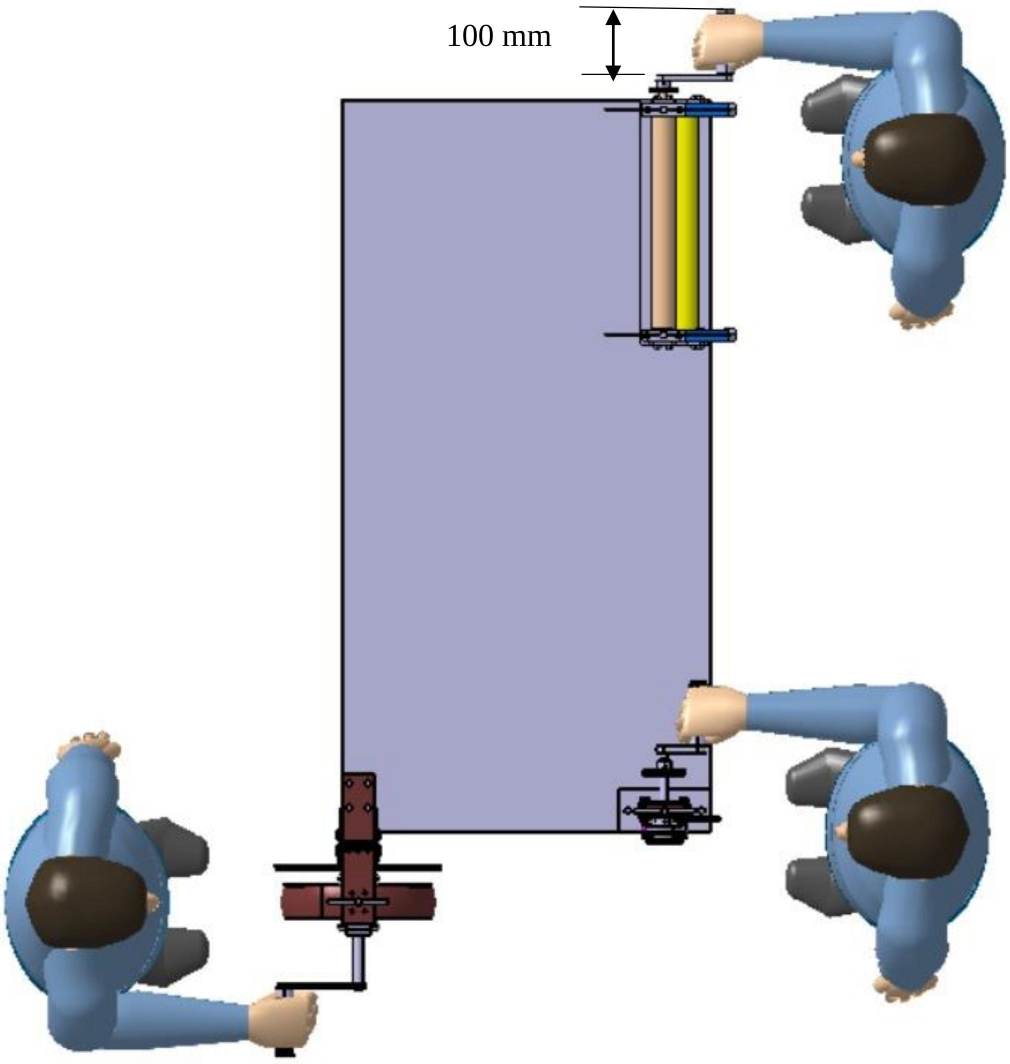


Figure 4.51: Top View of Work Station

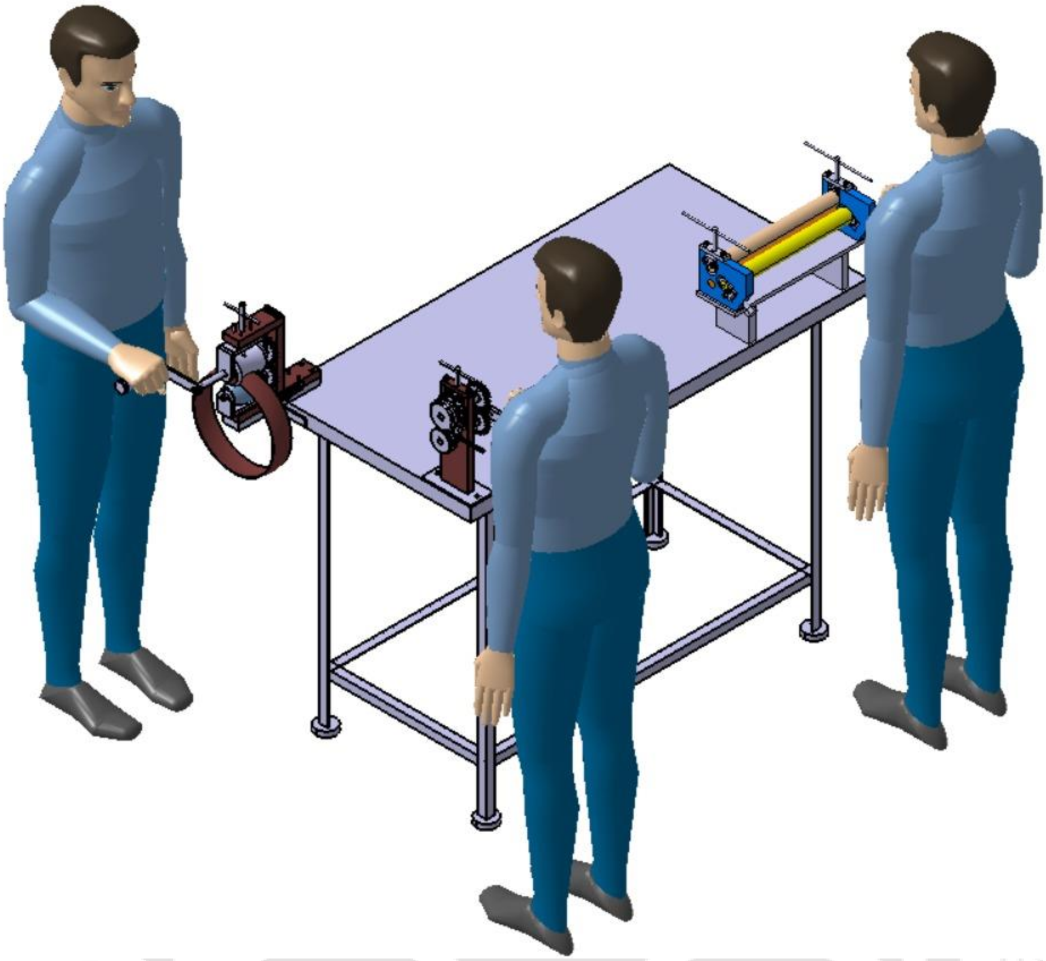


Figure 4.52: Perspective View of work Station

Workbench tools are also designed with the ergonomics of the user in mind. They're typically positioned at a height that allows for comfortable use while standing, promoting better leverage and reducing strain when applying force. This setup not only enhances productivity but also contributes to the overall health and well-being of artisans and craftsmen.

Table 4.7 :Anthropometric Parameters [126]

Parameters		**Percentiles**		
		5th	50th	95th
Elbow height	Male	945 mm	1039mm	1123mm
	Female	879mm	953mm	1039mm
	Combine	908mm	1022mm	1115mm
Hand grip length	Male	39 mm	50 mm	65 mm
	Female	41mm	50 mm	63 mm
	Combine	40 mm	50mm	64mm
Hand grip length	Male	82 mm	99 mm	109 mm
	Female	70 mm	86 mm	96 mm
	Combine	79 mm	96 mm	109 mm
Fist circumference	Male	240 mm	264 mm	294 mm
	Female	205 mm	229 mm	249 mm
	Combine	219 mm	247 mm	275 mm
Grip insight diameter max	Male	42 mm	49 mm	56 mm
	Female	40 mm	46 mm	52 mm
	Combine	41 mm	49 mm	56 mm

4.8 Results and Discussion

4.8.1 Concerning of Design and Development Phase

- First, tools are constructed without gears. The brass sheet was found to be difficult to bend throughout the hemming, shaping, and surface bending procedures, whereas the aluminium sheets were easily bent. As a result, gears are required to shape or form brass metal sheets during the cold-forming process.
- Another requirement is a big handle-mounted lever to prevent static muscular loading. It increases leverage, creates smooth gear flow, and reduces the need for manual labour.

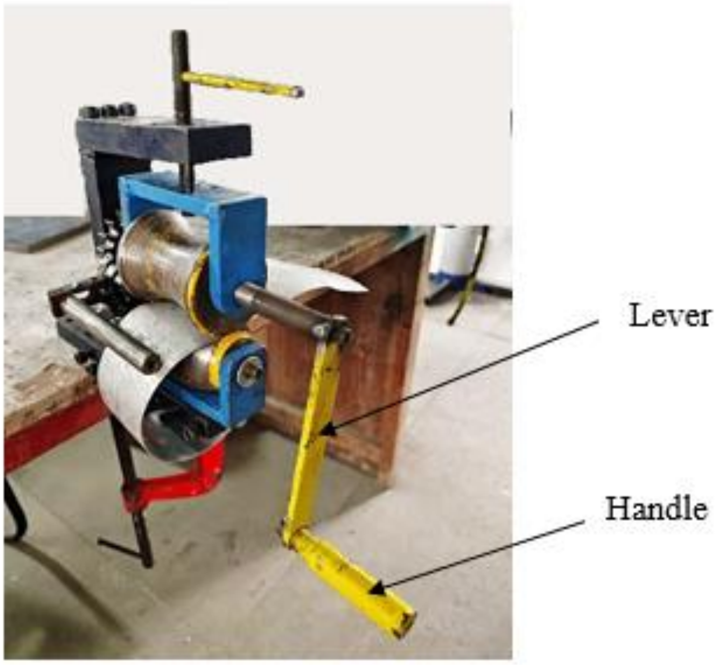


Figure 4.53: Shaping tool with large lever to improve leverage

- A shell is added to the handle. Shells glide along the handle base's surface as the handle is turned during usage. By doing this, stress isn't concentrated on the hand's delicate tissues.

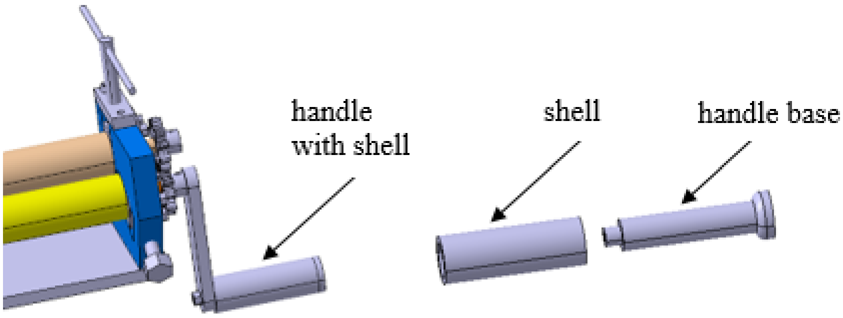


Figure 4.54: Handle with shell

4.8.2 Observations On the Hemming Tool Design and Development Phase

- For simplicity of operation, number has provided each die set.
- To hasten die configuration and make sure that die meshing is precise, keys are needed (shown in Figure 4.55). The key's width is 5.9 mm for the first set of dies and 7.7 mm for the second set. The die design is improved further to do away with this crucial requirement.

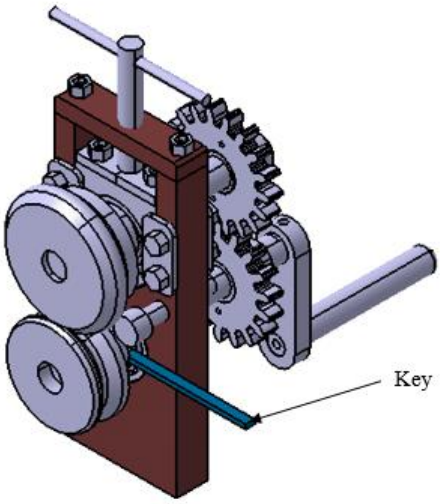


Figure 4.55: Hemming tool with key availability

- Sharp edges on die sets used for hemming have an impact on the finished craft's form. The performance of a tool is improved by sharp-edge filing.

4.8.3 Observations On the Shaping Tool Design and Development Phase

- It is found that the cylindrical bending of sheets is easily done by roller dies because the material is stretched unidirectionally. The metal sheet must be stretched in both the longitudinal and lateral directions during the shaping process to obtain a cylindrical shape with a curved surface. Before the final shaping process, the brass sheet needs to be vigorously hammered around the surface to create a cylindrical shape with a curved surface.

4.8.4 Observations On the Bending Tool Design and Development Phase

- There is a need for keys to set the side roller to achieve the required diameter of the panel with the given range of thickness

Table 4.8: Relation between t, d and h

Sheet thickness(t)	**Diameter(d) of panel form**	**Side roller adjustment distance (h)**
1mm	80mm	10mm
1mm	100mm	8mm
1mm	120mm	6mm
1mm	140mm	4mm
2mm	180mm	8mm
2mm	220mm	6mm
2mm	260mm	4mm

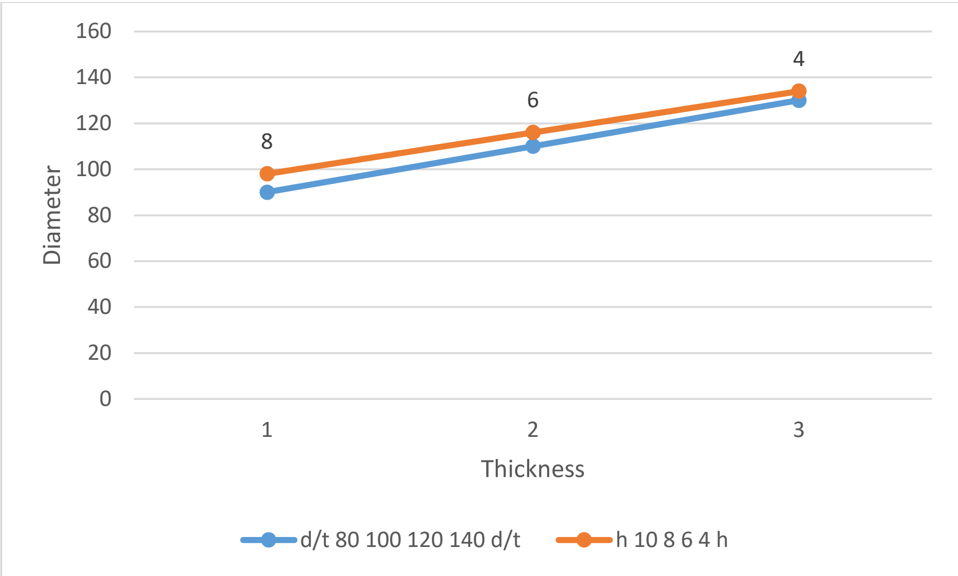


Figure 4.56: Graph to represent relation between t, d and h

4.8.5 Observation on Productivity

Hemming Tool

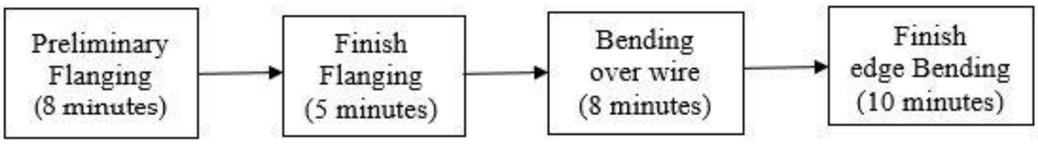


Figure 4.57: Traditional Hemming process flow map

Artisan works for 8 hours a day with an effective available time of 450 minutes.

total time required for hemming is 30 minutes

production capacity of hemming =450/30 =15 units

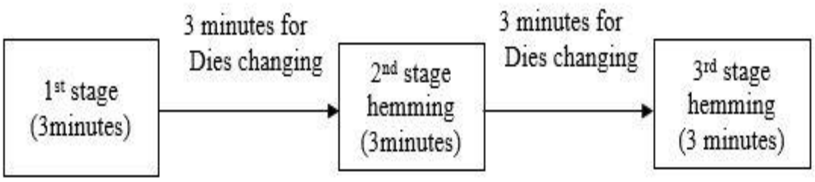


Figure 4.58: Hemming process flow map with intervened tool (Dies are changed at different stages)

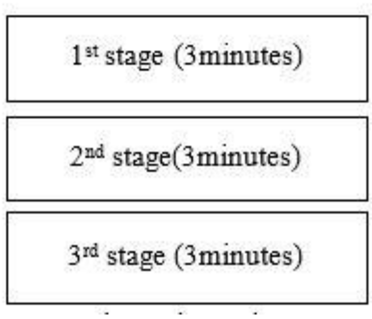


Figure 4.59: Hemming process flow map with three tools for three stage

Artisan works for 8 hours a day with an effective available time of 450 minutes. In case, Tool is same and Dies are changed in different stage of hemming as described in Fig 4.19 to 4.21

Total time required for hemming is 15 minutes

Production capacity of hemming =450/15 =30 units

In case for different stage different tool with specified dies are introduced then

Total time required for hemming is 10 minutes

Production capacity of hemming =450/10 =45 units

Production capacity of hemming improved by 75 percentage

Shaping Tool

In existing Method

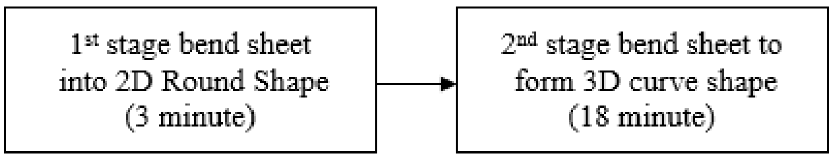


Figure 4.60: Shaping process flow map in existing method

Artisan works for 8 hours a day with an effective available time of 450 minutes.

Total time required for shaping is 21 minutes

Production capacity of shaping =450/21 =21 units

With intervened tool

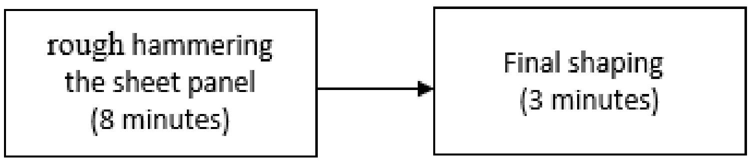


Figure 4.61: Shaping process flow map with intervene tool

Total time required for shaping is 11 minutes

Production capacity of shaping =450/10 =41 units

Production capacity of shaping improved by 75 percentage

Surface Bending Tool

In existing process

Artisan works for 8 hours a day with an effective available time of 450 minutes.

Total time required for surface bending is 3 minutes

Production capacity of surface bending =450/3 =150 units

with Intervened tool

total time required for surface bending is 1.2 minutes

Production capacity of surface bending =450/1 =450 units

Production capacity of surface bending improved by 67 percentages

4.8.6 Improvement in Productivity

Table 4.9: Percentage improvement in productivity

Craft/Product	Current Method		With Intervened tools		
	Standard time t1(min) per product	Work output (unit) per 8 hrs.	Standard time t2 (min) per product	Work (unit) output per 8 hrs.	% improvement in productivity ((t1-t2)/t1) *100
Kalshi	216	2	168	3	22%
Tow	128	4	95	5	25%
Gamla	113	4	75	6	34%
Kahi	70	7	60	8	14%
Korai	142	3	99	5	30%

Each craft goes through a different number of processes to complete the finished product. Therefore, variation in productivity is observed. Hence Improvement is considered based on tool wise process efficiency.

4.8.7 Cost Estimation

Analytical cost estimation techniques are employed for determining the costs associated with a product. Product cost estimation techniques are classified as:

i. **Qualitative Techniques**

- **Intuitive Technique:** Intuitive cost estimation techniques use past experience and expertise to generate cost estimates for parts and assemblies, aiding users in informed decisions and preparing cost estimates for new products.

- **Analogical Technique:** These techniques utilize similarity criteria derived from historical cost data of products with known costs.

ii. Quantitative Technique

- **Parametric Technique:** Intuitive cost estimation techniques use past experience and expertise to generate cost estimates for parts and assemblies, aiding users in informed decisions and preparing cost estimates for new products.
- **Analytical Technique:** The approach involves breaking down a product into its units, operations, and activities, each representing distinct resources consumed throughout the production cycle, and expressing the cost as the sum of these components [127].

For cost estimation we have considered Korai case (shown in Fig. 4.1(e)) for cost estimation.

Current market price of Korahi = ₹1000 = $ 12 (approx.)

Material cost = 60% of price = ₹600 = $ 7.3 (approx.)

Profit = 15% of price = ₹150 = $ 2 (approx.)

Process cost = 25% of price = ₹250 = $ 3 (approx.)

In Existing intervene process

Process cost improved by 17% = ₹250 × 17% = ₹43 per product = ₹47 per product (approx.)

Table 4.10: Costing details of each tool (material for tools is mild steel)

	Hemming Tool	**Shaping Tool**	**Surface bending Tool**	**Total manufacturing Cost in Rupees (₹)**	**Total manufacturing Cost in USD ($) 1$ = ₹82**
No. of Parts	26	19	26	-	-
Total Finish weight	6.5 kg	8 kg	24 kg	₹3465 (₹90/kg)	$42
Cutting face	19	28	50	₹4850 (₹50/face)	$59
Milling	7	4	8	₹950 (₹50/face)	$12
No. of drill	23	27	46	₹960	$12
CNC	2	2	-	₹800	$8
Turning	8	-	-	₹800	$8
Welding	-	3	-	₹600	$7

Total manufacturing cost = ₹12000 or $146 (approx.)

Total no of parts = 12000/47 = 255 parts

Comparison of the cost of existing process with the process using design intervened tool, reveals that after making 255 products, the cost of all equipment may be adjusted.

Mild steel is chosen for tool manufacturing due to its favourable properties such as ease of machining, affordability, and adequate strength for many applications. The roller parts require surface-hardening treatment. The current cost calculation does not consider the surface hardening costs. The choice of 20MnCr5 material, known for its ability to achieve a surface hardening of 40 HRc (Hardness according to Rockwell) and a complete hardening of 60 HRc, is highly recommended. The exceptional heat treatment properties of 20MnCr5 not only ensure optimal hardness but also contribute to enhanced durability and performance of the tool.

CHAPTER 5

Conclusion, Limitation and Future Scope

5.1 Concluding Remarks Against Research Questions

5.2 Limitation

5.3 Future scope of the research

CHAPTER 5

Conclusion, Limitation and Future Scope

The study on design interventions in manufacturing tools emphasizes the importance of adaptability for various handicrafts, cost-effectiveness, user-friendliness, and their substantial impact on enhancing quality and productivity. Scholars and practitioners in the field have highlighted the need for tools that can be easily customized to accommodate the diverse requirements of different handicrafts. This adaptability ensures that artisans can efficiently employ the tools across various crafts without significant modifications.

Moreover, the study underscores the economic aspect, emphasizing the importance of cost-effective solutions. Design interventions that are inexpensive and utilize locally available materials are deemed more sustainable and accessible for artisans, especially in cottage industries.

User-friendliness is another critical factor highlighted in the literature. Tools that are intuitive, easy to operate, and require minimal training contribute to the successful implementation of design interventions. This is particularly relevant in contexts where artisans may have varying levels of expertise and educational backgrounds.

Furthermore, the study consistently emphasizes the positive correlation between well-designed manufacturing tools and improvements in both the quality and productivity of handicrafts. Interventions that streamline processes, reduce errors, and enhance precision contribute to the overall advancement of the handicraft industry.

In conclusion, the literature on design interventions in manufacturing tools underscores the significance of adaptability, cost-effectiveness, user-friendliness, and their positive impact on both the quality and productivity of various handicrafts.

5.1 Concluding Remarks Against Research Questions

Validation of research question (RQ) is given below:

RQ1: What are the opportunities for innovation and design Intervention in brass metal handicraft manufacturing process?

In the realm of brass metal handicrafts, there are numerous opportunities for innovation and design intervention that can enhance the craft, making it more appealing, functional, and sustainable. Some potential areas for innovation are design aesthetics, cultural fusion, functionality, sustainability, customization and personalization, technology integration, educational initiatives, market expansion

To comprehensively examine opportunities within product development, planning, and market strategy, a thorough analysis is conducted with a central focus on consumers. This approach seeks to uncover insights into the industry's progression, encompassing diverse facets such as social impact, socio-economic factors, community engagement, accessibility, affordability, cultural conservation, long-term sustainability, and the policy implications involved.

The Assam brass handicraft sector faces significant challenges, including limited market connectivity, resistance to technology integration, and constraints on product diversification in rural areas. These hurdles result in reduced exposure and growth potential for artisans. Moreover, environmental concerns and pricing disparities further complicate the industry landscape. Overcoming these challenges is crucial for the industry's competitiveness. Embracing technology, managing resources responsibly, and finding a balance between tradition and innovation are key steps to ensuring the long-term sustainability and cultural authenticity of Assam's brass metal handicrafts.

In the context of sustaining market competitiveness, it is crucial for businesses to maintain client connections through affordable rates and high-quality products. Technological intervention is identified as essential for improving production processes and meeting consumer demands in the handicraft industry. Design intervention serves as a bridge between traditional craftsmanship and modern tools, fostering collaboration between designers and artisans. This collaborative innovation aims to revitalize the craft, addressing social, economic, ecological, and cultural aspects for sustainability. Integrating technology into traditional skills enhances artisan capacities, promoting competitiveness and enterprise development. However, challenges arise in technology adoption due to factors like cost, training, and perceived benefits. The Assam brass handicraft industry faces the need for effective manufacturing tools to improve efficiency and align with demand dynamics, emphasizing the importance of design interventions. Limited studies focus on adapting manufacturing tool design for brass metal handicrafts, highlighting the necessity for versatile, cost-effective, and user-friendly tools to enhance quality and productivity, ultimately improving the socio-economic conditions of artisans.

RQ2: What are the challenges for adopting advance tools and technology in brass metal handicraft sectors?

Skilled Labor Shortage:

Traditional handicraft sectors often rely on skilled artisans with specific craftsmanship. Integrating advanced technology requires a workforce with different skill sets. There may be a shortage of skilled workers who are familiar with operating and maintaining modern machinery.

Initial Investment Costs:

Acquiring and implementing advanced tools and technology involves significant initial costs. Many small and medium-sized businesses in the brass metal handicraft sector may find it challenging to make these upfront investments, hindering their ability to upgrade their processes.

Resistance to Change:

Craftsmen and artisans may be resistant to adopting new technologies, especially if there is a perception that these tools might replace traditional craftsmanship. There could be cultural or historical attachments to traditional methods, making it difficult to convince stakeholders of the benefits of modernization.

Customization Challenges:

Brass metal handicrafts often involve intricate designs and customized pieces. Adapting advanced tools to handle customization without compromising quality can be challenging. Traditional methods may offer a level of flexibility that is hard to replicate with automated processes.

Market Acceptance:

Consumers of brass handicrafts may have a preference for traditionally crafted items, viewing them as more authentic or valuable. Convincing the market of the quality and value of products produced using advanced technology may be a marketing challenge.

Infrastructure and Connectivity:

Access to reliable power sources, internet connectivity, and infrastructure support are crucial for the smooth operation of advanced tools. In some regions, especially those with a strong presence of traditional handicrafts, the infrastructure may not be well-suited for modern technology.

Training and Education:

Adequate training and education programs are essential for artisans to embrace and effectively use advanced tools. Lack of training resources and programs tailored to the specific needs of the brass metal handicraft sector can impede the adoption of new technologies.

Supply Chain Integration:

Integrating advanced technology may necessitate changes in the supply chain, from sourcing raw materials to distribution. Aligning traditional supply chain practices with the requirements of modern tools and technology can be complex.

Addressing these challenges requires a focus on design interventions in manufacturing tools that demonstrate versatility across different handicrafts, offer cost-effectiveness, user-friendliness, and significantly elevate both the quality and productivity. The goal is to enhance the livelihoods and socio-economic conditions of artisans in the cottage handicraft sector.

RQ3: How to formulate a sustainable tool design intervention in brass metal handicraft sector?

Creating a sustainable tool design intervention in the brass metal handicraft sector involves considering environmental, social, and economic factors. Here's a guide to formulate a sustainable tool design intervention:

Needs Assessment:

Conduct a thorough needs assessment to understand the current challenges and opportunities in the brass metal handicraft sector. Engage with artisans, craftsmen, and other stakeholders to identify specific areas where tool design can make a positive impact.

Environmental Impact Assessment:

Evaluate the environmental impact of current tool use in the sector. Consider factors such as energy consumption, material waste, and emissions. Identify opportunities to reduce the sector's ecological footprint through more sustainable tool design and usage.

Material Selection:

Choose materials for the tools that are environmentally friendly and have a minimal impact throughout their lifecycle. Consider recyclable materials, reduced resource extraction, and explore alternatives to traditional materials with a higher environmental footprint.

Energy Efficiency:

Design tools that are energy-efficient. This may involve incorporating technology that reduces energy consumption during the manufacturing process or tools that operate with renewable energy sources. Consider the entire life cycle of the tool, including energy use during production, operation, and disposal.

Customization and Flexibility:

Design tools that allow for customization and flexibility. This can reduce the need for multiple tools, minimizing waste and optimizing resources. Tools that can be easily adapted for various tasks contribute to sustainability by promoting resource efficiency.

Durability and Longevity:

Prioritize durability in tool design to extend the lifespan of the tools. Durable tools reduce the frequency of replacements, lowering resource consumption and waste. Additionally, design tools with modular components that can be replaced or upgraded, further extending their life.

Training and Capacity Building:

Include training programs for artisans and craftsmen on the proper use and maintenance of the new tools. This ensures that the tools are used efficiently and effectively, maximizing their lifespan and reducing the likelihood of premature replacements.

Local Sourcing and Production:

Promote local sourcing of materials and local production of tools. This not only reduces the environmental impact associated with transportation but also supports local economies. Consider establishing partnerships with local suppliers to create a more sustainable supply chain.

User-Centered Design:

Involve end-users (craftsmen and artisans) in the design process. Understand their needs, preferences, and workflow to create tools that are not only sustainable but also practical and user-friendly. This increases the likelihood of successful adoption.

Monitoring and Evaluation:

Implement a system for monitoring and evaluating the impact of the sustainable tool design intervention. Collect data on energy savings, material efficiency, and user satisfaction. Use this feedback to make continuous improvements and adjustments to the tool design and implementation strategy.

By incorporating these considerations, a sustainable tool design intervention in the brass metal handicraft sector can contribute to environmental conservation, economic development, and improved working conditions for artisans and craftsmen.

RQ4: How strategic design intervention can Improve productivity and quality in brass metal handicraft?

Intervened hemming tool improved process time by 75%, shaping tool improved process time by 75% and surface bending tool improved process time by 65% in batch production. Tools improve the health of artisans by eliminating the manual hammering process for hemming against an anvil. The Productivity of the tool will improve subsequently with a larger batch size. Quality defects like crack formation are also reduced due to uniform pressure to form with intervened tools. These tools will benefit both the individual craftsman and small entrepreneurs associated with the brass metal handicraft sector.

These tools assist the craftsmen in getting primary forms in the process; therefore, they don't affect the craftsmanship of the craft.

For cost estimation, we have considered the cost of Korai as a sample. Comparison of the cost of the existing process with the process using the design intervention tools reveals that after making 255 products, the cost of all equipment will be recorded at the breakeven point.

A strategic design intervention can significantly improve productivity and quality in the brass metal handicraft sector. Here are key strategies to consider:

Process Optimization:

Analyse the current production processes and identify opportunities for optimization. Streamline workflows, eliminate bottlenecks, and implement lean manufacturing principles to enhance efficiency. This may involve reorganizing workstations, introducing better tool layouts, and minimizing unnecessary steps in the production process.

Technology Integration:

Integrate advanced technologies that align with the traditional craftsmanship of brass metal handicrafts. This integration of computer-aided design (CAD) tools for precise designs. The goal is to improve accuracy, reduce waste, and enhance overall efficiency.

Tool Design and Ergonomics:

Design tools that are ergonomic and user-friendly. Comfortable and efficient tools can enhance the speed and quality of craftsmanship, reduce fatigue, and minimize the risk of errors. Involving artisans in the design process ensures that the tools are tailored to their needs and working styles.

Quality Assurance Systems:

Implement robust quality assurance systems at various stages of production. This includes inspection checkpoints, testing procedures, and quality control measures

Training and Skill Development:

Provide ongoing training programs for artisans to enhance their skills and keep them updated on the latest techniques and technologies. Investing in the skill development of craftsmen ensures that they can adapt to new tools and methodologies, leading to improved productivity and higher-quality outputs.

Material Management:

Implement efficient material management practices to reduce waste and optimize resource utilization. This includes inventory management systems, recycling initiatives, and exploring sustainable sourcing options. Efficient material handling can positively impact both productivity and environmental sustainability.

Customization and Flexibility:

Design processes that allow for customization of products while maintaining efficiency. This might involve flexible production lines or modular tool designs that can be easily adapted for different product variations. Customization can enhance market appeal and meet diverse customer demands.

Collaboration and Networking:

Foster collaboration within the sector and establish networks with suppliers, designers, and other stakeholders. Collaborative efforts can lead to the sharing of best practices, access to new technologies, and collective problem-solving, contributing to overall improvements in productivity and quality.

Market Research and Trend Analysis:

Stay informed about market trends and customer preferences. Regularly conduct market research to identify emerging styles, designs, and preferences. Adapting to changing market demands ensures that the brass metal handicrafts produced align with customer expectations, enhancing the perceived quality of the products.

Continuous Improvement Culture:

Cultivate a culture of continuous improvement within the organization. Encourage feedback from artisans and other staff, and use this feedback to make iterative changes to processes and tools. This continuous improvement mind-set ensures that the organization remains adaptable and responsive to evolving challenges and opportunities.

By strategically implementing these design interventions, the brass metal handicraft sector enhances both productivity and quality, leading to improved competitiveness, customer satisfaction, and overall sustainability

5.2 Limitation

5.2.1 Limitation in Design Intervention

While strategic design interventions in the brass metal handicraft sector can bring about positive changes, there are also limitations and challenges associated with such initiatives. Some of these limitations include:

Resistance to Change:

Artisans and craftsmen in traditional sectors may resist adopting new tools and technologies due to a strong attachment to traditional methods. Overcoming resistance to change can be a significant challenge and may require effective communication and training programs.

Initial Investment Costs:

Implementing strategic design interventions often involves significant upfront costs for acquiring new tools, technology, and training. Small and medium-sized enterprises (SMEs) in the handicraft sector may find it challenging to make these initial investments, impacting the speed of adoption.

Skills Gap:

The integration of advanced tools and technologies may require a different skill set than what artisans are traditionally accustomed to. There may be a skills gap that needs to be addressed through training and capacity-building programs to ensure effective utilization of new tools.

Cultural and Artistic Values:

Balancing the incorporation of modern technology with the preservation of cultural and artistic values in handicrafts can be challenging. Ensuring that new tools do not compromise the uniqueness and authenticity of handcrafted products is a delicate balance.

Infrastructure Limitations:

In some regions, especially those with a strong tradition in handicrafts, the infrastructure may not be well-suited for the integration of advanced technology. Limited access to reliable power, internet connectivity, and modern manufacturing facilities can pose significant challenges.

Market Perception:

Consumers may have a preference for traditionally crafted items, viewing them as more authentic. Convincing the market of the value and authenticity of products produced with advanced tools may require marketing and education efforts to shift consumer perceptions.

Environmental Impact:

While efforts are made to design tools and processes with sustainability in mind, there may still be environmental impacts associated with the extraction of raw materials, manufacturing processes, and the disposal of outdated tools. Balancing sustainability goals with the realities of production can be complex.

Regulatory Compliance:

Adhering to regulatory standards and certifications, both in terms of tool design and production processes, may pose challenges. Compliance with environmental regulations and safety standards may require additional efforts and resources.

Integration with Traditional Practices:

Integrating advanced tools seamlessly with traditional practices can be a complex task. Ensuring that new technologies complement rather than replace traditional craftsmanship is crucial to maintaining the authenticity of the handicrafts.

Risk of Overemphasis on Efficiency:

Focusing solely on efficiency and productivity improvements may lead to a potential loss of the artisan's personal touch and creativity. Striking a balance between efficiency gains and preserving the artistry of handcrafted products is essential.

Dependence on Skilled Labor:

Despite technological advancements, the success of design interventions may still depend on the availability of skilled labor. The sector may face challenges in attracting and retaining skilled artisans, particularly as traditional knowledge is passed down through generations.

Addressing these limitations, a holistic and adaptive approach, taken into account the unique characteristics of the brass metal handicraft sector and the needs of its stakeholders. Manufacturing tools are intervening to enhance the quality and productivity leading to improved competitiveness, customer satisfaction, and overall sustainability.

5.2.2 Limitation with all three intervene tools

Limitation with all three intervene tools are described as below:

i. **Hemming tool:**

   The newly introduce tool can handle the minimum 80 mm diameter panel required for hemming. This size is considered based on the minimum diameter of all existing products.

ii. **Shaping tool:**

   To complete the shaping process and plastically distort the metal sheet, an additional hammering operation must be carried out at the panel's centre.

iii. **Surface bending tool:**

   The newly created tool can only handle sheets with a maximum width of 350mm and a maximum thickness of 2.5mm. You can reach a minimum bend radius of 40 mm.

5.3 Future Scope of the Research

5.3.1 Future Research Directions for Advancing Sustainability and Innovation in Brass Metal Handicrafts

The future scope of research in the brass metal handicraft sector is vast and holds potential for addressing various challenges and opportunities. Here are some potential areas for future research:

Digital Craftsmanship: Investigate the intersection of traditional craftsmanship and digital technologies. Explore how digital tools, including virtual reality (VR) and augmented reality (AR), can be used to enhance design, training, and collaboration among artisans.

Cultural Preservation through Technology:

Examine how technology can be leveraged to preserve and document traditional crafting techniques, designs, and cultural heritage associated with brass metal handicrafts. This includes the creation of digital archives and educational resources.

Market Trends and Consumer Behaviour:

Analyze evolving market trends and consumer preferences in the context of brass metal handicrafts. Research can help artisans and businesses anticipate demand, adapt designs, and effectively market their products to changing consumer tastes.

Circular Economy in Handicrafts:

Explore circular economy principles in the handicraft sector, focusing on minimizing waste, promoting recycling, and creating sustainable product life cycles. Research can address ways to design products for longevity, repairability, and eventual recyclability.

Collaborative Platforms for Artisans:

Investigate the potential of digital platforms and networks to connect artisans, designers, and consumers. Explore how online marketplaces, collaborative design platforms, and community-driven initiatives can empower artisans and expand their reach.

Social and Economic Impact Studies:

Conduct studies on the social and economic impact of technological interventions in the brass metal handicraft sector. This includes examining changes in employment patterns, income levels, and overall community well-being resulting from the adoption of advanced tools and technologies.

Regulatory and Policy Research:

Examine the regulatory landscape governing handicrafts and propose policies that support the integration of technology while preserving cultural heritage and ensuring fair working conditions. Research can contribute to the development of regulatory frameworks that balance innovation and tradition.

Education and Skill Development:

Investigate effective strategies for educating and upskilling artisans to adapt to technological advancements. Research can explore the design of training programs that empower artisans to harness new tools while preserving traditional craftsmanship.

Cross-Disciplinary Collaboration:

Encourage cross-disciplinary collaboration between designers, engineers, anthropologists, and environmental scientists to address the multifaceted challenges in the brass metal handicraft sector. Integrating diverse perspectives can lead to innovative and holistic solutions.

As technology continues to advance and societal values evolve, research in the brass metal handicraft sector can play a crucial role in ensuring its sustainability, cultural relevance, and economic viability. The interdisciplinary nature of such research is likely to yield valuable insights and contribute to the ongoing transformation of traditional craftsmanship.

5.3.2 Future Scope for Intervened Tools

i. Hemming tool

Due to the varied diameter ranges (circumference) encountered in the current instrument, a brass sheet panel is now held in the hand while being used. Designing a holding component for the panel can be done as further work in this area. In order to make the tool better and more user-friendly. Additionally, SMEO (single minute exchange of dies) can use a progressive hemming tool for both linear and circular operations. Consequently, it can speed up die change.

ii. Shaping tool

Hammering provision within the tool can be undertake as future work.

iii. Surface bending tool

At present the roller diameter is fixed. Effect on bend radius with change in roller dia can be undertaken as future work.

Future work could encompass exploring alternative materials for tools. Investigating other materials commonly used in tool manufacturing can lead to a more comprehensive understanding of material selection and potential advancements.

Exploring casting techniques for handicraft development presents an exciting opportunity for future research. By leveraging casting methods, artisans can create custom tools to enhance their craft, fostering innovation and creativity within the community.

Young generation artisans are taking interest in new product diversification, and they want to improve craft and crafting process for kitchen utilities such as brass ladle shown in Figure 5.1. It will improve their confidence and courage to survive with competitor.

Figure 5.1 : Brass ladle currently manufactured in cottage industries

There is potential for the advancement of welding tools in the future. The tools needed can differ based on the welding method employed (such as MIG, TIG, Stick) and the characteristics of the project at hand. It is crucial to consistently adhere to safety protocols and don suitable personal protective gear when participating in welding tasks.

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2. Mahato, K.K., Kalita, P.C. (2023) “Empowering Creativity: Examining the Advantages of Handicraft Entrepreneurship for Young Innovators” *Journal of scientific and Industrial Research*, Vol 80, No 01, (under Review)
3. Mahato, K.K., Kalita, P.C. (2024) “Crafting Sustainability: A Review of Brass Handicraft Design Strategies” *Heritage and Sustainable Development* Vol. 6 No. 1, (under Review)

ANNEXURE-I Personal Detail of Brass Craft Artisans

Sr. No.	Name	Age (years)	Sex	Right handed (RH) left handed (LH)	Daily Working Hours	Working days per weak	Years in this profession
1.	Odut Ali	60	M	RH	8	6	44
2.	Arman Ali	35	M	RH	8	6	19
3.	Mohobbat Ali	38	M	RH	8	6	22
4.	Mehbut Ali	40	M	RH	8	6	24
5.	Muslimodhin Ahmed	55	M	RH	8	6	39
6.	Siraju Ali	38	M	RH	8	6	22
7.	Sirafot Ali	55	M	RH	8	6	39
8.	Ajijur Rohman	38	M	RH	8	6	22
9.	Amjed Khan	38	M	RH	8	6	22
10.	Najim Ali	55	M	RH	8	6	39
11.	Ekbal Ali	42	M	RH	8	6	26
12.	Rohman Ali	58	M	RH	8	6	42
13.	Tofik Ali	55	M	RH	8	6	39
14.	Firuj Khan	40	M	RH	8	6	24
15.	Jintu_Ali	38	M	RH	8	6	22
16.	Mukhej Ali	55	M	RH	8	6	39
17.	Dillur Ali	58	M	RH	8	6	42
18.	Imam Ali	48	M	RH	8	6	32
19.	Sohidul Ali	58	M	RH	8	6	42
20.	Janmohomod Ali	43	M	RH	8	6	27
21.	Ajijur Ali1	37	M	RH	8	6	21
22.	Raju Ali	48	M	RH	8	6	36
23.	Disen Ali	46	M	RH	8	6	30
24.	Sahebul Ali	39	M	RH	8	6	23
25.	Aslam Khan	35	M	RH	8	6	19
26.	Abdul Jofar Ali	31	M	RH	8	6	15
27.	Shadulla Ali	62	M	RH	8	6	46
28.	Xoru	58	M	RH	8	6	42
29.	Hafej Ali	57	M	RH	8	6	41
30	Minarul Ali	61	M	RH	8	6	45

ANNEXURE-II Posture adopted for making different craft items


Figure 1


Figure 2


Figure 3


Figure 4


Figure 5


Figure 6


Figure 7


Figure 8


Figure 9

Figure 10

Figure 11

Figure12

Figure 13

Figure 14

Figure15

Figure 16

Figure 17

Figure18

Figure 19

Figure 20

Figure21

Figure 22

Figure 23

Figure24

Figure 25

Figure 26

Figure27

Figure 28 Figure 29 Figure30

ANNEXURE-III Maximum duration of particular posture

Sr. No	Name (Figure from AnexureII)	Activity	Maximum duration of particular Posture adopted
1.	Minarul Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 12 minutes = 7 minutes = 13 minutes = 9 minutes
2.	Hafej Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 12 minutes = 8 minutes = 14 minutes = 7 minutes
3.	Xoru	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 10 minutes = 10 minutes = 13 minutes = 8 minutes
4.	Shadulla Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 12 minutes = 11 minutes = 13 minutes = 9 minutes
5.	Abdul Jofar Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 12 minutes = 19 minutes = 15 minutes = 7 minutes
6.	Aslam Khan	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 13 minutes = 20 minutes = 14 minutes = 9 minutes
7.	Sahebul Ali	Sheet cutting Shape making through hammering (forming) Soldering	= 9minutes = 18 minutes = 14 minutes

		Polishing	= 12 minutes
8.	Disen Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 12 minutes = 19 minutes = 15 minutes = 7 minutes
9.	Raju Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 12 minutes = 12 minutes = 13 minutes = 9 minutes
10.	Ajijur Ali1	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 12 minutes = 19 minutes = 15 minutes = 7minutes
11.	Janmohomod Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 13 minutes = 20 minutes = 14 minutes = 9 minutes
12.	Sohidul Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 9 minutes = 18 minutes = 14 minutes = 12 minutes
13.	Imam Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 9 minutes = 21minutes = 14 minutes = 11 minutes
14.	Dillur Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 9 minutes =22 minutes = 17 minutes = 9 minutes
15.	Mukhej Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 15 minutes =16 minutes = 15 minutes = 11 minutes

16.	Jintu_Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 12 minutes = 18 minutes = 15 minutes = 11 minutes
17.	Firuj Khan	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 11 minutes = 15 minutes = 14 minutes = 9 minutes
18.	Tofik Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 9 minutes = 21minutes = 17 minutes = 9 minutes
19.	Rohman Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	=18 minutes = 15 minutes = 11 minutes = 9 minutes
20.	Ekbal Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 15 minutes =16 minutes = 15 minutes = 11 minutes
21.	Najim Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 9 minutes = 18 minutes = 14 minutes = 12 minutes
22.	Amjed Khan	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 11 minutes = 15 minutes = 14 minutes = 9 minutes
23.	Ajijur Rohman	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 9 minutes = 21minutes = 14 minutes = 11 minutes
24.	Sirafot Ali	Sheet cutting	9 minutes

		Shape making through hammering (forming) Soldering Polishing	= 21minutes = 17 minutes = 9 minutes
25.	Siraju Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 9 minutes =22 minutes = 17 minutes = 9 minutes
26.	Muslimodhin Ahmed	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 12 minutes = 12 minutes = 13 minutes = 9 minutes
27.	Mehbut Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	=10 minutes = 15 minutes = 13 minutes = 11 minutes
28.	Mohobbat Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 12 minutes = 16 minutes = 13 minutes = 9 minutes
29.	Arman Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 13 minutes = 20 minutes = 14 minutes = 9 minutes
30.	Odut_Ali	Sheet cutting Shape making through hammering (forming) Soldering Polishing	= 12 minutes = 18 minutes = 15 minutes = 11 minutes

Annexure IV

Hemming Tool

Sr. N	Description	Parts quantity	Length(mm)	Width/Diameter(mm)	Thickness(mm)	Wt.(kg)
34	Upper roller set1	1		D80	40	0.725
33	lower roller set1	1		D60	37	0.453
	lower roller set2	1		D60	37	0.414
	upper roller set2	1		D80	40	0.071
	lower roller set3	1		D60	37	0.502
	upper roller set3	1		D60	34	0.217
19	LN bolt	4	20	M6		
29	Base Frame	1	180	80	20	1.4
15.1,15.2	Panel support	2	50	M8		0.012
25	bearing housing	1	56.5	53	20	0.2
26	bearing	2		D42	12	0.018
3	lower roller shaft	1	150	D20		0.249
5	Top roller shaft	1	132	D20		0.269
24,23	Gears	2		D68	9	0.042
27	Guide screw	1	80	D12		0.066
4	Guide lever	2	200	D6		0.064
28	guide screw lock plate	2	72	30	10	0.2
22	top plate of base frame	1	80	10	20	0.01
7	lever for handle	1	80	25	10	0.121
8	Handle	1	100	D15		0 .131
						5.033

Annexure V

Shaping Tool

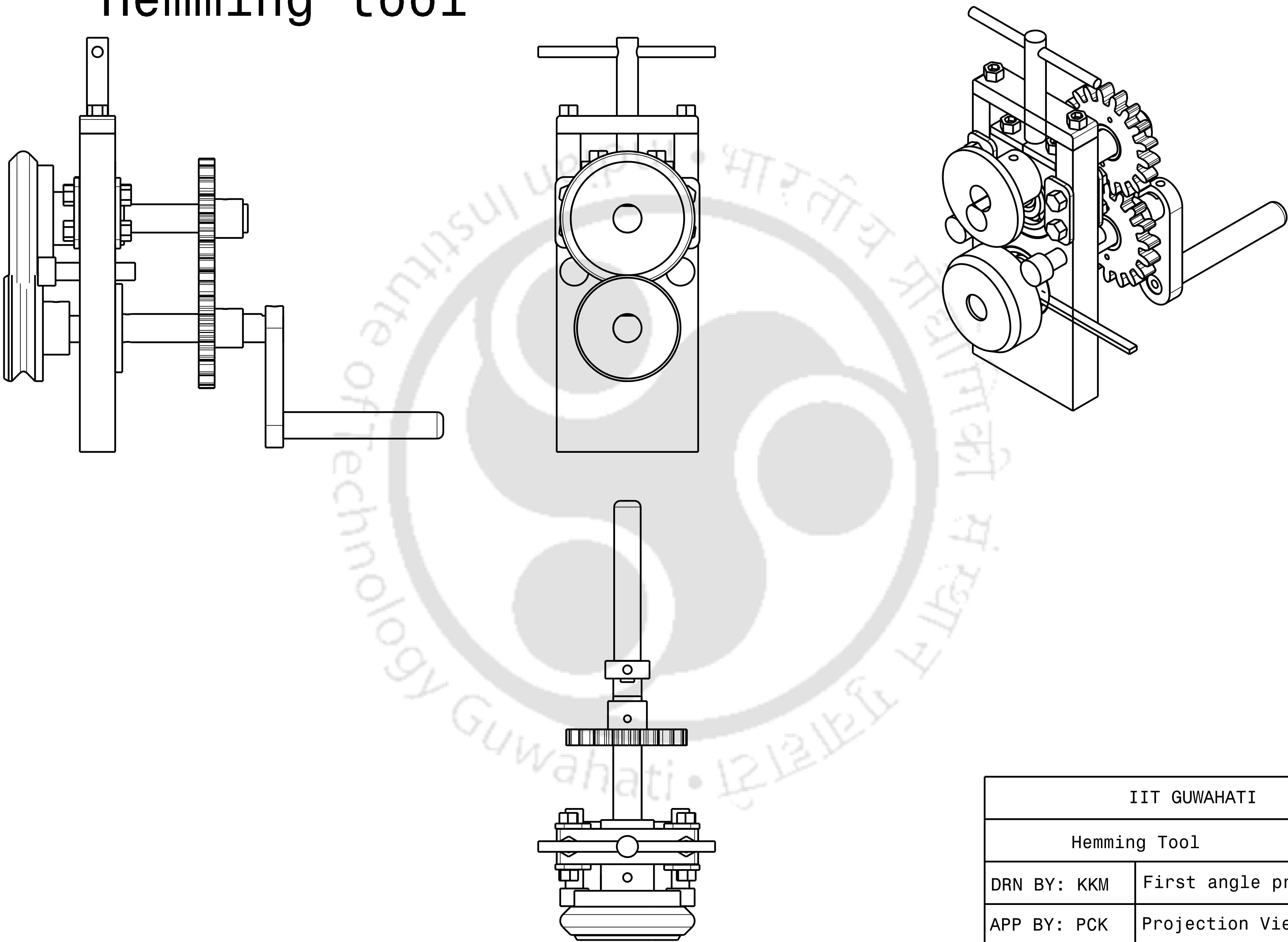
Sr. N	Description	Parts quantity	Length(mm)	Width/Diameter(mm)	Thickness(mm)	Wt.(kg)
35.1	base frame 1	1	245	50	20	1.818
35.2	base frame 2	1	175	50	20	1.367
35.3	base frame 3	1	135	50	20	1.017
1	lower roller die	1	90	D70		1.896
6	upper roller die	1	90	D80		1.8
25	arc part top roller frame	2	80	40	10	0.444
26	arc part of bottom roller frame	2	90	40	10	0.544
2	flat part broller frame	2	61	40	10	0.544
30	Gear	2		D68	10	0.232
31	Gearshaft	2	20	D22	4	0.048
11	Guide pin	2	50	D 6		0.022
7	Guide screw	1	100	D12		0.081
8	guide screw handle	1	100	D6		0.022
						9.835

Annexure VI

Surface bending tool

Sr. N	Description	Parts quantity	Length(mm)	Width/Diameter(mm)	Thickness(mm)	Wt.(kg)
21	base	1	402	116	10	3.655
1,2,3	Rollers	3	428	D38		9.792
5	side frame	2	132	110	20	3.438
10	Guide bar	4	41	32	21	0.536
23,24	Top plate of side frame	2	72	20	10	0.204
19,20	Lead screw	2	80	D12		0.132
27	Guid bar support	4	20	15	32	0.152
32	lead screw lever	2	200	D6		0.086
6	handle lever	1	114	12	10	0.221
7	handle	1	92	D20		0.048
30	gear	2		D50	8	0.102
31	gear support	2	20	D20	4	0.062
						18.428

Hemming tool



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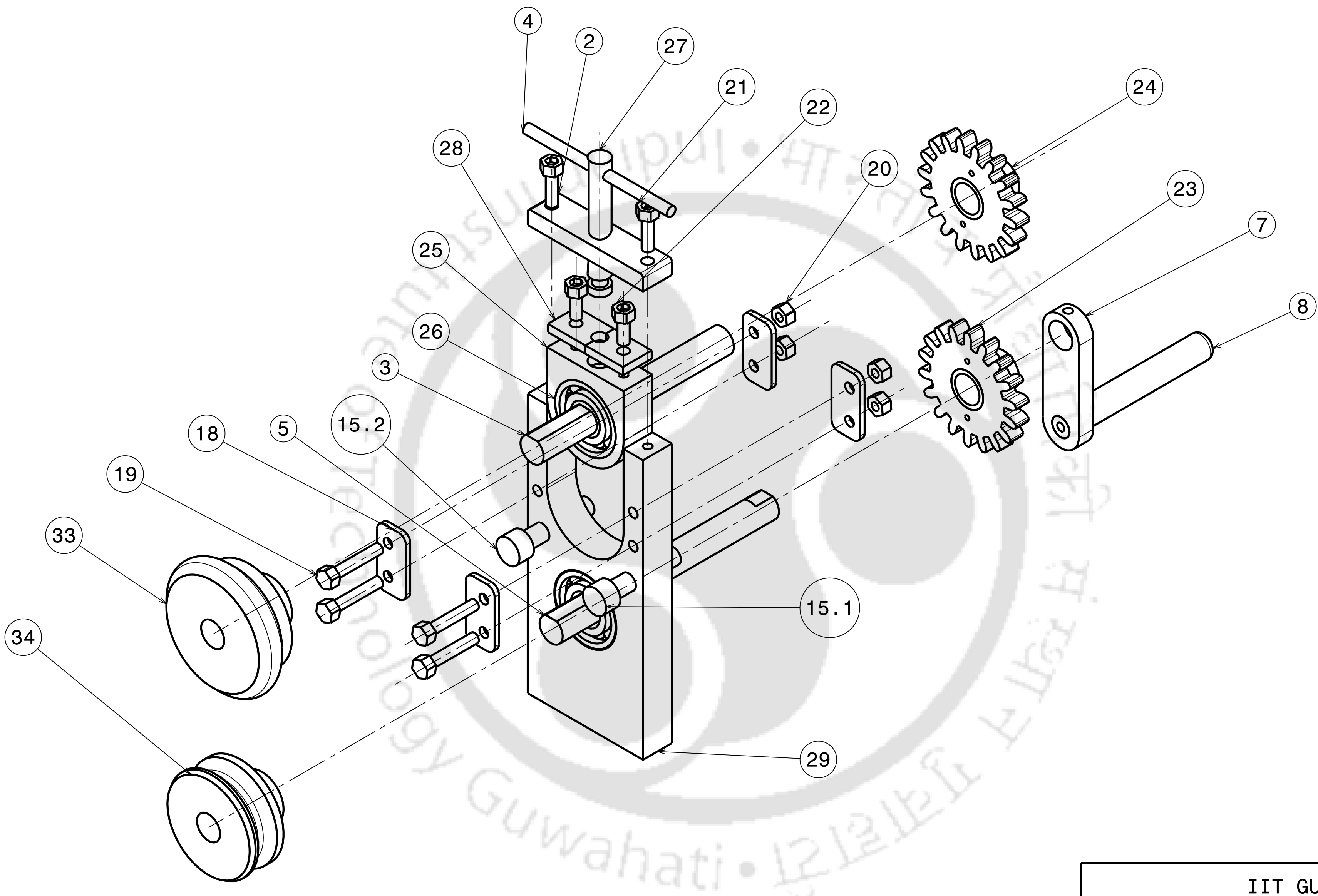

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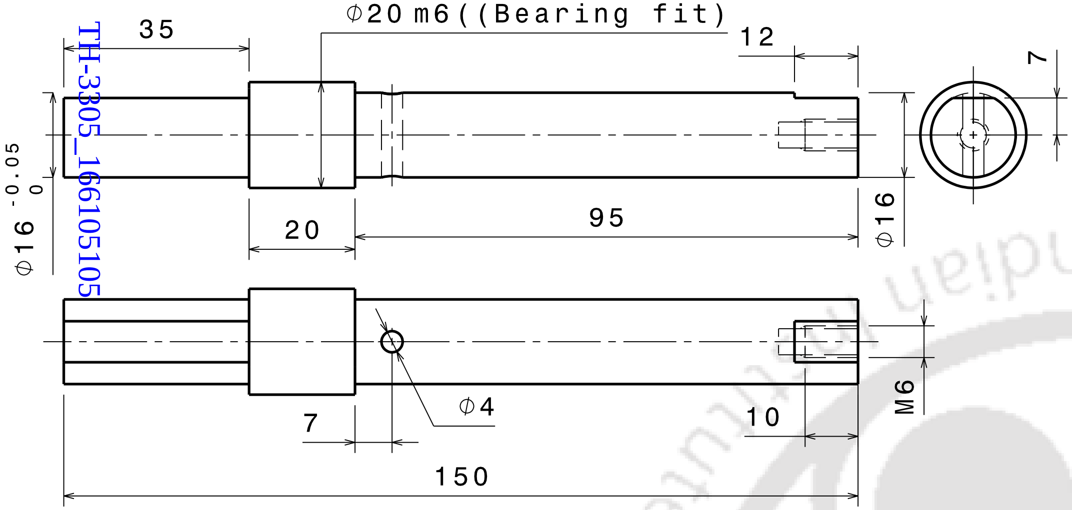

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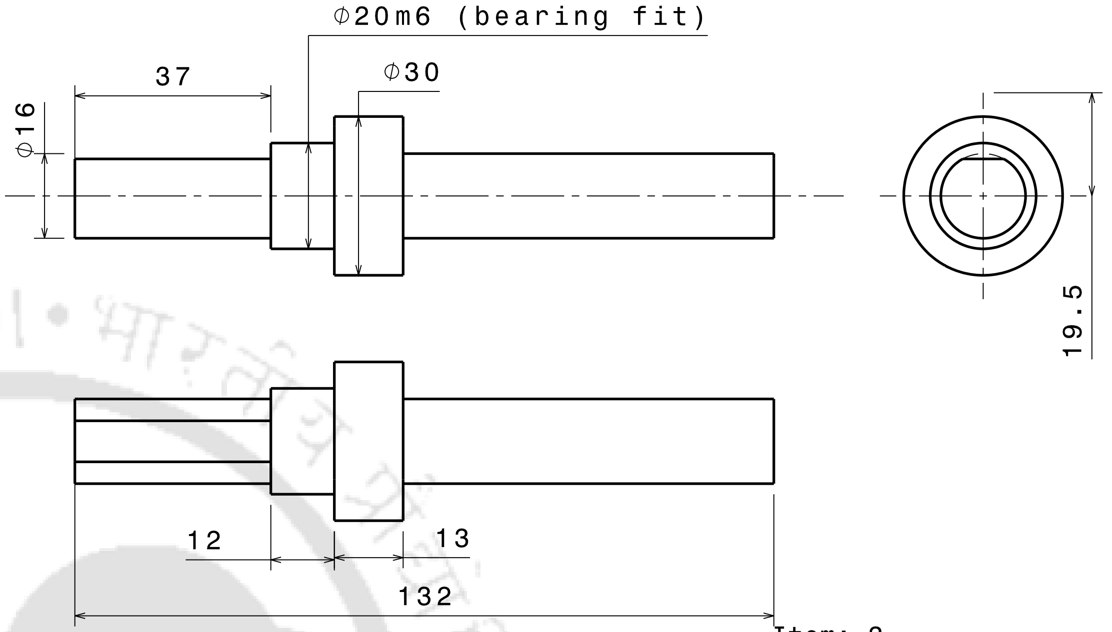

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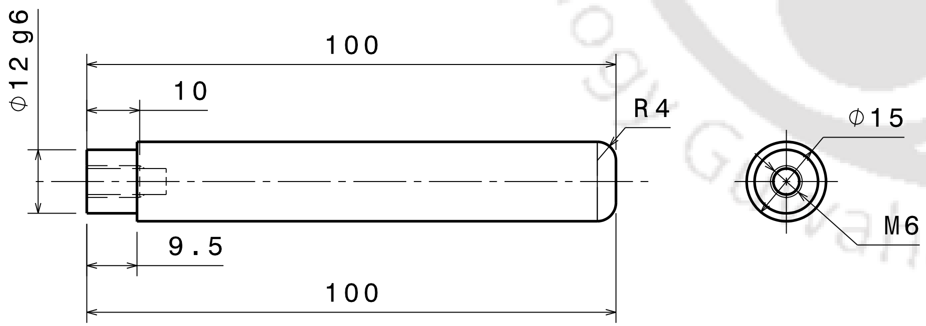

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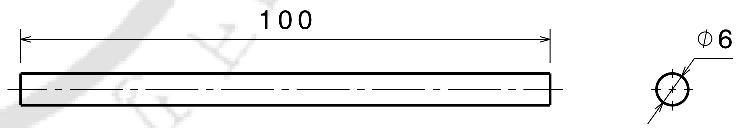

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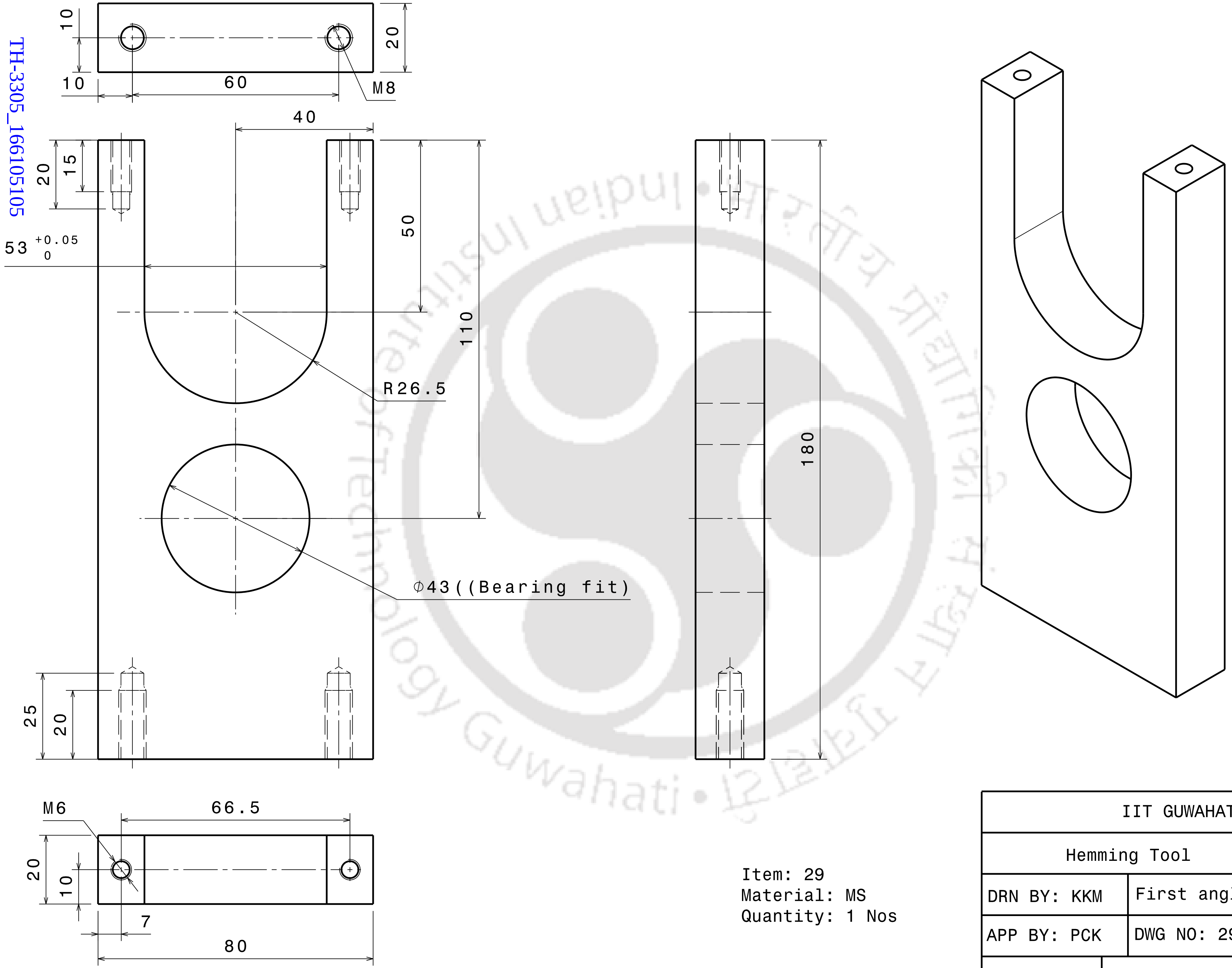

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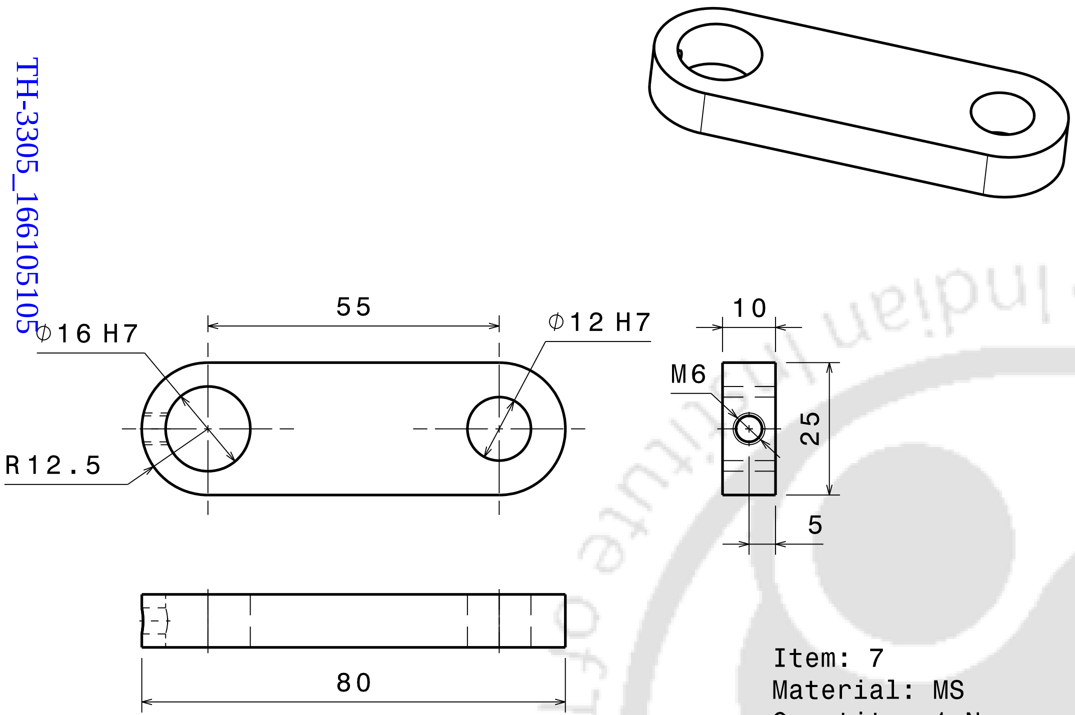

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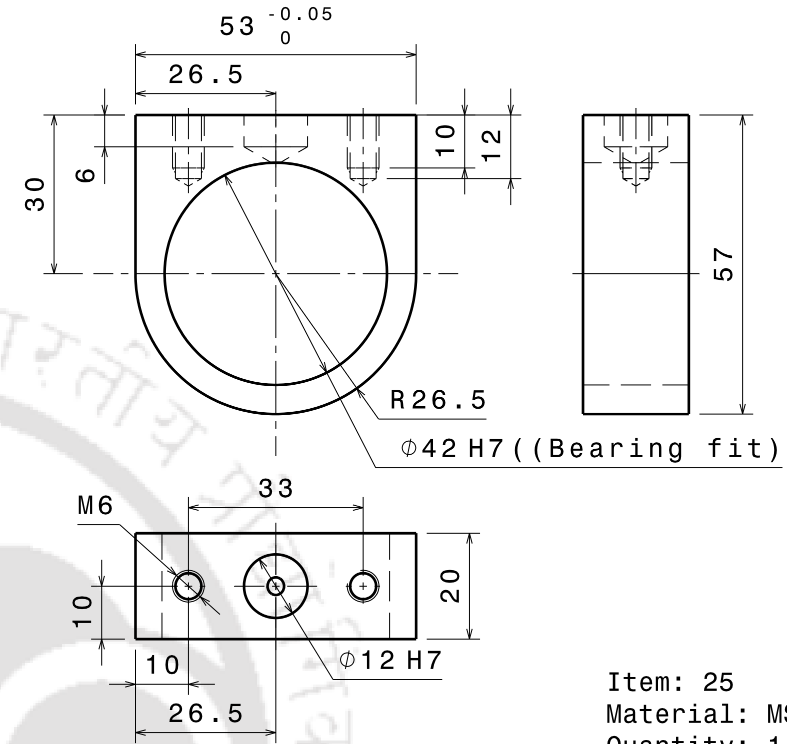

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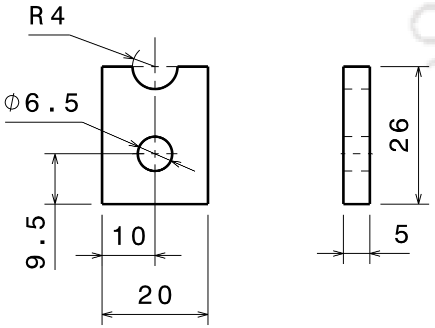

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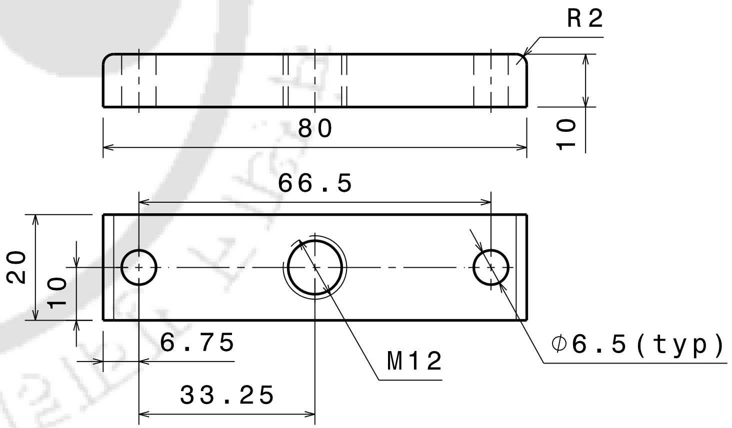

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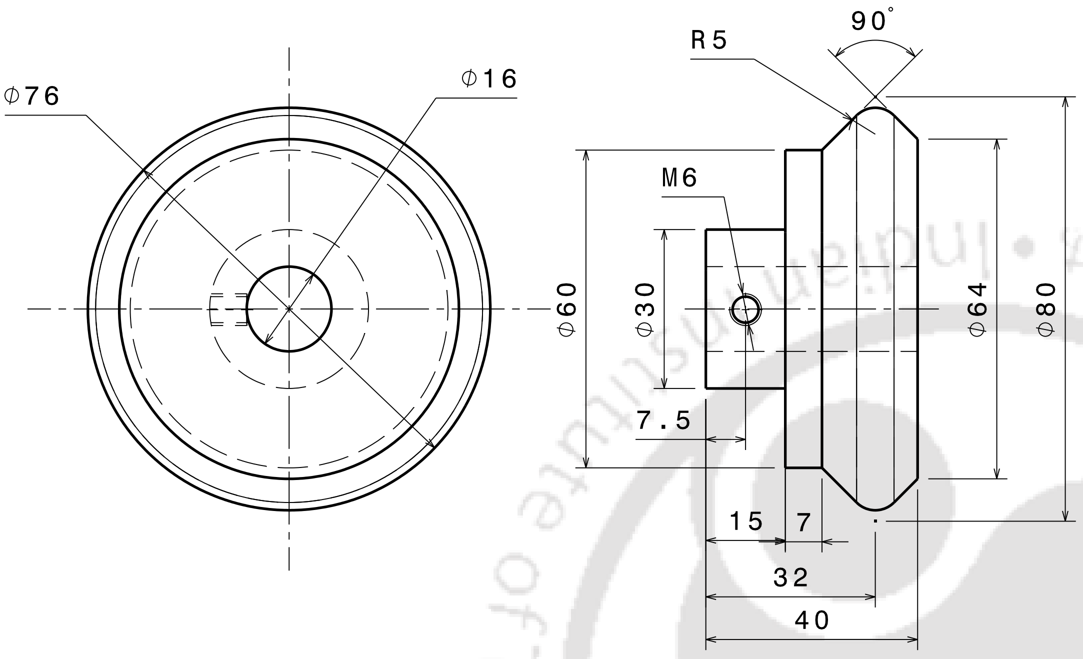

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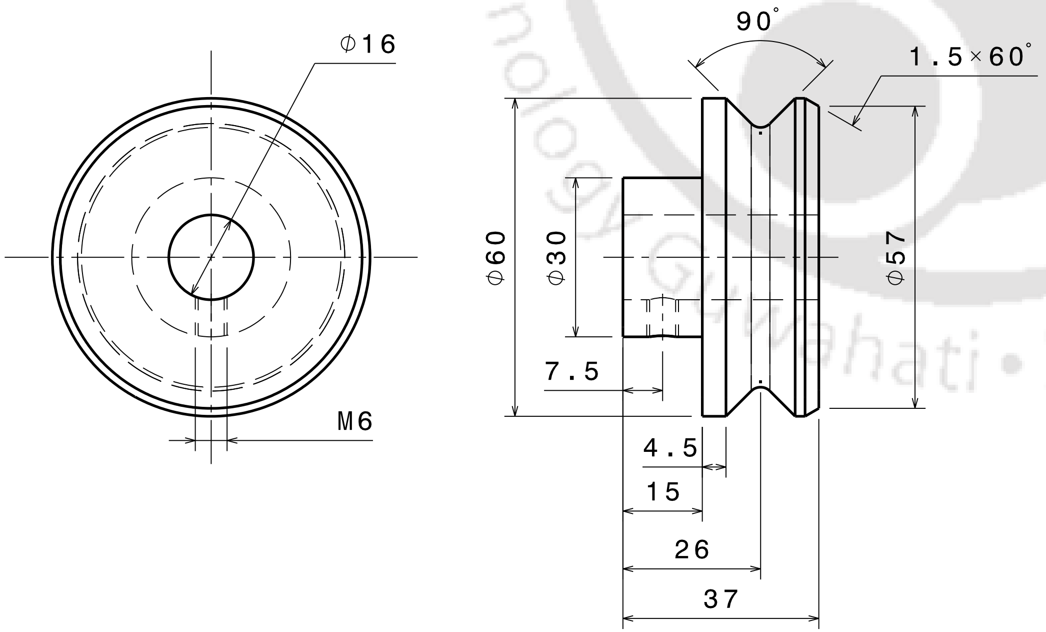

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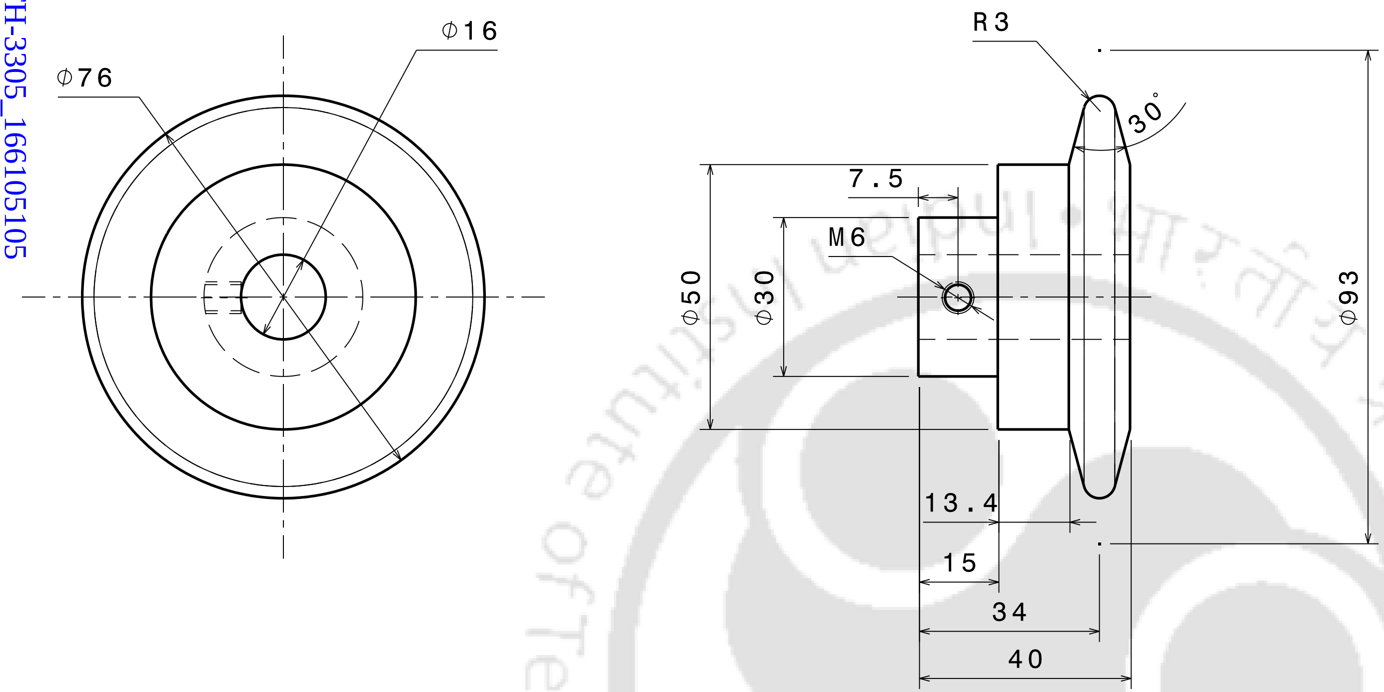

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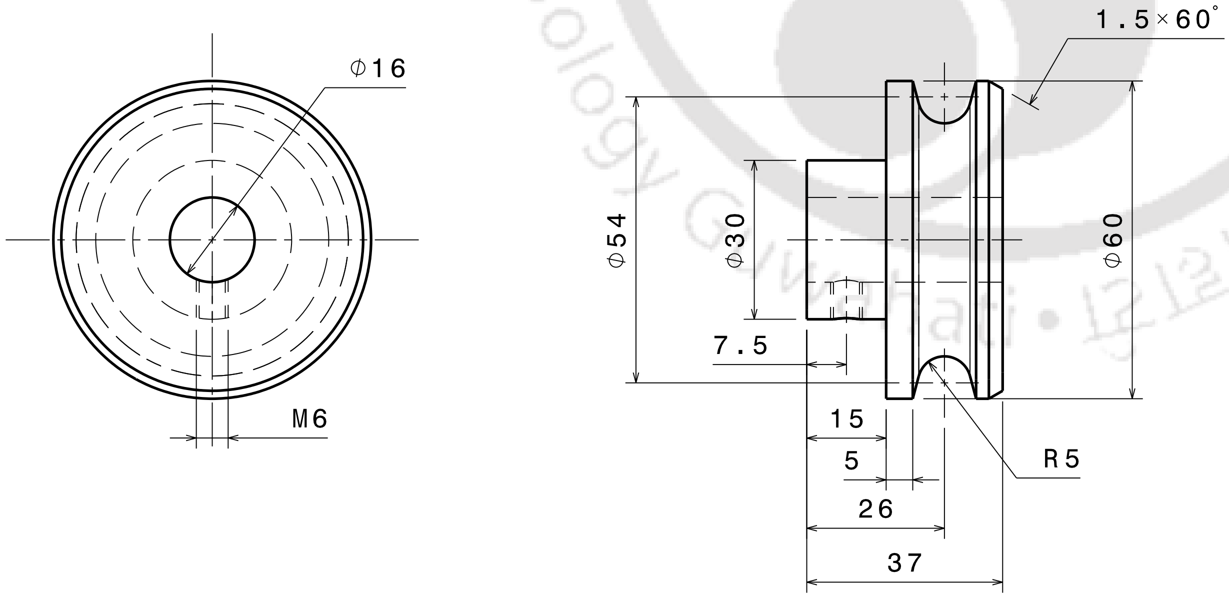

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Mtrl :MS

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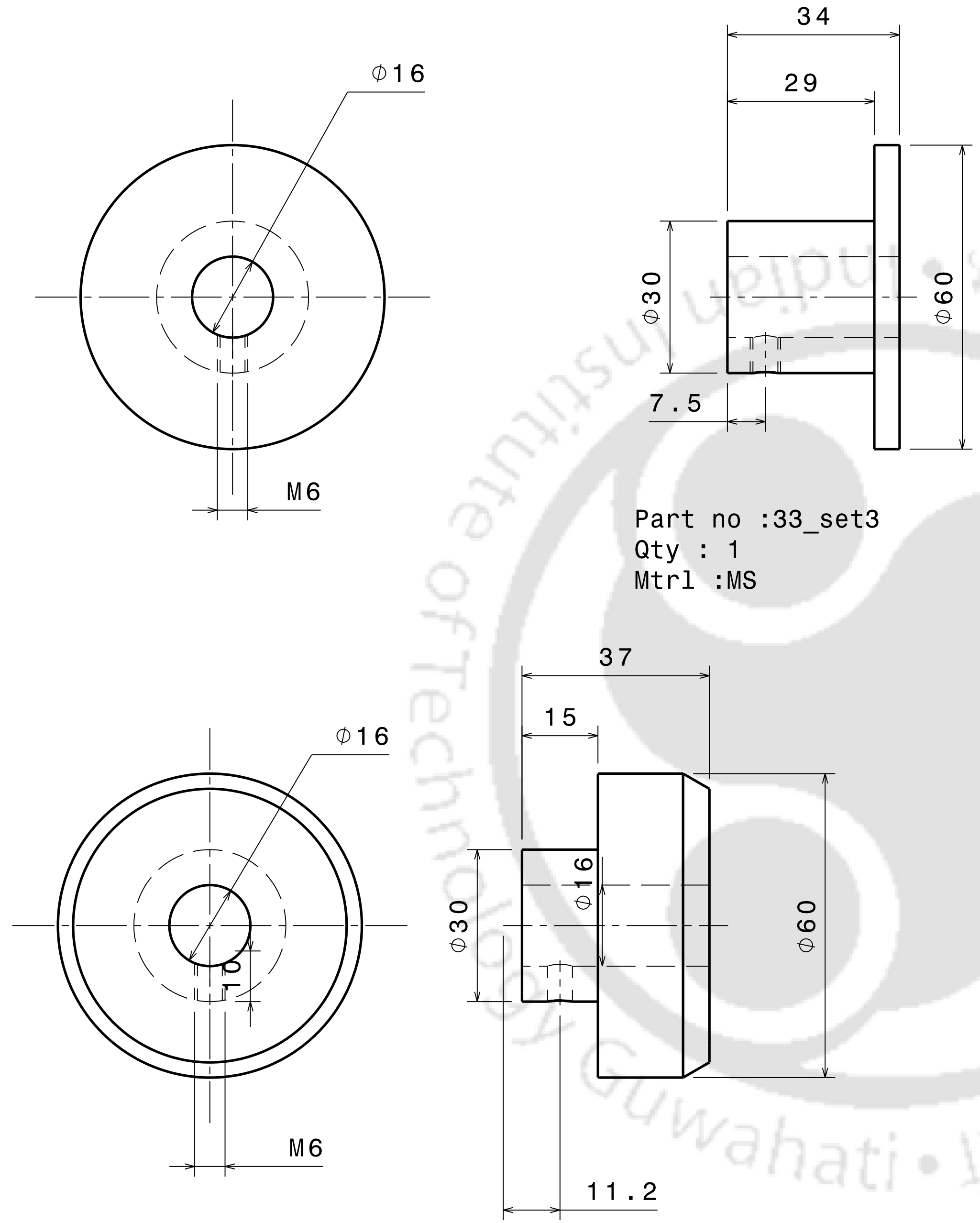

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Qty : 1
Mtrl :MS

Part no :34_set3
Qty : 1
Mtrl :MS

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HemmingTool		
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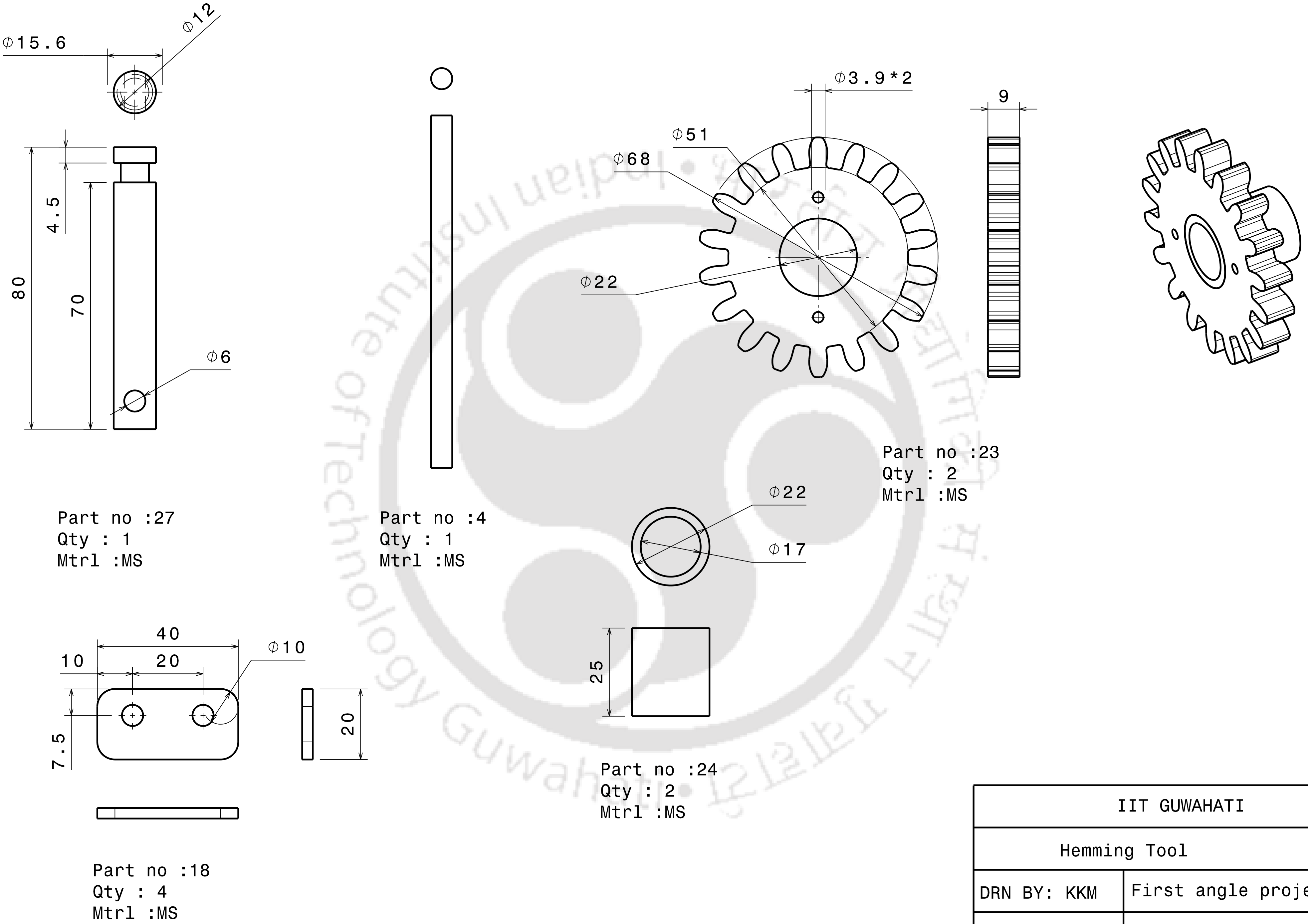

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Hemming Tool		
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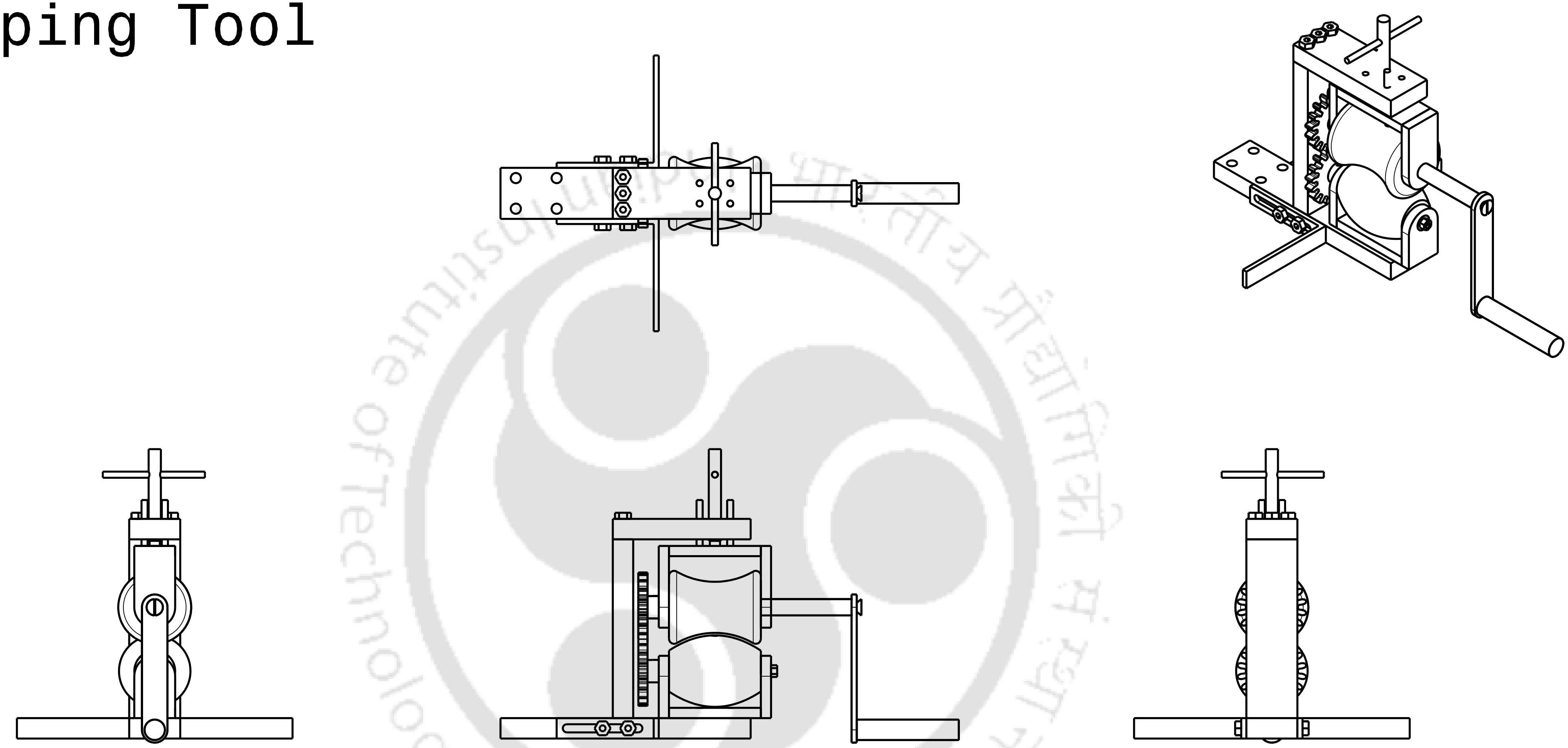
Shaping Tool



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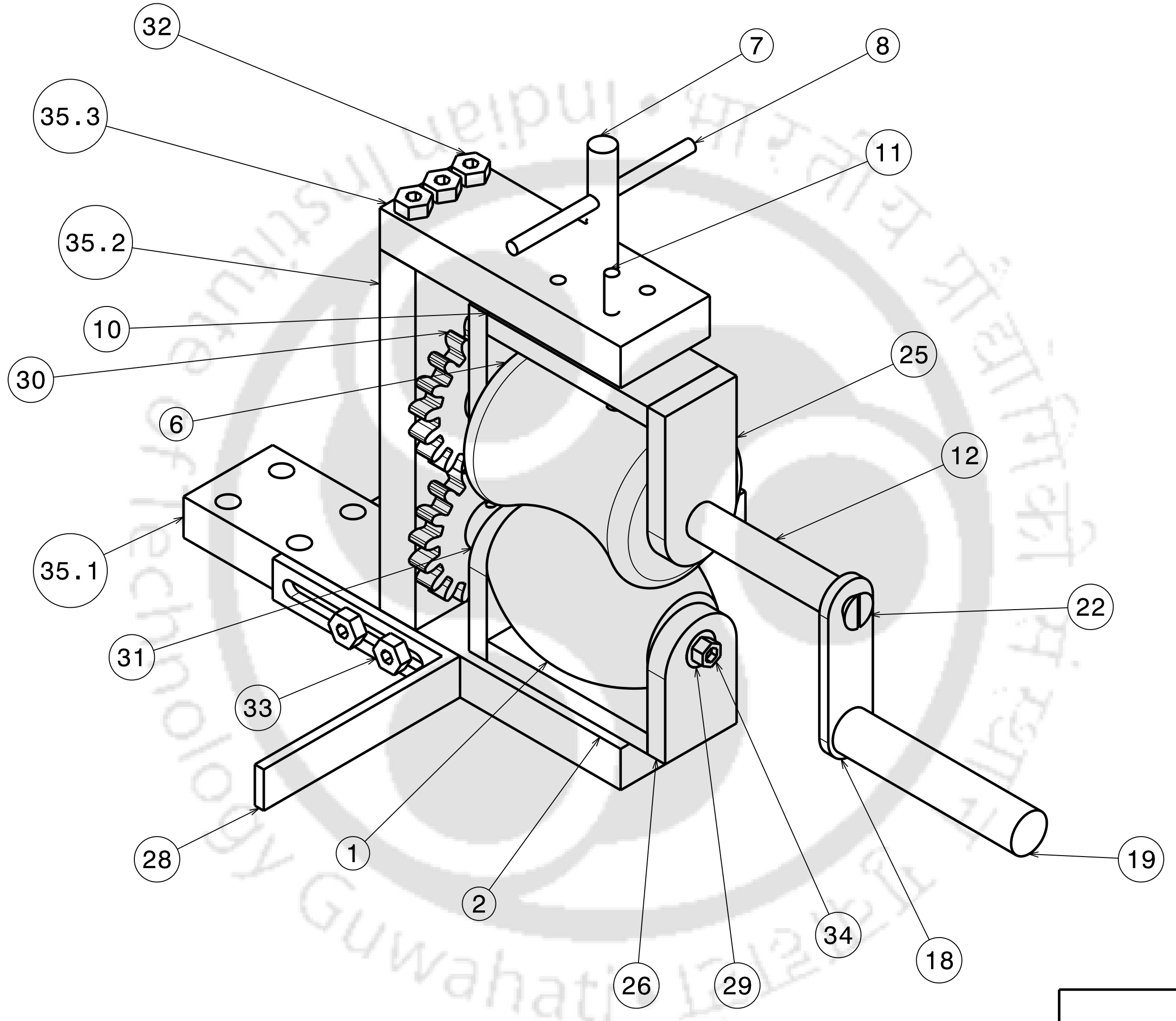

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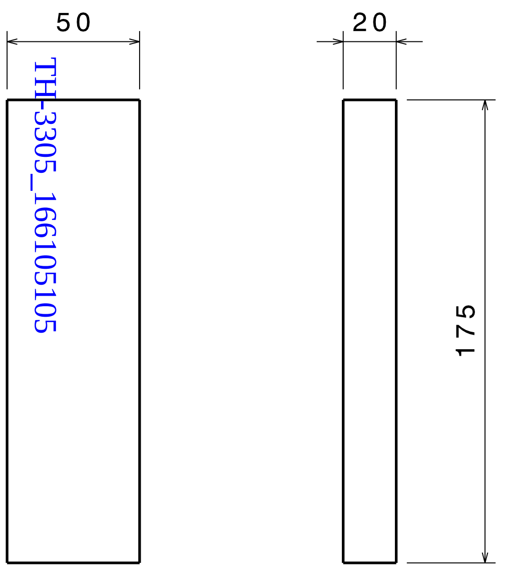

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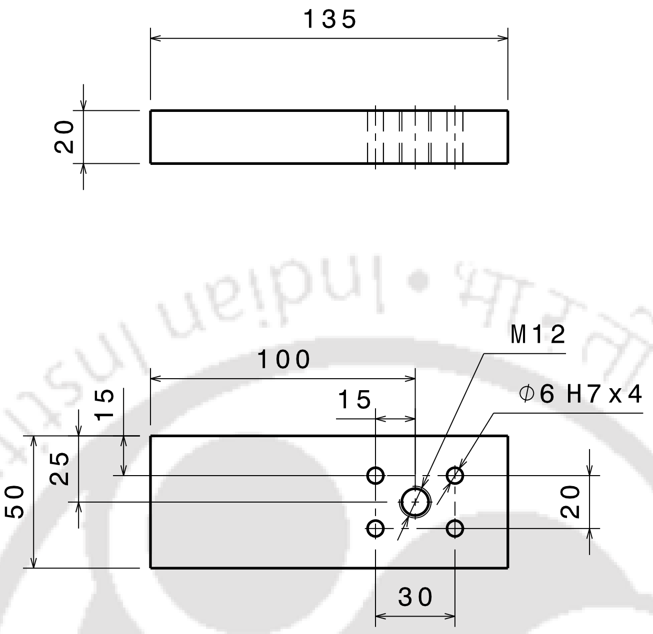
Matl. - MS



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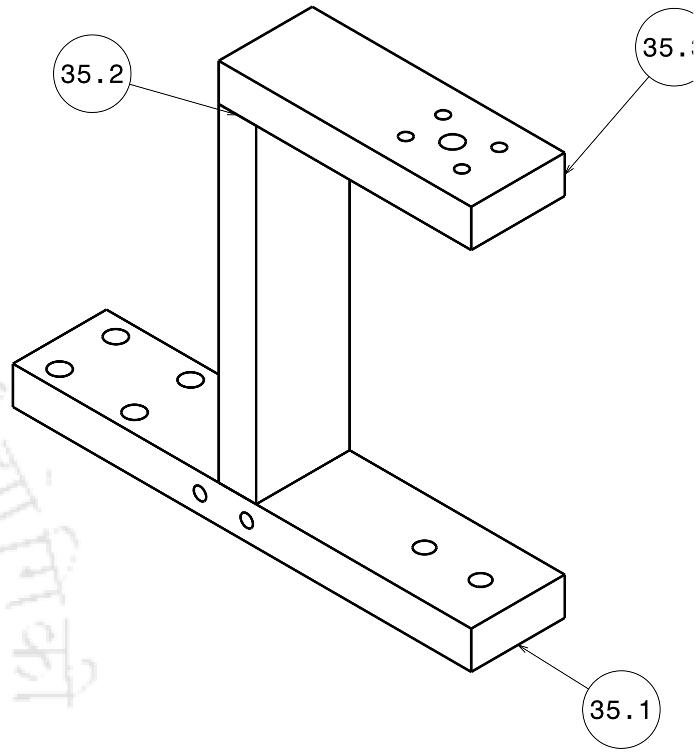

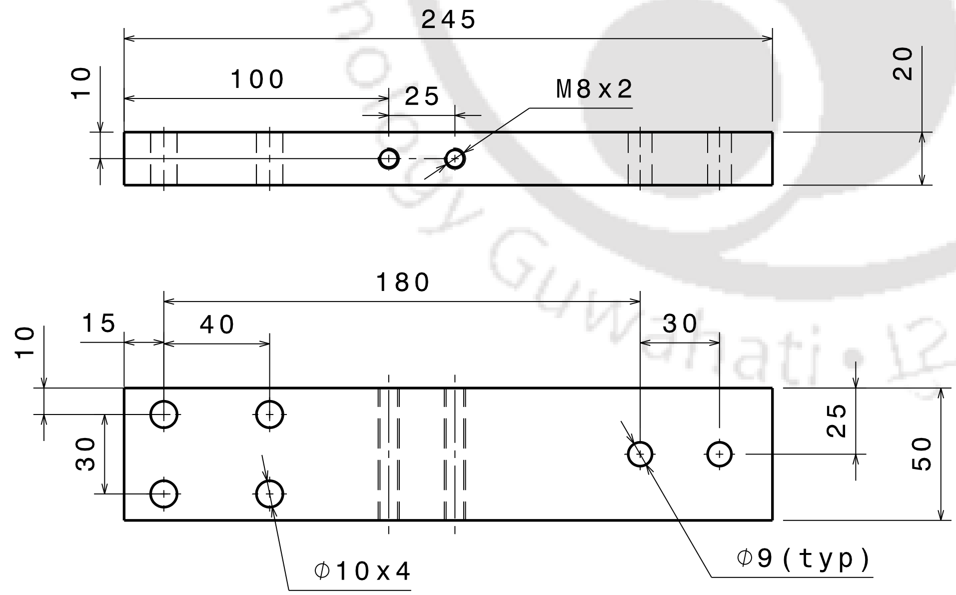

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Matl. - MS

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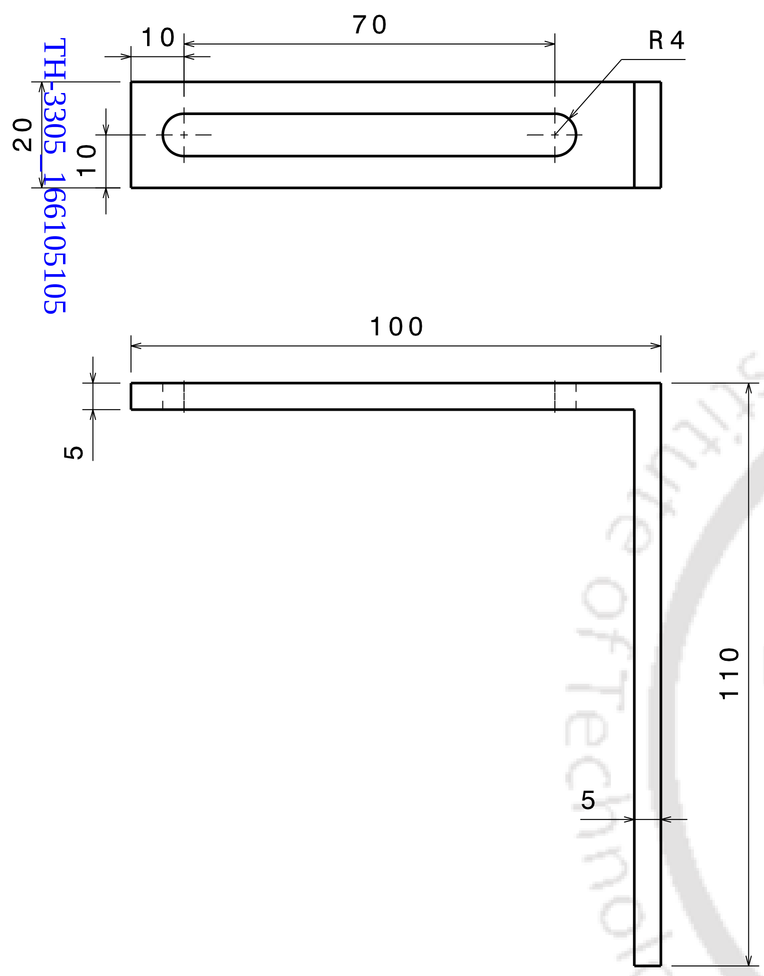

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Matl. - MS

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SHAPING TOOL		
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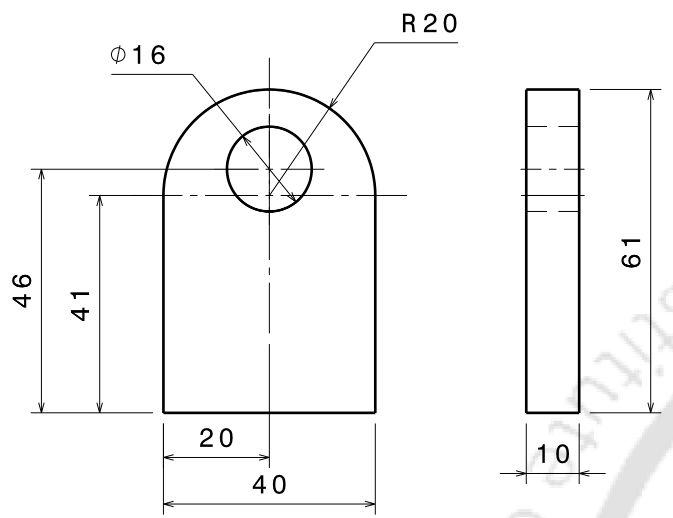

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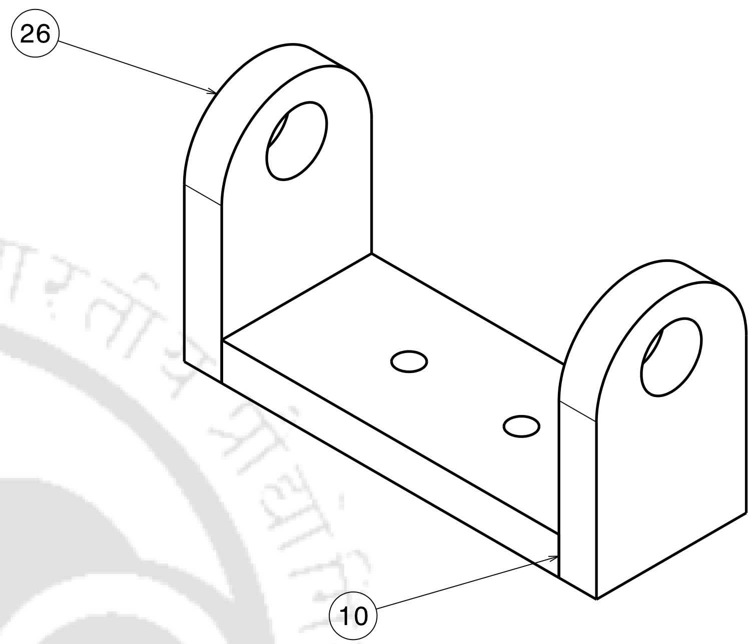

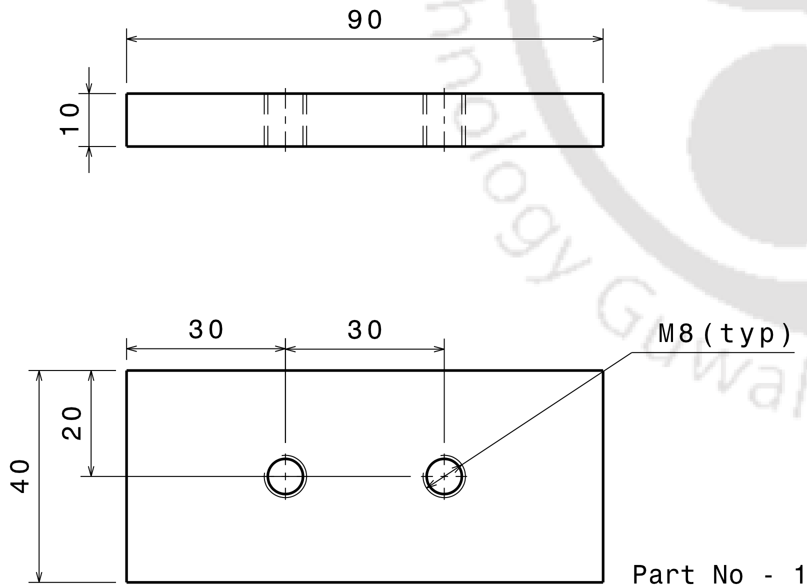

Part No - 10
Qty - 1 nos
Matl. - MS

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SHAPING TOOL		
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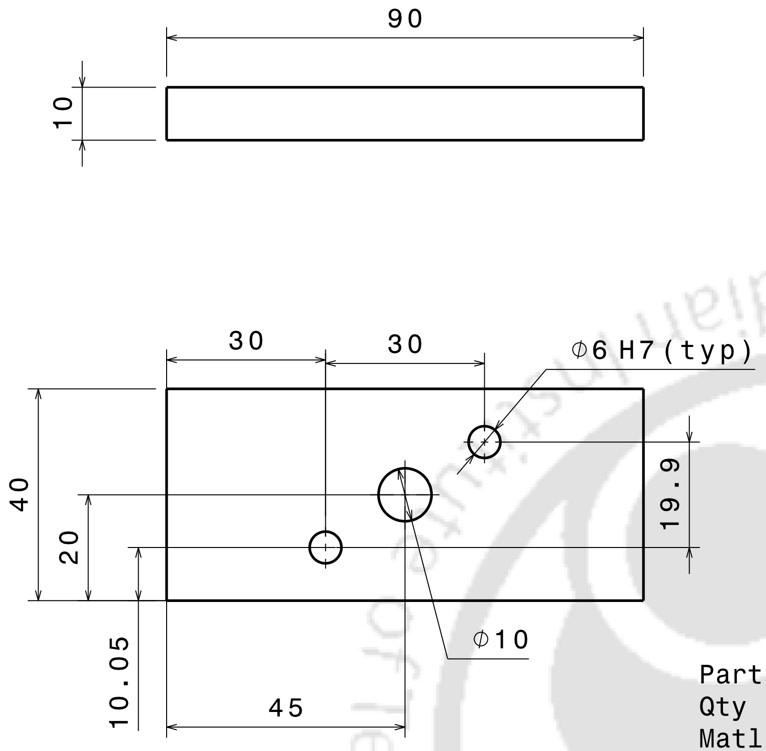

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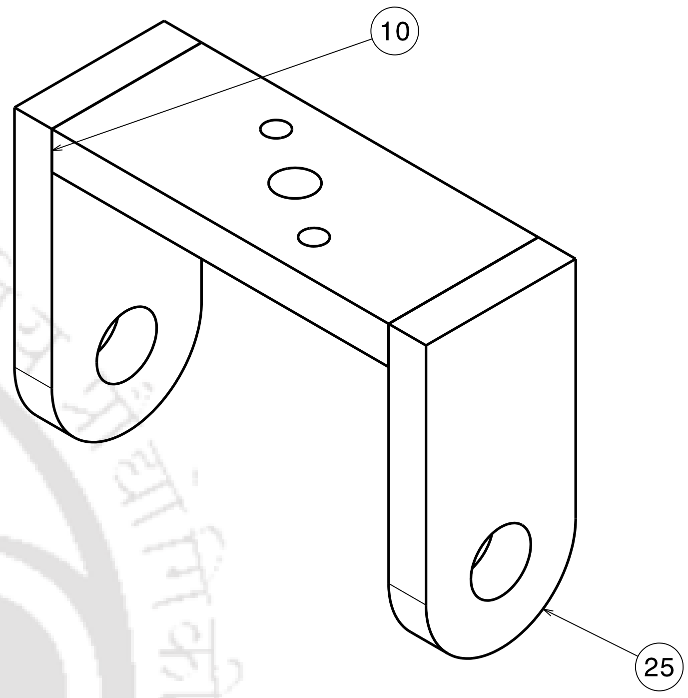

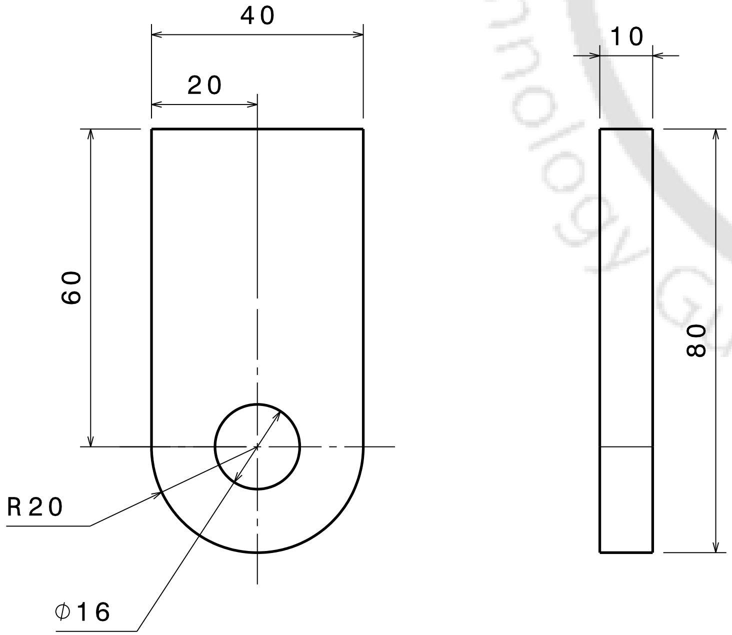

Part No - 25
Qty - 2 nos
Matl. - MS

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SHAPING TOOL		
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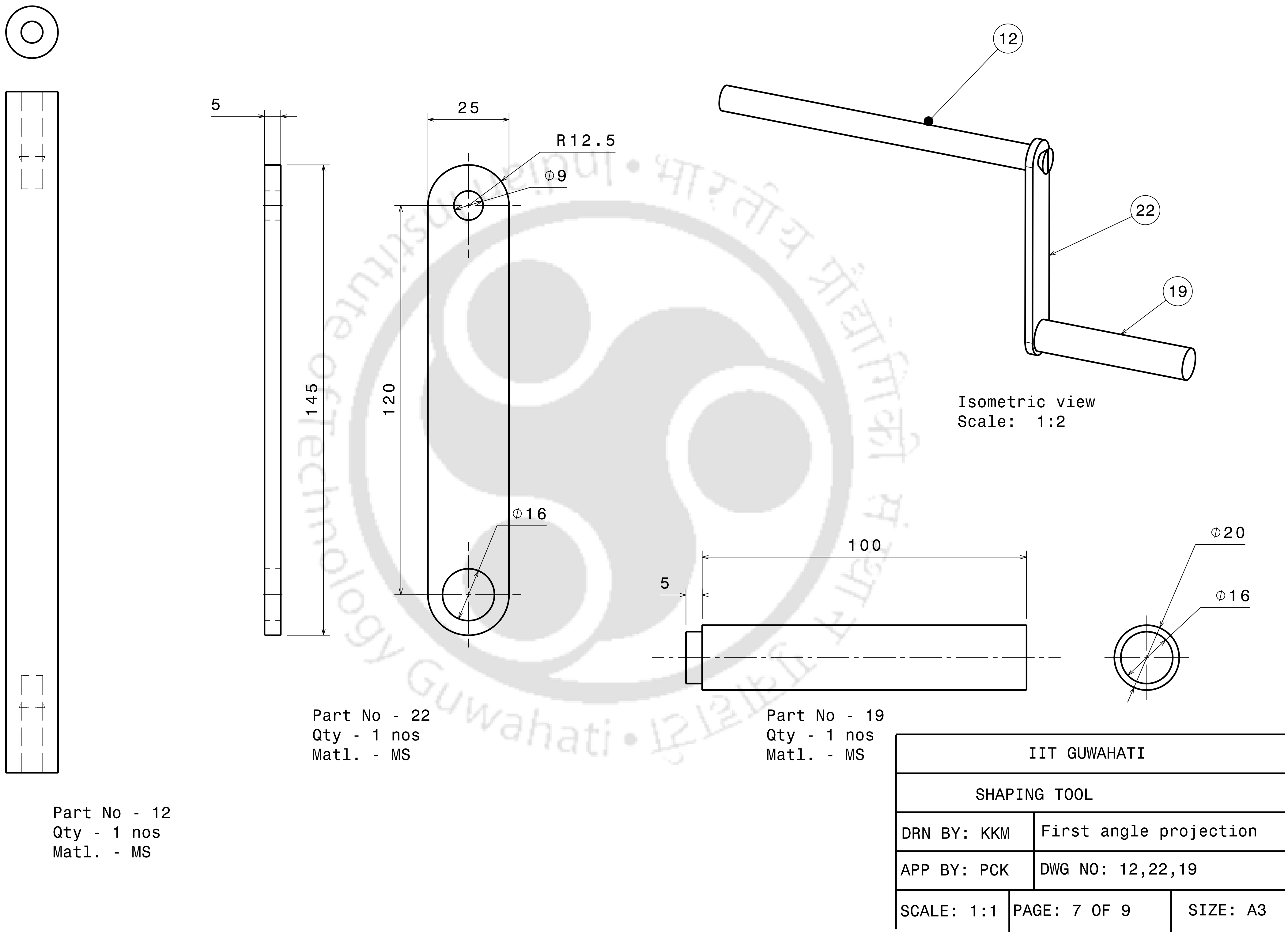
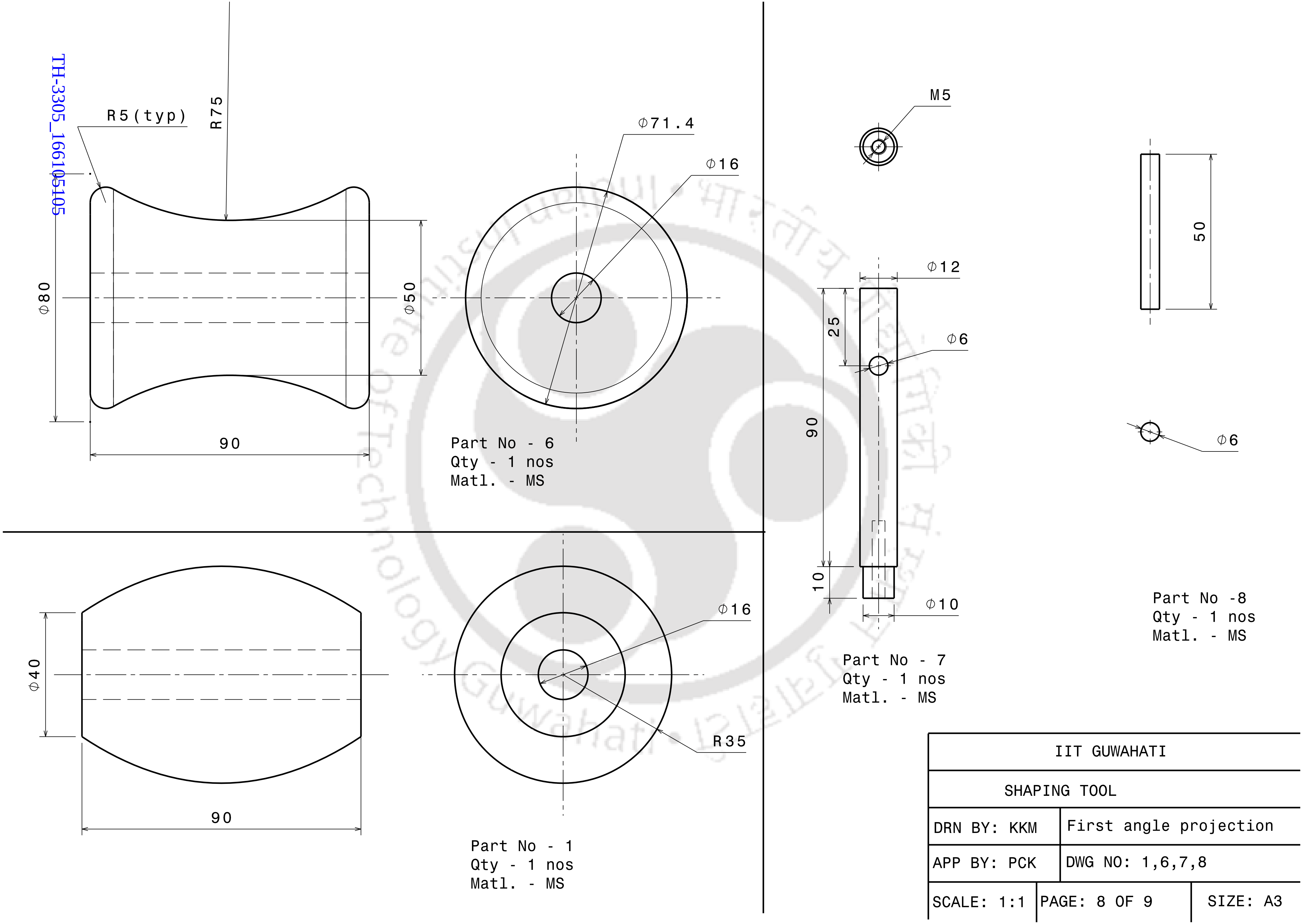
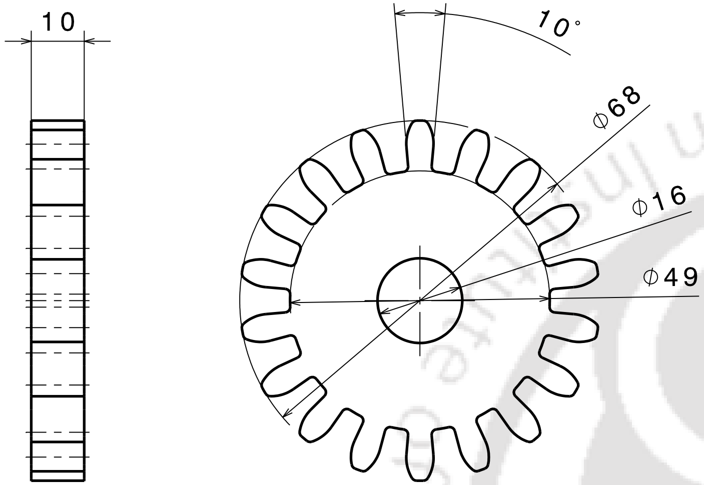
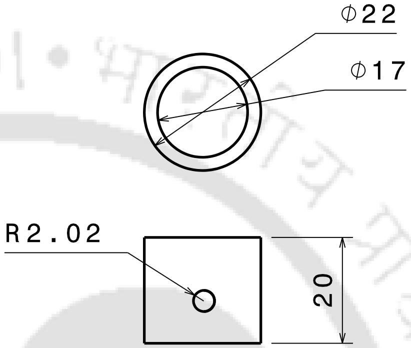

12
22
19
Isometric view
Scale: 1:2
5
25
R12.5
⌀9
⌀16
145
120
100
5
⌀20
⌀16
Part No - 12
Qty - 1 nos
Matl. - MS
Part No - 22
Qty - 1 nos
Matl. - MS
Part No - 19
Qty - 1 nos
Matl. - MS
IIT GUWAHATI
SHAPING TOOL
DRN BY: KKM
First angle projection
APP BY: PCK
DWG NO: 12,22,19
SCALE: 1:1
PAGE: 7 OF 9
SIZE: A3


R5(typ)
R75
Φ80
Φ50
90
Φ71.4
Φ16
Part No - 6
Qty - 1 nos
Matl. - MS
Φ40
90
Φ16
R35
Part No - 1
Qty - 1 nos
Matl. - MS
M5
Φ12
25
Φ6
90
10
Φ10
Part No - 7
Qty - 1 nos
Matl. - MS
50
Φ6
Part No -8
Qty - 1 nos
Matl. - MS
IIT GUWAHATI
SHAPING TOOL
DRN BY: KKM
First angle projection
APP BY: PCK
DWG NO: 1,6,7,8
SCALE: 1:1
PAGE: 8 OF 9
SIZE: A3

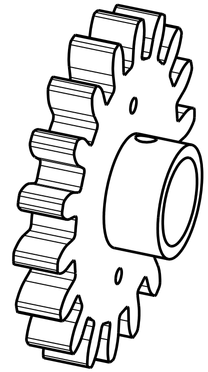
TH-3305_166105105



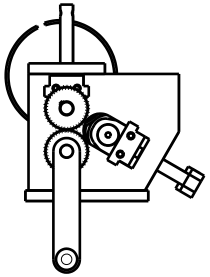
Part No - 30
Qty - 2 nos
Matl. - MS



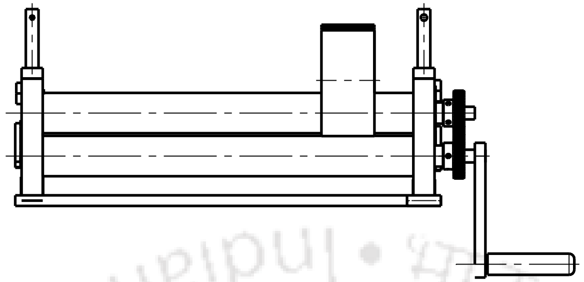
Part No - 31
Qty - 2nos
Matl. - MS



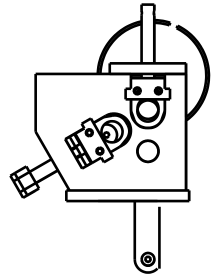
IIT GUWAHATI		
SHAPING TOOL		
DRN BY: KKM	First angle projection	
APP BY: PCK	DWG NO: 30,31	
SCALE: 1:1	PAGE: 9 OF 9	SIZE: A3



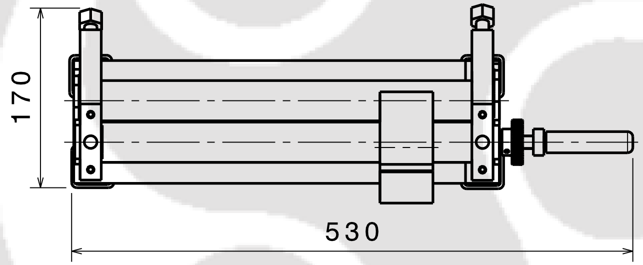
Right view
Scale: 1:5



Front view
Scale: 1:5

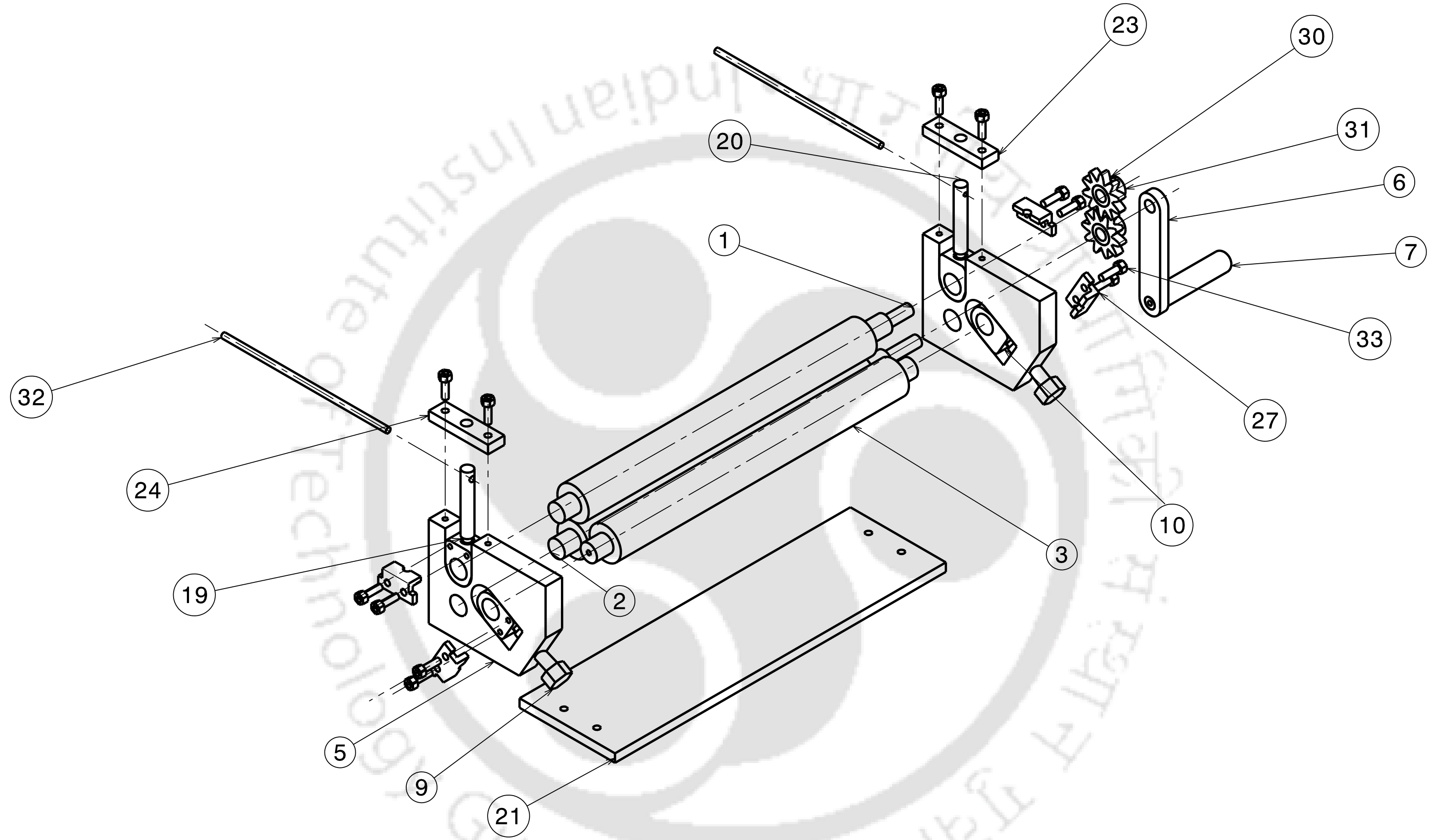


Left view
Scale: 1:5

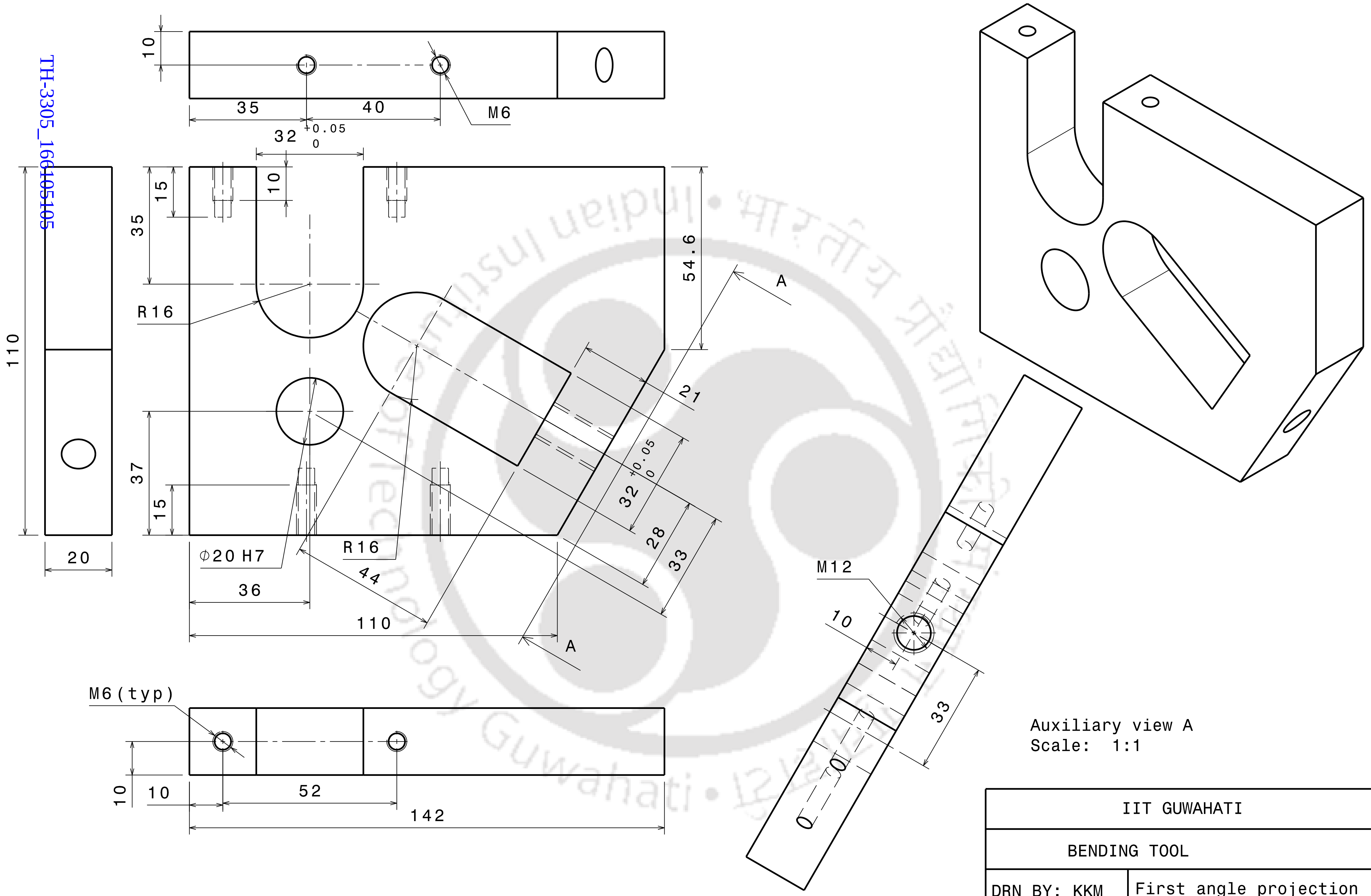


Top view
Scale: 1:5

IIT GUWAHATI	
BENDING TOOL	
DRN BY: KKM	First angle projection
APP BY: PCK	DWG NO:
SCALE: 1:5	PAGE: 1 OF 8 — SIZE: A3



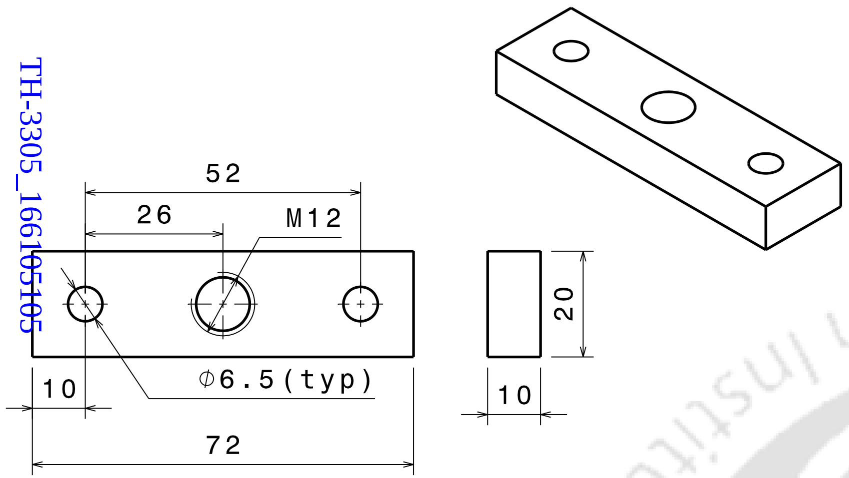
IIT GUWAHATI		
BENDING TOOL		
DRN BY: KKM	Explodes Isometric view	
APP BY: PCK	DWG NO:	
SCALE: 1:1	PAGE: 2OF 8	SIZE: A3



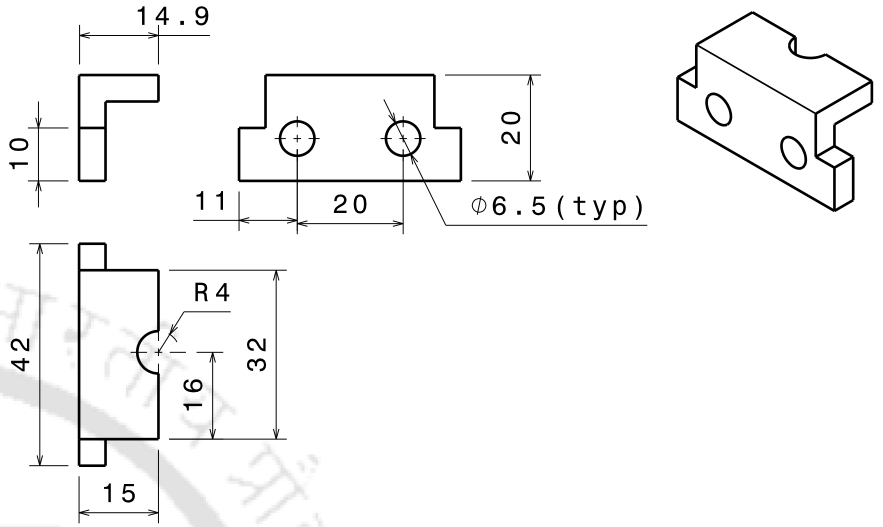
Auxiliary view A
Scale: 1:1

ITEM No: 5
Qty: 2 Nos

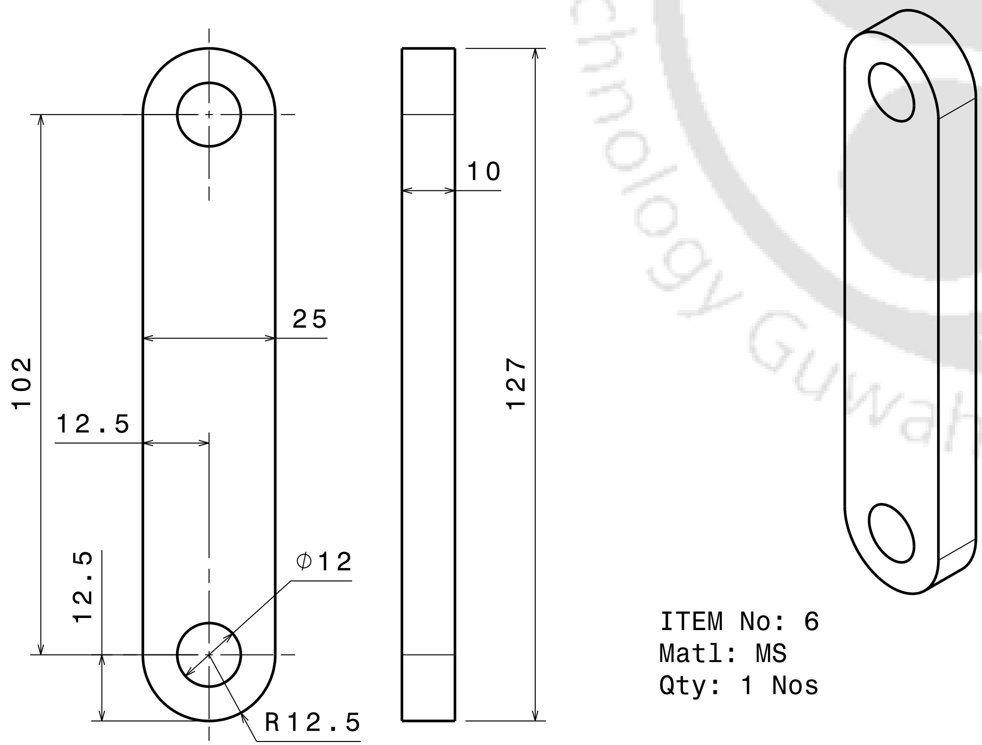
IIT GUWAHATI		
BENDING TOOL		
DRN BY: KKM	First angle projection	
APP BY: PCK	DWG NO: 5	
SCALE: 1:1	PAGE: 3 OF 8	SIZE: A3



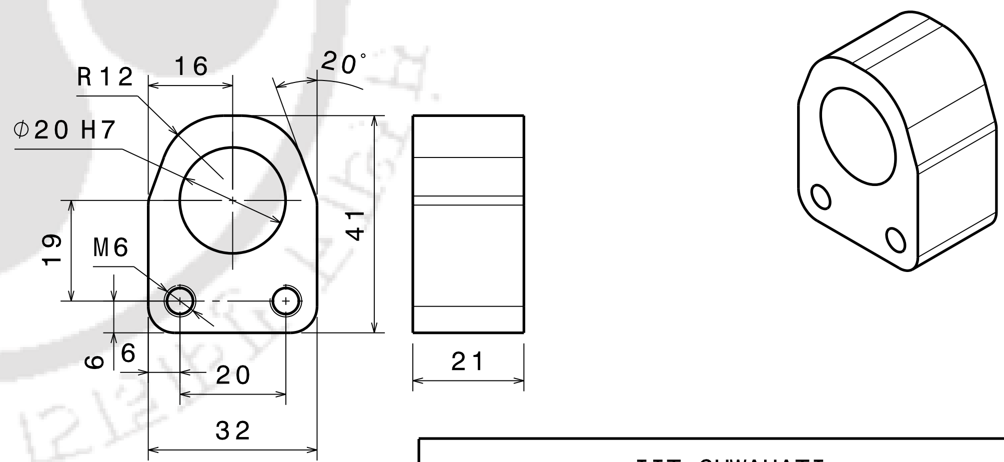
ITEM No: 24,23
Matl: MS
Qty: 2 Nos



ITEM No: 27
Matl: MS
Qty: 4 Nos

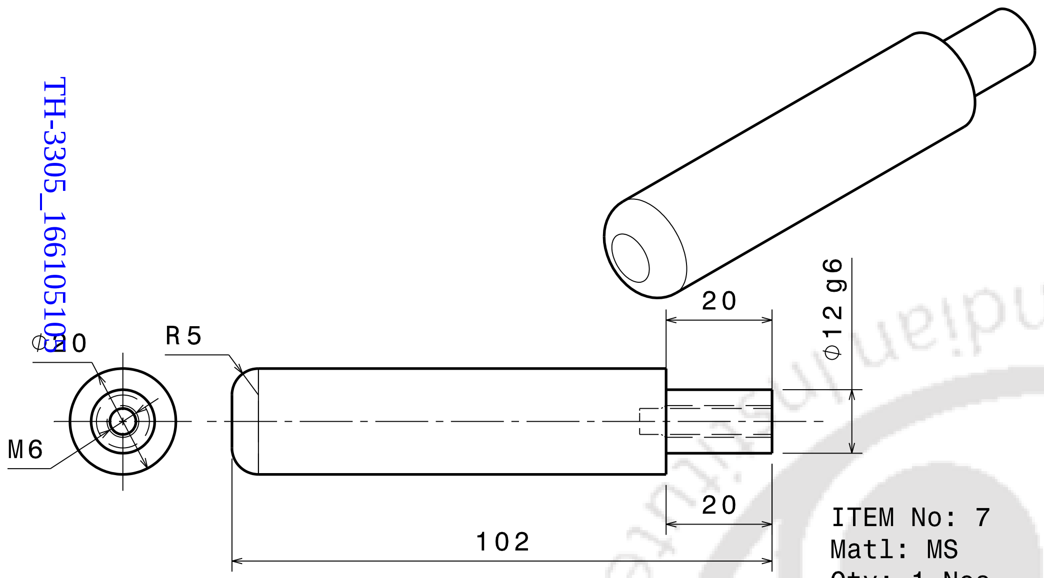


ITEM No: 6
Matl: MS
Qty: 1 Nos

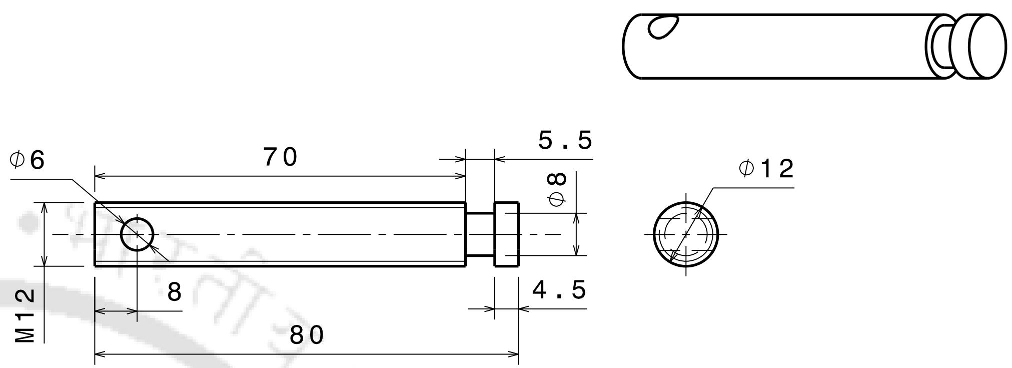


ITEM No: 10
Matl: MS
Qty: 4 Nos

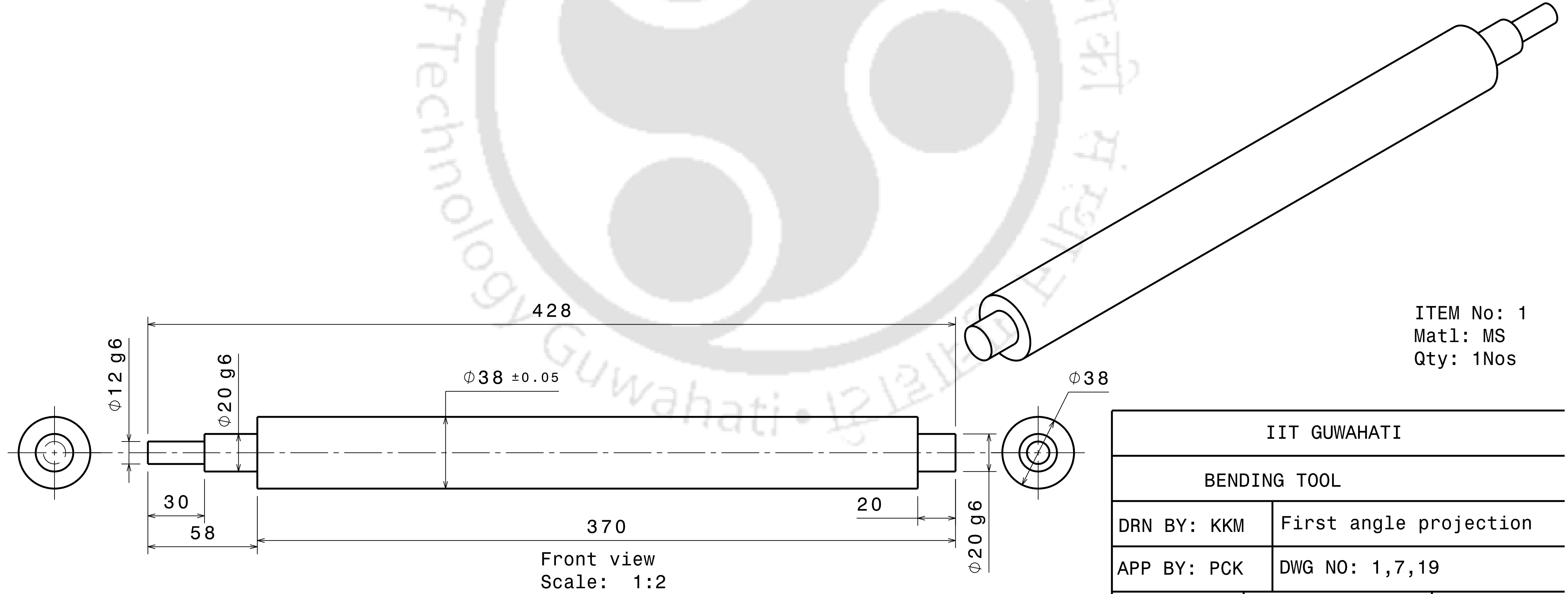
IIT GUWAHATI		
BENDING TOOL		
DRN BY: KKM	First angle projection	
APP BY: PCK	DWG NO: 6,10,24,23,27	
SCALE: 1:1	PAGE: 4 OF 8	SIZE: A3



ITEM No: 7
Matl: MS
Qty: 1 Nos
Wt. :

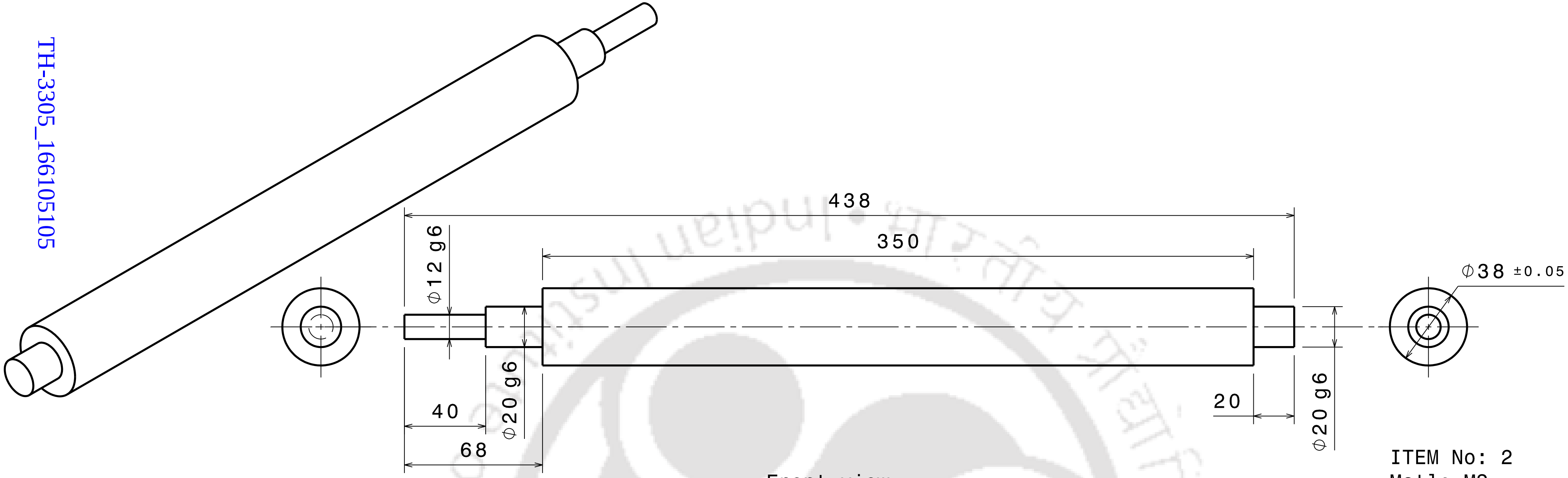


ITEM No: 19 or 20
Matl: MS
Qty: 2 Nos

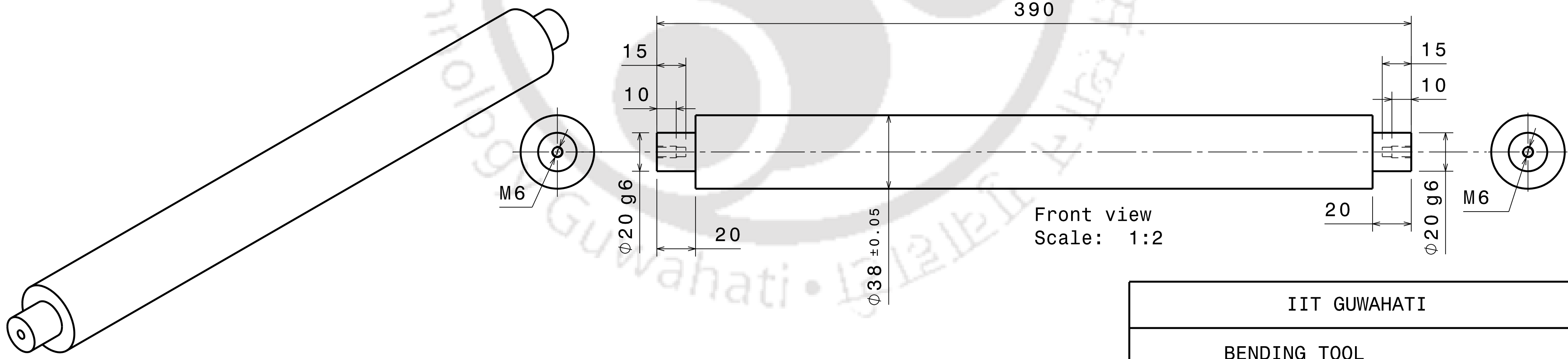


ITEM No: 1
Matl: MS
Qty: 1Nos

IIT GUWAHATI	
BENDING TOOL	
DRN BY: KKM	First angle projection
APP BY: PCK	DWG NO: 1,7,19
SCALE: 1:1	PAGE: 5 OF 8	SIZE: A3



ITEM No: 2
Matl: MS
Qty: 1 Nos



ITEM No: 3
Matl: MS
Qty: 1 Nos

IIT GUWAHATI		
BENDING TOOL		
DRN BY: KKM	First angle projection	
APP BY: PCK	DWG NO: 2,3	
SCALE: 1:1	PAGE: 6 OF 8	SIZE: A3

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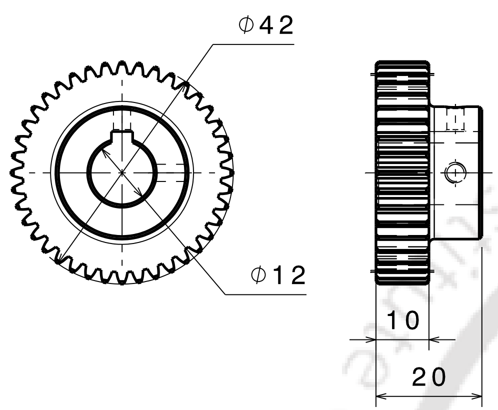
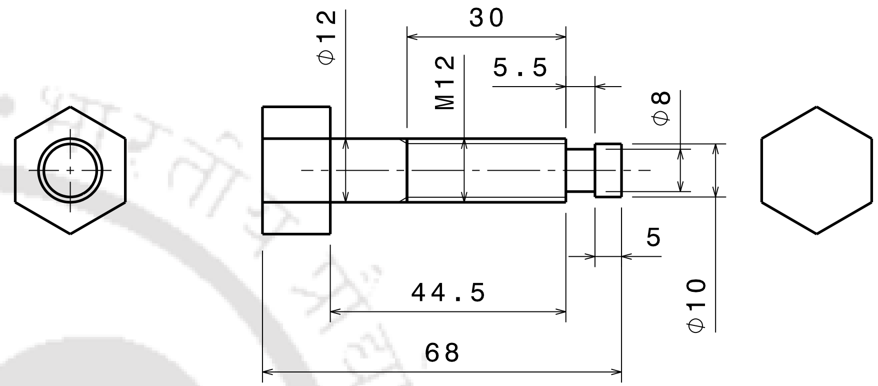
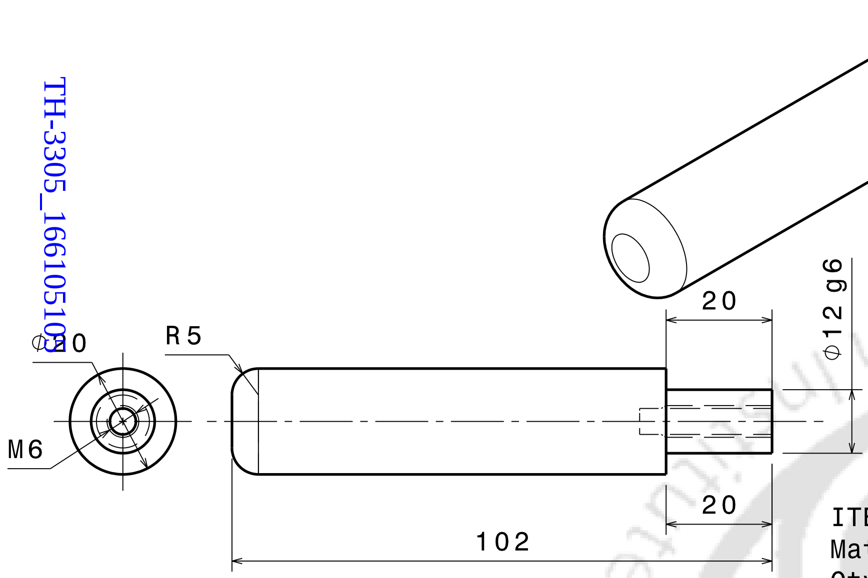


ITEM No: 30,31
Matl: MS
Qty: 2 Nos

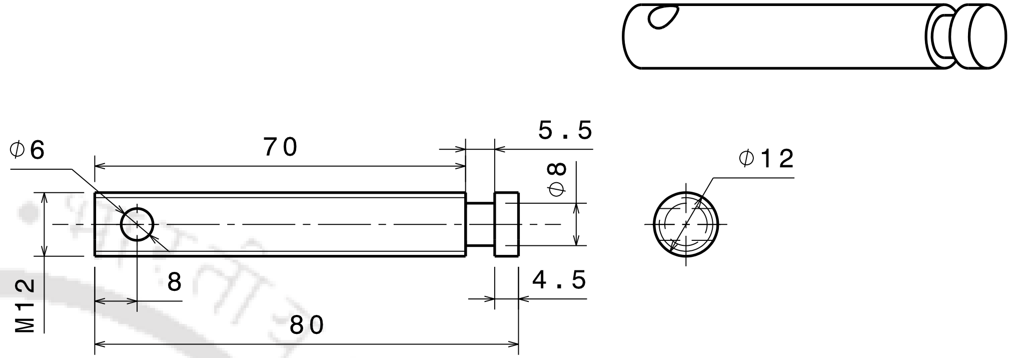


ITEM No: 9
Matl: M5
Qty: 2 Nos

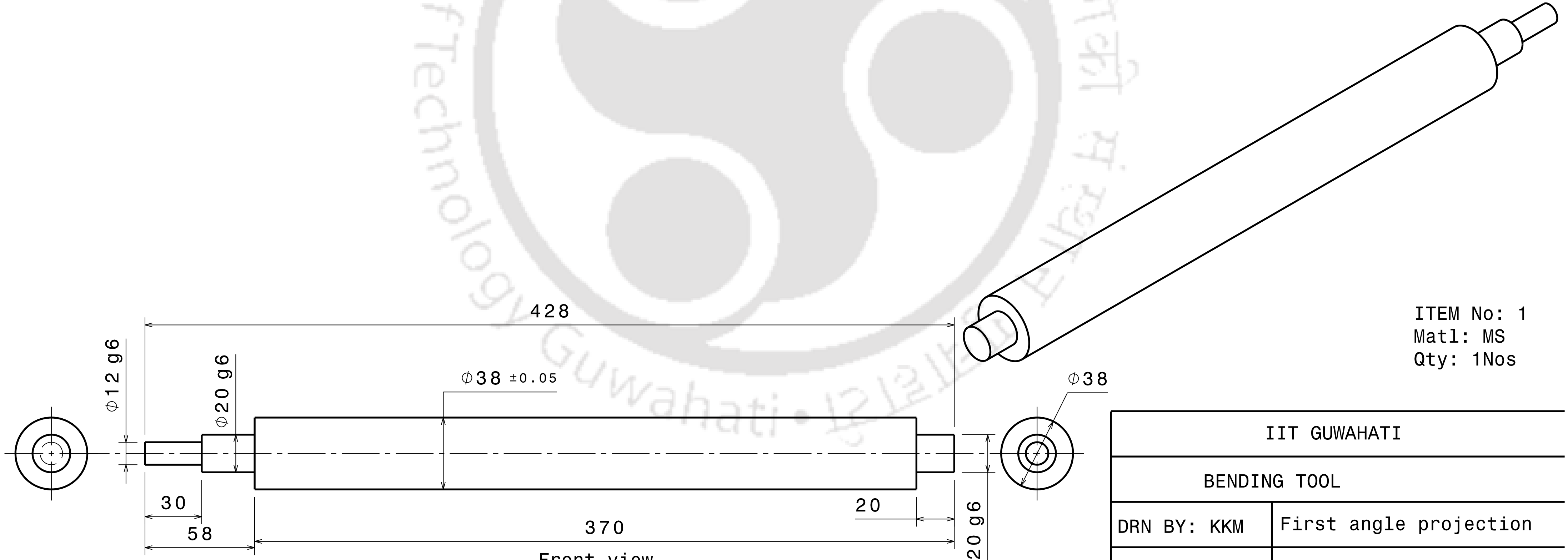
IIT GUWAHATI		
BENDING TOOL		
DRN BY: KKM	First angle projection	
APP BY: PCK	DWG NO: 30,9	
SCALE: 1:1	PAGE: 7 OF 8	SIZE: A3



ITEM No: 7
Matl: MS
Qty: 1 Nos
Wt. :



ITEM No: 19 or 20
Matl: MS
Qty: 2 Nos



Front view
Scale: 1:2

ITEM No: 1
Matl: MS
Qty: 1Nos

IIT GUWAHATI		
BENDING TOOL		
DRN BY: KKM	First angle projection	
APP BY: PCK	DWG NO: BT_P_005	
SCALE: 1:1	PAGE: 8 OF 8	SIZE: A3