Ergonomics Design intervention to reduce manual effort of Kolhapuri crafted footwear manufacturing without affecting the craftsmanship

A thesis submitted in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

Submitted by

Ganesh S. Jadhav

156105018

Under the supervision of

Dr. Urmi R. Salve

Department of Design

Indian Institute of Technology Guwahati

Guwahati, Assam, India

Dedicated to my family

Declaration Certificate

July 2019

I hereby declare that the thesis entitled "Ergonomics Design intervention to reduce manual effort of Kolhapuri crafted footwear manufacturing without affecting the craftsmanship" being submitted in the partial fulfillment for the award of Ph.D. degree, is an authentic work of my research work carried out during the period from January 2016 to July 2019 in the Department of Design, Indian Institute of Technology Guwahati under the supervision of Dr. Urmi R. Salve. The thesis has not been submitted by me earlier for any other degree or diploma.

Ganesh S. Jadhav
156105018
Department of Design
Indian Institute of Technology Guwahati

Certificate

July 2019

The thesis entitled "Ergonomics Design intervention to reduce manual effort of Kolhapuri crafted footwear manufacturing without affecting the craftsmanship" presented herein by Mr. Ganesh S. Jadhav. (Roll No. 156105018) was undertaken under my supervision. The volume of work submitted for the degree of Doctor of Philosophy of the Indian Institute of Technology Guwahati has not been submitted by him earlier for any other degree or diploma.

He has undergone four specified courses and fulfilled all the requirements as mentioned in the rules and regulations for submitting the thesis for the Ph.D. degree of the Indian Institute of Technology Guwahati.

Dr. Urmi R. Salve
Department of Design
Indian Institute of Technology Guwahati
Guwahati - 781039, Assam, India.

.

Acknowledgment

I would like to acknowledge God Almighty the giver of life, in whom we live, move, and have our being. I sincerely thank my supervisor, Dr. Urmi R. Salve (Department of Design) for patiently supervising and continuously supporting me during the entire PhD program. I also thankfully acknowledge the valuable time, advice and effort rendered by her for the completion of my PhD thesis. Special thanks also are due to my doctoral committee members, Dr. Sougata Karmakar (Department of Design), Dr. Pratul Chandra Kalita (Department of Design) and Dr. Sachin Singh Gautam (Department of Mechanical Engineering); for their time, careful observations and helpful instructions during the annual assessments and for granting approval to submit my PhD thesis. I would also like to extend my gratitude to the entire faculty and staff members in the Department of Design for their encouragement and help in times of need. I would like to express my heartfelt thanks to Prof. Debkumar Chakrabarti (Department of Design), Mr. M. Arunachalam (Research Scholar, Department of Design), Mr. Joseph (Former Chief Engineer; Philips Tool Division), Mr. Hemant Shete (Assistant professor, DACOE Karad), Dr. Naveen Virmani, Miss. Arunita Paul, Mr. Sarfaraz Alam for their assistance through meaningful discussions and friendly support. I also thankfully acknowledge the help rendered by final year students during my field visit. I also take this opportunity to extend my gratitude to Mr. Arun Satpue (Chairman Cobbler Community Kolhapur District) for granting me permission to conduct investigations in their establishments. The extremely supportive service rendered to me by the artisans of Kolhapuri Chappal cluster community of these organizations is thankfully acknowledged. Participation of the artisans in this study is the cause of research work, is also gratefully recognized. Finally I would also like to express my sincere appreciation to my beloved wife Dipali, Aai, Aapa and my wonderful daughter Divya for their sacrificial and unconditional support.

Ganesh S. Jadhav.

Contents

List of figures

List of Tables

SUMMARY

The footwear industry is an important segment of leather industry. Footwear industry is distributed in various parts of India. India ranks second among the footwear manufacturing countries next to China. The footwear manufacturing occupies a place of significance in Indian economy in view of its huge potential for employment, development and exports. The category of footwear industry is divided into two major halves. One is organized and other is unorganized, mainly craft based which has lot of varieties. Among them (craft based), Kolhapuri crafted footwear is prominent in Kolhapur, Maharashtra, western part of India. This particular craft has very significant presence in local economy as well as national economy (export and domestic market). This is a cottage based industry and mainly whole family involved in this craft based business. But the wellbeing of the Kolhapuri crafted footwear manufacturing artisans and their productivity is highly compromised due to various reasons. This crafted footwear production process involves various labor-intensive activities such as bottom sole making, skiving, punching, polishing, pattern cutting, heel attachment, upper strip preparation, stitching, finishing and final assembling. All these activities are divided among male and female workers of the house according to the heaviness of job types. Female workers are mostly involved in stitching, Veni (braid of leather) making, decoration and accessory preparation.

During field visit it was observed that all manufacturing operations in this industry are manual. Apparently it was observed that there is an inconsistency between operator's physical competencies and demands of physical task to operate tools/equipment which may leads to poor performance, low productivity and safety problems. While doing these various jobs artisans occupy apparently various non-optimal postures which may lead to development of occupational disorders. Further it was identified due to various reasons existing artisans are no more interested in their ancient craft business/profession. Based on field observation, discussion with various stakeholders of this craft, importance of its presence in national economy and detailed literature review, a need was felt to understand the whole manufacturing process in detail. Apart from this there was a need to study the involved tools/equipment, status of occupational health and any other intervention if required. It was identified in literature that effective solution/intervention

leads to improved efficiency, productivity and wellbeing of the artisans. Therefore it was expected that any intervention may inspire them to get back into this profession.

In view of the above a holistic process of design intervention to improve work techniques, tools and equipment for Kolhapuri crafted footwear manufacturing was taken as an approach. Present research focused on ergonomics design intervention to reduce manual effort of Kolhapuri footwear manufacturing without affecting the craftsmanship.

The present thesis was carried out in major three segments. Objective of the first segment of the study was to understand their working environment, identification of bottlenecks based on the severity of problems. This part explained ground level scenario which leads to an understanding of working conditions, current trend, manufacturing process, supply chain (from the production house to retail market), distribution of skill requirement in whole manufacturing process, scope of automation/semi-automation, used tools/equipment, price structure etc.

In this segment it was identified that working postures was not conducive for any workstations. Involvement of high manual and physical labor was one of the major concerned factors which may lead to decreased productivity, quality and increased material loss, rework, scrap, injury etc. Result of stakeholder's interview revealed 'loss of interest in their ancient craft business/profession' is one of the results of above identified factors. The whole manufacturing process was further distributed on the basis of skill dependency and possibility of operational intervention. The result showed that most of the tasks were skill dependent except skiving operation and sole & strip cutting operation has a scope of operational intervention. Further it was identified that sole & strip cutting operation requires more manual effort. Based on the above result sole & strip cutting operation were considered for technical operational intervention. Posture analysis revealed stitching and accessories preparation workstation may have scope of intervention although, intervention should not hamper the basic technical movement of the job.

In the second segment all varieties of interventions were conceptualized, screened and developed. Sole and strip cutting operation is being carried out by a traditional cutting hand tool called rappi (sharp edged tool). The used material in sole & strip making is leather (bullock, buffalo, cow and goat). Required hand force for sole & strip cutting operation were measured and found to be around 5 to 6 Kg which is quite difficult to produce manually during every cutting operation. The identified leather for manufacturing process was bullock, buffalo, and cow. Among all buffalo leather was found to be highest in strength. Therefore all cutting operation interventions were designed keeping buffalo leather in consideration. Sole cutting operation involves base and heel cutting. The challenge in existing sole making process was required high manual effort and keeping identical sizes in every production. In this research high manual effort was taken care by automated sole cutting machine and identical size preparation was taken care by cutting die. Both base & heel profile making were taken separately for design development. Both base and heel dies were designed using mild steel (EN8) and tested for its strength. While testing the dies in actual it was anticipated that in the long run of use there is a possibility of deformation in the die. This phenomenon may affect the whole process, quality, required force exertion, etc. Therefore a new iteration was generated, produced and tested. Test results revealed quality improvement in cutting operation as well as time reduction.

To operate the cutting die there was a need to develop a mechanism which can create sufficient pressure in controlled manner on the surface of dies so that dies can cut any leather. To achieve that, various designs were conceptualized and screened through Pugh chart. Various features of the design were identified based on the context of the application, availability of space, required quality & accuracy, time constraint, responses from craftsmen, etc. The required features were compactness, leather cutting effectiveness, manual effort reduction, rate of cutting, easy handling, maintenance cost. The concept which received highest score was manufactured physically and tested with newly designed dies for actual sole cutting operation. For strip cutting operation similar method was adopted and dies were prepared. Both sole & strip cutting operation were tested in terms of quality, production of identical shape, accuracy, required time & manual effort etc. All found to be satisfactory in actual.

From the first segment of the study it was also found that Veni (braid) making and accessories preparation require intervention but there is less scope of operational modification as these are highly skill based jobs and has significant impact on the essence of specific craft. After field observation, analysis of interviews with stakeholders, it was concluded that postural stress relief by design modification of workstation may alter (improve) physical load. Keeping that in mind both the workstations were virtually conceptualized, designed and tested for various ergonomics parameters. The result revealed a satisfactory improvement in postural load which may in turn enhance performance, well-being productivity, quality etc.

The final segment dedicated to evaluate impact of all varieties of interventions for up-liftment of this specific craft, way out to disseminate the outcome of research towards specific community. After understanding all the interventions in terms of operational involvement, functionality, operative procedure, space requirement, its impact on the essence of craft, quality and quantity of the product, productivity, the efficiency of workers, personal comfort, cost involvement, etc. was analyzed. In this part various workshops were conducted for stakeholders. Responses through unstructured interviews and discussion from various stakeholders were recorded. Content analysis of those responses revealed satisfactory results of all these interventions. Cost benefit analysis of major operational changes were also calculated and described to the stakeholders for their easy understanding and acceptance. 'Sharing of major facilities holding under one roof' was introduced to the stakeholder especially young enthusiast for encouraging them to continue their own ancient glorified business/profession.

The whole study depicted a holistic approach to enhance productivity, process, quality of Kolhapuri crafted footwear manufacturing whereas, human health in terms of occupational health was major consideration of the interventions. After implementation of all interventions, there was no impact in the main essence of this specific craft, which is remarkable contribution for any crafted product and handcraft industry. Therefore this methodology can be set as a benchmark for any such intervention for any improvement in craft based industries. Also designers can take this approach for any other relevant product design for this handcrafted industry.

Chapter I – Background

1.1 Current scenario of the footwear industry in global and Indian context

Footwear is one of the leading end products of leather (Kamble E., 2004). Nearly two-thirds of the world's total supply of leather is used for footwear fabrication (Sinha S., 2004; Ghosh A., 2012). The history of the global footwear industry reflects the structural shifts of this industry after 1970s (Kamble E., 2004). Until 1970s, all developed countries had their own footwear industries. Due to industrialization, various developing countries started producing and exporting footwear. This causes a direct effect on footwear manufacturing sector of developed countries (Kamble E., 2004). In early 1990s, the global footwear sector moved to developing nations like China, India, Thailand, and Indonesia (Sinha S., 1994). By the year 2017, China had become the biggest footwear producing and exporting country in the world. A report presented by Sherief et al (2000), revealed that China, India, Vietnam, (South East Asian), Brazil, Mexico (Latin American), Turkey (Middle East), Italy, Spain, Portugal (Europe) were the worlds' top footwear producing countries during 2000. In another report, it has been mentioned that China, Thailand, Vietnam, Taiwan, Indonesia, Brazil, and Hongkong are the major footwear exporters (Kamble E., 2004). The countries like USA, Japan, Germany, UK, France, Belgium, and Netherlands are the worlds' leading importers of footwear (Kamble, 2004). India ranks second among the footwear manufacturing countries next to China (Szubert Z., 2001). Due to advanced technological methods of shoe designing and manufacturing, India is earning further value for export in shoe production business (Sumangala D., 2008). Leather footwear manufacturing/fabrication is carried out mainly in three states of India such as West Bengal, Tamil Nadu and Uttar Pradesh (Sarkar, 2010). On the other hand, few researchers revealed that the leading footwear business centers in India are at Chennai, Ranipet, and Ambur in Tamil Nadu, Kolhapur and Mumbai in Maharashtra, Kanpur and Agra in Uttar Pradesh, Jalandhar in Punjab, and Delhi (Kamble E., 2004). Contradictions regarding the production and business locations are majorly due to different understanding and research requirement of various research groups. But the footwear industry is labor intensive and concentrated in small and cottage industry sectors (Tiwari R., 2013).

The Indian footwear manufacturing industry has established generous associations in the international production system. But, this footwear manufacturing industry is still conquered by industries that provide mainly to the national market over the artisanal fabrication system (Sarkar, 2010). Due to the encouragement of British government, first technologically modern tanning leather industry was established in 1857 (Bhosale B., 2000).

The leather business in the Western part of India is largely situated in the Maharashtra state (Bhoite R., 2015). In Maharashtra, various locations like Kolhapur, Mumbai, Thane, and Athani are primarily involved in the manufacturing leather wares, sandals and shoes. Figure 1.1 shows that India's footwear export has been improved from $1534.32 million in 2009-10 to $2531.04 million in 2013-2014 (Bhoite R., 2015). It is important to notice from the graph that in the year 2010, there is a decrement in the export of footwear. Otherwise, in all other years, it is consistently in increasing mode.

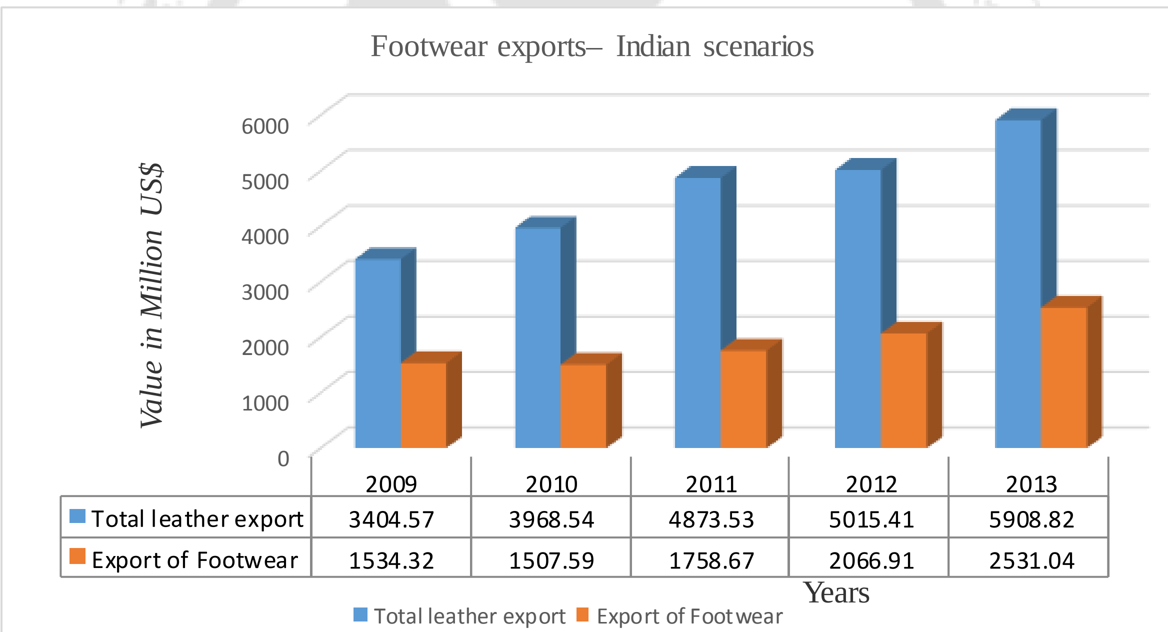


Figure 1. 1: Leather and footwear export

Source: Council for leather exports, (Sponsored by the Ministry of Commerce and Industry, Govt. of India) (2015)

In the global market, there is strong competition for Indian footwear. Various countries like China, Spain, Portugal, Brazil, Taiwan, and South Korea are major competitors of India in the world market (Rao P., 2001).

Figure 1.2 represents the distribution of leather and leather goods from the year 2007-08 to 2011-12. It is important to notice from the graph that the sale of footwear continuously increasing from 2007-2012.

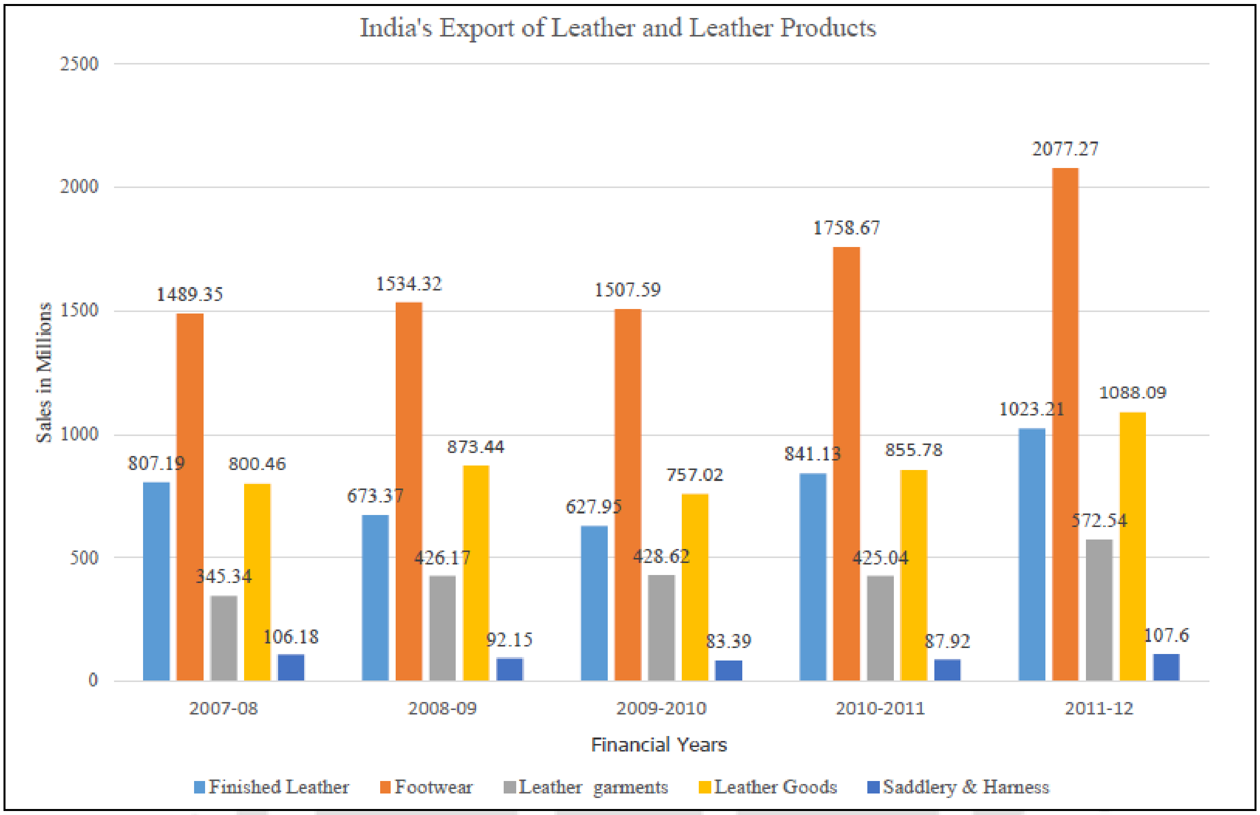


Figure 1. 2: Export of leather and leather goods

Source: Directorate General of Commercial Intelligence & Statistics, Govt. of India (2015)

1.2 Contribution of handcrafted products

India is the main supplier of handicraft products to the world market (Chowdhury S., 2016). All the handicraft industries in India are labor intensive. Various artisans of the country represent an ancient craft which has been passed from generation to generation for thousands of years. All these handicraft industries are spread all over nation in rural and urban areas. Handicraft industry provides a job to more than six million artisans (Chowdhury S., 2016). Artisans those are associated with handicraft industry are belonging to financially weaker section of the society (Chowdhury S., 2016). There is a significant contribution of female artisans in handicraft industry (Chowdhury S., 2016). Leather footwear and handicraft sector have contributed significantly over the years to the employment and foreign revenues as well (Kadam D., 1984; Kamble E., 2002).

Crafted footwear manufacturing is carried in various parts of the country (rural and urban cluster area). These clusters consist of small home-based workshops of family enterprise type business. The production of leather related crafts is carried out in different locations in India as shown in figure 1.3. These varieties are distributed throughout several geographical locations. Different types of crafted footwear's such as leather Kolhapuri footwear, embroidered juti's or Mojari in Rajasthan, traditional shoes in Sikkim and Ladakh are well-known footwear in the country (Lathra Y., 2000). Some varieties of handmade footwear are very much popular in India and abroad. In some of the countries, these crafts are exhibited in the form of an exhibition. The ethnic footwear "Kolhapuri footwear" from Maharashtra and "Mojari" from Rajasthan were first time exhibited in an international fair held in Germany (Lathra Y., 2000). It is seen that these Indian handcrafted footwear products are famous in the global market. Therefore, it is necessary to keep attention towards these products for their enhancement in terms of quality, aesthetic, etc.

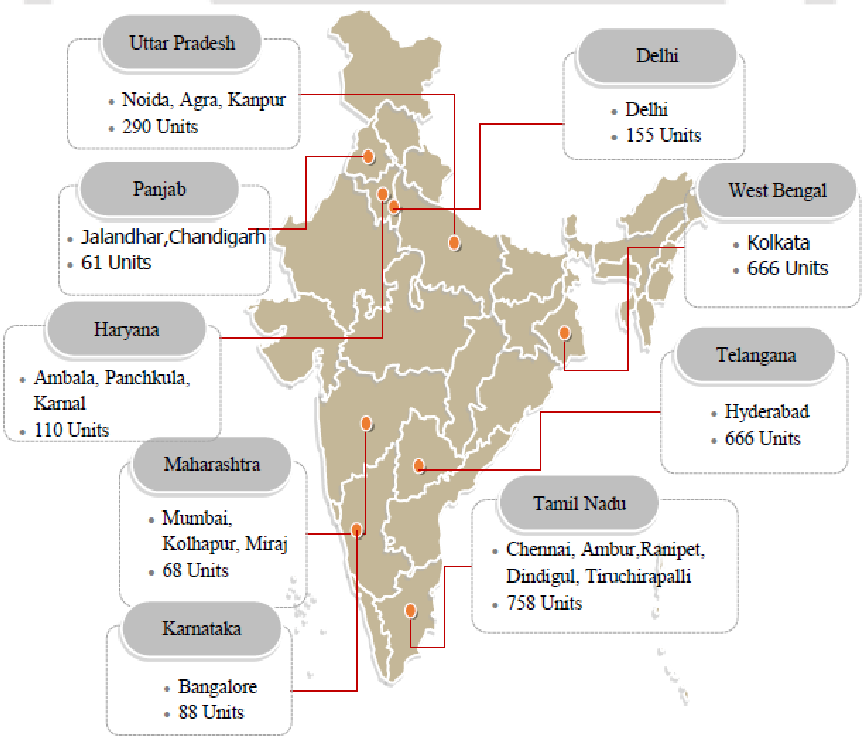


Figure 1. 3: Number of leather centers in India

Source: CLE (2015)

1.3 The Kolhapuri hand crafted footwear

Kolhapur is known for its art and handicrafts. Kolhapur is the biggest leather artisans' cluster in Maharashtra (Burute P., 2014). Kolhapur is famous for handmade leather footwear popularly known as 'Kolhapuri Chappal' (local name of footwear). The traditional well designed crafted Kolhapuri footwear is well-known not only in Maharashtra but also across the globe (Kamble B., 2002). Kolhapuri footwear is originally made in Kolhapur District. In Kolhapur district, these footwear is called as 'Paytaan'. These types of Kolhapuri crafted footwear are mainly manufactured in Kolhapur city and the surrounding villages. The different names of Kolhapuri footwear came into existence depending upon the location it was made like Kapshi, Pukari, Bakkali, Kachkadi, Paytaan, etc. (Burute P., 2014).

The concept of Kolhapuri footwear started during the 13th century (Burute P., 2014). From the literature, it was found that its production started in 1920 by Saudagar family (Burute P., 2014). This footwear became very famous when it had been sent to the retails store J. J. and Sons, Mumbai (Burute P., 2014). This special footwear's upper portion was very decorative and attractive that's why J. J. and Sons placed an order (from Kolhapur) for many more pairs (Burute P., 2014). Due to good quality and the novel nature of the product, there was a requirement of Kanwali footwear in the market. Therefore, Saudagar family expanded their footwear making work by educating the skill to artisans (Burute P., 2014). They received orders from Kolkata (West Bengal) where this type of footwear became more popular (Burute P., 2014). By 19th-century, Kolhapuri footwear became very famous as Kolhapuri and shortly after that, it was manufactured by residents of the adjoining towns and cities of Kolhapur and the brand was established as Kolhapuri footwear.

Kolhapuri footwear is made from processed raw leather of cattle. Grazing process is carried out on raw leather. Due to the grazing process, the leather becomes hard and durable (Burute P., 2014). This type of leather can be used for daily purpose. The uniqueness of any 'authentic Kolhapuri footwear' is that it is made up of pure leather and not any other artificial material. But there are other low qualities (by using some duplicate material, which is not from the original hide) of fashionable Kolhapuri footwear, where a raw processed leather is used in the upper side or portion and the sole being made of rubber. Some Kolhapuri footwear makes a peculiar sound while walking on the roads, gives an identity to this particular product. This sound is due to a particular type of seeds placed in between two sheets of the bottom sole which make that sound. These seeds are obtained from “Vinchu” tree (local name). Kolhapuri footwear is very comfortable to use and it is also believed to be good for health (eyes, back pain, diabetes, etc.) (Patil R., 2002). Even though, there is no scientific study or relevance of the above fact.

Kolhapuri footwear is manufactured not only in adjacent villages or towns of Maharashtra but also at Karnataka boarders such as Athani, Miraj, Jamkhindi, Kapshi, etc. In these villages or towns, every family member of home-based workshop contributes to the footwear making process. Family artisans are occupied for manufacturing of Kolhapuri footwear. The entire family produces nearly 40 to 50 pairs of footwear in a week. Kolhapuri footwear production involves labor-intensive activities such as bottom making, skiving, punching, polishing, pattern cutting, attachment of heels, ears & upper bottom making, stitching, finishing and final assembling as shown in figures 1.4. The male artisans are engaged in sole cutting, seasoning of leather and assembly whereas female artisans are responsible for stitching, upper portion decoration, accessories preparation and veni (braid) making, etc.

Raw leather of Cattle

Bottom making

Skiving

Punching

Pattern sole Cutting

Attachment of Heels

Upper Strip Preparation

Finishing

Sole Stitching

Colour Pasting

Preparation of Parts

Water dipping

Figure 1. 4: Different Workstations

Most of the footwear manufacturing artisans working in family enterprises are financially not strong and mostly belong to cobbler community (Kamble B., 2004). They do not use any machine and the manufacturing methods are very primitive and conventional in nature (Salve and Jadhav, 2017). The tools and equipment used by the artisans are also very primitive with no improvement over the years. In Kolhapur district, there are 5635 units and 10,000 leather artisans, of which more than 30% are women artisans (Burute P., 2014). Nearly 80% of units manufacture products for dealers who supply raw materials to these artisans (Burute P., 2014). The total turnover of Kolhapuri footwear from Kolhapur district is Rs.12 crores (Burute P., 2014). Kolhapuri footwear is famous and has a high demand at international market and is getting exported in more than 50 countries (Pereira F., 2000; Patil R., 2002; Burute P., 2014; Bhosale B., 2000). According to Burute P., (2014), this footwear is very popular in Pakistan as well. In spite of having high demand in national and international market young generation are not interested in continuing their ancestor's business/profession due to various reasons.

1.4 Manufacturing Process

Kolhapuri crafted footwear manufacturing falls under unorganized sector category (Salve et al, 2017). The manufacturing process (figure 1.5) of Kolhapuri crafted footwear is time-consuming. The footwear manufacturing task is performed in a seated working posture. There are near about 7 to 8 types of tasks while manufacturing of Kolhapuri footwear. The manufacturing workstation is very primitive in nature. It is mainly a small wooden block and a piece of marble is mounted on top of it. One skilled leather artisan requires 6 to 8 hours per day for manufacturing one pair of footwear (Burute P., 2014). The entire Kolhapuri footwear manufacturing process is manual right from the tanning phase to footwear finishing stage (figure 1.6). For manufacturing of the footwear, dead animal's skin or hide (buffalo, ox, and cow) is used to make the base of the footwear. The raw hide of an animal's skin is soaked in lime solution (Calcium carbonate) to remove impurities. Sisal plant fiber is used for stitching the skin into a bag shape. Skin in the form of bag is filled with a solution of babul and terminalia (ayurvedic plant seeds) and kept it for 18 to 20 days. Then the removed leather is dried in direct sunlight for 1 to 2 days. Terminalia seeds have ayurvedic and medicinal properties. These seeds are crushed over the leather and spread on it which prevents skin related diseases. One hide of buffalo is sufficient for the production of 20 pairs of the footwear (Burute P., 2014). After finishing this process dried leather is stored at room temperature in a dry place. Artisans then cut the stored leather according to their requirement. After the cutting process, they clean the same leather with the fresh water to remove dirty skin and make it soft with the help of a brush. Excess leather can be trimmed into required shapes, depending on the parts to be made.

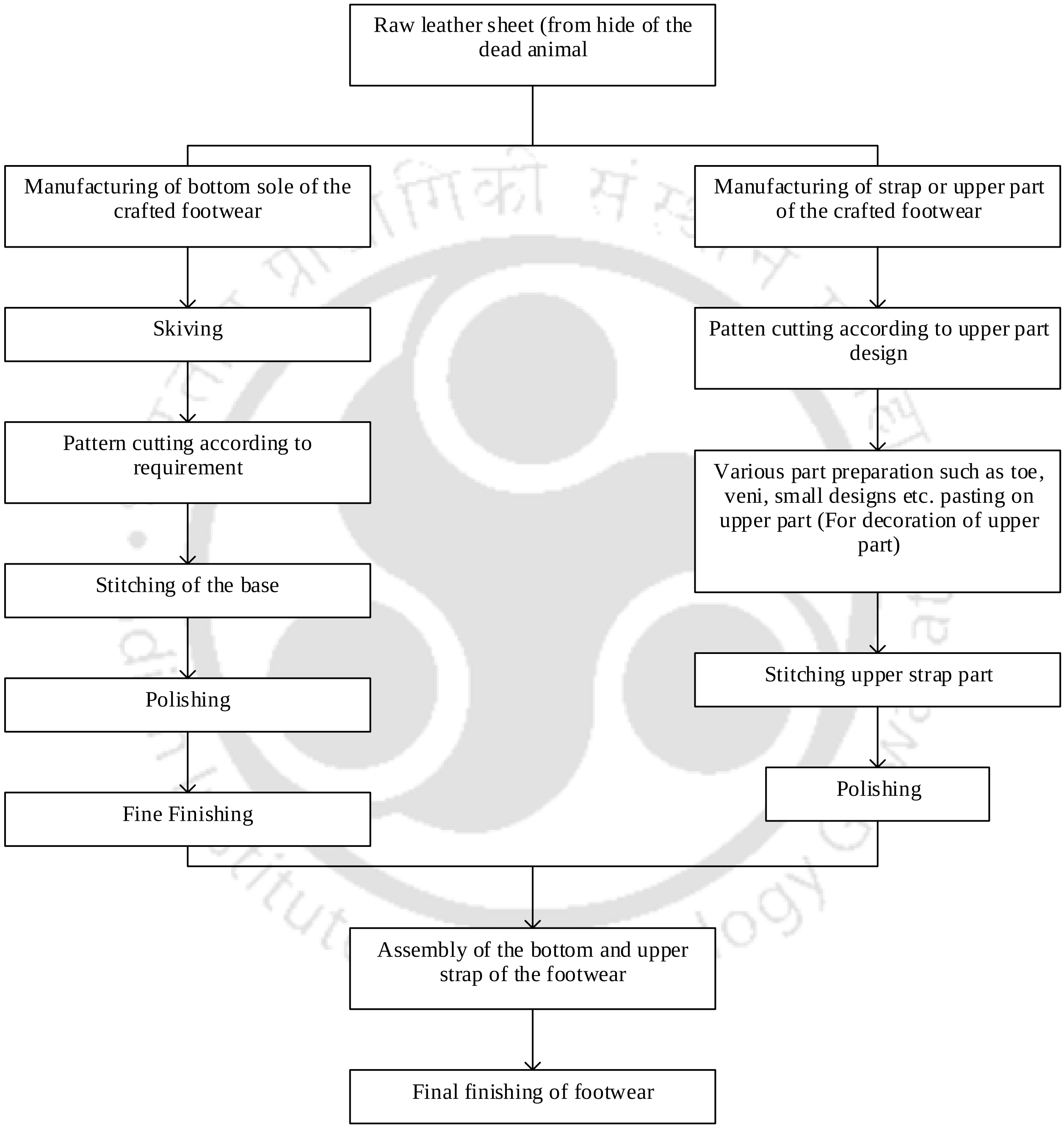


Figure 1. 5: Flow chart of the manufacturing process of Kolhapuri footwear

a. Hide of the dead animal

b. Hide kept in lime solution

c. Hide in the form of bag

d. Mixture of hirda poured in bag

e. Hide dried

f. Hide storage at room temp

g. Sole preparation using a stencil

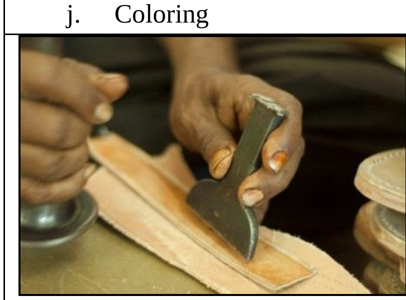
h. Sole hammering

i. Stitching

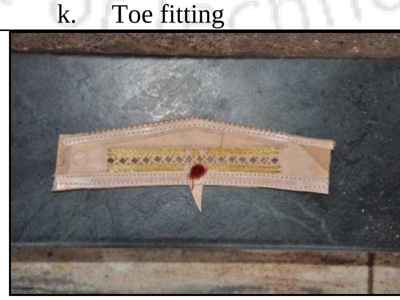
j. Coloring

k. Toe fitting

l. Strap fitting



m. Pattern making



n. Strap with golden thread

o. Decorated strip pasting

Figure 1. 6: Manufacturing process of Kolhapuri footwear

During manufacturing of base sole, artisan place the master piece on leather sheet and mark the outer line by pencil. Then cut the marked surface with help of rappi (sharp edged tool). Generally, the thick part of the leather is used to make a shoe or base sole of the footwear. Then, the leather is deeply hammered using Asti hammer (cobbler anvil) to make the surface flat and smooth. When stitching activity is carried out, the needle used for stitching is dipped into bee wax for easy penetration. Nylon threads and leather from cow tail is used for the stitching. Simultaneously, upper part of the footwear is prepared on other workstations. Then according to the type of footwear, artisans decorate different patterns on the upper strap. Generally, goat leather is used to decorate the upper strap of the footwear. Various types of punches are also used to make the decoration of upper part.

Most of the tools used for manufacturing Kolhapuri footwear are of tailor-made. Different decorative elements are pasted using local adhesive material. Then a solution of the color in water is pasted on the first layer of the footwear. The mixture of cream and color is applied in the second layer. After that polishing, finishing is done in the last layer. Toe and straps (upper part) are the main components of the footwear. After finishing, these two components are fitted on the footwear. Strap (upper part) designs may vary according to the type of footwear. The straps are made from goat leather and they are curved in shape. Simultaneously, different patterns according to the type of footwear are made by punching. Then decorated strips or bands of leather are glued on the strap (upper part) and hammered for a permanent fix. As per the design requirement, some small pieces of leather are added on the strap to make it attractive. Some specific patterns of the design may vary from male and female footwear. Sometimes, the golden threads can be used to decorate the straps of the footwear. Different types of patterns, veni (braid) and decorative designs attract the customer.

There are two types of Kolhapuri footwear based on the users' gender. One is specially made for male e.g. Meharban, Kapsi, Pukari, Gandhi, Bakkalnali, Plain, Paper Kapsi, Kurundwadi, Shahu, etc. and other for females, e.g. Nache Mayuri, Six Veni, Masoli, Gadarpata, Agutapata, Banthe, etc. (figure 1.7).

 Shahu Chappal	 Kurundwadi Chappal	 Kapashi Chappal	 Gandhi Chappal
 Pukari Chappal	 Paper Kapsi Chappal	 Bakkalnali Chappal	 Shahupuri Chappal
 Puda Punching Chappal	 Meharban Chappal	 Lal gonda Chappal	 Khas Kolhapuri Chappal

Figure 1. 7: Different types of Kolhapuri footwear

1.5 Tools and Equipment

There are varieties of operations such as sole/bottom making, skiving, stitching, punching, assembling, preparation of various parts, etc. while manufacturing of Kolhapuri footwear (Burute P., 2014). In footwear manufacturing operation, different traditional hand tools are used such as anvil hammer, knife, cactus, pattern tool, needle, toe fitting tool, punches, etc. (Burute P., 2014). These are the main tools used in the production of Kolhapuri footwear. These tools usually are used for the basic operations like slicing, cutting and sewing of leather as shown in table no.1.1.

The table below shows some traditional and conventional tools are being used during the manufacturing of Kolhapuri crafted footwear.

Table 1. 1: Tools used in manufacturing of Kolhapuri crafted footwear

Tools	Description
	**Country Hammer** It is used for thumping the sole and foot-bed. It can be majorly used on the lower part of the footwear.
	**Big Rappi (Knife)** This rappi is used in basic sole preparation. The various patterns are produced with the help of this sharp-edged tool.
	**Asti (hammer)** Metal hammer is used for beating the leather. The various small parts of the footwear are pasted on the footwear.
	**Sisal Leaf (Cactus)** Sisal Leaves are used during the tanning process. Raw leather cutting is done with the help of this tool.
	**Khurpa** The Khurpa tool is used to smoothen the leather. This tool is also used as a skiving tool. The raw leather can be smoothened with the help of this tool.
	**Pattern Tool (Thodapaekapathi tool)** This tool is used to provide wave influence or zigzag form of designs shapes. This tool helps to engrave the design on the footwear.

	**Needle** The needle is used to stitch the base sole of leather with nylon threads. The corner side of the base sole is being stitched with the help of a needle.
	**Nail removing tool** With the help of this tool, strap is nailed to the base. During manufacturing, some nails are fitted temporarily to hold various designs in order to remove these nails this tool is used.
	**Toe fitting tool** With the help of this tool, toe loop is added to the footwear base sole.
	**Sewing machine** Different design patterns on the strap are coupled with the help of a stitching machine. The upper part sewing is done with the help of a sewing machine.
	**Punches (large design)** Punches are used for punching large designs on the sole of the footwear. The various designs are engraved on the bottom sole of the footwear.
	**Punches (small design)** Punches are used for punching small designs on the sole of the footwear. These punches are manually engraved on the lower sole of the footwear.

	**Palagana (Kargoti stone)** This type of stone is used to the sharpening of all the tools. Some used tools are re-sharpened on this stone.
	**Punches (wave design)** Different punches are used to create different decorative patterns on the base of the footwear. According to the type of the footwear punching design may vary from footwear to footwear.

These tools are available in Kolhapur and Mumbai. The cost of these tools is around three to four thousand rupees based on the verities and the manufacturer (Burute P., 2014). Figure 1.8 shows that the structure of the crafted Kolhapuri footwear.

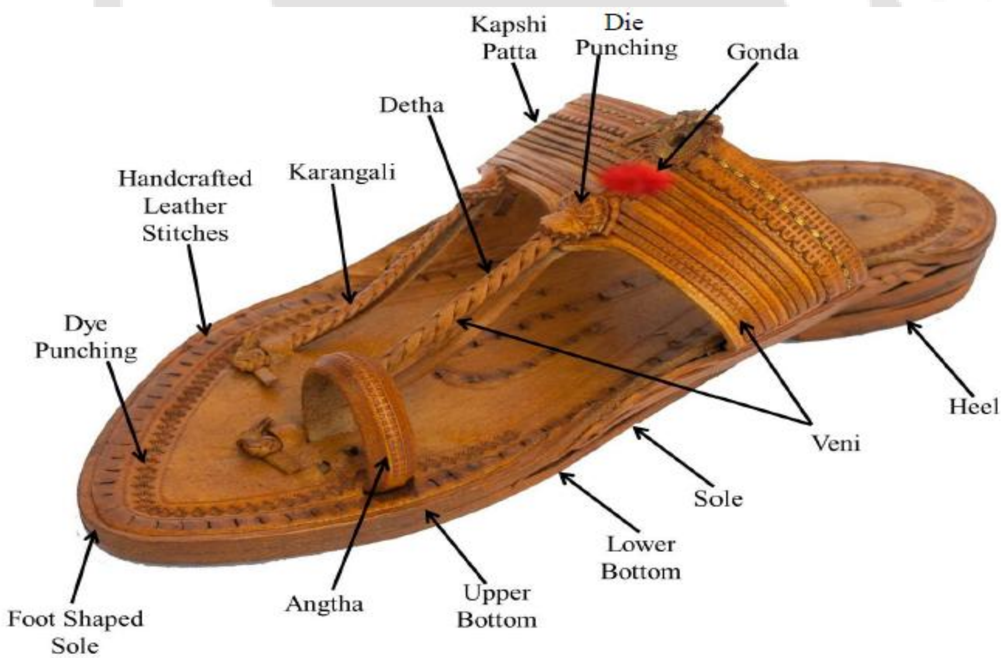


Figure 1. 8: Structure of Kolhapuri crafted footwear

1.6 Location map of Kolhapuri footwear leather Industry

Kolhapur district is located in Maharashtra, India. It is known as Dakshin Kashi, i.e. Southern Kashi (Burute P., 2014). There are 12 taluka places in the Kolhapur district as shown in figure 1.9. There are lots of tourist attractions in and around Kolhapur.

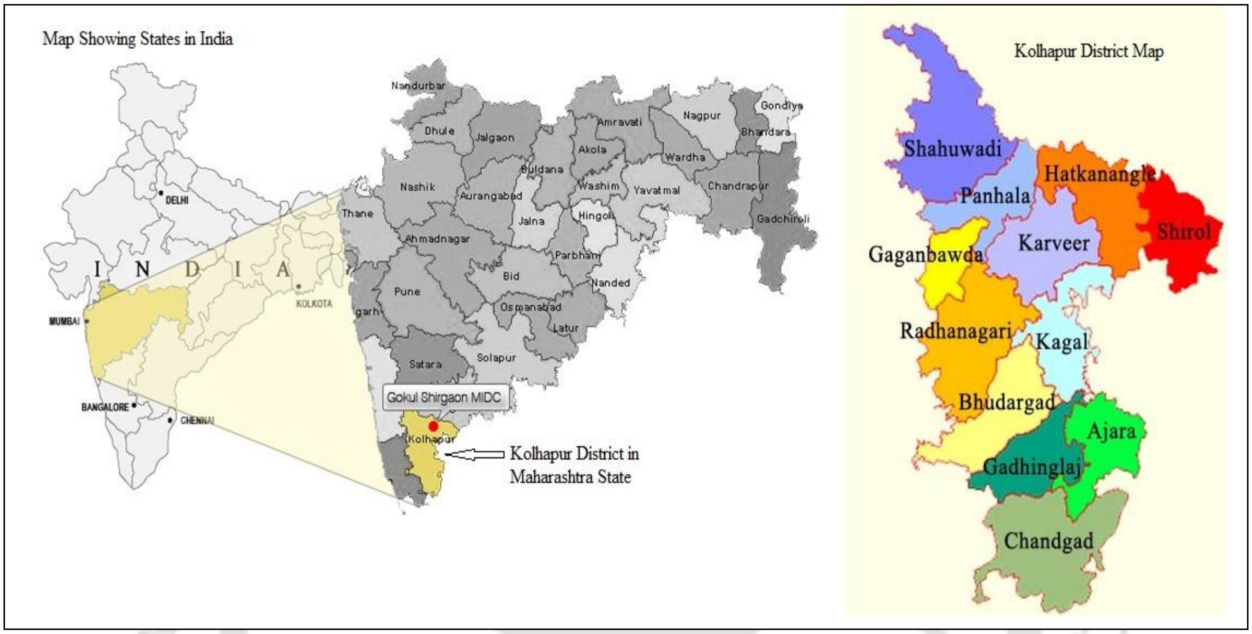


Figure 1. 9: Geographical Existence

1.7 The need for the study

The Kolhapuri crafted footwear manufacturing industry is largely unorganized and craft-based. Huge manpower including both genders is involved in this manufacturing process (Burute P., 2014). Kolhapuri footwear manufacturing industry plays a vital role in the socio-economic development of Kolhapur as well as Maharashtra and it considered as glory of the state (Burute P., 2014). But Kolhapuri footwear sector is currently experiencing a downward trend in its sales (Burute P., 2014). Probable reasons behind this phenomenon are not well researched or taken into consideration by any research body.

Every step of this process requires higher concentration and skilled inspection. A huge number of artisans are directly or indirectly connected and promoted from it. The literature says that any improvements in any workstation design can improve the output of the users (Pheasant S., 1991). Although, this craft demands high manual labor, productivity, and safety, it is involved in the economic status of the province, both genders are employed in this craft, there is rare study or technological intervention for any improvement of this downward trend of the craft.

In view of the above, there is strong need to understand the causal effect relation between various factors affecting the productivity, reduction in sale, reduction in quality, and reduced interest among the manufacturer in their own ancient business and many other contributory factors. Therefore a study was conceptualized titled “Ergonomics design intervention to reduce the manual effort of Kolhapuri crafted footwear manufacturing without affecting the craftsmanship”.

Chapter II- Literature Review

2.1 Introduction

Kolhapuri crafted footwear is an ancient unique handicraft of India. Being handicraft and cottage based industry adopted process & tools, way of communication to the customer, marketing of product, designs etc. are very traditional and conventional in nature. Before formalizing research methodology of this study it was evident to understand existing literature related to this industry. Kolhapuri crafted footwear is very much localized/native concept of India. Therefore scientific publications directly related to this industry are rarely available.

In view of the above it was decided to conduct a literature survey on similar industries where production process, used tools & techniques, workstations, product marketing, occupational health etc. are similar in nature. To understand explicitly about leather industry, its performance & opportunities in national and international market, various issues in footwear industry, importance of technological intervention in revival of craft etc. various national & international publications were also considered for literature review.

2.2 Methodology for Literature Review

Literature was searched explicitly under different related search topic. These were:

- Global and domestic leather industry and present status of leather artisans
- Design intervention for revival of craft
- Work-related health study of crafted footwear making artisans
- Design intervention in similar industries (footwear)

Each topic was searched electronically using databases like Science Direct, Google Scholar, and Research Gate. Literature was also searched and included from the central library of Indian Institute of Technology Guwahati, Shivaji University Kolhapur and NITIE, Mumbai.

2.2.1 Global and Domestic Leather Industry and present status of leather artisans

Leather industry is an old and important contributor of Indian economy. There are various available literatures which explain its presence, importance, issues, process, used tools and many other factors. Earning from foreign exchange and domestic employment through leather industry is extremely prominent in Indian context (Acharya, 1985; Kumar S., 1997; Kamble B., 2002; Gupta et al, 2007; Sundar, 2007: Basu, 2010; Burute P., 2014; Ahmed R., 2016). Basu in 2010 revealed that Indian leather and footwear production industry stands second amongst all countries after China where India's export was reported as 44.32%. Selvakumar and Sundar, (2007) mentioned that exports of leather and leather goods amounted to US$ 1617.90 million in 1997-98, US$ 1963.55 million in 2000-01 and US$ 2379.44 million in the year of 2004-05.

It is being reported by Gupta et al (2007) that one decade ago approximate employment only through leather industry was 2.5 million in India. But he expected a downward trend in Indian leather industry because of altered quality of raw leather and other work related issues. Although, specifically he expected more growth in leather footwear industry, detailed nature of growth was not clear in the research paper.

Kamble E., 2002 in his study observed that not only organized leather industry has reported contribution in Indian economy but also handmade leather footwear is noticeable. India's leather accessories segment is at 5^{th} place in the international level of export (Basu S., 2010).

Various literature pointed out that promoting product brand name, training, technological intervention may have an important impact in unorganized footwear industry in Indian context (Kamble E., 2002; Burute P., 2014; Ahmed R., 2016) although, detailed methodology, types of interventions, case studies etc. not being reported in most of the literature. Therefore there is a huge need to understand current context of Kolhapuri crafted footwear and possibilities of improvement in existing scenario.

2.2.2 Design Intervention for revival of craft

Handicraft industry follows traditional method of production irrespective of its location, context, and types. Artisans are very much dependent on their ancestors for learning the skills, techniques, tools & equipment, production process etc. Any handicraft product is closely associated with local culture leading to create uniqueness, elegance etc. which resist the artisans to adopt any new technological intervention in the manufacturing process (Kumar S., 1997; Kappor and Mittar 2014). But there are evidences which confirm that any technological interventions enhance all production related parameters although, maintaining the identity of the specific crafts always a challenge for any researchers (Barman and Hazra 2017; Chatterjee S., 2015; Hani and Das, 2017). Studies reveal that variations in traditional existing designs, some innovative ideas/changes can be a helpful tool for rejuvenation of craft (Ghosh A., 2012; Kapur and Mittar 2014).

Till date handicraft industries involve in providing basic livelihood of many native people who can invest comparatively less capital in their craft business (Kumar S., 1997; Ghouse S., 2012; Burute, 2014; Kapur and Mittar 2014). Ghosh A., (2012) in his research identified various factors such as skill development, technical enhancement, market development, environmental awareness, safety, innovation in design play a crucial role in the sale of traditional handicrafts (Ghosh, 2012). There are documentary evidence that Indian handicraft industry is the key contributor to export, foreign revenue, and employment generation (Ghouse S., 2012; Madan A., 2013). Due to modern mass factory made craft production which has verities in style, design, color etc., handicraft industry is facing challenges in satisfying the market demand in terms of low cost, customized product etc. (Kumar S., 1997; Zhan et al, 2017). But handicraft artisans are reluctant to adopt any new technical intervention and they are not in a position to cope up with market demand causing downward trend of such handicraft industries (Burute, 2014). Conventional philosophies of stationary and retrograde Indian craft technology are the main cause of non-responsive nature towards changing market demand (Sarkar S. 1998; Madan A., 2013; Zhan et al, 2017). The new design and novelty are necessary for making elite crafts more sustainable (Madan A., 2013; Zhan et al, 2017).

In one of the case studies carried out by Chatterjee S. during 2015 revealed that technical intervention of metal foundry enhanced quality and productivity of 'Dokra' craft which is one of the oldest craft in West Bengal, India. In another research Barman and Hazra (2017) mentioned that while implementing any intervention for handicraft industry researchers need to consider only non-effective processes in craftsmanship in particular craft.

In another case study carried out by Giovanni and Martina, (2016) revealed that new technological system enhance quality and efficiency of knitwear sector. In their study, they have mentioned that due to use of new tools, craftsman can visualize actual design of crafted product and make changes according to user's suggestion.

Sethi et al, (2005) mentioned that design intervention and its record can help in documenting various manufacturing processes, tools, and materials used in a craft sector. The preserved database will help for next generation of artisans in information, knowledge, skills of traditional techniques and processes of certain craft. Sethi et al, (2005) further mentioned that craft productivity improvement can be achieved through multiple approaches, first increase direct work rate (i.e. wrench time), second use technologies, new materials, and innovative methods to improve efficiency and third to reduce rework (Sethi et al, 2005).

Kapur and Mittar (2014) revealed that in India during last 30 years total number of artisans has been reduced by 30%. They suggested that there is need to re-invest or re-thinking in artisans to maintain the history and ancient culture. Due to development in industry and expansion of urbanization, an old artisan user relationship has broken down and been substituted by traders (Kapur and Mittar, 2014). The requirements of the craft user or consumer may be in terms of its design, aesthetic appearance, color, usability, etc. offer business opportunities as well as technical challenges to craftsmen. The unstable market nature of handmade craft products offers strategic planning to grasp global consumers but delayed response or customer mis-promise can push handmade traditional craft products out from the market, replacing them machine-made crafts (Kapur and Mittar, 2014).

Hani and Das (2017) concluded in their study that there is a need to establish some design guidelines for keen practitioners who are associated with craft sector. Due to such kind of guidelines or instructions, future designers or innovative artisans perform design activity in their traditional craft sector or taking craft as an encouragement (Hani and Das, 2017). These design guidelines will help to maintain a balance between artisan's ongoing conventional practice and design intervention. Hani and Das (2017) also mentioned in their study that to improve craft, design is important but the original craft identity should be retained before applying any design changes.

In western world, people and organizations are trying to remember and recognize the lost crafts (Hani and Das, 2017). In recent times, improvements in technology, machinery, and computer discipline have adapted the creative perspective of every individual (Nathalie and Franck, 2010) therefore, design intervention is an edge between traditional and innovativeness that ties craft production to the requirements of current living (Knorringar P., 1998; Nathalie and Franck, 2010; Venkatachalam R., 2013).

Design intervention is product development process which involves the design of the new product, redesign of an existing product, change in its shapes, aesthetic look, colors; exploring new market opportunities, smearing traditional skills to achieve new opportunities, improvement in material, processes, new tools, etc. (Shan et al, 2013). The purpose of design intervention is to motivate the craftsman and artisans to bring their innovation to next level. The design interventions sometimes are not only product based intervention but it can also be a technological intervention which helps artisans to make the process fast and efficient without changing original method to produce crafts (Frank P., 2010).

There are several Indian government schemes developed to revive and redesign various dying crafts (Kaur P., 2011). Although, various researches tried to find out "how technological contribution can revive the handcraft in various sector especially in the Indian context?" (Kaur P., 2011), it is not still in practice. In view of the above a specific need has been identified such as context specific design intervention for any craft may be a best solution to continue/revive of that particular craft.

2.2.3 Work-related health study of crafted footwear manufacturing artisans

Majority of studies on musculoskeletal disorder (MSD) are being conducted in bag making, jewelry making, manufacturing sector, craft industry etc. (McCann, M., 1996; Loewenson R., 2000; Gangopadhyay et al, 2011; Aghali et al, 2012; Giri et al, 2012; Minh, 2014; Dianat and Salimi, 2014; Ramakrishnappa et al, 2014; Vieira et al, 2015; Almeida et al, 2017). Some researchers (Magnusson M., 1998; Champoux and Brun, 2003; Reid, 2010; Dianat and Salimi, 2014; Almeida et al, 2017) studied MSD symptoms and related issues among the workers who were associated with footwear industries as well. They mentioned that effective approach is required for prevention of health related issues in footwear sector.

Dianat and Salimi (2014) studied MSD symptoms and its consequences among the workers involved in Iranian hand crafted footwear called 'Giveh' which is very similar in nature as Kolhapuri crafted footwear in India. They reported high prevalence of various MSD symptoms which is mainly associated long period of continuous work, poor working postures and feeling stress due to work. They further predicted ergonomics design intervention of traditional hand tools and workstation may be one of the solutions to overcome the MSD related problems. Aghali et al, 2012 highlighted various MSDs of shoe manufacturing workers in Iran and recommended improved work postures and training for better execution of task to reduce MSDs. Vieira et al, 2015 identified females are more susceptible to MSD symptoms in footwear manufacturing similar to any other industry. Apart from MSD there are other occupational risks such as used chemicals, leather dust, levels of illumination/ventilation, personal factors etc. (Keyserling et al, 1992; Kristensen et al, 1997; Magnusson M., 1998; Szadkowska et al 2003; Champoux and Brun, 2003; Todd et al, 2008; Ganguly S., 2008; Reid, 2010; Gangopadhyay et al, 2011; Phatate R., 2011; Aghali et al, 2012; Tiwari R., 2013; Minh, 2014; Afonso and Pinho, 2014; Vieira et al, 2015; Salve U., 2017; Salve U., 2018).

In a study Gangopadhyay et al, 2011 mentioned used adhesives during footwear manufacturing has huge potential to develop various cardiorespiratory disorders. Leather dusts produced during footwear manufacturing are expected to come in contact with injured body parts which may cause various infections including cancer (Acheson et al 1982; Szadkowska et al 2003).

In another study Tiwari R., (2013) identified occurrence of eyestrain was reportedly high for footwear manufacturing workers. He recommended use of personal protective equipment may be a probable solution to reduce such effect.

From the literature survey it was found that the workers who are associated with manufacturing of footwear have high prevalence of musculoskeletal symptoms. In this literature analysis of data suggests that there is a necessity of effective operational implementation program for handcrafted/traditional footwear manufacturing artisans.

2.2.4 Design intervention in similar industries (footwear)

Some studies articulates that better fitment of shoe sole/last, can improve the whole quality of footwear (Dootchai et al, 2008; Sarghie et al, 2017). For specific age group, specific designed shoe sole helps more satisfaction of the users. Technological intervention such as 3D molding has direct impact on the above fitment issues (Luximon and Luximon Y., 2009; Sarghie et al, 2017).

Further literature identified that problem of shoe fitment can cause foot injury, foot-pain, distortion, etc. among elderly population (Dootchai et al, 2008). To avoid such challenges customization or better fitment is the only possible solution which can be achieved using computer based and internet based systems (Champoux and Brun, 2003). Further due to online marketing, maintaining standard size is absolute requirement of this industry (Xiao and Zhang, 2011). Organized shoe manufacturing industry adopted various advanced technology to cope-up the situation. Few researchers also mentioned that manufacturer should understand the thin line between shoe sole structure and foot shape. If that can be achieved then it becomes easy to satisfy the customer (Xiao and Zhang, 2011).

In developing countries, small labor-intensive industries are similar to handmade footwear manufacturing units, so efforts made to study and understand the different factors to be considered the development of intervention in such similar industries.

Most of the researchers carried out technological improvement in footwear manufacturing industry which is organized in operations. Sarghie et al, (2017); Bogdan et al, (2017) observed that feet sizes of Romanian elderly female vary from the general female population and the problem can be overcome by designing, developing and manufacturing authentic footwear suitable for those particular elderly groups. A similar Thai study confirmed that elderly population is prone to foot injury, foot-pain, distortion, etc. due to improper shoe sizes (Dootchai et al, 2008). In another study it was significantly identified that technical intervention of shape, size, and fitment is best solution for improved accuracy (Luximon and Luximon Y., 2009).

Nowadays consumers and companies in organized sector are moving towards mass customization (Xiao and Zhang, 2011). Majority of the footwear manufacturing companies are facing a challenge to provide good suitable shoes to the customers (Xiao and Zhang, 2011). Due to the development in computer science and internet technology the majority of the people are buying footwear and shoes from the internet (Xiao and Zhang, 2011). Therefore, a computerized advanced methodology should be used in footwear production. Xiao and Luximon (2011) proposed an effective method to assess the difference between shoe mold and foot.

While implementation of intervention especially in developing countries there are various challenges such as cost, effectiveness, repair & maintenance, productivity etc. which should be taken into consideration during new development (Rafeeq, 1996). Majority of the workers/artisans are engaged in craft sector are financially weak (Burute, 2014). Champoux and Brun, (2003) mentioned that there are various reasons such as imperfect knowledge about new technology, requirements of various skills, required time and money, training of workers, safety and occupational health issues etc. cause non-acceptance by the craftsmen of new technological intervention.

The current literature review tried to enlighten various aspects of crafted footwear as well as craft industry, leather industry and related occupational health issues. Also this review helped in understanding various facts related to technological intervention and its impact on enhancement of craft. Difficulties, human factor issues faced by researchers and craftsmen while implementing design intervention were also analyzed. Based on all these literature it was prominent that there are many unexplored areas of research is still in nascent stage in the context of Indian craft industry. It helped the researcher to formulate research questions and identify specific aim and objectives of the current research.

2.3 Summary of literature survey

Based on the above critical evaluation of various literatures, few research questions were identified. Figure 2.1 represent the summery of literature review.

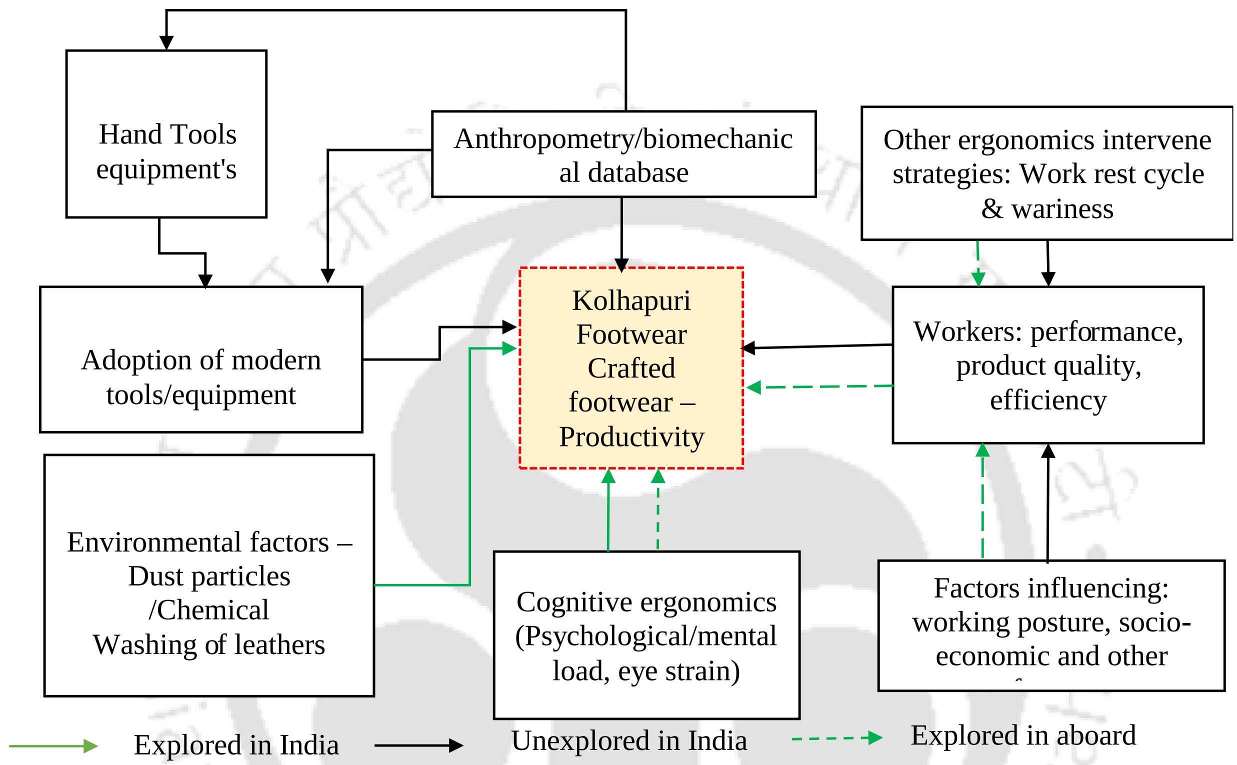


Figure 2. 1: Summary of literature review

It is evident that various ergonomics studies are available on crafted footwear manufacturing in context of need of intervention. Further, literature suggested that any design and technological intervention has an impact on the craft manufacturing process, productivity, and wellbeing of the workers. Although, a lot of technological interventions are available in organized footwear sector but now a days there is need to implement such interventions in unorganized sector. Also, it is suggested that modification/newness is the necessity of any craft for sustaining in the modern market. But there is no study available which can give any explanation on the downward trend of the Kolhapuri footwear craft. Therefore, few research questions arise as follows.

2.4 Research Questions

1) What are the probable causes of the current dying situation of Kolhapuri footwear craft?
2) What are the bottlenecks or problems in the manufacturing process?
3) Is it possible to solve the problem through any type of intervention?
4) Is there any effect of the intervention on the basic essence of craft or not?

2.5 Aim

The study aims to develop design intervention based on ergonomics principles for Kolhapuri footwear manufacturing to improve productivity and wellbeing of the native workers.

2.6 Objectives

1. To understand the real-life situation and problems of traditional craftsmen who are involved in the Kolhapuri footwear manufacturing process.
2. To identify areas (workstation/process/methods/strategy) of intervention based on the gravity of problems and impact of the same on basic essence of craft.
3. To evaluate ergonomics characteristics of identified problems to get a direction of intervention.
4. To generate intervention(s) strategies/ideas/concepts to solve the previously identified problem(s) and enhance productivity, quality of life and related parameters.
5. Analyze and test the newly developed intervention.

2.7 Hypothesis

Ha: Ergonomics and design intervention of Kolhapuri footwear manufacturing tools and equipment will reduce the manual efforts of users; in addition, it will contribute to overall rejuvenation of the Kolhapuri footwear craft industry.

2.8 Phases of the study – Overall methodology followed

This research aimed to take an effort to apply numerous ergonomic principles and assessment techniques for design interventions of tool and equipment suitable for Kolhapuri crafted footwear manufacturing artisans. The general research methodology adopted to undertake the research goal is shown in figure 2.2.

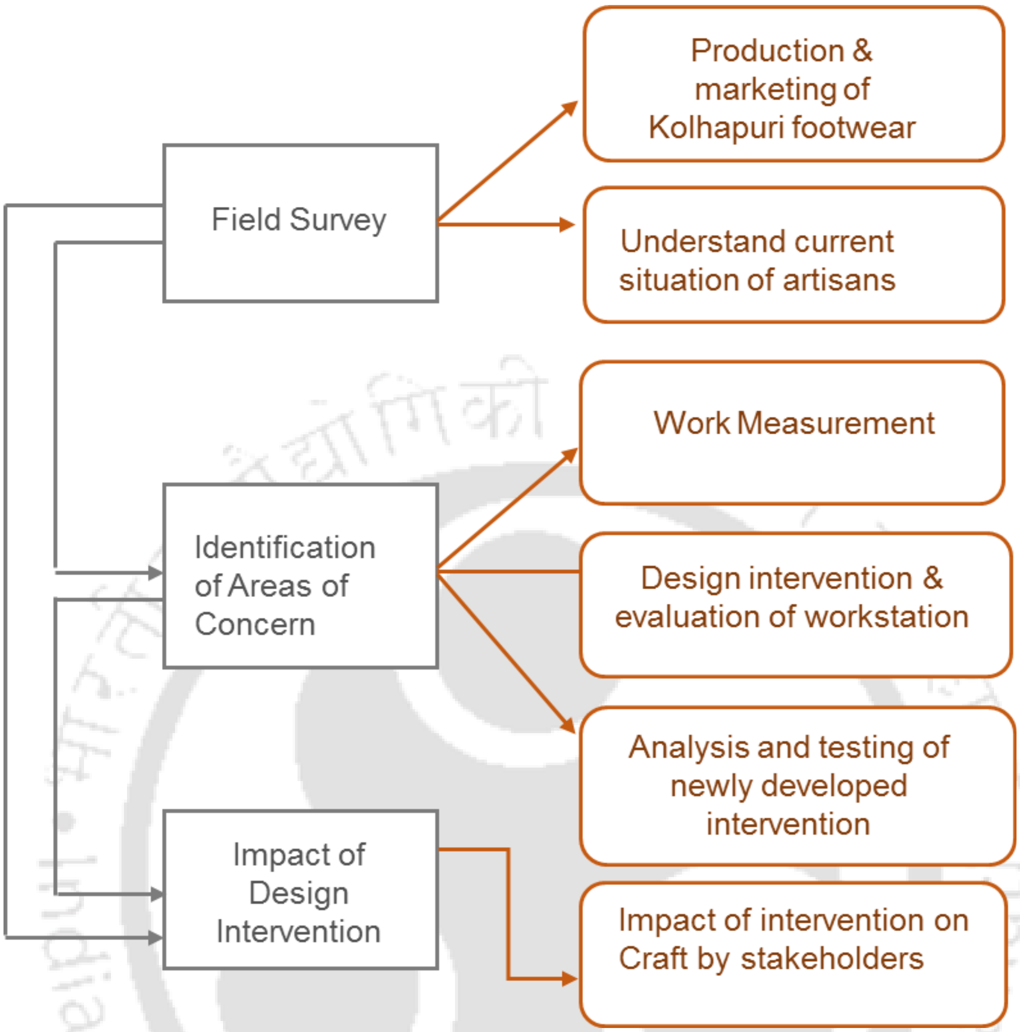


Figure 2. 2: Layout of the overall methodology

Step 1: Field survey to understand the real-life situation and problems of traditional craftsmen who are involved in Kolhapuri footwear manufacturing process.

In this step, field study was carried out in Kolhapur district to know the entire footwear manufacturing processes, current situations of the artisans, and problems of traditional artisans who are involved in Kolhapuri footwear manufacturing process. Different questions were asked to craftsman regarding their occupation and their business. Manufacturing processes and their methods were studied in this phase. Different problem of artisans were identified from a field survey. Procurement of demographic data and job description data of footwear manufacturing workers were collected during a field visit.

Step 2: Identification of different workstations, processes, methods, strategies of Kolhapuri footwear manufacturing.

In this step, different time-consuming areas have been identified. Time study technique tool is used to determine time-consuming activities. Various operators were interviewed and recognized those activities which require more manual effort. According to the problems of the craftsman, bottleneck areas where identified, where design intervention is possible.

Step 3: Generation of various design interventions strategies/ideas/concepts to solve the identified problems.

In this step, based on the nature of the problem and severity of the issues, various design concepts were identified by using Pugh chart. The design intervention was proposed and its ergonomic evaluation and a cost-benefit analysis were carried out. An ergonomic analysis was carried out using Digital Human Modelling (DHM).

Step 4: Postural load evaluation of the workers who were associated with footwear manufacturing activities.

Step 5: Proposal of design intervention in terms of the workstation to reduce postural stress for stitching and accessory preparation artisans. In the analysis and testing, the proposed designs were evaluated through virtual simulation (DHM).

Step 6: Analysis of impact of the proposal of interventions on the revival of the craft by stakeholders.

Chapter III – Current scenario of artisans engaged in crafted Kolhapuri footwear manufacturing

This chapter aims at finding out the ground level scenario which can explain the current trend, end customer preferences, manufacturing process, supply chain (from the production house to retail market), distribution of skill requirement in the whole manufacturing process, the scope of automation/semi-automation, used tools and equipment, price structure, etc. The whole study was based on various unstructured interviews covering all the above information with various stakeholders of the industry. Among the stakeholders, craftsmen were considered as a major contributor to this industry. Apart from craftsmen, entrepreneurs, the government authorized distributor, head (chairman) of the cobbler community, traders, etc. also participated in this part of the study. The outcome of this supposed to provide a specific direction of intervention.

3.1. Kolhapuri footwear industry

To understand the market of Kolhapuri crafted footwear data was gathered from various sources such as personal discussion with the chairman of cobbler community, Kolhapur, traders, shopkeepers, and small entrepreneurs. Although the data was not documented anywhere as there is incomplete no written evidence. It has been identified over the discussion that the demand of which crafted footwear is quite high but supply is not as per requirement. The causes of this mismatch were identified as scarcity in availability of raw materials, low daily labor wages, lack of skilled manpower, inadequate technological support, inadequate supportive government policies, etc.

According to local documentation, per year turnover reduced approximately 6% within one decade (Burute, 2014). The data has been represented in table 3.1.

Table 3. 1: Annual turnover of Kolhapuri footwear industry

Year	Turnover	Pairs/year
2000	1,80,56,000/-	1,70,000
2010	1,70,30,000/-	1,55,000

Source: Discussion with Mr. Satpute (Chairman Cobbler community Maharashtra) (2018)

A similar report was also being quoted by Burute 2014, although figure and facts were not exactly the same. The discrepancy may be due to different adopted methodology and sources of data. Further Burute, 2014 in his study identified that downward sale of original Kolhapuri hand crafted footwear is an impact of the use of plastic, rubbers, and footwear duplication, which had not been identified in present study.

3.2. Current status of tanning industries in Kolhapur

Tanned leather is the major raw material for any leather product. For manufacturing of Kolhapuri crafted footwear, easy availability of tanned leather is essential. In recent years due to changes in state government policies, the tanning industry is completely banned at Maharashtra. The data of a number of tanning industry and labor involved in this job are presented in table 3.2.

Table 3. 2: Tanning units in the Kolhapur district

Year	Units of the tanning industry	No. of people engaged
1948	40	150
1985	80	1400
2012	10	75
2018	0	0

Source: Discussion with Mr. Satpute (Chairman Cobbler community Maharashtra) (2018)

Table 3. 3: Cost of different leathers used in Kolhapuri footwear

Nature of leather	Use of particular leather in footwear	Cost in Rupees		
		2010	2013	2018
Buffalo leather	Preparation in lower sole	160/-	190/-	280/-
Cow and Bullock Leather	Upper sole preparation	180/-	220/-	320/-
Calf leather	Upper belt	130/-	150/-	200/-
Sheep and goat leather	For the preparation of various parts	100/-	140/-	170/-
Tail leathers	For making a thread for Sewing Upper and Lower Sole	50/-	80/-	100/-

Source: Discussion with Mr. Satpute (Chairman Cobbler community Maharashtra) (2018)

Due to above fact artisans need to get tanned leather for manufacturing of crafted footwear, from various nearby states. Due to high transportation charges, per Kg leather cost has been increased substantially. But at the same time the final product cost has not increased proportionately. The data is represented in table 3.3.

3.3. Kolhapuri crafted footwear manufacturing process

As per cobbler communities' documentation numbers of artisans are decreasing in every year. In 2012, total manpower involved in this craft was only 10000, whereas the count of involved manpower was 21000 in the year 2000. The reasons behind this decline were not identified till date. Burute (2014) in his study explained this nature of declination by "lack of technological intervention due to less financial support". He further mentioned that in other various cities, footwear manufacturing had been improved by using technological intervention.

Quality of raw material, availability of modern trendy fashion in footwear, conventional manufacturing processes & practices, footwear size standardization and alternate designs were major contributory factors identified by the stakeholders. The impact of the above contributory factors are presented in table 3.4.

Table 3. 4: Causal factors identified by stakeholders

Stakeholder	Quality of raw material	Conventional manufacturing process and practices	Alternative design	Modern trendy fashion in footwear	Footwear size standardization
Craftsmen (N= 15)	Yes	Yes	NA	NA	NA
Entrepreneurs (N=15)	Yes	Yes	Yes	No	Yes
Distributor (N=10)	NA	NA	Yes	Yes	No
Traders (N=10)	NA	NA	Yes	Yes	Yes
Customers (N=15)	NA	NA	Yes	Yes	Yes

From the field survey, it was further noticed that crafted footwear manufacturing artisans are not well motivated due to lack of awareness of their importance in this elite ancient craft. Also, due to various constraints in adoption of modern technology in manufacturing process, retail customer directly, availability of resources in terms of fund and land, etc., artisans are less motivated to continue or join these home-based enterprises. The similar nature of this unit has also been discussed by Burute P., 2014.

The field survey was also catered to identify the distribution pattern of crafted footwear from manufacturing house to retail customer. The pattern is being mentioned in figure 3.1.

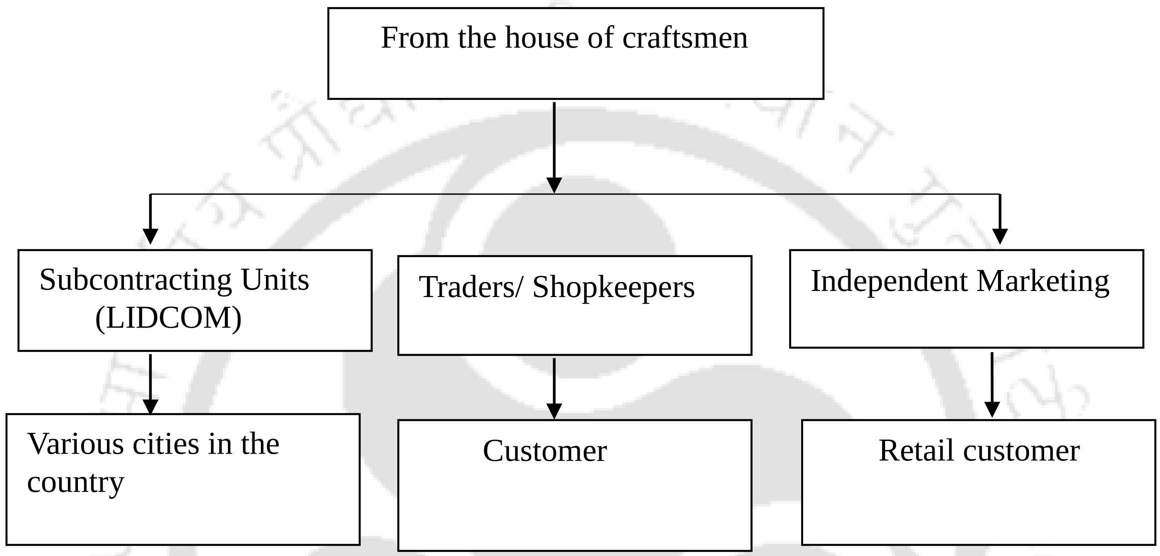


Figure 3. 1: Supply Chain of Kolhapuri crafted footwear

3.4. Identification of the areas of concern (workstation/ process/ methods/ strategy)

Direct observations, video recordings, photography techniques, work measurement techniques, individual discussion with artisans through unstructured interviews were the major tools adopted in this part of the study. The manufacturing process was thoroughly understood from craftsmen as well as by direct observation. It has been identified that there were two specific categories of job for whole manufacturing process. Those were skill dependent job and skill independent job. Also involvement of manual effort in terms of individual physical use of hand, force, repetition, time spend on the job were identified. Each and every step of the manufacturing process was analyzed on the basis of skill requirement, impact on the essence of craft, involvement of manual labor/effort, possibilities of intervention in operation. The result is presented in table 3.5.

Table 3. 5: Identification of the areas of concern

Name of the Workstation	Skill requirement	Impact on the essence of the craft	Manual effort	Possibility of intervention in the operation
Skiving	No	No	No	Yes
Lower sole cutting	Yes	Yes	Yes	Yes
Stitching	Yes	Yes (very high)	Yes	No
Preparation of Veni (Braid decoration from leather)	Yes	Yes (Very high)	No	Partially
Accessories preparation apart from Veni (Braid)	Yes	Yes (Very high)	No	Partially

Total five major manufacturing operations were identified. Among all, apart from skiving all operations require skill and have an impact on the main essence of craft, although, the impact is varied in nature. Stitching, Preparation of Veni (Braid decoration from leather) & accessories required very high skill and have a direct impact on beauty & aesthetic of the footwear. Also, craftsmen mentioned, any changes in the manufacturing process of these components may alter the basic essence of craft, whereas there is probability of making little any changes in the sole cutting process. As per manual effort is concerned, subjective responses has a very high positive value for sole cutting and stitching activities.

A small experimental set up was established using generic weighing balance as a major instrument and stopwatch, to identify average force requirement while sole cutting operation. The subjects were asked to perform their operation (only sole cutting) on the surface of the weighing balance. A full cycle of sole cutting operation was observed and recorded. Ten samples were collected. Result revealed that the whole sole cutting (for one piece) operation requires continuous exertion of 5 to 6 kg. hand force for approximately three minutes. Experimental set up is presented in figure 3.2.

Figure 3. 2: Measurement of force required for sole cutting activity

From the field survey, it was identified that three types (buffalo, Bullock, and cow) of leather are in use for Kolhapuri crafted footwear manufacturing. Thickness is varied in nature based on types. Effort requirement for sole cutting and stitching mainly dependent on the thickness of leather.

Direct observation and video recording of stitching operation revealed that it is repetitive in nature (12 cycles per minute for wrist). But participants have a reservation on any technical intervention for stitching activity as this requires high skill and its impact on the essence of the craft is very high. Similar results were also found for veni (braid) and other accessories preparation.

Through participatory ergonomics approach, it has been identified that partial intervention in terms of small tool design may enhance the quality and efficiency of veni and other accessories preparation.

3.5. Work measurement of manufacturing processes

To understand manual effort, work measurement technique was adopted. Time study using standard methodology used for collecting standard required time of each identified jobs. Time study is defined as the technique of evaluation for time to allow to a trained worker, working at a usual speed to complete an identified job by using the stated method (ILO, 1991). Time study is not only used to increase productivity but also to improve the existing processes. The general outcomes of the time study are as follows

1. New introduction of method or process
2. Change in method and material
3. Preparation of incentive system for the job
4. To find out the bottlenecks in the operation
5. To find out idle time or low output of the equipment involved in the production process
6. Determination of excessive cost associated with the job

A qualified worker is having the required physical aspects, who possess required cleverness, education, and who have acquired the necessary skill and knowledge to carry out the work in hand to satisfactory standards of safety, quantity, and quality (ILO, 1991). The craftsmen of the present study were involved in this particular type of job from their childhood as the industry was cottage/home based in nature. Any worker who had one year of working experience in terms of full manufacturing process (starting from skiving to final assembly of footwear) was considered as a qualified worker for time study. Stopwatch, study board, time study forms, small calculator, a digital clock were used during time study. Various workstations from various units were selected for time study.

Twenty videos of each operation were collected using videography techniques and were analyzed in a laboratory using above mentioned time study tools. Allowance(s) (9%) was added according to ILO guideline. The result is presented in table 3.6. Individual data sheet of each operation is as given in Annexure II.

Table 3. 6: Time study sheet of Kolhapuri crafted footwear manufacturing

Sr. No.	Name of the Operation/ Process	Basic Time (Min)	Allowance %	Standard Time (Min)
1	Skiving	0.6	9	0.71
2	Cutting base Profile of the footwear	2.1	9	**2.33**
3	Grinding outer profile of the footwear	0.3	9	0.38
4	Polishing	1.3	9	1.40

5	Punching	0.8	9	0.89
6	Pasting	0.9	9	1.07
7	Stitching	11	9	**12**
8	Trimming	0.2	9	0.18
9	Water dipping	0.42	9	0.46

Total nine operations were identified for complete manufacturing of one piece of Kolhapuri crafted footwear. From the above result, it has been identified that few operations are the major contributory factor causing high manual labor and time consuming for a particular job. These are sole cutting (2.33 minutes) and stitching (12 minutes) operation. All other operations are consuming significantly less time ($P < 0.05$) as compared to sole cutting and stitching. As the computed F (F=12.57) exceeds the critical F (F critical = 4.49) so, it is inferred that two groups differ significantly represented in table 3.7.

Table 3. 7: Anova table for time study data

Sources of variation	Sum of squares	df	Variances	F
Between groups	-1071.16	1	-1071.16	**12.57**
Within groups	-1363.22	16	-85.20	
Total	-2434.38	17		

The result of Table 3.5 showed that technical intervention in terms of tool/ process modification will hamper the essence of the craft. Therefore, it has been decided that sole cutting operation can be a major intervention point in terms of tools/equipment/process to enhance the manufacturing process of the craft. In this particular sole cutting activity, manufacturing or preparation skill is not required. The exact shape of the footwear is important in this particular activity. Sole cutting activity is noon effective in craftsmanship. The particular outer shape of the sole can be create with the help of automation/ semi-automation. Sole cutting intervention will help to enhance the manufacturing process of craft.

Chapter IV-Intervention of sole and strip cutting Operation

4.1. Introduction

The sole cutting operation was analyzed in terms of process, used tools, the time required, required wrist force, repetition of wrist movement, preparation of identical pairs, etc. The process detailing revealed that the craftsmen need to use a high amount of skill, although the quality is not being ensured. There is a lot of scope of erroneous movement due to mild attention disturbance (quality mindedness) which results in an alteration in quality, material loss, rework, scrap, etc. Taking review from various stakeholders, availability of resources, possibilities to adopt the intervention, it has been identified that any modification in the operation of sole cutting is possible only when intervention confirms no alteration in the essence of the craft but minimize all above-identified issues/obstructions. Any ergonomic intervention through design modification confirms human comfortability & efficiency, enhanced productivity, quality of the product (Robertson M., 2003; Hendrick, 2003). Based on the literature survey, field study and user requirement, an ergonomic design intervention approach was adopted for this intervention.

4.2. Sole cutting operation

In the existing situation, there is no specific manufactured workstation available for sole cutting operation. Workers seat on a floor with folded legs and forward bended posture using locally arranged workstation. The nature of workstation is a small wooden block which is mounted on a marble stone. Approximate dimensions (length, height, and width) of marble stone is 1, 1.5 and 0.25 ft. respectively. The working table is thick marble stone on which cutting activity is carried out. This marble stone is placed on the floor (Figure 4.1).

Figure 4. 1: Workstation for sole cutting and cutting operation

The daily routine analysis identified that a worker spends approximately 8 to 9 hours while working for 3-4 hours at a stretch if he/she is only responsible for sole cutting operation. Further, it is identified that as this operation requires high wrist force, the male community takes the responsibility of the cutting job.

4.3. Detailed study of current sole preparation workstation

Shape of the masterpiece needs to trace on the plain leather using a pen or pencil (Figure 4.2).

Figure 4. 2: Stencil marking for preparation of sole

Using traditional hand tool called rappi (local name of the sharp-edged tool), the leather is being cut according to the traced shape. The adopted postures while carrying out these operations are presented in figure 4.3.

Main objective of the development of the cutting tool was to reduce the manual force of the footwear artisans. Thus it was decided to make cutting tool in order to cut the base and heel sole of the footwear. Major requirement of the cutting sole is to achieve an identical shape of the base of footwear. To acquire the identical shape of the base and heel of the footwear there was need of the cutting die which can fulfill the basic need. Thus it was decided to produce cutting die set for base and heel sole cutting operation. The base and heel sole cutting dies as per drawing can create a required shape as per requirement.

Figure 4. 3: Workers doing footwear base (sole) cutting operation

4.4. Design development of intervention

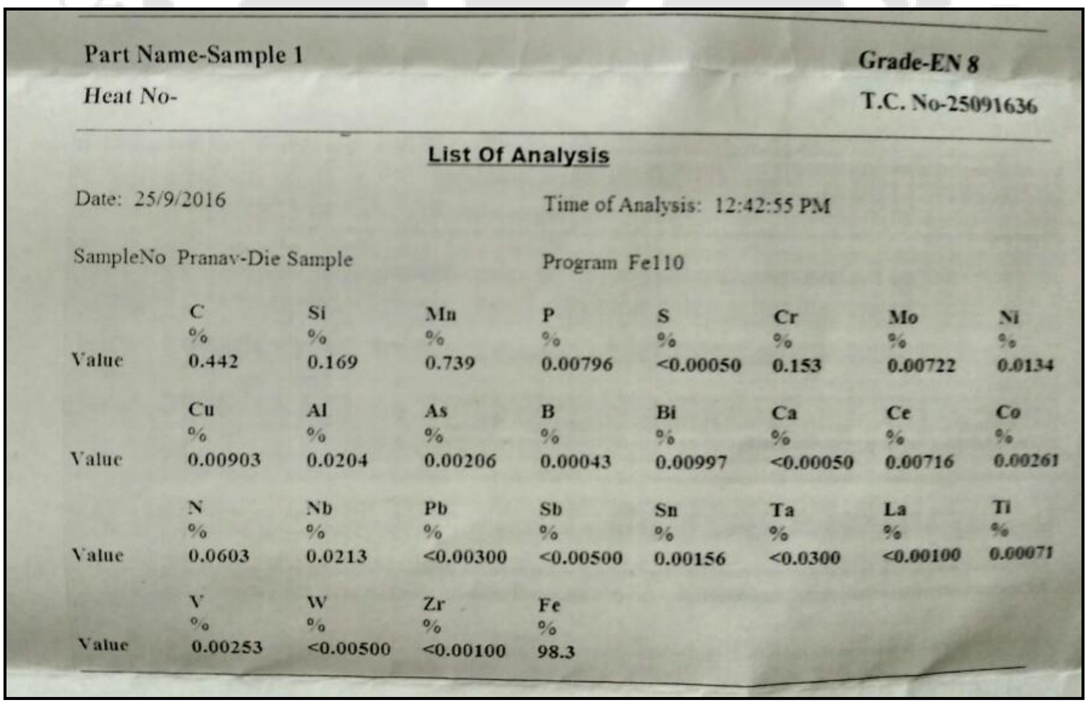
Preparation of identical shape can be achieved by any automated or semi-automated system (Chen, 2014). Die preparation is a general solution, practiced in industry for any identical parts manufacturing (Taylan A., 2001; Changrong et al, 2014). To solve the above-mentioned issues of sole cutting operation use of dies identified as one of the best solutions.

4.4.1. Material selection for die

The selection of suitable material is an important step in engineering design (Haik Y., 1997). The existing tool used for sole cutting operation is called rappi (sharp-edged tool) (figure 4.4) is made up of steel. Therefore, in order to confirm the same a small piece of Rappi (sharp edged tool) is analyzed through metallurgical testing.

Figure 4. 4: Rappi (sharp-edged tool) tool used for sole preparation

The Optical Emission Spectrometer was used for steel material analysis (Sturm V., 2000). A small piece of Rappi (sharp-edged tool) material was tested under Optical Emission Spectrometer (Annexure I). Under this Optical Emission Spectrometer (OES), various metals and alloying elements composition were obtained. The metallurgical or material analysis represents the percentage of Carbon (C), Silicon (Si), Manganese (Mn), etc. and other material composition in the Rappi (Sharp-edged tool) material. The result of the metallurgical testing of tool material is as follows (figure 4.5).



Part Name-Sample 1 Grade-EN 8

Heat No- T.C. No-25091636

List Of Analysis

Date: 25/9/2016 Time of Analysis: 12:42:55 PM

SampleNo Pranav-Die Sample Program Fe110

	C %	Si %	Mn %	P %	S %	Cr %	Mo %	Ni %
Value	0.442	0.169	0.739	0.00796	<0.00050	0.153	0.00722	0.0134
	Cu %	**Al %**	**As %**	**B %**	**Bi %**	**Ca %**	**Ce %**	**Co %**
Value	0.00903	0.0204	0.00206	0.00043	0.00997	<0.00050	0.00716	0.00261
	N %	**Nb %**	**Pb %**	**Sb %**	**Sn %**	**Ta %**	**La %**	**Ti %**
Value	0.0603	0.0213	<0.00300	<0.00500	0.00156	<0.0300	<0.00100	0.00071
	V %	**W %**	**Zr %**	**Fe %**				
Value	0.00253	<0.00500	<0.00100	98.3				

Figure 4. 5: Metallurgical testing report of Rappi (sharp-edged tool) material

The material after the analysis was found to be EN8 (Mild steel). The mechanical properties in a sample of Rappi (sharp-edged tool) were as follows:

Maximum Stress- 750-850 N/mm^2

Yield Stress- 470 N/mm^2

Proof Stress- 455 N/mm^2

Elongation- 15%

Hardness 200-250 (BHN)

EN8 is mild steel material and have mechanical properties like tensile strength, toughness and wear resistance, welding properties and durability etc. (Cullen M, 2014). This type of mild steel material is used where machine parts are subjected moderate to heavy stresses (Cullen M, 2014). It is mainly used in bushings, hollow and solid shaft, gears, bolts, and various keys, etc. Based on properties of EN 8, it has been decided, EN 8 would be the material for manufacturing of cutting die.

4.4.2. Development of cutting die

The sole of the crafted footwear divided into two components, one is the main shape of the sole (base) and other is heel. These two components vary in size based on feet size and gender. In the footwear industry, standard sizes are available based on global locations. In the present intervention, use of standard size in the Indian context has been considered. For experimental purpose female size, 7 (the majority of the female population use this size) was selected (figure 4.6).

Figure 4. 6: Base and heel shape of female footwear (No.7)

For the development of drawing, Initial Graphics Exchange Specification (IGES) co-ordinates were identified by using Co-ordinate Measuring Machine (CMM) (Lee J., 1997). The make of CMM machine for this experiment was Accurate India. The measuring range, accuracy, and resolution were X-axis- 500 mm, Y-axis- 600 mm, Z axis- 400 mm, 2.5 microns, 0.5 microns respectively. The photograph of the original machine is presented in figure 4.7.

Figure 4. 7: Co-ordinate Measuring Machine (CMM)

This machine works on the principle of sensing distinct points on the surface of component with a sensing probe (Figure 4.8). The mechanical probe was used for measuring coordinate of the sole. Figure 4.8 represents the measuring procedure of base and heel with the help of sensing probe on CMM.

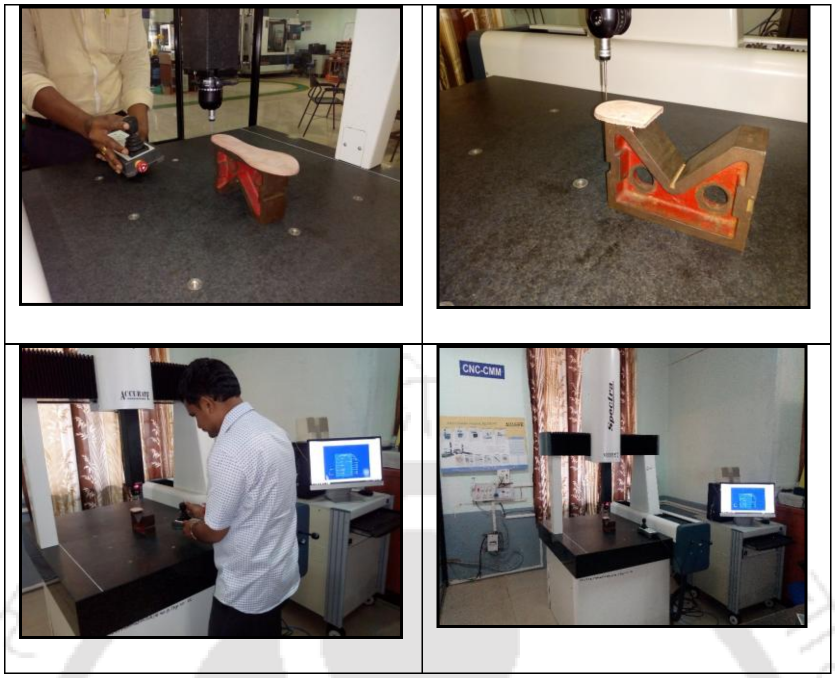


Figure 4. 8: Sole profile measurement on CMM

The measurement of base and heel sole were carried out with the help of mechanical sensing probe. These Initial Graphics Exchange Specification (IGES) co-ordinates of base and heel sole are then imported in modeling software (PRO-E) to prepare 2D and 3D drawing of the die. All these points were joined in the PRO-E CAD software (figure 4.9).

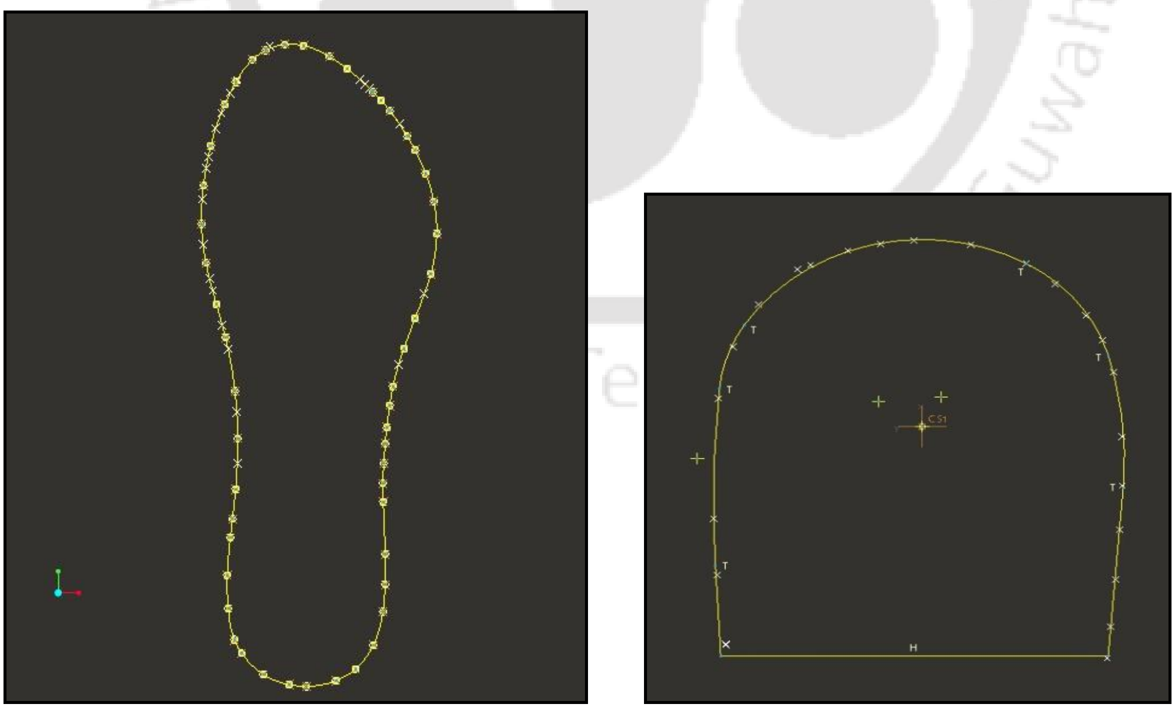


Figure 4. 9: Footwear sole coordinates on CMM

From the image of coordinate's, all the coordinates were joined with proper geometrical shapes like line and arcs. The IGES coordinate file from CMM software imported into PRO-E (CAD) software. All these curves were formed with engineering dimensions like length, angle, and radius.

Then 2D drawing and 3D model of base and heel part were prepared (figure 4.10 - 4.12).

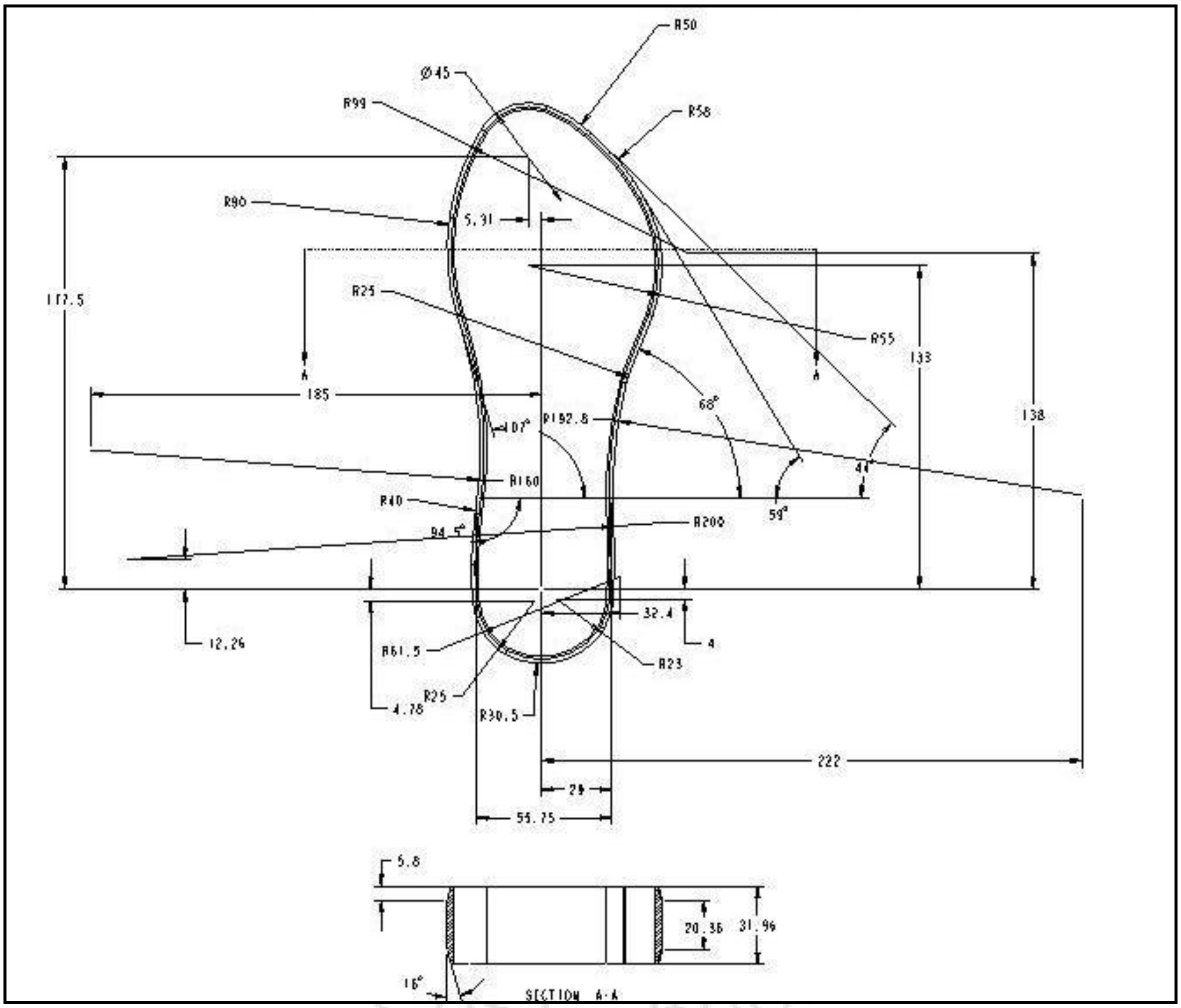


Figure 4. 10: 2D drawing of base die

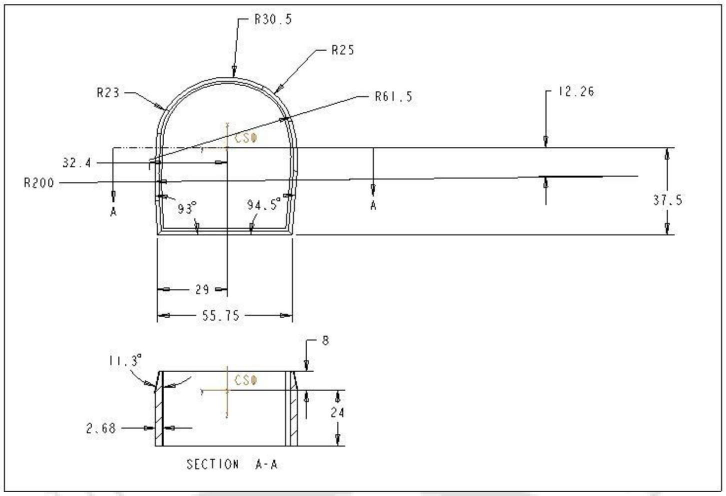


Figure 4. 11: 2D drawing of heel die

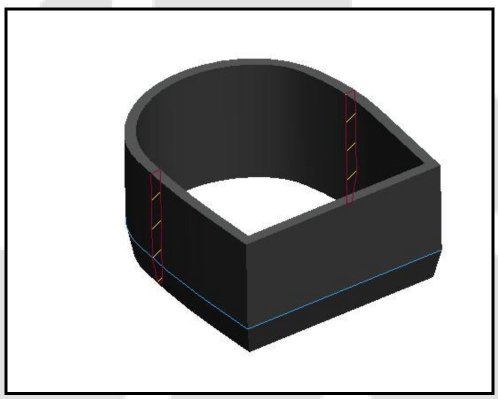


Figure 4. 12: 3D Model of base and heel die

4.4.3. Finite element analysis of cutting die

The Finite Element Analysis (FEA) is a numerical method to find an estimated solution by dividing any region into small sub-regions. The solution within each sub-region that satisfies the governing equations can be reached more simply than that required for the entire region. FEA is used for die analysis in order to predict deflection and stress distribution accurately for the relevant components, to make sure that, it could be operated safely (Shinde G., 2015). ANSYS has been used in this particular study.

Step 1: Modeling

ANSYS offers various types of analysis. The static structural analysis of die was carried out. Base and heel die was modeled using PRO-E software and imported in the ANSYS geometry as shown in figure 4.13.

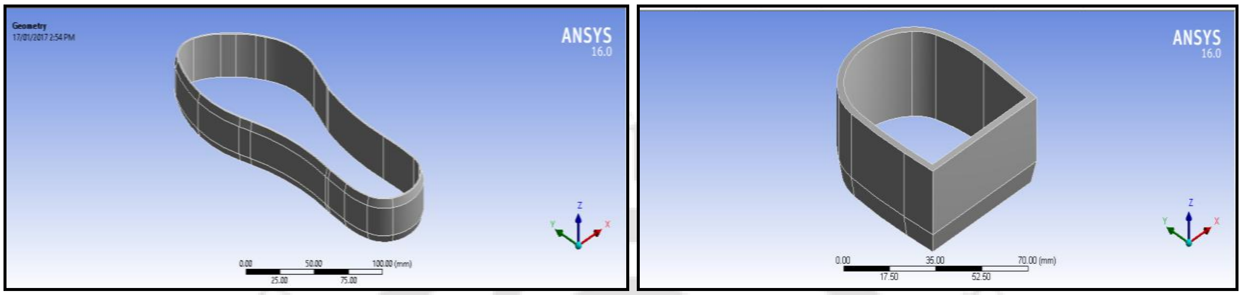


Figure 4. 13: Modeling of the base and heel die

Step 2: Meshing

Hexahedral elements were used for meshing. Convergence study was carried out for finding out optimum mesh size and time step. The optimum mesh size was 3 mm and it used for all simulations. Meshed model is shown in figure 4.14.

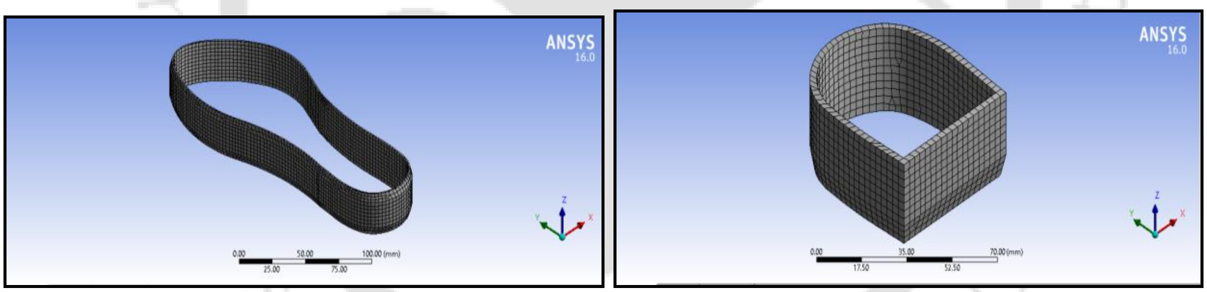


Figure 4. 14: Meshing of base and heel die

Step 3: Material used

The material used for the die is medium carbon steel EN 8. The properties used for the material has been discussed earlier. The yield stress value for EN8 material is 465 MPa.

Step 4: Static Structural Analysis

After several trials, the optimum pressure required to cut the leather piece in the required shape found to be 12 MPa. This maximum pressure was applied on the punch plate so that die can operate. The applied pressure on both the dies is shown in figure 4.15.

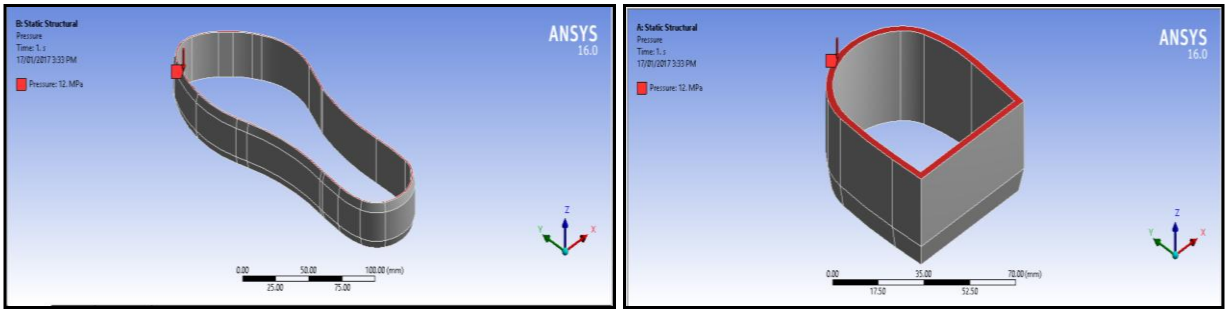


Figure 4. 15: Pressure applied on the base and heel die

Step 5: Total Deformation

Total deformation of the base and heel die under the application of pressure is shown in figure 4.16 and 4.17 respectively. It was observed that because of applied pressure, the cutting edge of the die is not affected as the deformation obtained in that area is zero.

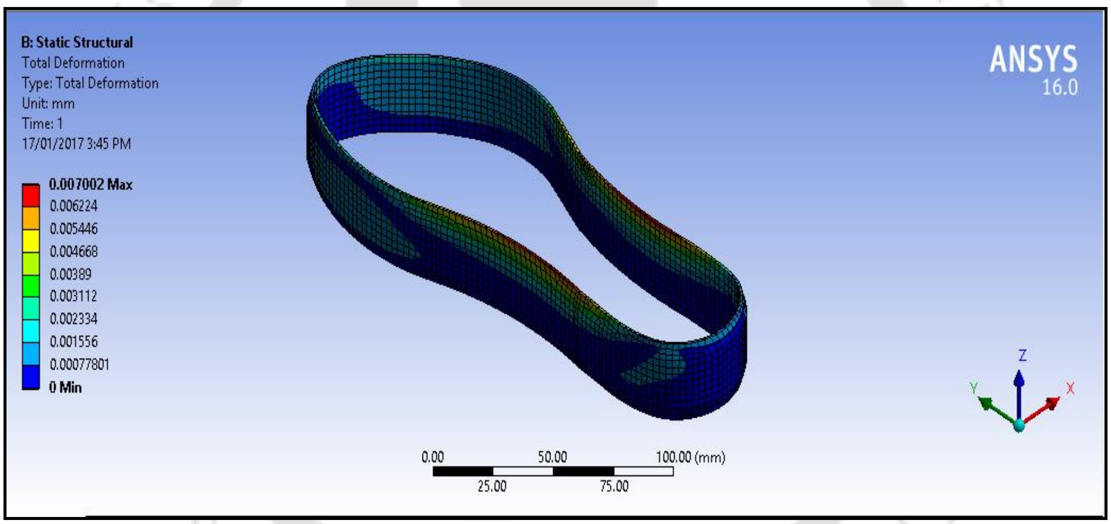


Figure 4. 16: Total deformation of the base die

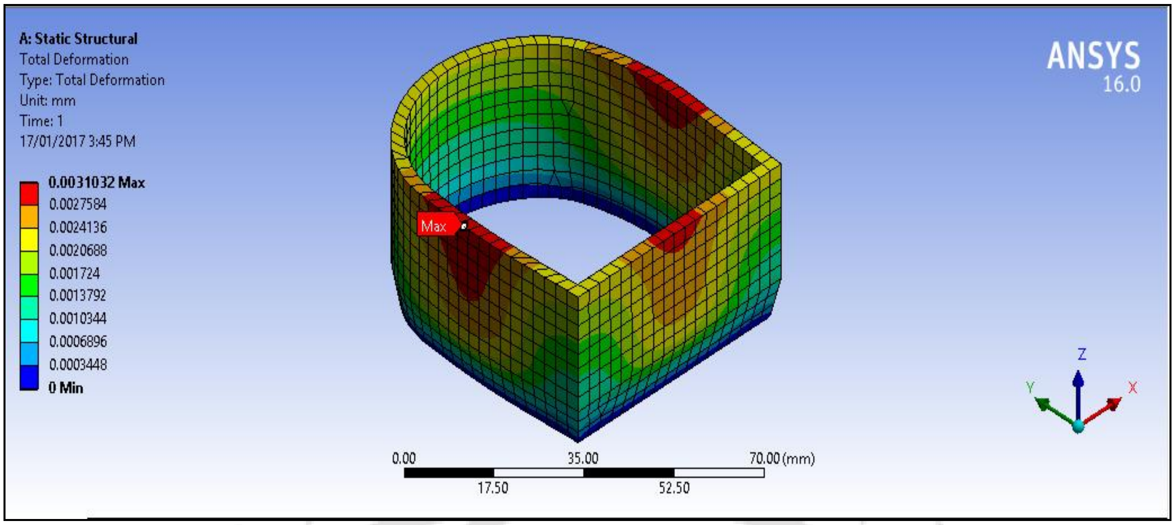


Figure 4. 17: Total deformation of the heel die

Step 6: Equivalent Von Mises stress

Total equivalent von-Mises generated stresses in the base and heel die under the application pressure is shown in figure 4.18 and figure 4.19 respectively.

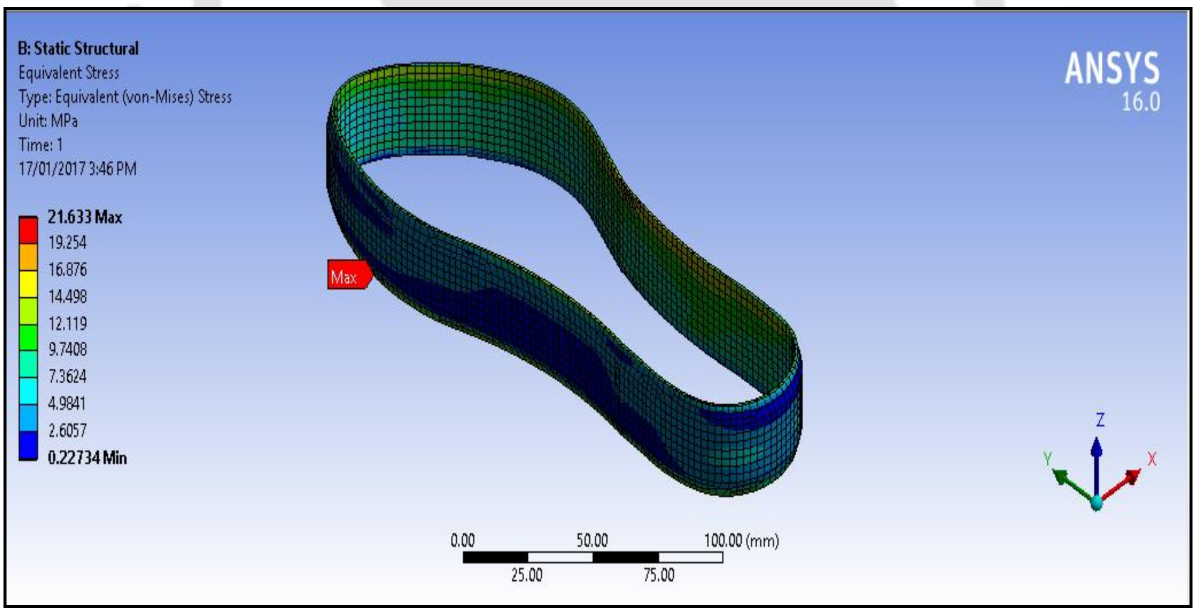


Figure 4. 18: von-Mises stress in the base die

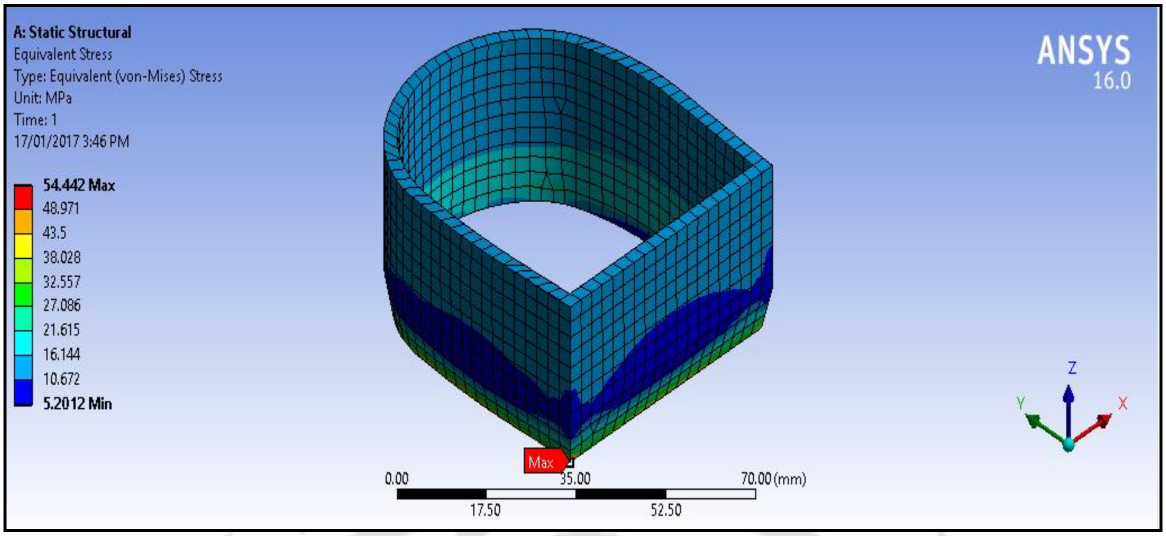


Figure 4. 19: von-Mises stress in the heel die

At the bottom of the die minimum von-Mises stresses were observed. The values of von-Mises stresses observed at bottom of base and heel die are approximately 22 MPa and 54 MPa respectively. These stress values are less than yield stress value (465 MPa) of EN8 material. Therefore, the design is considered safe.

4.4.4. Manufacturing of cutting dies

Figure 4. 20: Actual base and heel die

In die design, the single shear cutting angle was provided to the piercing punch. Shear depth can be provided at 2/3 thickness of shear material. Inner link plate has 5 mm thickness. So 3.33 mm shear depth and angles are provided to piercing punch. In design, sharp edges have not been given at the end of punch because of stress concentration can affect the edge of the punch.

Cutting forces can be reduced up to 30% of required cutting force by giving shear depth to punch.

These manufacturing designs (figure 4.20) were made by using the conventional forging method. Two strips of EN8 material of thickness 3 mm and width 32 mm were selected to manufacture die. These strips were hot forged to get the required shape. Small strips were welded on the inner cavity of formed shape to give strength and support to die. The cutting edges of the dies were manufactured with the help of grinding operation by providing angle as per drawing. These cutting dies were tested for its function. This entire manufacturing process of cutting die was carried out in Pune industrial area.

4.5. Development of context-specific sole cutting hydraulic machine

The newly developed dies need to be operated in such a way that at one goes the highest thickness of leather can be dissected. For that operation, the operator needs to generate approximately 35 KN which has been identified using a small experimental set up has been described in following section.

4.5.1. Calculation of cutting force to cut the footwear leather

Leather samples of Kolhapuri footwear manufacturing were collected. It includes animal's hides such as cow, buffalo, and bull. Compressive Testing Machine (CTM) (figure 4.21) was used to measure the cutting force of the leather. Generally, this machine is used in civil engineering application to measure the strength of the cement block. The leather was placed below the newly designed dies. The force was applied from upper side on the die. The results were recorded in Kilo Newton (KN).

Figure 4. 21: Compressive Testing Machine (CTM)

The cutting forces were found on CTM trials are as follows:

Table 4. 1: Cutting force Measurement for base sole

Material	Trials (Load in KN)				Average (KN)	SD
	1	2	3	4		
Cow	30.5	31	31.5	30.5	31	0.47
Bulk	32	31.5	33	31.5	32	0.70
Buffalo	34	33.5	34.8	33.7	34	0.57

There were four trials carried out on three types of leather (cow, buffalo, and bulk). The average cutting forces for all leathers were considered for press machine design. Table 4.1 and Table 4.2 represents different force values for various types of leather samples of both base and heel sole.

Table 4. 2: Cutting Force Measurement for heel sole

Material	Trials (Load in KN)				Average (KN)	SD
	1	2	3	4		
Cow	24.4	25.1	24.9	24.7	24.8	0.29
Bulk	26	25.9	26.2	25.4	25.8	0.34
buffalo	27.5	27.9	27.4	27.6	27.6	0.21

Form the above table, it has been identified that 34 KN is the maximum required force irrespective of types of leather and die. The factor of safety was considered as 1.35 (Bhadari, 1995). Based on the given allowable margin, total force was calculated as 5 ton. (Total force = 1.35 x 34= 45.9 KN).

To generate 5-ton force required machinery, arrangements were identified from the literature and industrial practice. It had been noted that manual, pneumatic and hydraulic are the alternative available options for pressing operation. Pneumatic press machine works on the principle of pressure and compressed air system which is infrastructure wise difficult to accommodate in cottage based environment (Jadhav, 2014). Use of manual force and generating pressure to cut the leather cannot be considered as a solution as this study aims at reducing manual force for sole cutting operation. Therefore, designing a suitable hydraulic press machine was taken as an approach of generating 5 ton to cut the leather sole.

4.5.2. Identifying suitable hydraulic press for leather cutting

In order to achieve 5 ton of force on the leather surface, it has been decided hydraulic press machine would be the best available solution while considering total cost, easiness of operation, availability of resources and infrastructure, quality of cutting, training required for operation. Through a local market survey, it has been identified that there is no readily available press machine which can generate 5-ton force on the leather surface. The ranges varied from 10 tons to 100 tons capacity. Therefore, a need was generated to develop customized hydraulic press machine for sole cutting operation.

4.5.3. Functional modeling of hydraulic press machine

The concept of black box diagram and functional tree diagram were taken as the initial approach for the development of hydraulic press machine (Haik Y., 1997). The schematic process diagram is shown in figure 4.22 and 4.23.

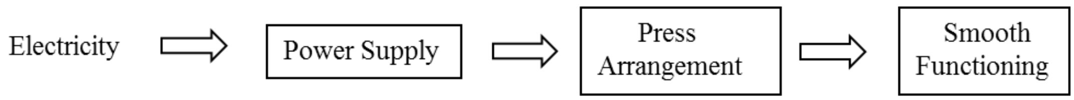


Figure 4. 22: Simple black box diagram of a hydraulic press machine

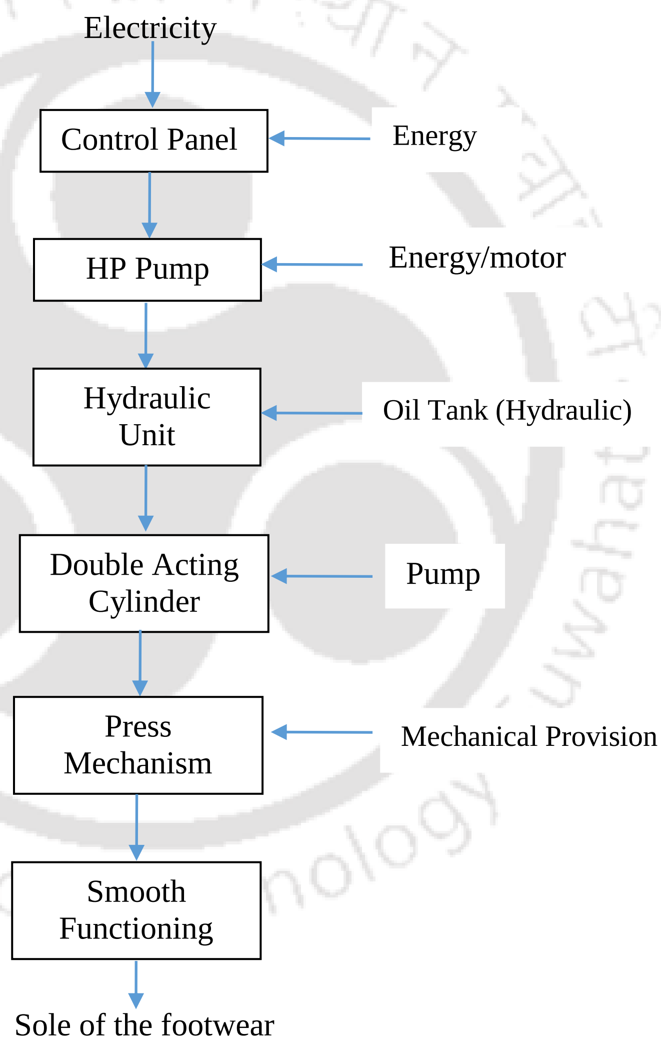


Figure 4. 23: Functional tree diagram of hydraulic press machine

From the above figures, it was cleared that for smooth functioning (cutting sole of the footwear), there should be a hydraulic unit along with electric power supply.

4.5.4. Concept development for press machine

Based on the design generated from black box diagram (figure 4.22), functional tree diagram (figure 4.23), and availability of resources different concepts were generated. Brainstorming, participatory ergonomics, content analysis, feasibility analysis were the major approach to develop concepts. Various features of the design were identified based on the context of the application, availability of space, required quality & accuracy, time constraint, responses from craftsmen, etc. The required features were compactness, leather cutting effectiveness, manual effort reduction, rate of cutting, easy handling, maintenance cost. All concepts are presented in figure 4.24.

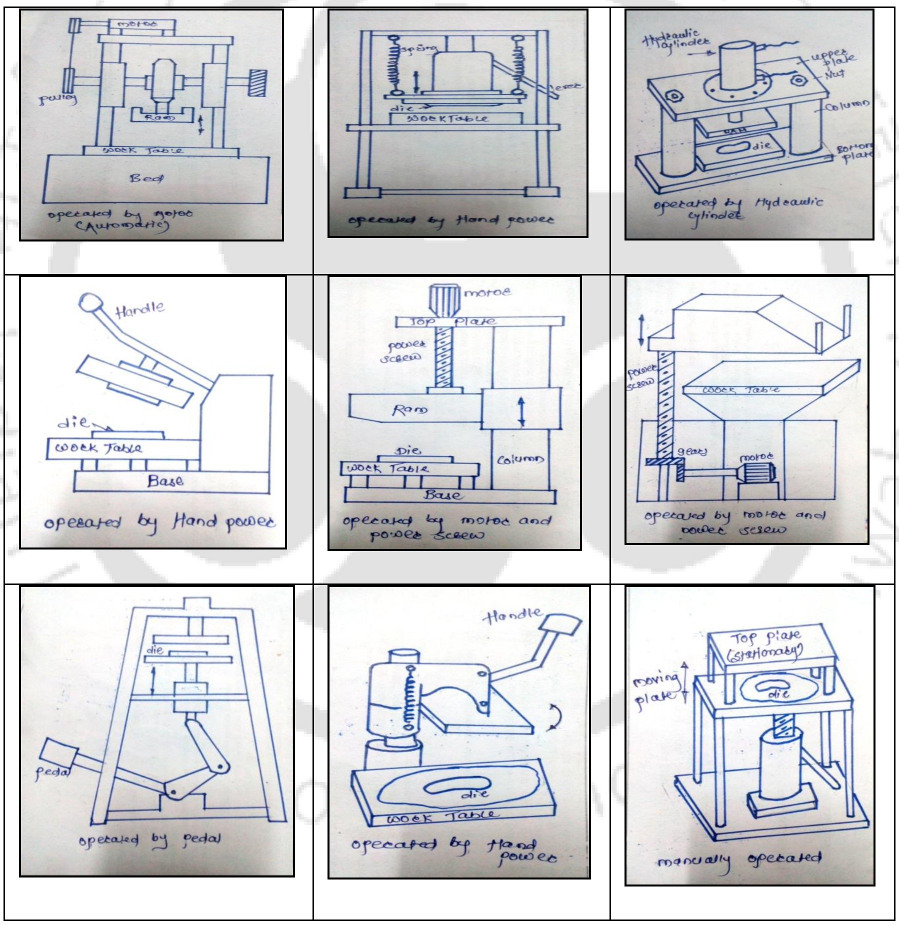


Figure 4. 24: Different Concepts of mechanism for press machine

All concepts are explained in figure 4.25 to figure 4.33 in terms of mechanism and working process.

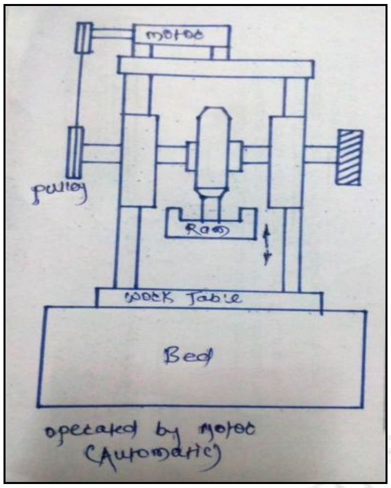


Figure 4. 25: Concept 1

Concept 1

This Mechanism will be operated by motor. Rope and pulley arrangement will be used to transmit power from motor to gear, to gear shaft ram is attached which will move up and down and press force will be obtained. This is automatic mechanism.

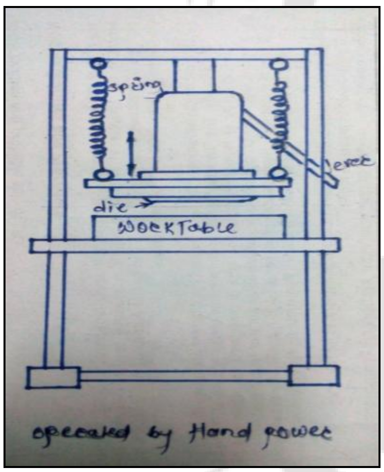


Figure 4. 26: Concept 2

Concept 2

This mechanism will be operated by hand power. Lever will be pressed against spring power to press die on working table. When lever is released, ram will move up due to spring back action. This is manual mechanism.

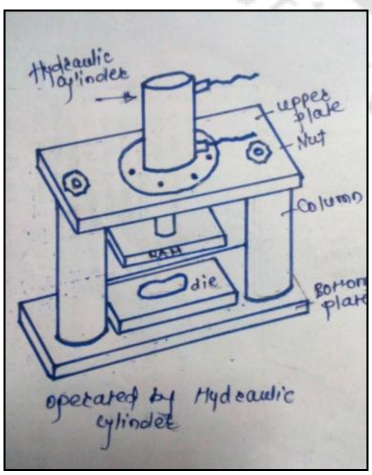


Figure 4. 27: Concept 3

Concept 3

This mechanism will be operated by motor. Motor will drive the hydraulic cylinder which is at the top, at one end of cylinder ram is attach which will press the die on working table. Hydraulic power pack used to control operation of hydraulic cylinder. This is automatic.

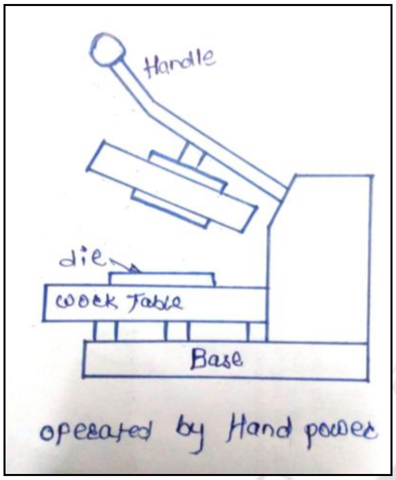


Figure 4. 28: Concept 4

Concept 4

This mechanism will be operated by manual hand power. Press plate is attached to lever which will be pressed against die to cut leather on work table.

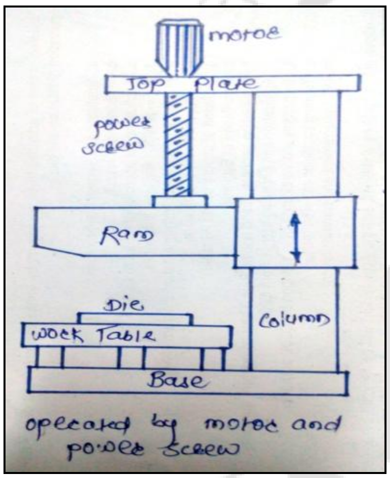


Figure 4. 29: Concept 5

Concept 5

This mechanism will be operated by power screw. Motor is used to drive power screw; moving Ram which moves up and down is attached to power screw. This Ram will press die against work table.

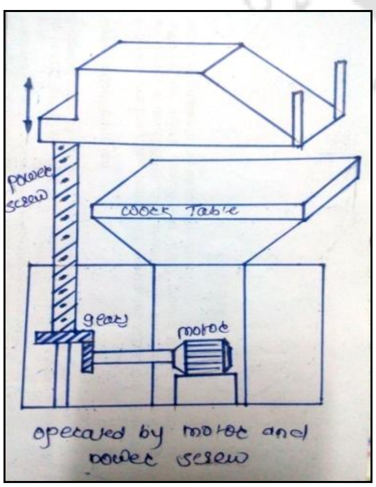
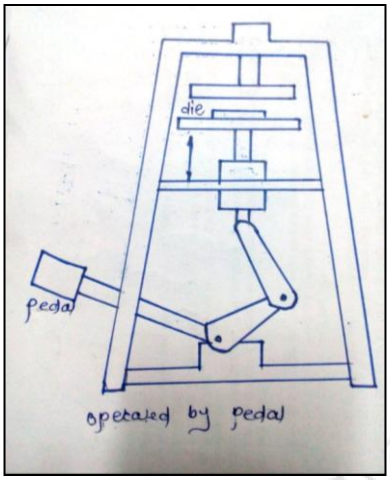


Figure 4. 30: Concept 6

Concept 6

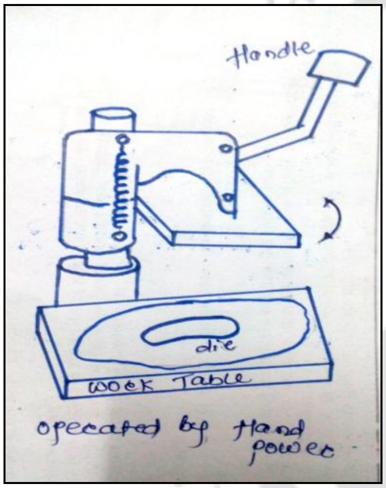
This mechanism will be operated by power screw. Power screw will be driven by motor. Big Ram will be attached to power screw at top.



Concept 7

This mechanism will be pedal operated. Work table is moving in this case, when pedal will be pressed mechanism presses the work table against top stationary plate and cutting force will be obtained.

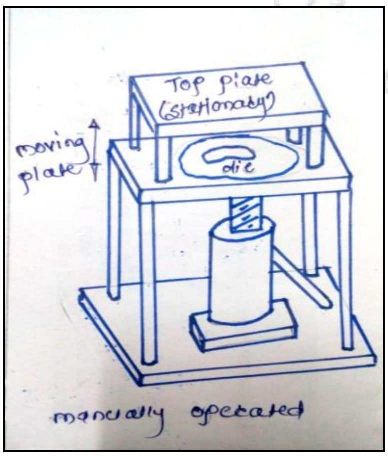
Figure 4. 31: Concept 7



Concept 8

This mechanism will be operated by hand power. Top moving plate will be pressed against spring power on bottom plate to obtain cutting force.

Figure 4. 32: Concept 8



Concept 9

Work table is moving, which is pressed against top stationary plate. This mechanism is manually operated using lever.

Figure 4. 33: Concept 9

4.5.5. Concept selection

The Pugh chart (Pugh S., 1996) was used for concept screening. It is an important and simple graphical method which considers user design requirements, used in the current study for the concept selection process (Okudan G., 2008). Following steps were followed to develop Pugh matrix.

Step 1: Criteria's for selection were classified and described.

Step 2: One design concept was selected as the baseline (standard).

Step 3: All the possible design concepts were compared with the baseline design concept and assigned score with:

0 = same; +1 = better; -1 = worse

Step 4: For each design option, the total score was calculated by summing the number of "+1" and "-1". After that, total score of each design was checked. It was found that concept 3 has maximum score.

Step 5: Concept 3 was selected and re-examined for the decision.

The developed Pugh matrix for all nine concepts is presented in table 4.3.

Table 4. 3: Pugh chart for hydraulic press machine

Criteria	Weightage	Concepts								
		1	2	3	4	5	6	7	8	9
1.Easy construction	0	1	1	1	1	-1	-1	1	1	1
2.Compactness	0	-1	-1	1	1	-1	-1	-1	1	-1
3.Rate of cutting	0	-1	-1	1	-1	1	1	-1	-1	-1
4.Cutting effectiveness	0	-1	-1	0	-1	0	0	-1	-1	-1
5.Effort Reduction	0	-1	-1	1	-1	1	1	1	-1	-1
6. Ease of handling	0	1	1	1	1	1	1	1	1	1
7.Installation Cost	0	-1	-1	-1	-1	-1	-1	-1	-1	-1

8.Maintanance cost	0	1	1	-1	1	-1	-1	1	1	1
Sum of +ve		3	3	5	4	3	3	4	4	3
Sum of –ve		-5	-5	-2	-4	-4	-4	-4	-4	-5
Total score		**-2**	**-2**	**3**	**0**	**-1**	**-1**	**-0**	**0**	**-2**

From this Pugh chart, it was observed that concept number 3 had a maximum total score. Hence, it was selected for further design and development.

4.5.6. Block diagram

A block diagram was prepared to understand all the required component of the selected concept in a conventional and sequential setup and presented in figure 4.34 and table 4.4 respectively.

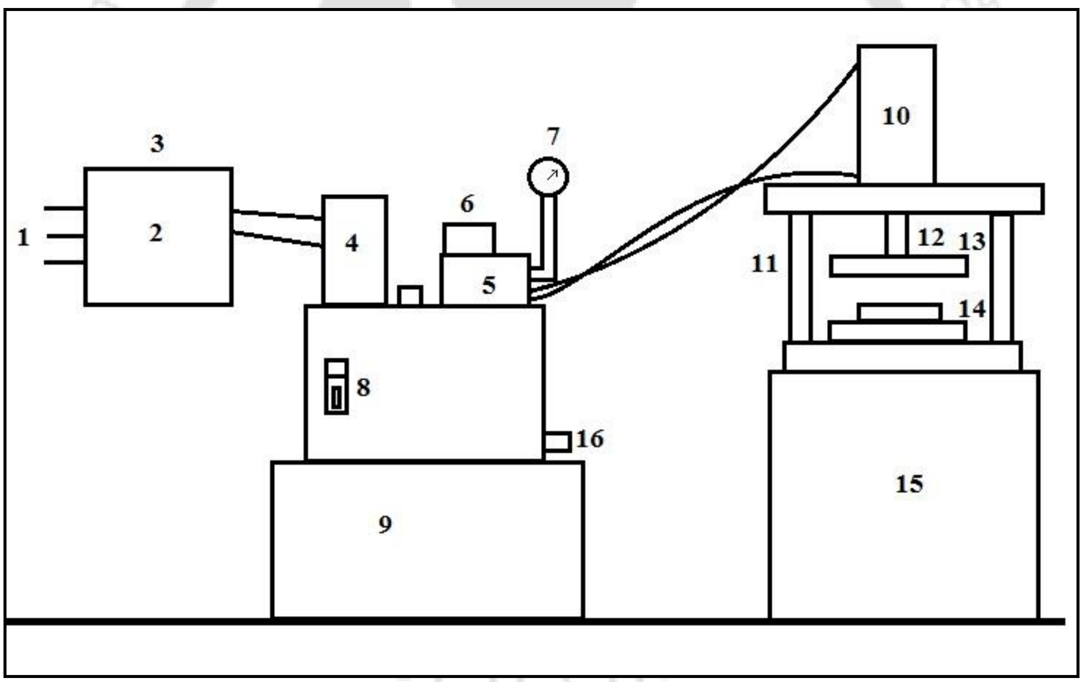


Figure 4. 34: Conventional Setup of machine

Table 4. 4: Parts of the hydraulic press machine

Parts of the hydraulic press machine			
1	Three phases ac supply	9	Concrete Base
2	Control board	10	Double Acting Cylinder
3	Switch Panel	11	Vertical Rod
4	1 HP Pump	12	Piston Rod
5	Metal Block	13	Upper Plate
6	Direction Control Valve	14	Lower plate
7	Pressure Gauge	15	Concrete base
8	Oil Level Indicator	16	Drain plug

4.5.7. Design of hydraulic system

Following reverse engineering calculation, hydraulic system was analyzed and designed as follows.

Total required force = 1.35 x 34= 45.9 KN= 45900N

Therefore, design consideration force is 45900N

Assume Initial working pressure = 10 MPa = 100 bar.

Calculations of Piston Parameters and Calculation of Piston diameter

F_p =Pressure force = N= 45900N

P_w = Normal working pressure = 10 MPa =10 N/ mm^2

A = Pressuring area of cylinder

D_p = Diameter of piston in mm

A = 45900/10= 4590 mm^2

A = Fp/ Pw = 45900/10= 4590 mm^2

$D_p = (4 \times A/3.14)^{1/2} = (4 \times 4590/3.14)^{1/2}$ = 76.42 mm.

As per the design, calculation piston diameter was selected as 76.42 mm. According to piston diameter and with reference to the catalog of hydraulic cylinder (Annexure III) other bore, thread dimensions were selected. According to the size of piston, dimensions such as bore and thread diameters are considered for design. After selecting piston diameter, bore diameter and thread dimension, 2D drawing of the double acting hydraulic cylinder was prepared (figure 4.35).

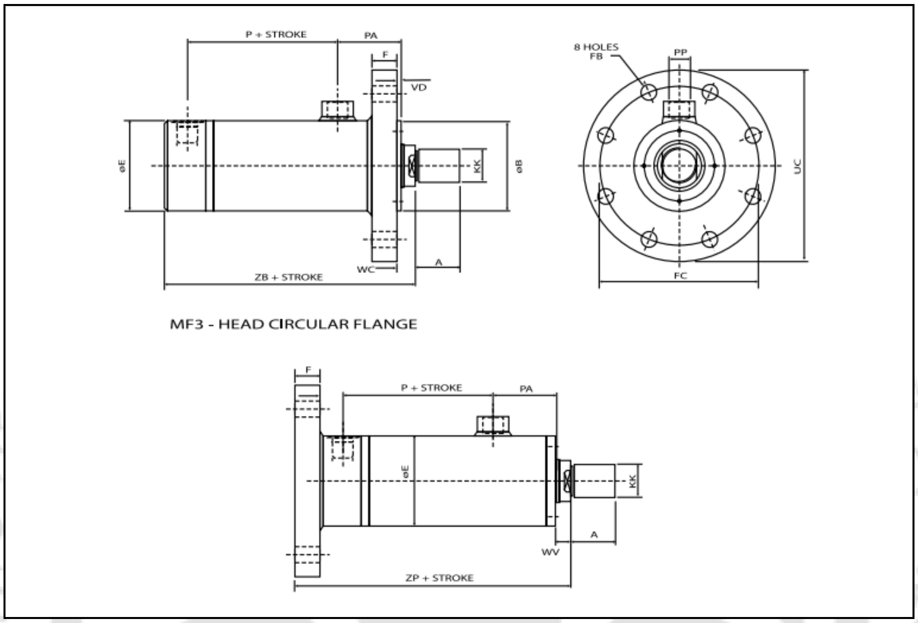


Figure 4. 35: 2D drawing of double acting hydraulic cylinder

Usually for medium application, mild steel and carbon steel are used to manufacture machine (Shinde G., 2015). In this particular application, structural steel EN8 material was used.

The different machine parts are shown below:

Top plate

In the selected concept, top plate is a metal surface on which power pack needs to be mounted. The power pack has six threaded holes to fix with the top plate and has working diameter 114 mm. So, top plate dimensions were selected to be 500 mm x 200 mm. The two holes were provided at a distance of 150 mm from the center for fixing the columns with the top plate. Threaded Holes were having a diameter of the 30 mm with 2 mm pitch which was separated from the center at a distance of 150 mm. The thickness for the top plate was taken as 25 mm. For fixing hydraulic cylinder on the top plate 114 mm diameter was provided at the center. Also, six threaded holes were provided around top plate at equal angle to fix hydraulic cylinder with the top plate. 3D modeling of the top plate was done using CATIA CAD modeling software which is shown in figure 4.36.

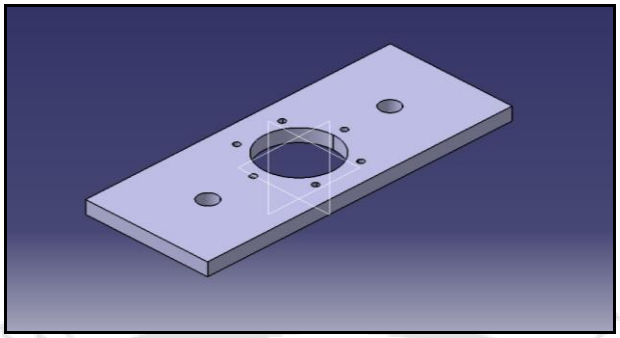


Figure 4. 36: Top Plate

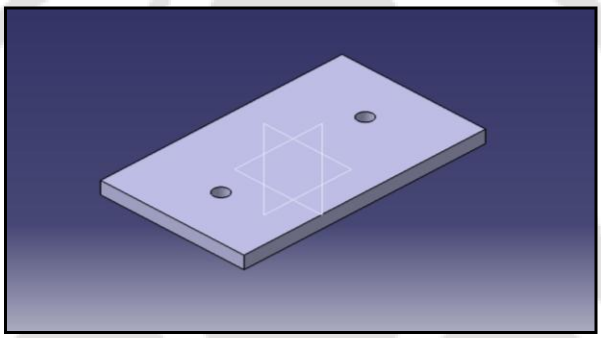


Figure 4. 37: Base plate

Base Plate

On the base plate, two columns need to be placed and die specified for this application needs to operate exactly in the middle. Total area required for die is 150 x 70 mm^2. So, dimensions of the base plate need to be 500 mm x 300 mm. 3D modeling of the Base plate is done using CATIA modeling software which is shown in figure 4.37.

Column

The Column acts as vertical support to the top plate. The top plate is supported by using two vertical identical columns. As the distance or space between the top plate and bottom plate is 250 mm. In between the top plate and bottom plate, there is a punch which is connected to the hydraulic arrangement. Generally, column segments are a) Square b) Circular c) Rectangular. As mentioned, above the height of the column is 250 mm.

For the manufacturing ease, the cross-section of the column selected was circular. The diameter of the column considered was 40 mm and cross section area was $0.031m^2$.

For fixing column with the base plate and top plate, extended external threading was provided. This column has a diameter 30 mm and height 80 mm. The column was demonstrated as shown in figure 4.38.

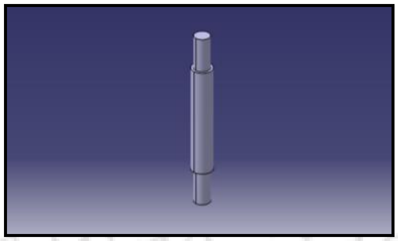


Figure 4. 38: Column

Nut

The top plate is fixed with the column with the help of nut. The diameter of extended part on the column was 30 mm, so from the catalog of nut (Annexure IV), M30 nut was selected for the machine.

Following are the specifications of the nut

Pitch = 3.5 mm, Height (k) = 15 mm, Width (s) = 45 mm.

Complete assembly of all components was prepared using CATIA CAD modeling software as shown in figure 4.39.

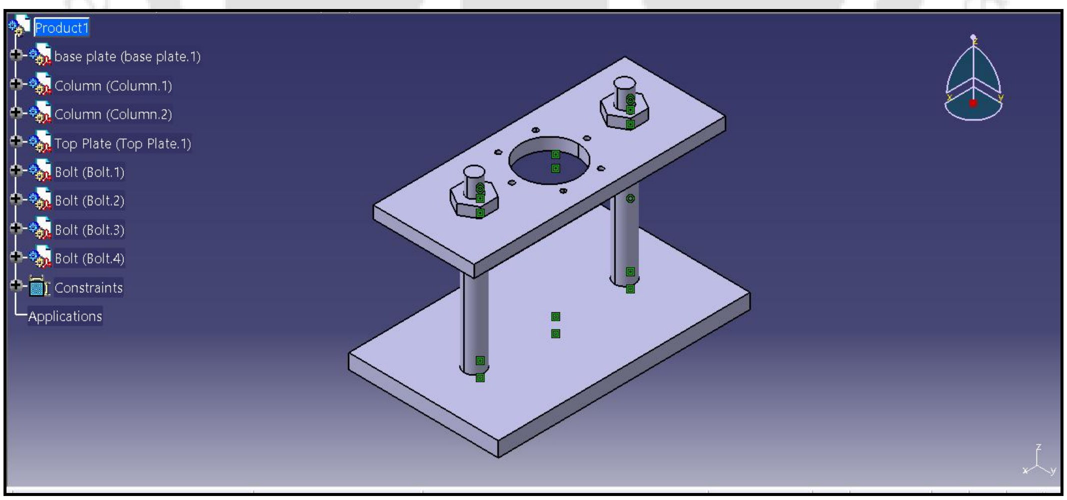


Figure 4. 39: Assembly of Machine

4.5.8. Finite element analysis of the machine

Machine parts viz. base plate, column, top plate, bolts are made up of structural steel. FEA consist of six steps like geometry, meshing, material used, static structural analysis, von-Mises stress and total deformation (Shinde G., 2015). For the analysis, ANSYS software was used. The steps are as follows.

Step 1: Modeling

The 3D model of sole making machine was developed in CATIA V5 R19 as per the required dimension (figure 4.40). The developed model is used for structural analysis in ANSYS workbench.

Step 2: Meshing

Hexahedral elements were used for meshing. Convergence study was carried out for finding out optimum mesh size and time step. The optimum mesh size was 3 mm and used for all simulations. Meshed model is shown in figure 4.41.

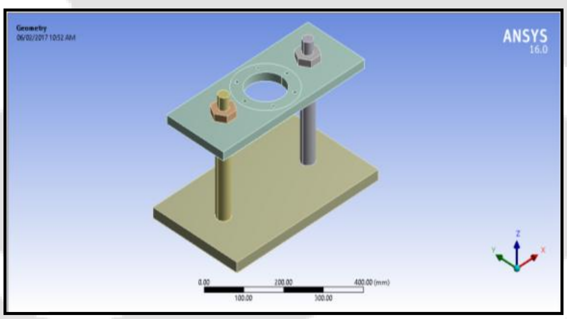


Figure 4. 40: Modeling of machine

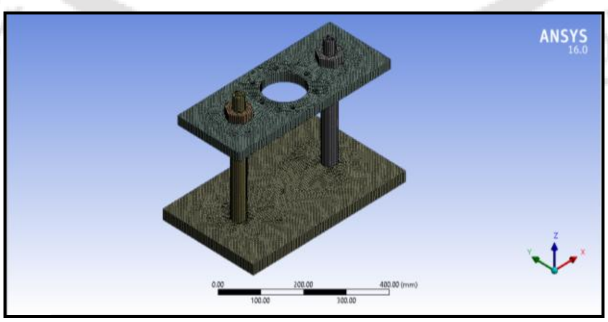


Figure 4. 41: Meshed Model

Step 3: Material used

The material used for the structure is medium carbon steel.

Step 4: Static structural analysis

Analysis of static structure to identify load on physical structures and its components is presented in figure 4.42.

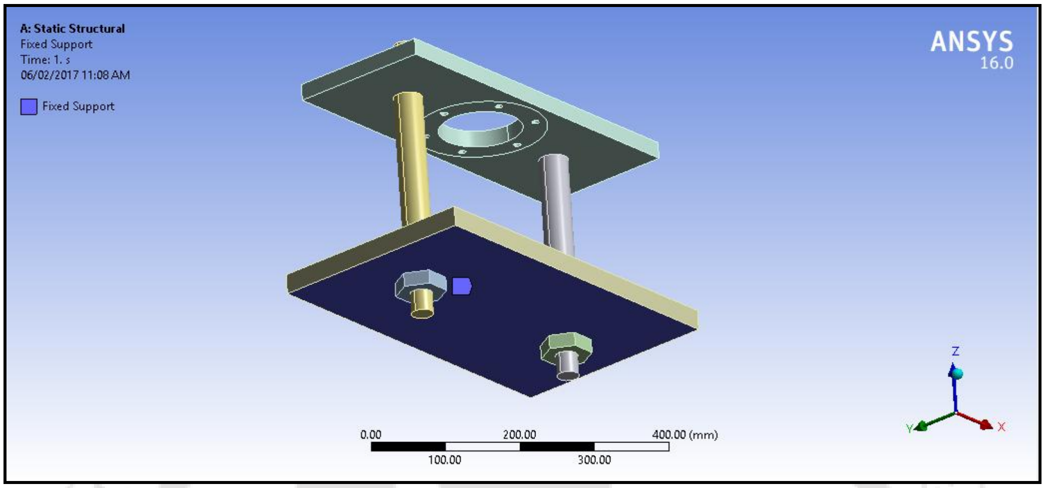


Figure 4. 42: Static Analysis

As identified, earlier maximum possible applied force on the top of the plate as per design consideration is 12 MPa. To understand the deformities of the metal parts, 12 MPa was simulated in the software and the result is presented in figure 4.43.

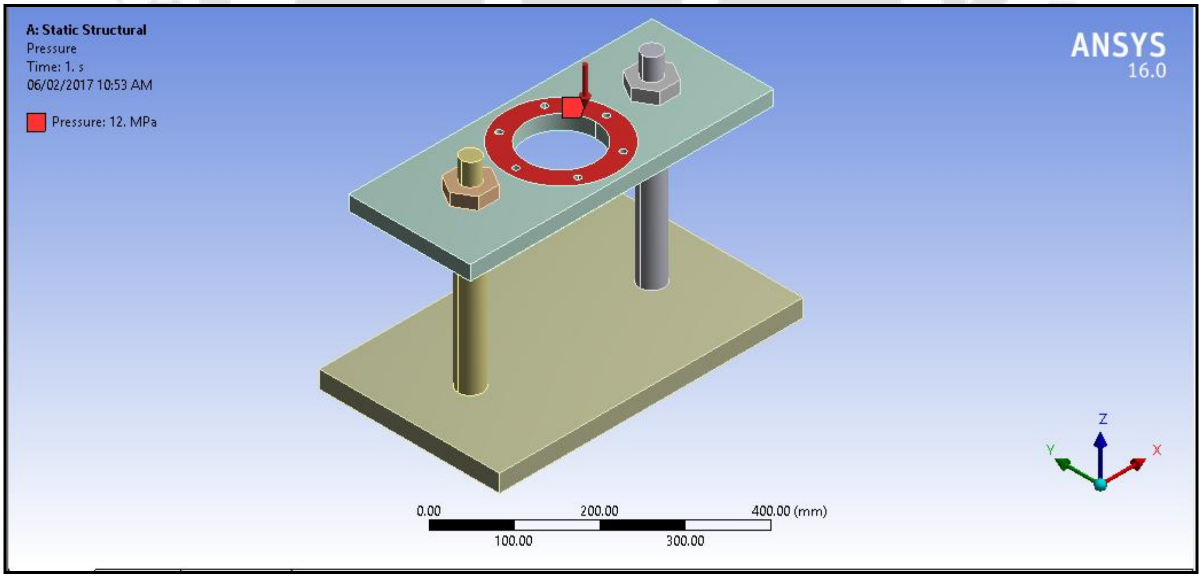


Figure 4. 43: Applied Pressure on Machine

Step 5: Total deformation

Total deformation was identified as 0.3499 mm which is negligible as per total metal thickness (figure 4.44).

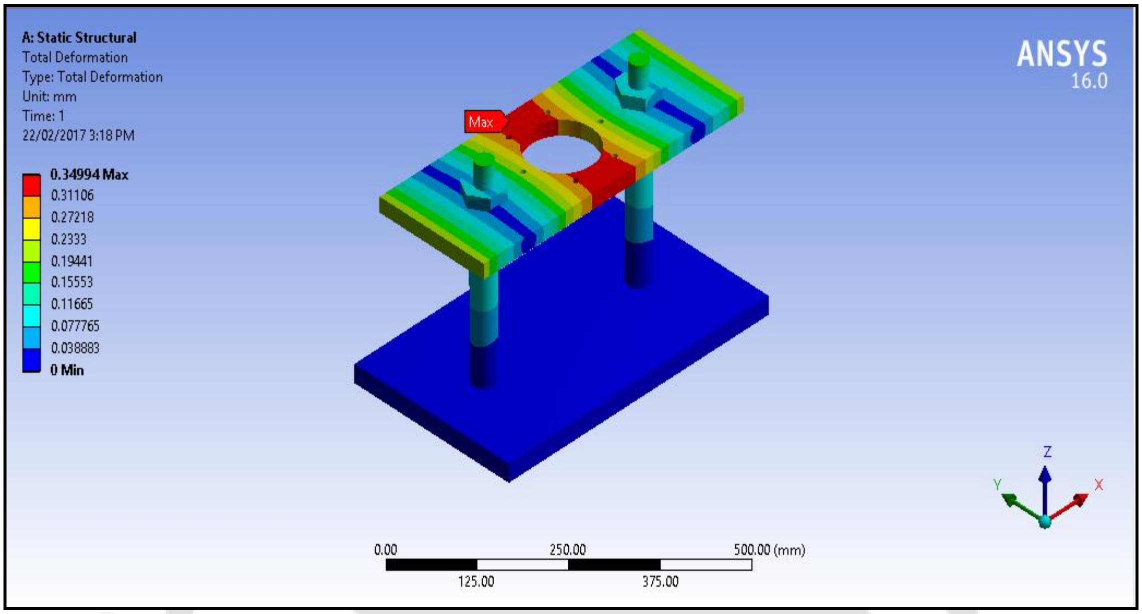


Figure 4. 44: Total deformation

Step 6: von-Mises stress

After the successful simulation run, the maximum von-Mises stress was observed on the structural part of the machine is 223.01 MPa (figure 4.45). Therefore, it has been identified that the design is safe and can be taken for further physical prototyping.

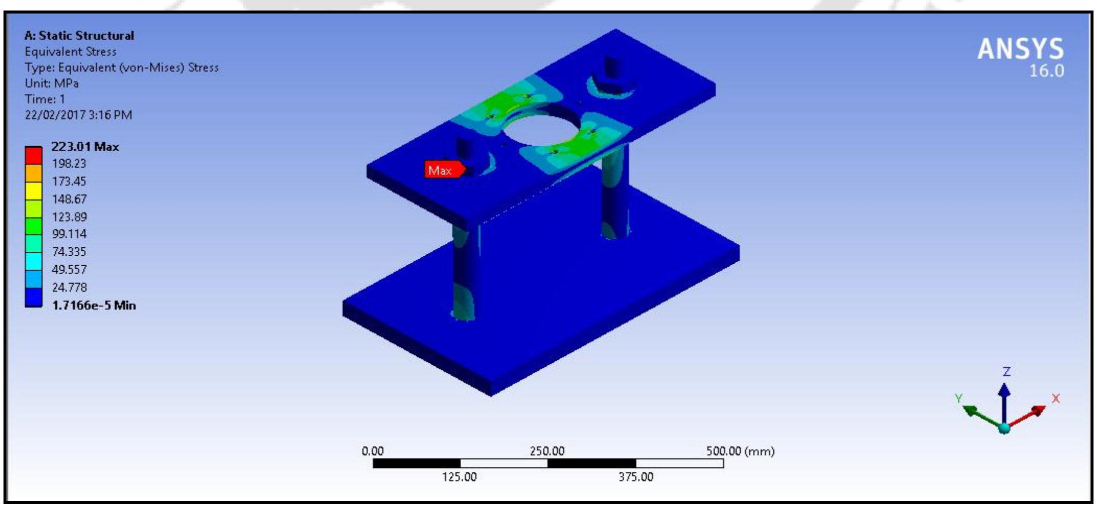


Figure 4. 45: von-Mises stress

4.5.9. Parts of Machine

The overall setup was divided into two major components such as Control Panel and Hydraulic Power Pack. Functional description of basic parts of the press machine are as follows:

- **Control Panel**

A readymade control panel was used for power supply and is shown in figure 4.46.

Figure 4. 46: Control panel

- **Hydraulic Power Pack**

The three-phase induction motor (figure 4.47) was used to drive the hydraulic pump on the oil tank. It is mounted on the top of the oil tank. The motor works on three-phase AC supply of voltage 415 volt 50 Hz frequency. It has a 0.75 kW rating with 1415 rpm rotor speed.

Figure 4. 47: Three phase induction motor

- **4/3 Direction Control Valve:**

A 4/3 DCV valve (figure 4.48) was used which has 4-way, 3-position to control the position of operation. In this valve, the pressure port is connected to the pump and another port is connected to the tank (reservoir). The remaining two working ports are connected to the actuator. Apart from the valve, other characteristics such as suitable fluid, working temperature, viscosity, etc. were taken into consideration.

Figure 4. 48: 4/3 Direction Control Valve (DCV)

- **Pressure Gauge:**

Pressure gauge (figure 4.49) of range 0-5600 psi was used for measuring oil pressure flowing through hydraulic power pack. The pressure gauge was calibrated with dimensions and unit considered was kg/sq.cm.

Figure 4. 49: Pressure Gauge

- **Oil Tank:**

A cubical oil tank (figure 4.50) with dimensions 30 X 30 X 30 was made by using 6 square plates of size with 4 mm of thickness. They were welded together by continuous butt welding. A separate plate of 6.5 cm was welded to the bottom plate of the tank for support and the holes were also provided for fixing the tank on table or concrete base. A separate hole was drilled for fitting oil filler cap. Other related accessories were strainer, oil filler cap, oil level indicator, wire mesh filter & drain plug.

Figure 4. 50: Oil Tank

4.5.10. Newly fabricated context specific hydraulic press machine

Figure 4.51 represents the newly fabricated context specific hydraulic Press Machine to cut the leather as per requirement, placing the raw leather in between upper and base plate. In this particular hydraulic press machine, force generation for cutting, transmission and amplification processes were accomplished by using fluid or oil under pressure. This mechanism was designed to cut the sole with less amount of force.

Figure 4. 51: Hydraulic press machine

4.6. Testing of design intervention

The newly developed dies along with hydraulic press machine were tested for its functionality at the original manufacturing area by the artisans. The result was satisfactory in terms of its functionality, quality of the output, reduction in manual effort in terms of force exertion, the time required. Time study (table 4.5) was carried out as per previously described method & guidelines and identified that required standard time has reduced significantly ($P < 0.0005$). It was found that basic time for a single piece reduced to 70%. The table represents a time study sheet of sole cutting operation after implementation of the intervention.

Table 4. 5: Time study sheet of sole cutting activity after intervention

Time Study Sheet				
Name:	Ganesh Jadhav		Date:	15/5/2018
Product Family:	Kolhapuri Footwear		Crew:	1
Product:	Footwear		Posture:	Sitting
Machine/Tool:	Sole cutting Machine			
Operation:	Cutting Profile of Footwear			
Sr. No	Element Description	BasicTime (Min)	Allow. (%)	Std. Time (Min)
1	Frequently occurring job	0.66	0	0.66 (40 Seconds)

4.7. Further design modification of the sole cutting dies

In the new design, two metal strips were joined by advanced forging method as discussed in previous section. While testing the intervention in the actual field, it was anticipated that in the long run of use there is a possibility of deformation in the die. This phenomenon may affect the whole process, quality, required force exertion, etc. Although, to understand the actual data it requires a longitudinal study which is not under the prevue of the current objective.

Based on anticipation and discussion with subject matter expert, it was decided to go for an alternate design of the dies which can ensure the above-identified problems.

In order to overcome the deformation of the cutting surface, the modifications were done in such a way that uniform pressure can be applied on the surface of both the dies. Electro Discharge Machining (EDM) (Shaaz A., 2014) was used for dies manufacturing as this ensures accurate machining of components. Actual drawings were modified from the previous design. Easy assemble and dissemble was one of the major consideration. Both the dies were considered separately for manufacturing starting from 2D drawing till physical prototype. Figure 4.52 represents a modified design of cutting dies.

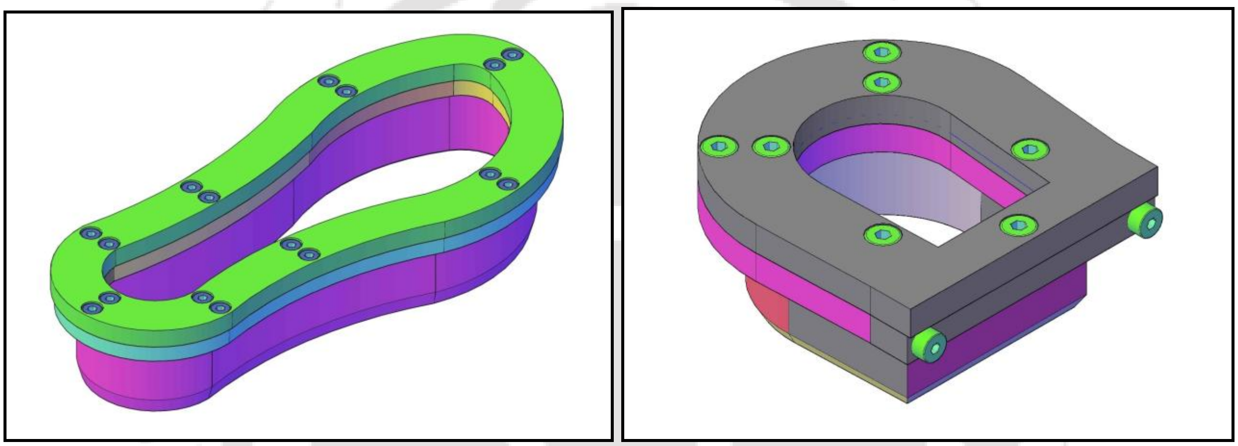


Figure 4. 52: CAD model of modified base and heel die assembly

A CAD model of both the dies (base & heel) were developed using CATIA V5. In the earlier design of FEA, it was found that the stress values and deflection were very less than the yield stress value of EN8 material. Therefore, in this particular design further FEA was not required. Various stages of manufacturing such as drilling, insertion of a spring steel blade, milling, assembling, etc. and finished dies (base and heel) are presented in figure 4.53 and figure 4.54 respectively.

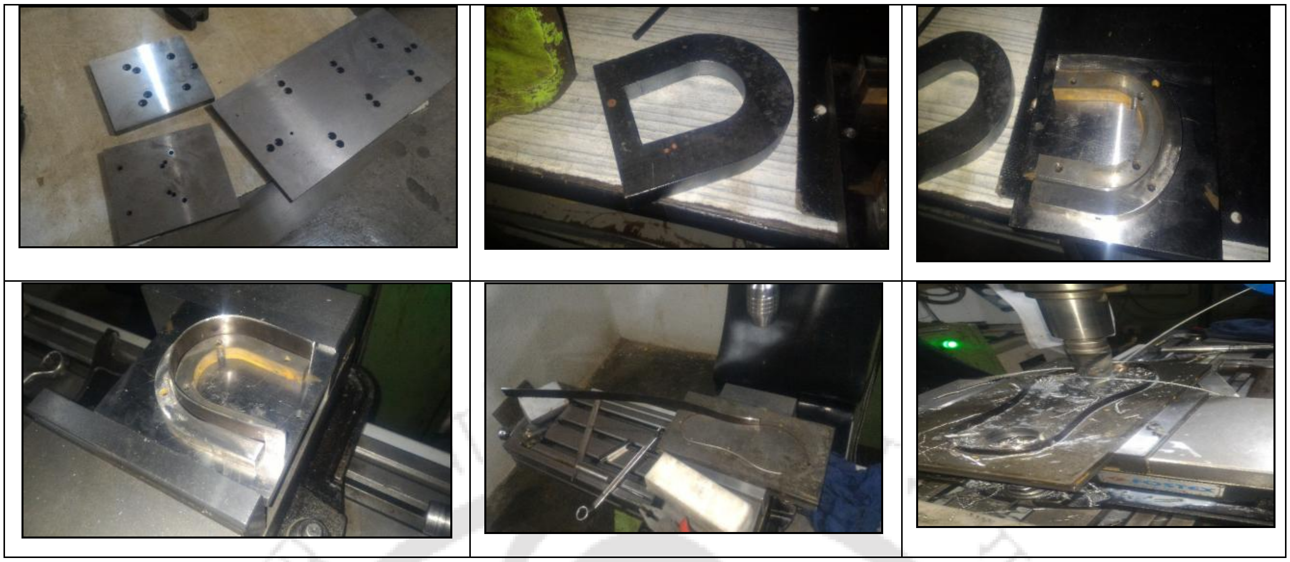


Figure 4. 53: Stages of manufacturing

Figure 4. 54: Finished base and heel die

In the old design, whole pressure was applied on 3 mm thick strips of dies. This causes excessive stresses and moreover, there were chances of cutting edge deterioration and bluntness to it. In the modified design, plates were provided on the upper side of the die so that uniform pressure can be applied on the cutting edge. Both the dies were manufactured in such a way that any unskilled person can assemble or disassemble the components of dies. The use of easily replaceable low-cost spring steel blades ensures easy operation and maintenance of the die for the long run.

The modified dies were tested along with hydraulic press in the same fashion as it was tested for old dies. The quality of the outcome was checked in terms of quality of the finished product (sole: base & heel) and impact of the finished product on the main essence of craft. Figure 4.55 and figure 4.56 represents the sole cutting quality before and after the intervention. It was found that the quality of sole cutting has been improved. The main essence of the craft was also not changed.

Figure 4. 55: Sole cutting by hand before intervention

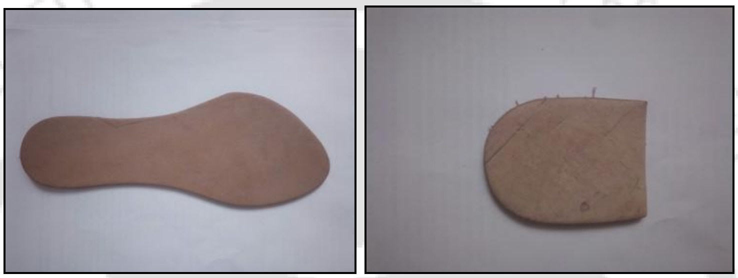


Figure 4. 56: Sole cutting by machine after intervention

4.8. Approximate cost-benefit analysis of sole cutting machine

The sole cutting machine is proposed for Kolhapuri footwear manufacturing artisans. The entire Kolhapuri footwear manufacturing process is carried out in the Kolhapur district. Kolhapur district's many villages are contributing to footwear production. The proposed hydraulic press machine requires electric supply. All the villages have sufficient electric supply in the Kolhapur district. During the summer duration, only 4 to 5 hours power shut down takes place and in the remaining hours, power supply is easily available. Therefore, power supply doesn't affect the productivity of the sole cutting and pressing machine.

In the proposed sole cutting and press machine 1 Horse Power (HP) motor was recommended.

1HP = 746 Watts

746 X 8 Hours (Hrs.) = 5968 watt hrs.

= 5.968 KW/Hr. (Kilo Watt/Hour)

= 6 Unit (1Kw/hr. = 1Unit)

Total Investment on the machine = 40000 Rupees. (Hydraulic press and dies)

Assuming 10% annual maintenance cost = 4000 Rupees.

Total cost = 44000 Rupees.

Assuming 240 days of efficient working =240x 12 = 2880 hours of working

Per hour cost for a year = 44000/2880 = 15.27 Rs. /hr.

We can earn approximately 16 Rs. /Hr. from the machine.

Accordingly, if 60 pieces/hr. are produced then cost of production = 25 paise/piece. The operating cost of the machine will be 25 paise/piece, the worker can charge according to their convenience. The payback period of the machine will be only one year. If a worker can produce 100 pieces/hr. and if they charge 4 Rs. cost for each piece then they can earn 400 Rs. daily.

The main benefit of the sole cutting machine is that there is no need to purchase machine individually. Artisans can use a single machine according to their cluster arrangement so that everyone can utilize it according to their requirement. Also, the sole cutting efforts and the cutting time was reduced so that workers can use this time for manufacturing of other footwear's or activities. There is no need for skilled worker to operate the sole cutting machine.

4.9. Designing a specific workstation for sole cutting operation and its virtual simulation

The newly designed context specific sole cutting machine needs to be operated through a specific workstation. This need was identified during user testing of the machine with modified dies. Based on the requirement, a simple virtual workstation was designed with available local anthropometry database (More S., 2014)) in CAD. The height, breadth, and length of the table are 1051 mm, 600 mm, and 1500 mm respectively. A storage place is provided to store raw material, soles after cutting, tools & accessories under the working surface. Figure 4.57 represents the newly developed context specific sole cutting machine mounted on its specifically designed workstation.

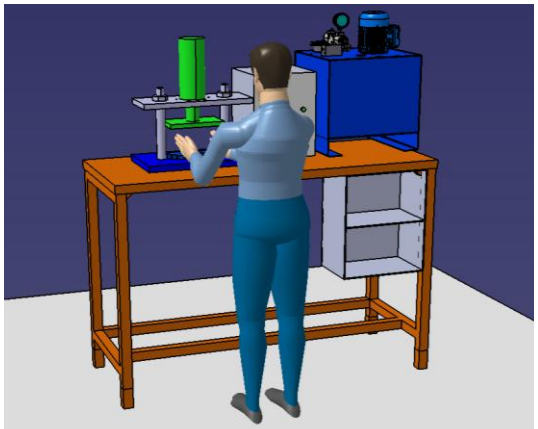


Figure 4. 57: CAD model of sole cutting workstation

The virtual workstation was simulated with various manikins of different sizes to understand the compatibility, comfortability in terms of reach and visual field (Karmakar et al, 2012). Digital Human Modelling (DHM) (Demriel and Duffy 2007; Madan Mohan et al, 2008; Sanjog et al, 2012; Sanjog et al, 2016) using CATIA V5 was used to simulate the virtual environment. The methodology adopted for the same is presented in figure 4.58.

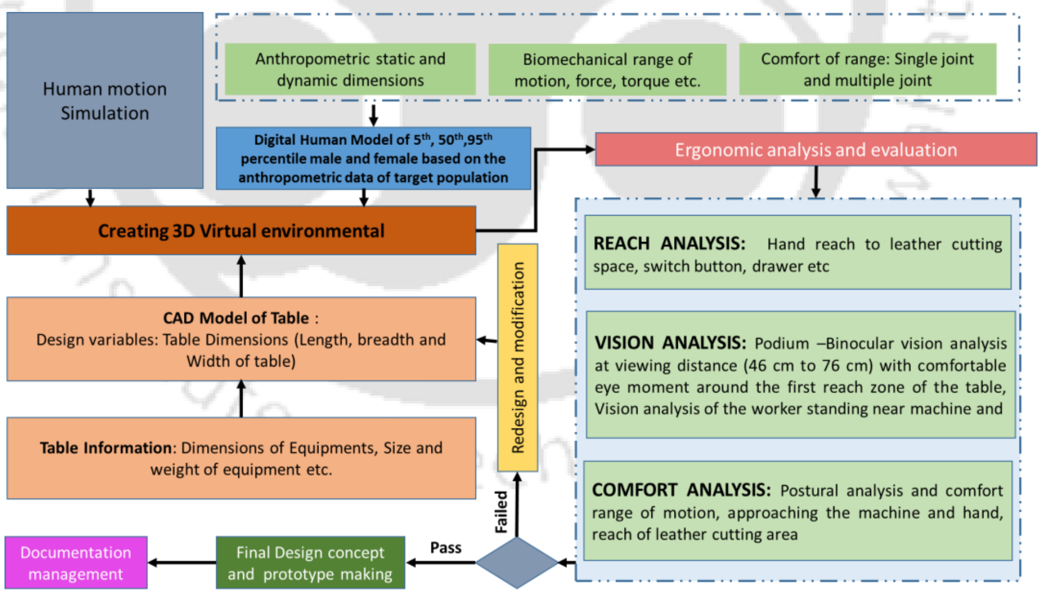


Figure 4. 58: Methodology adopted for sole cutting workstation

The CAD model of the sole cutting workstation (figure 4.57) and digital human models (manikins) were integrated into 1:1 scale. The groups in a population covering the smallest, medium and the largest body measurements were presented by 95th percentile, 50th percentile, and 5^{th} percentile male respectively. In order to confirm the worker's compatibility in the proposed sole cutting workstation (to access the components), the work envelope of the manikin was generated and analyzed.

4.9.1. Vision analysis

The sole cutting workstation model was integrated with 5^{th} percentile female, 50^{th} percentile male and 95^{th} percentile male (figure 4.59) respectively for DHM vision analysis. The focus distance was 300 mm. Head flexion was 8.2^0, 8.5^0 and 11.2^0 respectively with focal distance 300 mm and ponctum proximum distance was 50 mm. Horizontal monocular 100^0 degree and horizontal ambinocular 120^0 were kept for field of view analysis along with 35^0 top view. The result of DHM analysis revealed that the majority of the work surface area is visible with comfortable, irrespective of any percentile and gender.

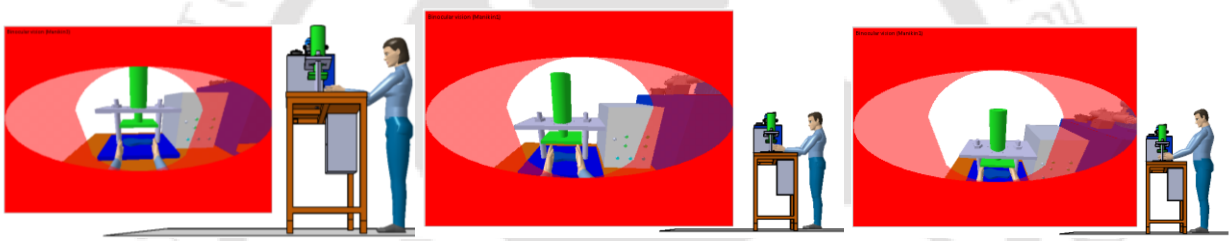


Figure 4. 59: Vision analysis of 5^{th} p female, 50^{th} p pooled & 95^{th} p pooled male

4.9.2. Reachability analysis

To understand easy and comfortable access to all parts of the machine which need to be operated (placement of sole, control panel, storage), reach was checked using 95^{th} p male, 50^{th} p pooled and 5^{th} p female data. The result is presented in figure 4.60.

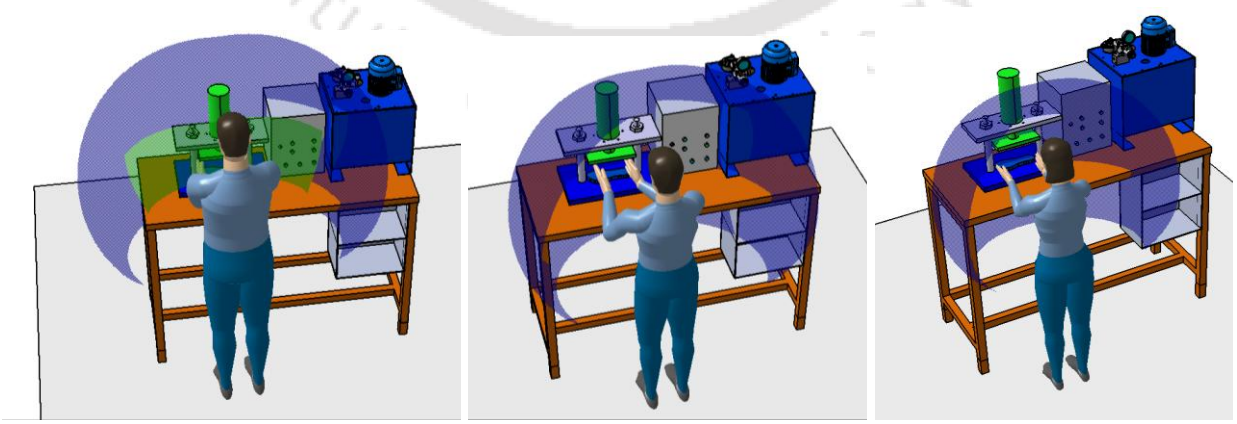


Figure 4. 60: Reach analysis 95^{th} p male, 50^{th} p pooled male and 5^{th} p female

Table 4.6 represents arm and forearm angle of 95th p male, 50th p pooled male and 5th p female respectively.

Table 4. 6: Arm and forearm angle of 95th p male, 50th p pooled male and 5th p female

Population	Arm angle (degree)	Forearm angle (degree)
95th p male	40	33.5
50th p pooled male	44	40
5th p female	50	55

The above two results (vision and reach) revealed that newly designed workstation is acceptable as per the vision and reach are a concern except for 5th p female and 50th p pooled percentiles joints angle which can be improved by providing step-stole.

4.9.3. Posture analysis while using context-specific sole cutting workstation

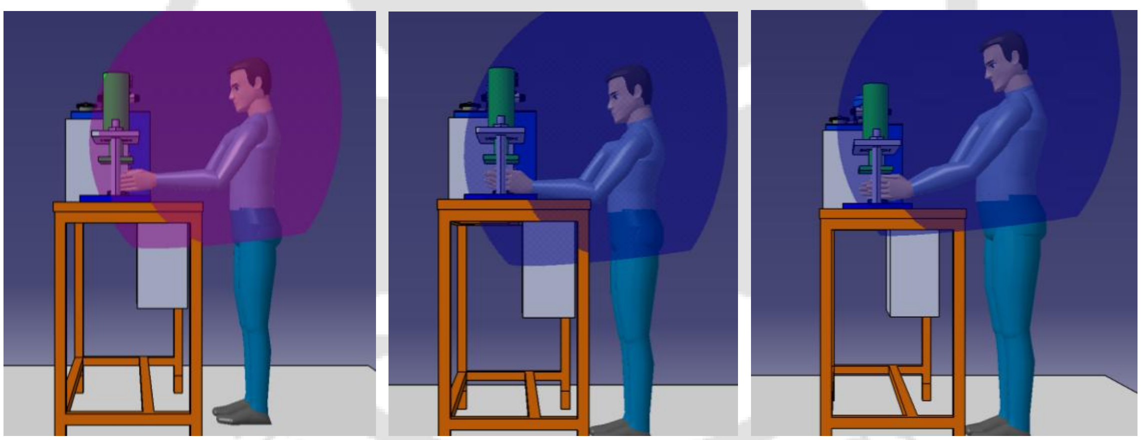


Figure 4. 61: RULA analysis of P 5th, P 50th & P 95th percentile male (left to right)

The test process and iteration process followed for all percentiles (figure 4.61) in the postural load analysis (Binoosh S., 2017; G. Madhan M., 2008). These jobs are standing in nature but there is lower body movement. The worker needs to stand on even surface with equal distribution of load on both feet. The results observed as RULA grand score of '3' for P 5th P 50th & P 95th percentile male for all percentiles respectively which indicates negligible risk level in certain design conditions (as shown in the figure). The head flexion was observed 8^{0}, 9^{0} and 11^{0} respectively.

4.10. Complete workstation to operate a sole cutting machine

After getting a satisfactory result for vision and reach analysis in a software simulated condition, physical prototype (figure 4.62) was manufactured using locally available metal and wood.

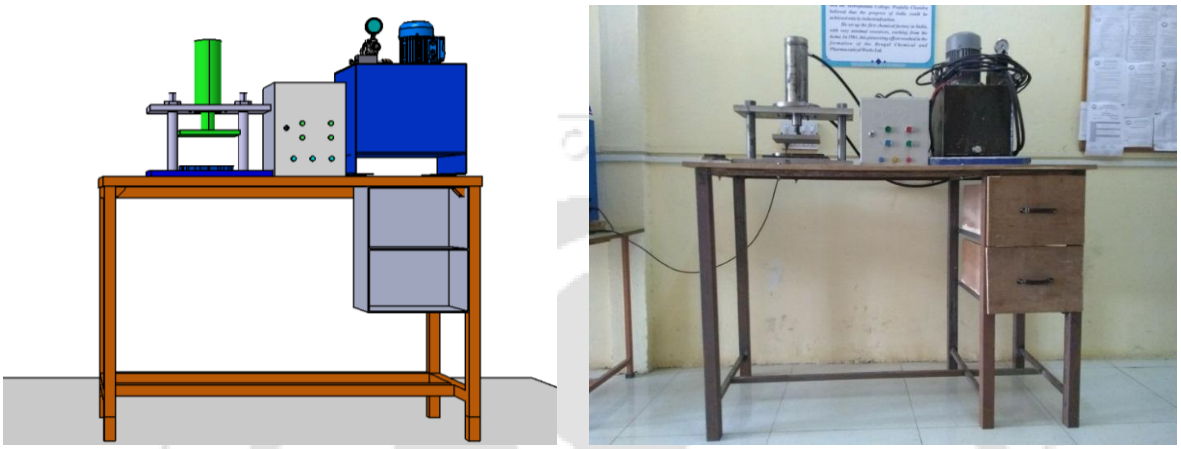


Figure 4. 62: Sole cutting workstation a: CAD model; b: Actual workstation

4.11. Intervention to enhance veni (braid) and other accessories preparation

As mentioned in the earlier chapter III, there was need for design intervention (partially) in preparation of veni (braid) and other accessories. Veni (braid) making is a process where small strips (approximate 12 to 18 cm length and 25 to 30 mm width) of leather (thickness 2 mm) are weaved together to give various forms. To get these small strips, a piece of leather needs to cut in required shape using the same tool rappi (sharp-edged tool) which is traditional sole cutting operation with the help of hand. Same strips are being used for other accessories preparation. Also, there are some more requirement of equal sized (approximately size 15 to 20 cm) leather (thickness 2 mm) strips which also being prepared by rappi (sharp-edged tool). At the beginning of the chapter, it has been identified that use of rappi (sharp-edged tool) required manual effort. Therefore a need was generated to provide some intervention to enhance strips, making the process in terms of reduction in time and enhanced quality of the strips.

The same manufacturing process as mentioned in die preparation was adopted for the intervening strip making process. Two types of dies were prepared and tested with actual leather. The various drawings were created using CAD software (figure 4.63).

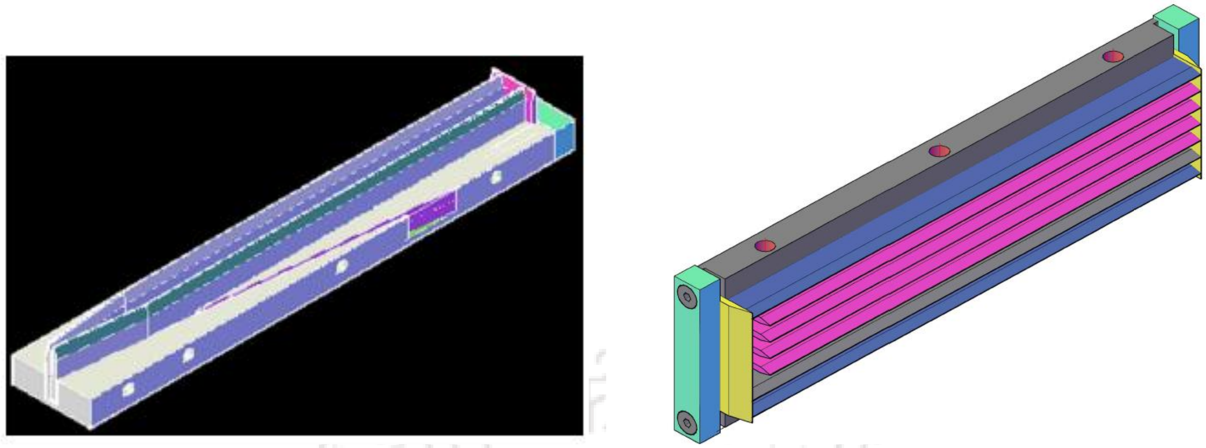


Figure 4. 63: Single and parallel strip cutting die

One of the actual die for strip preparation is presented in figure 4.64.

Figure 4. 64: Actual model of strip cutting die for cutting parallel strips

Both the dies were tested using the same hydraulic press machine as manufactured for sole cutting machine. The quality of the output (strip of the leather) was compared in terms of size and estimated required time with the outcome of the traditional method. The result revealed that the size and quality of the leather strips are as same as the outcome without intervention whereas, the required time to cut ten leather strips using strip cutting die reduced substantially. Responses (92 %) of the craftsmen confirmed that using the leather strips dissected by strip cutting dies are not having any marked difference from the traditional one. All of them further confirmed that use of both the interventions (sole cutting and leather strip cutting) satisfactorily enhanced the quality of the outcome, reduction in perception in force requirement per unit involved time. Using both the intervention, a full piece same design of Kolhapuri footwear was prepared and responses were taken about its identity from various stakeholders. A double-blinded test (McCann, 2007)) was conducted to understand any change in the essence of the craft of the product with and without intervention. A third person (student from local engineering college) was assigned experimental work whereas all stakeholders were considered as respondent. An unstructured interview with all stakeholders was conducted by which assigned student had to identify various elements (size, shape, quality of veni (braid), color, decoration, stitching, etc.) of that particular footwear. None of the stakeholders could differentiate between footwear manufactured before and after the intervention. Therefore, the objective of this study was fulfilled satisfactorily.

In the literature, it was identified that craftsmen of Kolhapuri footwear, are not interested to continue this ancient craft for various reasons (Burute P., 2014). It was further notified in literature, there are rare studies available which explain the status of occupational health of various crafted footwear. Also, from field study, it was perceived that there is a need to understand, occupational health status especially in terms of work-related musculoskeletal disorders and its related causal factors. Therefore, in the next chapter, an initiative was taken to evaluate the health status of the artisans engaged in Kolhapuri hand-crafted footwear manufacturing.

Chapter V-Intervention of stitching and accessories preparation

Result of table 3.5 and 3.6 revealed that stitching and preparation of accessories of crafted Kolhapuri footwear manufacturing have an opportunity for intervention. It is also notified in table 3.5 that there is no scope of intervention in terms of process, tools & equipment for both (stitching and accessories preparation) activities. As it is not possible to do an intervention for process, tools & equipment, it is not possible to do any intervention for force exertion, repetition, vibration, etc. although; vibration is not at all available in the workstation because of the nature of work. Therefore, it was decided to understand the postural load on the workers while using these two (stitching and accessories preparation) workstations and relevant intervention.

5.1. Posture analysis

Rapid Upper Limb Assessment (RULA) (Corlett & Bishop, 1976; McAtamney & Corlett 1993) was used to evaluate the working postures of workers working on stitching and accessories preparation workstation. Videography and photography techniques were used for posture recording. Frequently occupied postures from dominating hand side were selected for analysis. Data were collected for twenty female participants from each workstation. All 40 participants participated in the study after understanding the motive of the research with signed informed consent.

5.1.1. Statistics

The sample size was small and collected data did not pass the normal distribution test. Therefore non-parametric statistical techniques were used. Mann-Whitney U test was used for interpretation of data. Statistical analysis of the data was performed with SPSS software version 23.0.

5.1.2. Demographic details

Demographic data of the 40 female workers are presented in Table 5.1. The female worker's age were ranging from 18 to 66 years (mean=42.1years; SD=±13.8 years). The average weight and height of the workers were 165.2 ±4.9cm and 59.2 ±10.2 kg respectively. Majority of the workers were married (92.5%) and their education level were secondary school (7.5%), primary school (27.5%) and illiterate (65%).

Table 5. 1: Demographic details of female footwear manufacturing workers (n=40)

Study variables	
Age (years)	
Mean (SD)	42.1 (13.8)
Range	18-66
Weight (kg)	
Mean (SD)	59.2 (10.2)
Range	42–80
Height (cm)	
Mean (SD)	165.2 (4.9)
Marital status (% sample)	
Married	92.5
Single	7.5
Education (% sample)	
Illiterate	65
Primary school	27.5
Secondary school	7.5

5.1.3. Job characteristics

Job characteristics of the 40 female Kolhapuri footwear manufacturing workers are presented in table 5.2. The mean daily working time is 7.8 (SD=1.5) hours. Majority of the workers were doing their work more than 2 hours continuously without break (>10 min). The percentage of each RULA score (i.e. Score A, Score B, and grand score) is also shown in table 5.2.

Table 5. 2: Job characteristics of female footwear manufacturing workers (n=40)

Study variables	
Job experience (years)	
Mean (SD)	14.7 (8.0)
Range	1–34
Daily working time (h)	
Mean (SD)	7.8 (1.5)
Range	4–10
Duration of continuous work without break (10 min)	
<1 h	37.5
1–2 h	27.5
>2 h	35.0
RULA score A (%)	
	4(10)

1–4	
≥ 5	36(90)
RULA score B (%)	
1–4	0(0)
≥ 5	100(40)
RULA grand score (%)	
1–4	0(0)
≥ 5	100(40)

5.1.4. Distribution of RULA scores

The working postures of stitching & accessories preparation are presented in figure 5.1.

a

b

Figure 5. 1: Female workers working on stitching & accessories preparation

Table 5. 3: Distribution of RULA scoring for female footwear manufacturing workers

Workstation	RULA score	Upper arms n (%)	Lower arms n (%)	Wrists n (%)	Score A	Neck n (%)	Trunk n (%)	Legs n (%)	Score B	Grand score n (%)
Stitching (n=20)	1	_	2 (10)	–	–	–	–	12 (60)	–	–
	2	4 (20)	6 (30)	-	–	2 (60)	–	8 (40)	–	–
	3	5 (25)	12 (60)	5 (25)	–	8 (40)	11 (55)	–	–	–
	4	9 (45)	–	15(75)	–	9 (45)	9 (45)	–	–	–
	5	2(10)	–	–	–	1 (5)	–	–	–	–
	6	–	–	–	5 (25)	–	–	–	–	–
	7	–	–	–	3 (15)	–	–	–	4(20)	20(100)
	8	–	–	–	8 (40)	–	–	–	11(55)	–
	9	–	–	–	4 (22)	–	–	–	5(25)	–
	Mean (SD)	3.45(0.94)	2.50 (0.68)	3.75 (1.0)	7.55 (1.09)	3.5 (0.88)	3.4 (0.51)	1.40 (0.50)	8.10 (0.78)	7 (0)
Accessories Preparation (n=20)	1	_	4 (20)	–	–	–	–	13 (65)	–	–
	2	5 (25)	8 (40)	-	–	–	3 (15)	7 (35)	–	–
	3	9 (45)	8 (40)	6 (30)	–	4 (20)	10 (50)	–	–	–
	4	5 (25)	–	14(70)	4 (20)	15 (75)	7 (35)	–	–	–
	5	1(5)	–	–	3 (15)	1 (5)	–	–	–	–
	6	–	–	–	8 (40)	–	–	–	7 (35)	4 (20)
	7	–	–	–	4 (20)	–	–	–	3(15)	16 (80)
	8	–	–	–	1 (5)	–	–	–	7(35)	–
	9	–	–	–	–	–	–	–	3(15)	–
	Mean (SD)	3.10 (0.85)	2.20 (0.76)	3.70 (0.47)	5.7 (1.16)	3.8(0.48)	3.2 (0.69)	1.35 (0.48)	7.3 (1.1)	6.8 (0.41)

The percentage of each RULA score (i.e. Score A, Score B, and grand score for each body part) is shown in table 5.3 Stitching and preparation of various parts were considered for posture analysis. The upper arms score of both workstations workers was generally 3.45 and 3.10, which means that the upper arms were slightly abducted and flexed between 45° and 90°. The lower arms score for the majority of workers was also between 2 and 3, indicating working across the midline of the body with elbow flexion less than 60° or more than 100°. The wrist score was between 3 to 4, which means that the wrists of workers were in extension (sagittal plane) of up to 15° and twisted mainly in mid-range. The neck and trunk scores of the majority of footwear workers was in between 3 and 4. This indicate that the workers' necks and trunks were in more than 20° to 60° flexion to the front. Due to the awkward sitting postures of the footwear making workers, the risk scores of the legs were found to be stressful. The final RULA grand score was ranged from 6 to 7 with an average score of 6.1. Table 5.4 also shows that no one of the workers had the final RULA grand score of 1 or 2, which is an acceptable working posture.

Table 5. 4: RULA grand score observed in female footwear manufacturing workers (n=40)

RULA		Final score (scale 1–7) Mean (SD)	p[a]
Grand Score	Stitching	7 (0)	0.013
	Preparation of various parts	6.8 (0.41)	

The mean RULA grand scores of stitching and preparation of various parts were 7 and 6.8 respectively shown in table 5.4. To investigate further, RULA grand score considers for statistical analysis (ordinal regression). The analysis revealed that the RULA grand score was statistically different from each other (as shown in Table 5.3). The posture score A of preparation of various parts and stitching workers were compared by Mann–Whitney test and similarly, posture score B also compared by the same test. A Mann–Whitney test indicated that the posture score A was greater for stitching workers (Mdn = 27.60) than for preparation of various parts (Mdn = 13.40), U=58, p=0.0001). Similarly, posture score B, A Mann–Whitney test indicated that the posture score A was greater for stitching workers (Mdn = 552) than for preparation of various parts (Mdn = 268), U=123.5, p=0.029). This has been found from statistical significance difference in final/grand score among the two workstations (Stitching and Accessories preparation). Although, the grand score is significantly different between these two workstations, individual grand score indicate an immediate intervention to enhance the posture. Therefore, workstation design of both the operation was taken into consideration for intervention.

5.2. Intervention for stitching workstation

The major consideration of this intervention was local context, no impact on traditional stitching method, availability of space, etc.

5.2.1. Stitching task & its artisan

In terms of skill, stitching is a very important task for Kolhapuri hand crafted-footwear manufacturing process. A sale and quality of hand crafted footwear depends on the stitching quality carried out by artisan. Workers having one year of continuous stitching experience is considered as an experienced worker having accurate stitching skill and can produce quality products. In the present study, experienced workers were considered.

In stitching task, nylon, threads, and wax are used for the sewing operation. Figure 5.2 shows a traditional stitching operation.

Figure 5. 2: Stitching task and its outcome

The majority of the workforces of stitching and accessories preparation are female who wares traditional Indian attire while doing the job. Consideration of regular clothing is very important in the local context and home-based workstation design.

Figure 5. 3: Female artisans clothing style

5.2.2. Design development

The design intervention process may follow an originality design method or adaptive design method or variant design method. The selection of the design method depends upon the context-specific of the design problem. It also depends upon user/customer requirements vs. the availability of existing products (Otto K.N., 2003).

5.2.3. User requirements

The requirements of female artisans for the new design were collected from a focus groups verbal discussion technique. Moreover, it helped to understand the demand for female stitching artisans regarding proposed workstation. It was challenging for the artisans to express the accurate method to achieve a quality product as these jobs were very much skill dependent and no standard method was readily available. Hence, naturalistic (Otto K.N., 2003) observation was attempted. A thorough observation along with video recording was the only possible way to understand the complexity of job and workstation. By this, context-specific requirement identification for the workstation was achieved.

The requirement summary from focus groups discussion and naturalistic observations are stated below:

- The new design expected to provide a seating arrangement elevated from the floor with necessary adjustments like forward-backward (anterior-posterior), inferior-superior movement of seating arrangements. It is likely making a natural or ideal sitting posture for a fatter/slimmer, taller/shorter, mid-aged or older (above fifty) and experienced female artisans, who work more than 2 hours continuously. It should solve the difficulties with present stitching task that is being performed on the floor in a crossed leg seating posture. Present stitching seating position constrain the anterior-posterior movement and does not allow to keep their legs in relax position over a longer duration of work.
- The proposed design needs to provide a clamp/hold arrangement for the working material (sole-leather) with necessary adjustments like forward-backward, angular movement of working material to support a high-level of visually and physically skill demanding task. It should possibly solve the present difficulties of holding a working material with a foot (in folded knee posture), refer figure 5.1.

- This craft industry is home based in nature, a lot of infrastructural development for the craft is not affordable by the craftsmen. Therefore, any new design needs to be low cost with a simple operation which can be operated by even an illiterate person. It should also help a fresher or less experienced young artisan to become a skilled artisan.

5.2.4. Solution through readily available stitching workstation

In order to satisfy the female artisan's requirements, a market survey was conducted for currently available hand-woven sole stitching related workstation. Some of the existing hand-woven leather stitching workstations were found through online makers like eBay, kentsaddlery and leather craft pattern. The commercially available stitching workstations (antique stitching pony or stitching pony) are shown in figure 5.4. These workstations are in use for handmade shoemaking in western countries. These types of workstations are of low cost and provide seating support for the thighs of workers. The inspiration of new design development for stitching workstation was an arrangement of these stitching ponies. Although, direct adaptation of the same types of ponies was not possible because of the local context. The traditional attire of native Indian female is SAREE which resist the female to occupy a posture where both legs needs to be separated by any narrowly flattened sit (refer figure. 5.3). This clothing style resists the leg range of motion of the female artisans while performing the task. Further, the currently available stitching ponies are also not having sufficient structure to hold leather sole.
On the other hand, few workstations are available which provides proper material clamping feature. However, the cost is very high and it is not affordable by the craftsmen. Therefore, taking inspiration in existing stitching pony, and local context and craftsmen's responses, a new design development was carried out.

Figure 5. 4: Commercially available stitching equipment

5.2.5. Proposed concept

A concept was proposed (figure 5.5) by considering the idea of existing products, requirements of users and existing design guidelines for similar industries (Veisi et al., 2016). Based on the design, a brief CAD model of newly conceptualized stitching pony was prepared and tested virtually for its ergonomics aspects.

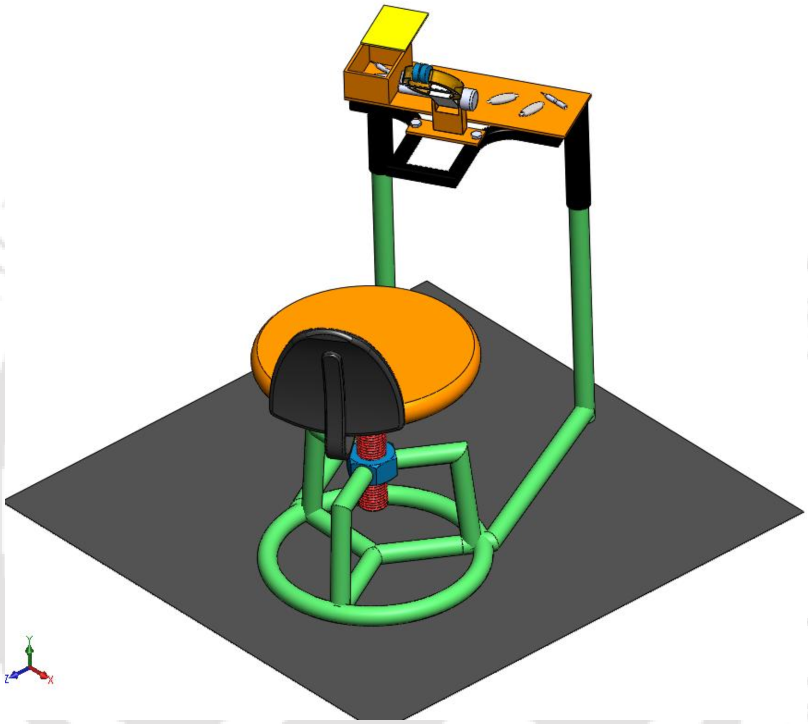


Figure 5. 5: Developed stitching workstation

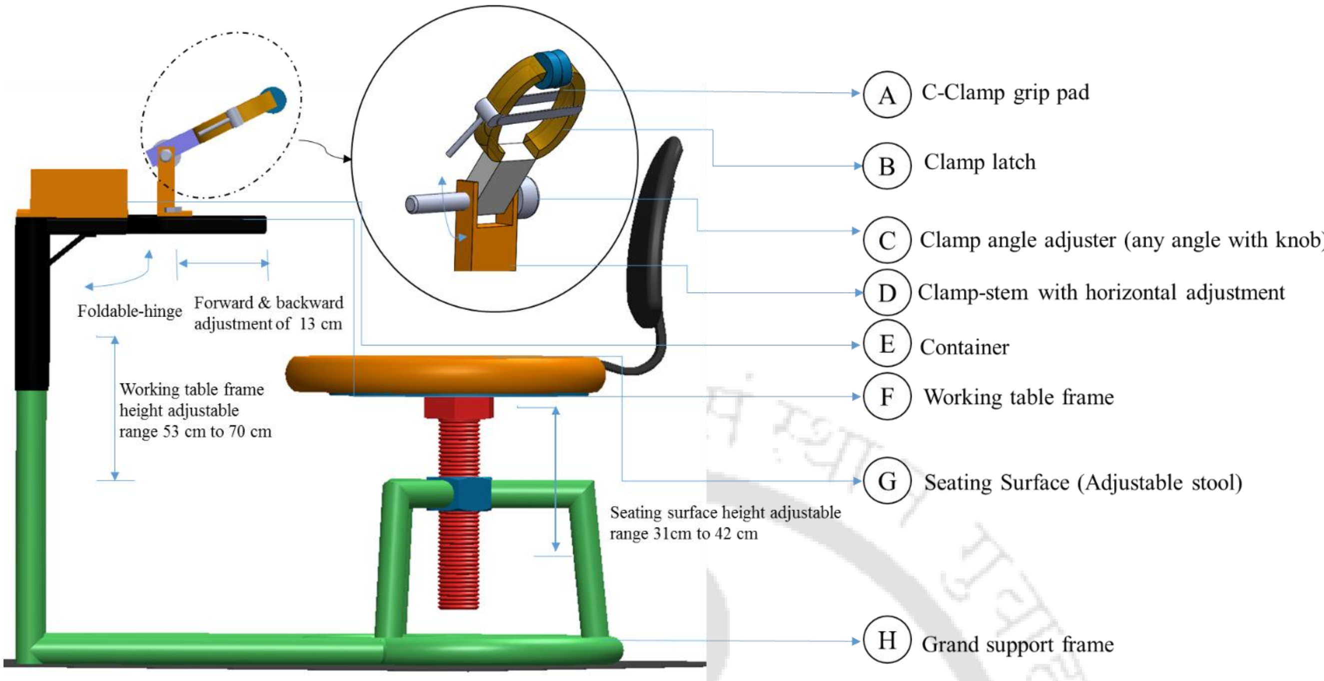


Figure 5. 6: Proposed stitching workstation and its major parts

The functional description of proposed stitching workstation (figure 5.6) parts are as follows:

(A) C-Clamp grip pad is to hold the base/upper sole (material) while stitching. It might make the task controllable and easier.

(B) Clamp latch has been provided in one of the 'C' clamps to lock/unlock the sole material during stitching operation. The locking and unlocking mechanism work in such way that two metal strips connected c-clamps and the latch moves up/down for lock/unlock.

(C) Clamp angle adjuster is to offers 180^0 free angular adjustment for the base/upper sole (material) while stitching. This helps to cover the area of the base/upper sole with fewer hand movements during stitching operation. It can be operated by adjusting the knob provided beside the clamp-stem.

(D) Clamp-stem is including with c-clamp grip setup and angular adjuster setup. It can move front/back and lockable in desired location. The front/back range of clamp-stem (0-13 cm adjustment) assist the female artisans to move the sole material instead of their anterior-posterior movements.

(E) A small container is kept in the working table for storage the stitching tools like a needle, nylon thread, etc.

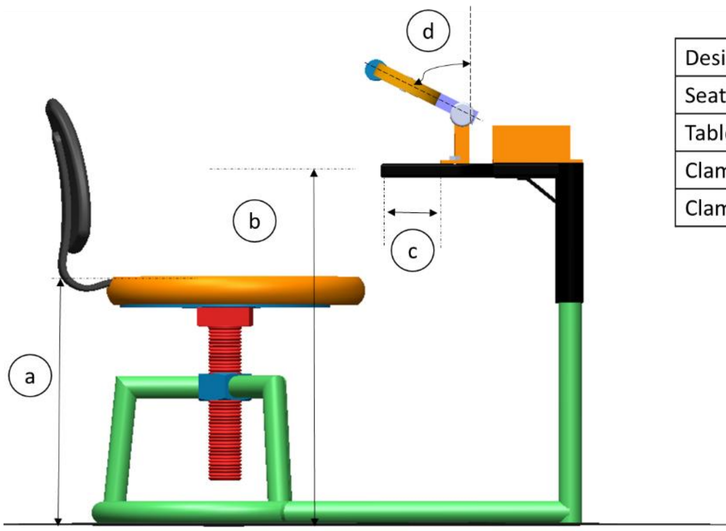
(F) Working table frame is comprised with a small container and clamp setup, which aids in angular/front/back adjustments for a better artisanship like satisfying visual and physical demands. The working table frame has a height adjustable range of 17 cm (53 to 70 cm from the ground to working table surface), which allows a comfort leg groom space for a wide range of people. It can regulate at every 4 cm through a buckle lock. This frame can fold through a hinge, which solves the purpose of storage and egress after work.

(G) Seating surface with a backrest affords an adjustable range of 11 cm (31 to 42 cm from the ground to seating surface) by a stud-bolt and nut setup under the seat. The seat height can be controlled by rotating the stud-bolt. These siting arrangements support a female artisan to maintain a natural posture with less fatigue over a period of more than 2 hours without a break of less than 10 min.

(H) Grand support frame connects the seating surface and working table frame with a circular cross-section tube. This rigid frame maintains stability thought-out the stitching task.

The proposed design avails various adjustable features like such as (a) seat height, (b) table height, and (c, d) clamp angular/forward/backward adjustments (notated and shown in figure 5.7). The adjustable ranges are hypothetically furnished in the proposed design. These furnished adjustments may or may not be suitable for a local female artisan. Even though it suits, the best comfortable combination of seat/table/clamp adjustments is unknown. The compatibility evaluation of proposed design for a desire human population would be possible using virtual digital human modeling method. This method would also help to find out where seat/table/clamp adjustments were fit for a comfortable stitching operation by users covering at least 90% of the female along with clearances and vision capabilities.

From initial observation, it was found that the working posture of sewing female worker demands a forward leaning posture for better stitching activity. However, the backrest has been provided for additional support to get some relaxation during rest time.



Design Parameters	Notation
Seating surface height	a
Table height from floor	b
Clamp distance (forward move)	c
Clamp rotate adjustment	d

Figure 5. 7: Adjustment parameters of the stitching workstation

5.3. Digital human modeling simulation for ergonomic assessment

The digital human modeling (DHM) simulation approach as adopted for the sole cutting operation was considered for ergonomic analysis of newly designed stitching workstation. Computer-aided Design (CAD) of proposed stitching station is created. The CAD model of the proposed design created in solid works involves use of commands such as part features - extruded and revolved, sketch, assembly features like move, mate etc.

5.3.1. Vision analysis

This aid to investigate the best visibility of stitching material in the binocular view field of female DHM models by iterating design parameters. Subsequently, the boundary condition applied are view cone angle 25^{o}, focus distance 300 mm and binocular view display scale 1:2. It was observed that best visibility of stitching material was obtained within recommendation limit of 25^{o} view cone at 15^{o} to 16^{o} head flexion of percentiles (as shown figure 5.8).

Figure 5. 8: Vision analysis of 95th percentile, 50th percentile and 5th percentile of female

5.3.2. Thigh clearance analysis

Thigh clearance helps to examine the distance available between the thighs of female DHM models and work table. The design variable changed repeatedly to get sufficient clearances for all percentiles. Following iteration, the clearance was obtained as 52.4 mm, 54.0 mm, and 61.7 mm for 5th percentile, 50th percentile, and 95th percentile respectively (as shown in figure 5.9). The observed results were found within allowable limits for a free movement of the thigh.

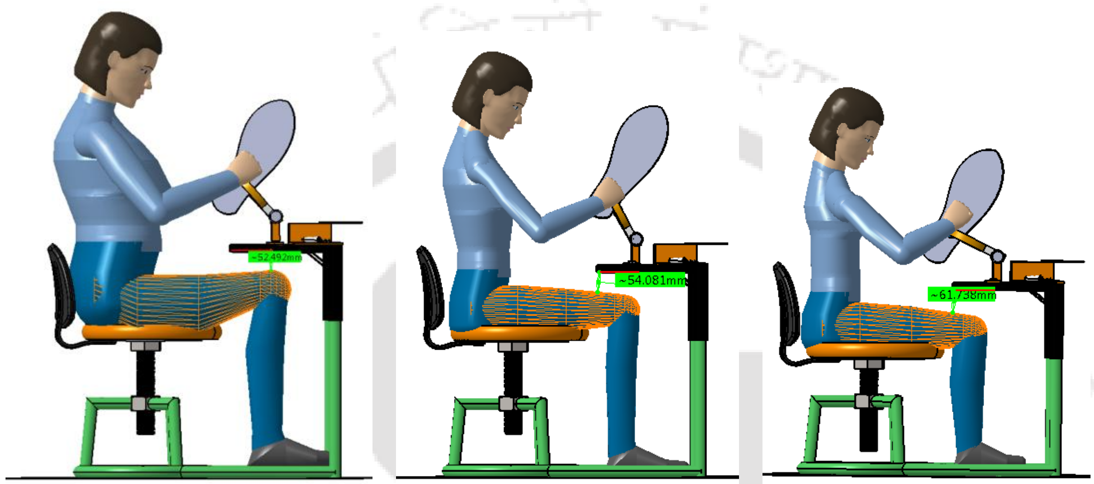


Figure 5. 9: Thigh clearance analysis 95th percentile, 50th percentile and 5th percentile of female

5.3.3. Comfort analysis - using RULA

Stitching job was identified as sedentary in nature and newly designed stitching workstation demands a seating working posture. Therefore, RULA was adopted for postural load identification. The result of RULA in the software simulated environment is shown in figure 5.10.

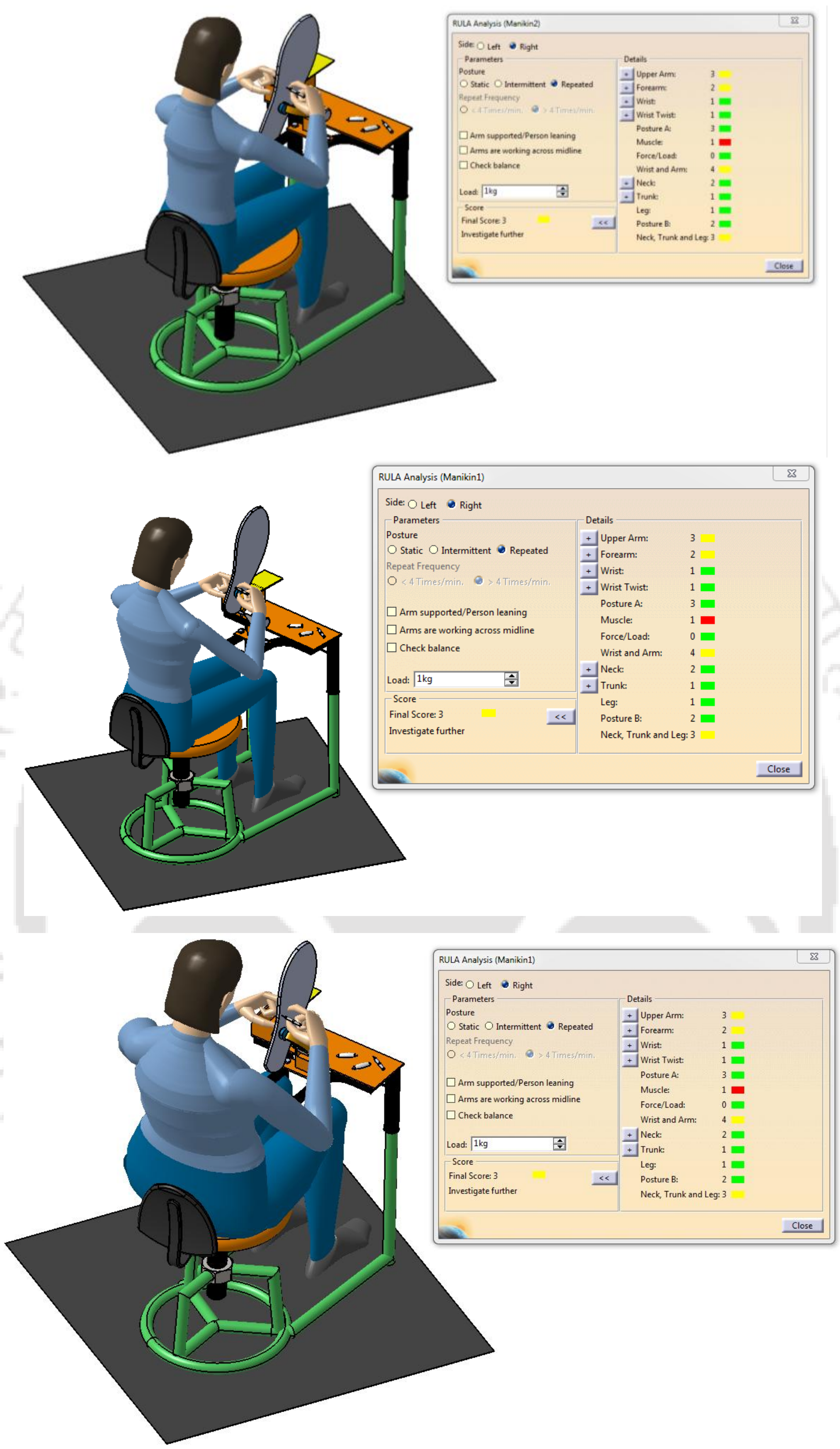


Figure 5. 10: Comfort analysis - RULA of 5th percentile, 50th percentile, and 95th percentile, of female (top to bottom)

The RULA score revealed that newly designed stitching workstation improved the work posture substantially (earlier grand score-7; current score-3).

For the RULA grand score 3, all three types of percentile design dimensions of newly designed stitching workstation are presented in Table 5.5.

Table 5. 5: Improved RULA Scores with design variables

		95th P	**50th P**	**5th P**
Design Parameters or variables	Seating surface height	394.56	402.36mm	353.77mm
	Table height from floor	615.165	567.96mm	518.10mm
	Clamp distance adjustment	0 mm (maximum backward adjustment)	67.73mm (forward move)	86.33mm (forward move)
	Clamp angular adjustment	37.41°	28°	62.3°
RULA Scores	Posture A	3	3	3
	Posture B	2	2	2
	Grand Final	3	3	3

5.4. Intervention of context-specific multipurpose workstation

Result of postural analysis in the earlier part of this chapter revealed that posture adopted by female workers need immediate intervention to enhance the working conditions. To understand the existing workstation pattern of accessories preparation, previously recorded videography and photography were reanalyzed. It was found that the existing workstation is nothing but a small wooden block mounted on a marble stone. Also, it was found that the same workstation is being used for skiving, punching, color pasting and trimming. Therefore, a multipurpose common workstation was planned to design which will help all craftsmen (apart from stitching, sole and strip cutting) to occupy their traditional seating posture, although posture will be more close to natural alignment.

Physical local market and online market were searched for any workstation which can readily use as a multipurpose workstation for Kolhapuri crafted footwear manufacturing. Therefore, a need for new design conceptualization was taken into consideration. A new design concept (figure 5.11) of multipurpose workstation was generated based on the user's requirement, field survey, nature of work, tools to be used, availability of space, natural (following native culture) way of siting etc.

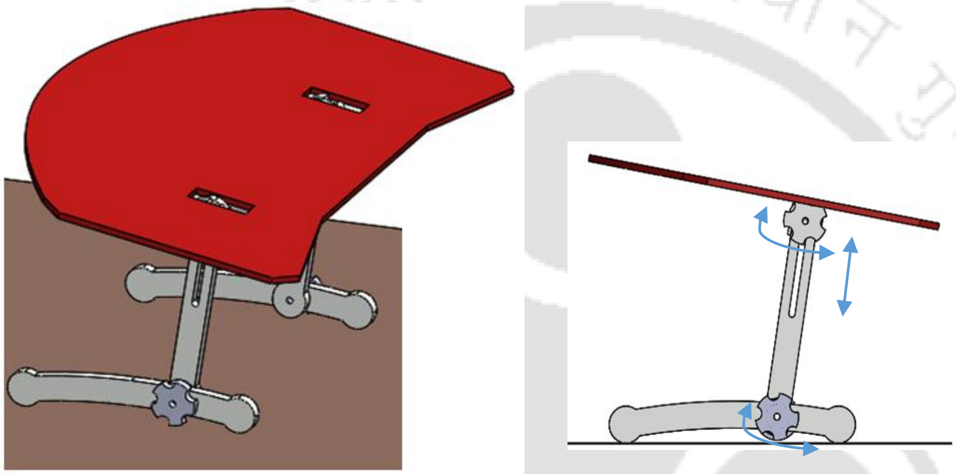


Figure 5. 11: CAD model of the proposed multipurpose workstation without dimension

At the first step of workstation design, relevant anthropometric data is essential (Pheasant, 1987). But there is no ready data available for design development of this context-specific multipurpose workstation. Based on the requirement selected anthropometric variables were measured from local populations (craftsmen). The measured anthropometric variables were normal sitting height, erect sitting height, mid shoulder, right knee, elbow to elbow relaxed, knee to knee, right buttock-knee length, arms reach length, and heights. Definitions and measuring procedures of these variables were referred from Chakrabarti D., (1997). The entire data was collected according to the Helsinki protocol (2001). The total number of participants was 35 including both gender, age ranged from 18 to 66 years. The data is presented in table 5.6.

Table 5. 6: Anthropometric body dimension of workers

S.No	Parameters			Percentiles					
	R.No	Parameters	Minimum	5th	50th	95th	Maximum	Mean	±SD
1	200	Normal sitting height	669	670	801	861	864	783	68
2	201	Erect sitting height	710	712	871	940	951	843	78
3	202	Mid shoulder	485	489	572	830	846	572	79
4	203	Right Knee	170	189	231	268	561	237	62
5	205	Elbow to Elbow relaxed	389	478	532	620	622	540	48
6	206	Knee to Knee	498	509	578	720	723	605	74
7	207	Right buttock-knee length	427	450	513	552	556	506	31
8	209	Arm reach lengths and heights	1119	1154	1283	1442	1448	1309	89

5.4.1. CAD model development with a featured dimension of proposed multipurpose workstation

The multipurpose workstation was designed for shorter and taller people with height adjustment provision to avoid height mismatch. Local anthropometry data was considered for defining the design dimensions. The CAD model of the proposed multipurpose workstation is shown in figure 5.12.

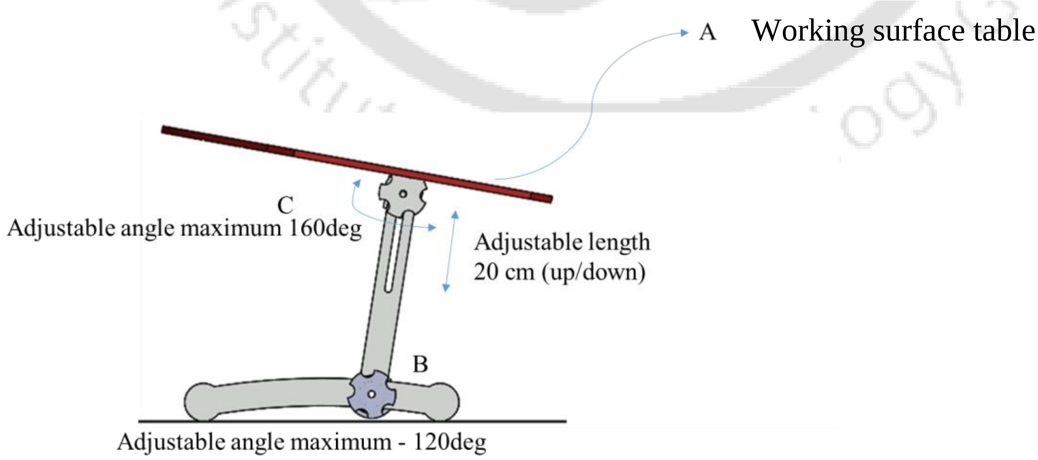


Figure 5. 12: CAD model of proposed multipurpose workstation

The detailed description of various parts are shown in figure 5.12 as follows.

- A- Working surface table, with angular adjustability of C, the dimensions are overall length 991mm, overall breath 700 mm and thinness 10 mm.
- B- Angular adjustable knob for table-leg, which helps to adjust the angle of table legs and kept it stable for regular work.
- C- Angular adjustable knob for table-working-surface, which helps to adjust the angle of the table working surface to keep the working surface comfort for all percentiles.

5.4.2. Virtual simulation of Context specific multipurpose workstation for ergonomic assessment

The digital human modeling (DHM) simulation approach as adopted for the sole cutting operation was considered for ergonomic analysis of newly designed context specific multipurpose workstation. Computer-aided Design (CAD) of the proposed workstation is created. The CAD model of the proposed design was created in CATIA V5 software.

5.4.3. Vision analysis (multipurpose workstation)

The proposed multipurpose workstation model was integrated with 95^{th} percentile male, 50^{th} percentile male and 5^{th} percentile female respectively (Figure 5.13). Vision analysis is the best visibility of working activity in the binocular view field of DHM models, by iterating design dimensions. The focus distance is 300 mm while all three percentiles were interfaced with the proposed workstation. Neck flexion was 18^{o}, 17^{o} degrees and 17^{o} degrees respectively with focal distance 300 mm. It was observed that the best visibility of the working surface was obtained within recommendation limit of 25^{o} view cone at 10^{o} head flexion for all percentiles.

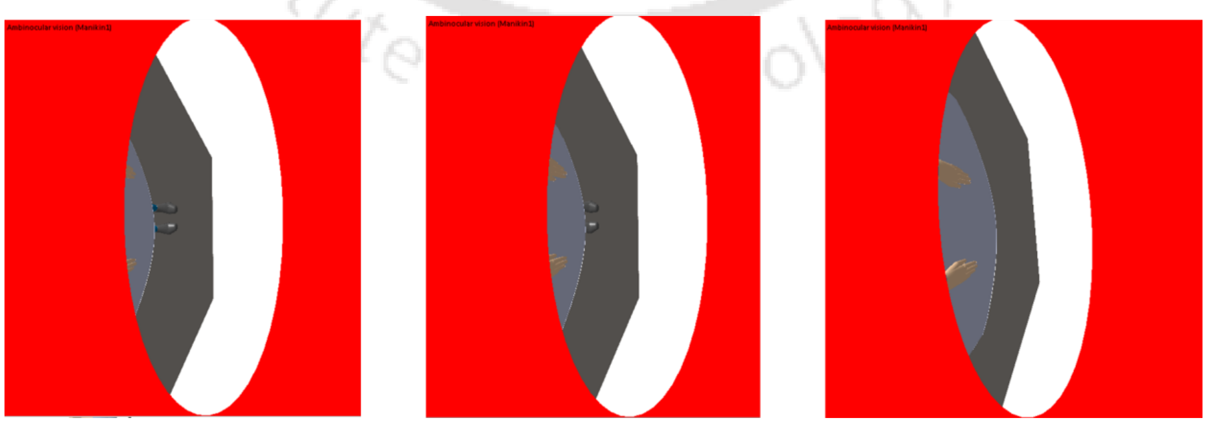


Figure 5. 13: Vision analysis 95^{th} p male, 50^{th} p male, and 5^{th} p female

5.4.4. Thigh clearance analysis (multipurpose workstation)

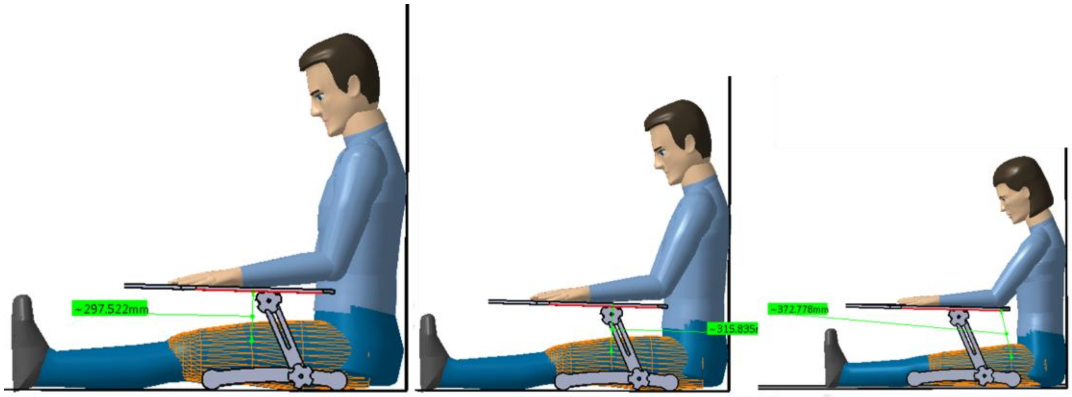
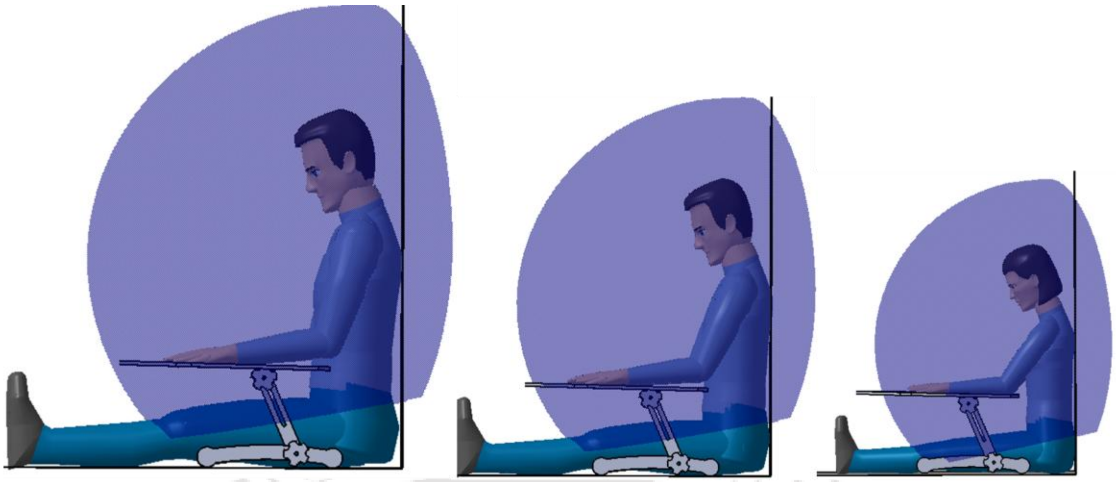


Figure 5. 14: Thigh clearance analysis 95th p male, 50th p pooled, and 5th p female

The DHM analysis confirms that proposed design has sufficient thigh clearance (300 mm, 315 mm and 372 mm for 5th percentile, 50th percentile, and 95th percentile respectively) for all three types of percentile consideration within allowable limits for free movements of the thigh (figure 5.14).

5.4.5. Reach analysis (multipurpose workstation)

The unreachable distance of 95th percentile male, 50th percentile pooled, 5th percentile female (figure 5.15) from the edge of the table was 0, 2 and 5 cm respectively at 70⁰ table working surface angle. The nature of work confirms that workers need to perform their task within the midline of the body and keeping material closer to the body. Therefore, the unreachable peripheral area will not hamper much on craftsmen job.



Unreachable distance of 95th p male from the edge of the table is 0 cm @ 70deg table working surface-angle

Unreachable distance of 50th p pooled from the edge of the table is 2 cm @ 70deg table working surface-angle

Unreachable distance of 5th p female from the edge of the table is 5 cm @ 0deg table working surface-angle

Figure 5. 15: Reach analysis 95th p male, 50th p pooled and 5th p female

5.4.6. Postural load analysis (multipurpose workstation)

The results observed are as follows: RULA grand score of '3' each for P 95th, P50th & P5th percentile for all percentiles, which indicates negligible risk level in certain design conditions (as shown in figure 5.16).

Figure 5. 16: RULA analysis of 95th p male, 50th p pooled, and 5th p female

Both workstation (stitching and multipurpose) design helps to improve postural load exposure keeping the basic nature of task intact. Virtual simulation models were discussed with craftsmen involved in varieties of the job involved in Kolhapuri crafted footwear manufacturing. The respondents apparently accepted the designs and were satisfied, mentioning comfortable, easiness, postural improvement, etc. Both the design virtually confirmed that human comfortability was taken care with satisfactory results. Human comfortability in any workplace is one of the important aspects of productivity improvement in terms of quality and quantity (Vink et al, 2006). Therefore, it is expected that implementation of all interventions operation, as well as workstation, will help the craftsmen to enhance the quality of the crafted product, save time, posture, etc. At the beginning of the study, phenomenon of less motivation and interest in the ancient craft was notified by the various stakeholders. But after discussing all varieties of intervention proposed in this research with craftsmen, gave inner willing to revive their craft was conceptualized. In view of the above, a need was felt to understand the impact of all varieties of the proposed intervention on the revival of Kolhapuri crafted footwear manufacturing.

Chapter VI-Impact of proposed intervention on the revival of craft

The purpose of this part of the study was to disseminate the study outcome towards the society so that grassroots level craftsmen can be benefited. To achieve that local state government policy maker (Maharashtra Khadi Gramodyog Mandal (MKGM)) was contacted. After understanding all the interventions in terms of operational involvement, functionality, operative procedure, space requirement, its impact on the essence of craft, quality and quantity of the product, productivity, the efficiency of workers, personal comfort, cost involvement, etc. MKGM agreed to support the new interventions so that the very ancient craft of Maharashtra, India can once again keep their significant footprint in national and international market although, it was challenging for researchers to confirm the above without longitudinal study.

It was predicted end user's responses may give an understanding of level of acceptance of these interventions. Keeping that in mind total four workshops along with Maharashtra Khadi Gramodyog Mandal (MKGM) and all stakeholders were held to discuss the varieties of features of all interventions (sole & strip cutting, stitching, and multipurpose workstations). The characteristics of participants are shown in table 6.1. As this crafted manufacturing process is very much cottage/home based in nature, it was difficult to differentiate the nature of each stakeholder. For example, a craftsman who has better financial background may work as an entrepreneur. If the same person is interested in community work, he can be a member of cobbler community/co-operative society. Therefore, major two varieties (craftsmen & entrepreneurs) of stakeholders were considered for analysis of responses. Proper registration was maintained to understand the nature of the involved participants.

Table 6. 1: Location wise Workshop participant

Workshop No.	Workshop Location	No. of Craftsmen	No. of Entrepreneurs
1	Kolhapur	80	24
2	Panhala	59	22
3	Kale	72	31
4	Gadhinglaj	72	21

Content analysis (Downe W., 1992) was taken an approach to understand responses given by the stakeholders during workshops. The content analysis is a flexible method, used in qualitative research and employs extensive choice of questioning techniques to generate conclusions or results and put them in a particular context (Marilyn & Marsh, 2006; White M., 2006). The content analysis is classified into two categories such as conceptual and relational type analysis. These types of analysis find the phrases of texts among the concepts (Siregar et al, 2011).

Overall reviews were carried out by participants of the workshops of all interventions. The review was obtained from them as they are the one who will implement these interventions in the actual context. Eighty-two percent of participants of the workshop actively participated in the survey. The survey was conducted in three phases consecutively. One phase was consisting of sole and leather strip cutting dies along with workstations, the second phase was stitching workstation and the third phase was multipurpose workstation. Sole and leather strip cutting was demonstrated physically about its functionality, operational procedure, and relevant information. Both stitching & multipurpose workstation was explained to the participants using digital mode, various printed handouts, verbal description about its function and arrangement.

Participants of each workshop were divided into three groups and each group was asked to give their views about their understanding of all four interventions. The responses were collected in an unstructured manner. Questions were asked as "how they like the intervention?", how they find it useful for their craft?, how do they think the intervention will affect the ancient nature of the craft?, how they find interesting to use these interventions in their day to day manufacturing process?, how valuable these interventions are for them in terms of continuing their craftsmanship?, how affordable these interventions are?, how they plan to host these interventions at the workplace? and how they would like to share the facility with other craftsmen? etc. From the descriptive answers, common text was identified and put into a logical manner to interpret participant's view about all these interventions. Various phrases were used as a factor to interpret the intervention. The phrases are useful for their craft in following ways: craft modernization, easy to use, impact on craft, helpful for continuing the job, less force exertion, affordability, maintenance, safety, quality of the finished product, etc. The answers were interpreted to grade above-mentioned factors in three categories. The sentence which gives wide appreciation and 'wow' feelings about the intervention was considered as excellent, second which gives feeling of moderate acceptance was considered as good and all negative comments were considered as bad.

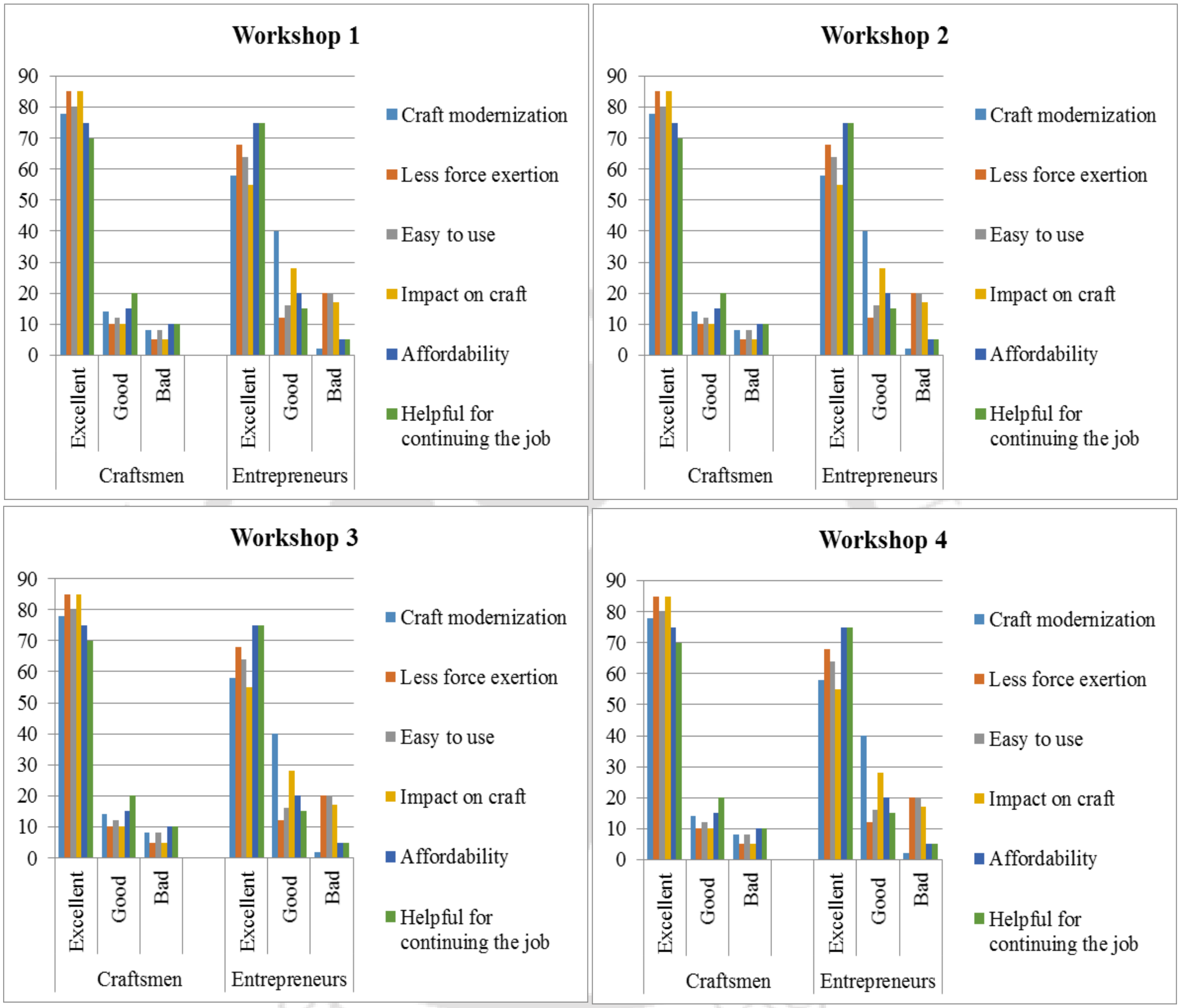


Figure 6. 1: Feedback of sole and leather strip cutting dies along with workstation

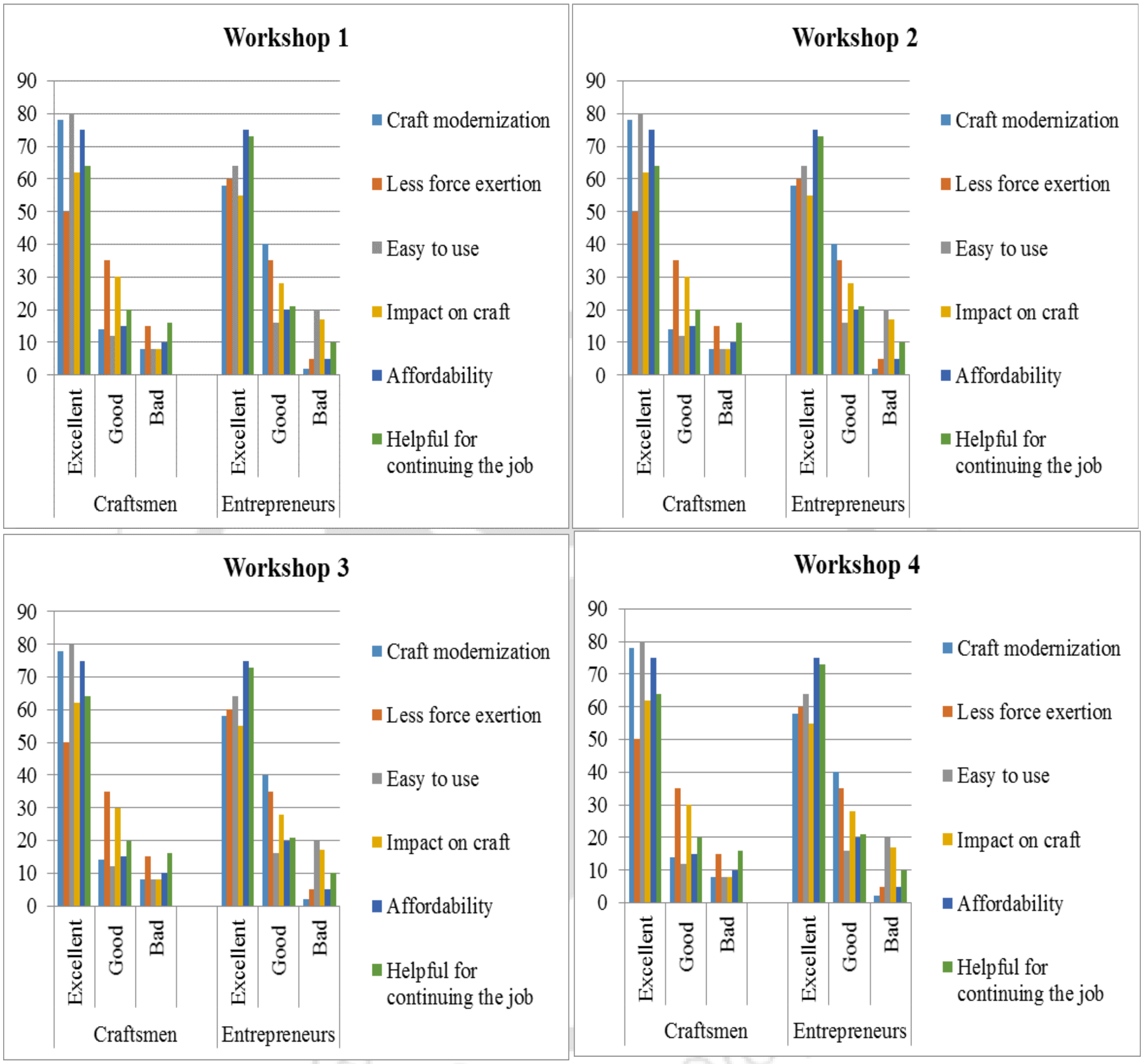


Figure 6. 2: Feedback of stitching workstation

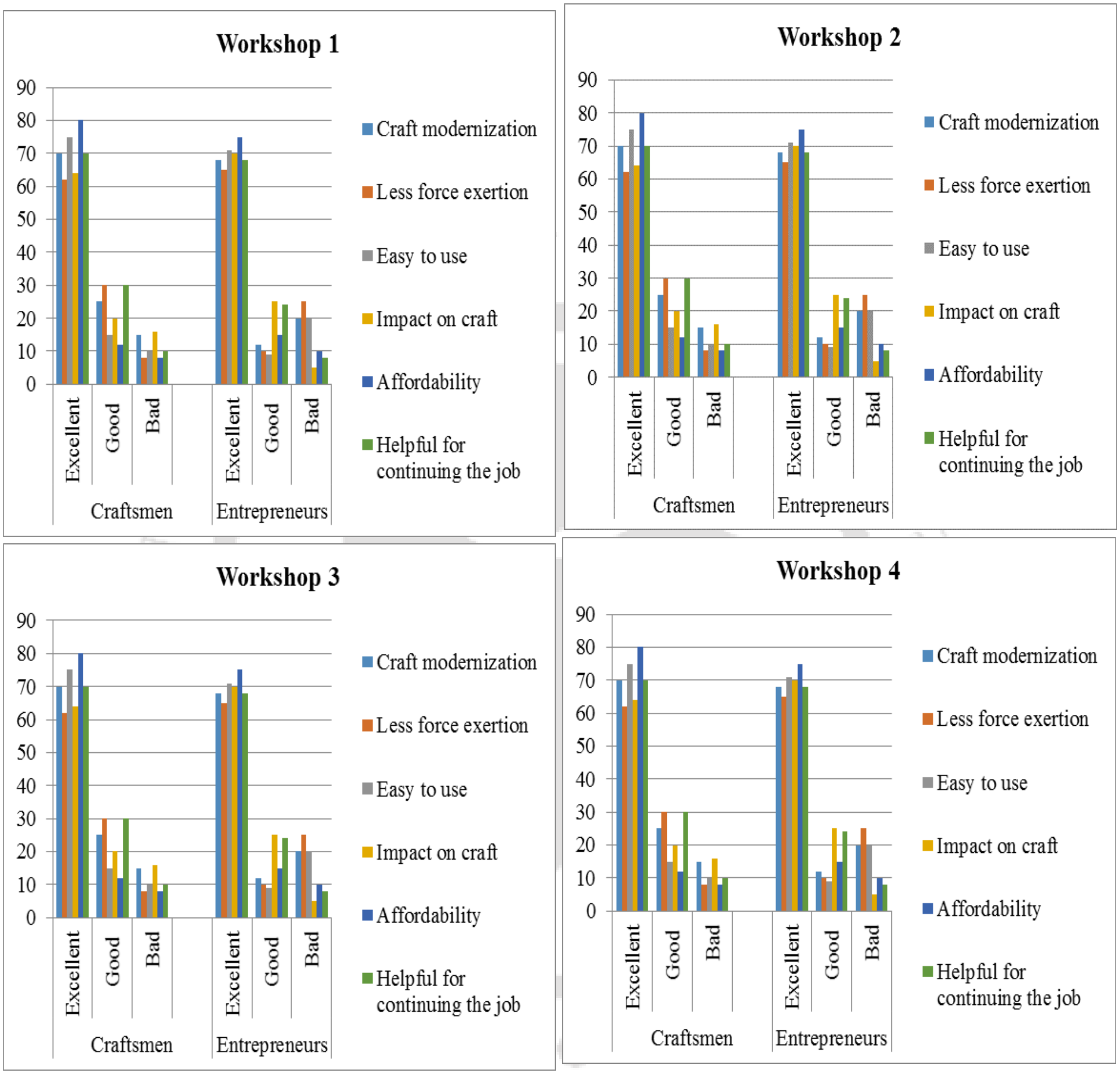


Figure 6. 3: Feedback of multipurpose workstation

The results of the content analysis of the interviews are presented in the following figures 6.1, 6.2 and 6.3. The results of the content analysis revealed that the majority of the artisans and entrepreneurs expressed their wide acceptance for all the interventions. They appreciated the effort of the research team for taking an interest in this ancient craft. Involvement of government agency further confirmed proposed interventions has a direct impact on the craft and the related society. Government agency also confirmed, and took an initiative to host all these interventions in a common resource center. Many entrepreneurs raised their interest to host these interventions at their place for their own enterprise and also to share their knowledge and experience with other craftsmen on payment basis.

All the above findings give an indication that all the interventions will help the craftsmen community to revive their ancient craft. Although, the implementation of interventions in actual was not possible to evaluate due to time constraint and can be considered as a limitation of this study.

Chapter VII-General discussion and conclusion

7.1. Discussion

The current research aimed to understand various reasons of inculcating interventions in ancient hand craft manufacturing of Kolhapuri footwear. Throughout the research, various causes/bottlenecks were identified and possible solution in terms of the technical intervention was provided. The study was comprised of both quantitative and qualitative analysis of the research data.

This study is not the first evidence where technological intervention is taken as an approach for revival/revitalization of any craft or traditional manufacturing (Kapur and Mittar, 2014; Ghouse S., 2012). Although, a detailed description of those interventions is not readily available for methodological adaptation. Also, direct technological adaptation of any other industry to revive this specific craft-based industry was not possible because the nature of the process & operations, used tools & equipment, the importance of specific essence of craft, context-specific requirement. Therefore, this study has novelty in terms of various new interventions and methodological description to revive any such craft related dying industry.

A general methodology which has been followed in this particular research work is as follows.

1. Identifying the current status of the industry.
2. Analyzing the nature and process followed in the industry.
3. Identification of various bottlenecks in the manufacturing process.
4. Categorizing those identified bottlenecks based on the weightage of the problem.
5. Analysis of detailed operation and workers involved in the job.
6. Participatory approach to derive intervention brief.
7. Development modification and testing of the intervention keeping ergonomics principle as a major consideration.
8. Promoting the intervention program involving government agencies along with native craftsmen community of the specific craft.
9. Analyzing the participatory responses of the stakeholders about the intervention.

10. Conducting a motivational and awareness program to up-lift the specific craft.

11. The above methodology can be adopted for any such relevant area although specific changes and modification are required based on the context of research.

Figure 7.1 represents flow chart of general methodology.

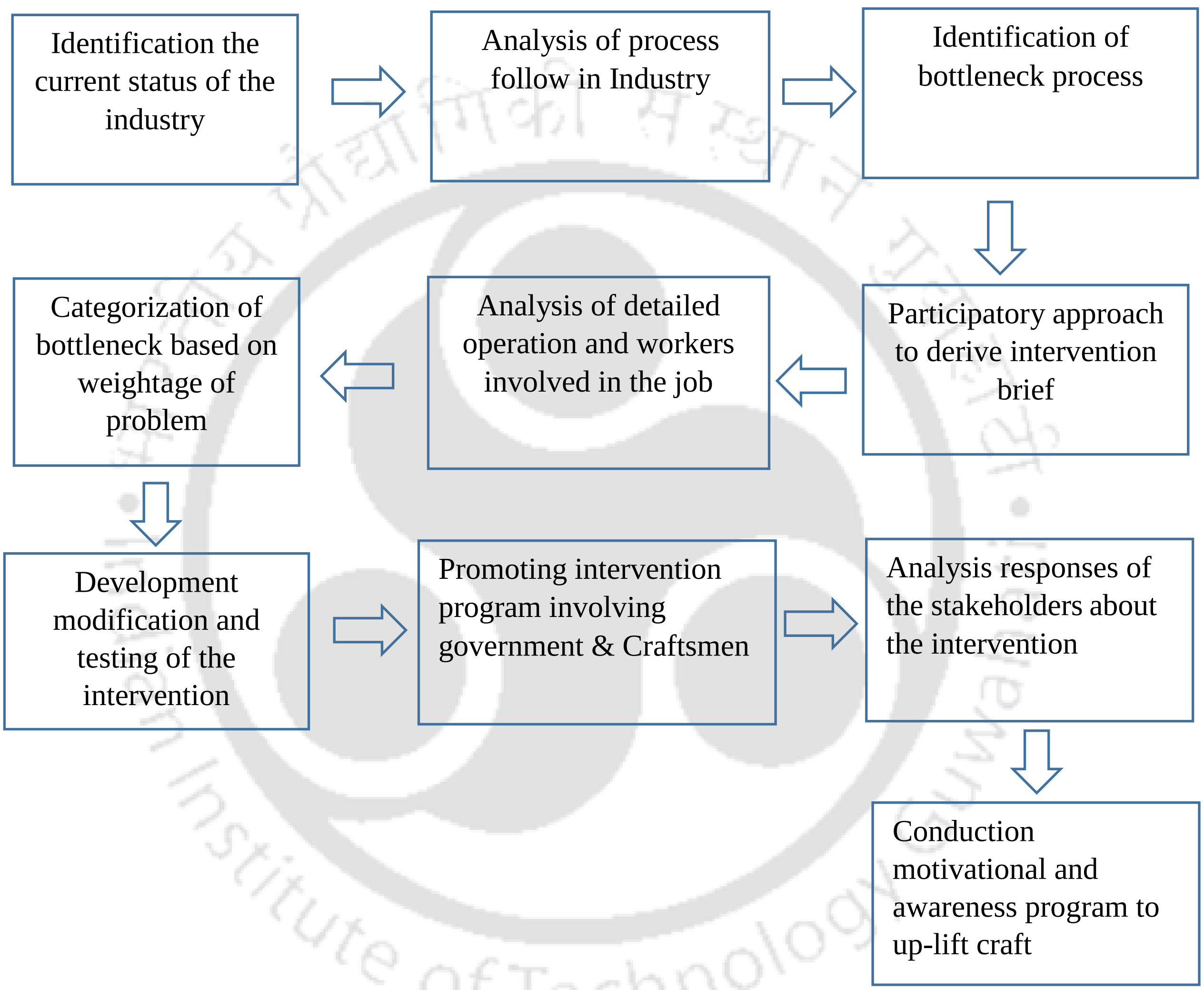


Figure 7. 1: Flow chart of general methodology

7.2. Conclusion

Kolhapuri footwear manufacturing is an elite craft which is glorious from ancient history. In today's date, it is obsoleted in nature and causal factors were identified namely as manufacturing process, primitive nature of tools and equipment's, diminishing the interest of local habitat in this craft. It has been found through analysis, ergonomic design intervention (partial atomization, workstation design) improved manufacturing process as well as productivity without affecting the actual essence of the craft. Improved manufacturing process created a temporal space for the local habitat to rethink on the craft, skill development initiative, product diversification, business opportunities, etc. Social workshops were conducted in various sessions. The data indicated that there is a need for above-mentioned design interventions and will be accepted by the society in a positive manner. Young enthusiasts from local habitat may take up insight into these interventions and rejuvenate the identity of Kolhapur by showcasing Kolhapuri footwear in the domestic and international market.

7.3. Limitations

On field implementation of all the interventions and collecting data regarding actual long term impact of these interventions on the craft, was not possible due to time constrains.

7.4. Future scope

The current research proposed interventions mainly based on operation and craftsmen wellbeing from ergonomics perspective using design methodology. However, there are other varieties of possible intervention such as product diversification, aesthetic modification, packaging, supply chain & marketing, craft promotional exhibitions, and many others.

References

Acharya B. (1985). Study of Scheduled Caste Leather Workers: Socio-Economic conditions in Karnataka. *Sociological Bulletin*, 22, 206-220.

Acheson E., Pipped E., Winter P. (1982). Nasal cancer in the Northamptonshire boot and shoe industry: Is it declining? *British journal of cancer*, 46, 940-949.

Aghali M., Asilian H., Parinaz P. (2012). Evaluation of Musculoskeletal Disorders in Sewing Machine Operators of a Shoe Manufacturing Factory in Iran, *Journal of Pakistan Medical Association*, 62, 20-25.

Ahmed R. (1996). Development Perspectives of Indian Footwear Industry. Women's Employment in Industry A case of Indian Footwear CLRI Chennai & Department of Human Geography, University of Amsterdam the Netherlands, 71-74.

Basu S. K. (2010). Status of Leather Industry in India, *Laghu Udyog Samachar*, 78, 9-15.

Bhoite R.H. (2015). Socio-economic study of unorganized domestic leather artisans and labor in Mumbai in the post-globalization era. Thesis (Ph.D.). Dept. of Economics. Pune University, 81-92.

Bhosale B. V. (2000). Leather Artisans in the informal sector of Mumbai, Informal Sector in India: Challenges and Consequences, Published by LAP Lambert Academic Publishing, Germany, 77-79.

Binoosh S., Mhadan M., Ashok P., Dhana S., (2017). Virtual postural assessment of assembly work in a small scale submersible pump manufacturing industry. *Work*, 58(4), 567-578.

Bogdan S., Aura M., Mariana C., Elena R. (2017). Comparative anthropometric study regarding the foot of elderly female population. *Procedia Engineering*, 18, 182-186.

Burute Prakash Y. (2014). Sustainable livelihood of leather artisans in Kolhapur district. Thesis (Ph.D.). Department of economics, Shivaji University Kolhapur, Maharashtra, India, 39-43.

Champoux, D., Brun, J. (2003). Occupational health and safety management in small size enterprises: an overview of the situation and avenues for intervention and research. *Safety Science*, 41 (4), 301–318.

Chakrabarti D. (1997). Indian anthropometric dimensions for ergonomic design practice. ISBN - 8186199150. India: National Institute of Design.

Changrong C., Tan W., Hengan O., Yan H., Xianzhi T. (2014). A review on the remanufacture of dies and molds. *Journal of Cleaner Production,* 64, 13-23.

Corlett E. A. and Bishop R. P. (1976). The technique for Assessing Postural Discomfort, *Ergonomics,* 19 (2), 175-182.

Cullen M. Moleejane, Kazeem O., Olukayode L., Ayodele, Graeme J. (2014). Microstructural features and mechanical behavior of unalloyed medium carbon Steel (EN8 Steel) after subsequent heat treatment. Proceedings of the World Congress on Engineering and Computer Science, 2, 22-24.

Dianat I., Salimi A. (2014). Working conditions of Iranian hand-sewn shoe workers and associations with musculoskeletal symptoms. *Ergonomics*, 4, 602-611.

Dootchai C., Natthiya T., Siriporn J. (2008). Proper shoe sizes for Thai elderly. *The Foot*, 18, 186–191.

Downe W. (1992). Content analysis: method, applications, and issues. *Health care for women international*, 13(3), 313-321.

Franklin Pereira, (2000). Artistic leatherwork in India- the sandal makers of Kolhapur. *The Leather crafters journal,* 6, 8-11.

Ganguly S. (2008). Agra-Centre of the Indian Footwear Industry. *World Footwear*, 7, 79-93.

Gangopadhyay S., Ara T., Dev S., Ghoshal G. and Das T. (2011). An Occupational Health Study of the Footwear Manufacturing Workers of Kolkata, India. *Studies on Ethno-Medicine*, 5 (1), 11-15.

Ghosh A. (2012). Triggering innovation and creativity in traditional handicrafts sectors - An Indian perspective. *Management Insight,* 8(1), 67-71.

Ghouse S. (2012). Indian handicraft industry: problems and strategies. *International Journal of Management Research and review*, 7, 1183-1199.

Giri P.A., Meshram P.V., Kasbe A.M. (2012). Socio-demographic determinants and morbidity profile of people engaged in bag making an occupation in an urban slum of Mumbai, India. *National Journal of Community Medicine*, 3, 601-606.

Gupta S., Rocky G. and Ronak T. (2007). Challenges faced by the leather industry in Kanpur. Project report, 15-45.

G. Madhan Mohan, Prasad P., Sudarmathi V. (2008). Simplified procedure to analyze work posture of foundry men through the rapid upper limb assessment. *International Journal of Environment and Health*, 2(2), 225-238.

Haik, Y., & Shahin, T. (1997). Engineering Design Process. Cengage Learning. 102- 106.

Hani U., Das A. (2017). Design Intervention in the Handloom Industry of Assam: In the Context of a Debate between Traditional and Contemporary Practice. *Research into design and communities*, 1 (65), 999-1006.

Hazara K., Barman (2017). Prospect of traditional craft in present economy: a study of the earthen doll of Krishnagar, West Bengal. *International Journal of Management.* 8, 75-81.

Hendrick (2003). Determining the cost–benefits of ergonomics projects and factors that lead to their success. *Applied Ergonomics*, 34, 419-427.

Jadhav G., Jamadar V., Gunwant P., Gajghate S. (2014). Role of Kaizens to Improve Productivity: A Case Study. *Applied Mechanics and Materials*, 592, 2689-2693.

Karmakar, S., Pal, M. S., Majumdar, Deepti, & Majumdar, D. (2012). Application of digital human modeling and simulation for vision analysis of pilots in a jet aircraft: a case study. Work: A Journal of Prevention, Assessment, and Rehabilitation, 41, 3412-3418.

Kadam D. (1984). A study of leather and footwear industries in Kolhapur City, M.Phil Dissertation submitted to Shivaji University, Kolhapur. 33-37.

Kamble E. (2002). Transition in Socio-Economic Status of Artisans with specific reference to Charmakars. In: Informal Sector in India: Challenges and Consequences, LAP Lambert Academic Publishing, Germany. 17-32.

Kamble B.S. (2004). An economic analysis of leather footwear units: A case study of Athani taluka in Belgaum district. Thesis (Ph.D.). Dept. of Economics. K.L.E. Society's, G.I. Bagevadi College Nipani. 21-27.

Kapur H., and Mittar S. (2014). Design intervention and craft revival. *International Journal of Scientific and Research Publications*, 4 (10), 719-722.

Kaur P. 2011. The revival of Punjab's Traditional Handicraft: Phulkari. *Asian Journal of Management*, 2 (1), 28-38.

Keyserling, W. M., Brouwer, M., & Silverstein, B. A. (1992). A checklist for evaluating ergonomic risk factors resulting from awkward postures of the legs, trunk, and neck. *International Journal of Industrial Ergonomics*, 9(4), 283-301.

Kristensen B., Fallentin N., Ekdahl C. (1997). Criteria for classification of posture in repetitive work by observation method: A review. *International Journal of Industrial Ergonomics*, 19, 397-411.

Knorringar Peter (1998). Economics of Collaboration in Producer-Trader Relations: Transaction Regimes between markets and hierarchy in the Agra Footwear cluster. *Small Business Economics*, 10 (2), 193-195.

Kumar, Subas C. (1997). Indian Leather Industry: Growth, Productivity, and Export Performance, APH Publication, New Delhi, 6-9.

Lathra Y. (2000). Footwear Trade; Emerging Market and India's Opportunities. *Leather age*, 1, 123-129.

Lee J., Mou J., Shen Y., (1997). Sampling strategy design for dimensional measurement of geometric features using a coordinate measuring machine. *International Journal of Machine Tools and Manufacture*, 37 (7), 917-934.

Loewenson R. (2000). Occupational Hazards in the Informal Sector: A Global Perspective. *Health effects of the new labor market*, 16, 329–342.

Luximon, A., Goonetilleke, R.S., Tsui, K., 2003. Footwear fit categorization. In: The Customer Centric Enterprise. *Advances in Mass Customization and Personalization*, 7, 491-499.

Luximon A.,Luximon Y., 2009. Shoe-last design innovation for better shoe fitting. *Computers in Industry*, 60, 621–628.

Magnusson M.L. and Pope M.H. (1998). A review of the biomechanics and epidemiology of working postures. *Journal of sound and vibration*, 215, 965 – 976.

Madan A. 2013. The Power of Innovation: Craft Revival, Empowerment and Sustainable Livelihood. *Department of Economics*, 13-23.

Martina M., Fedrica G. (2016). Knitwear design new visions: smart- K project. How the traditional craft methodologies are evolving into new scenarios thanks to technological innovation. School of Art & Design Nottingham Trent University Nottingham, UK, 338-343.

McAtamney, L. and Corlett E. (1993). RULA: A survey method for the investigation of work-related upper limb disorders. *Applied Ergonomics*, 24, 91-99.

McCann, M. (1996). Hazards in Cottage Industries in Developing Countries. *American Journal of Industrial Medicine; 30*, 125–129.

McCann, D., Barrett, A., Cooper, A., Crumpler, D., Dalen, L., Grimshaw, K., Sonuga-Barke, E. (2007). Food additives and hyperactive behavior in 3-year-old and 8/9-year-old children in the community: a randomized, double-blinded, placebo-controlled trial. *The lancet*, 370(9598), 1560-1567.

Minh K.P. (2014). Work-related depression and associated factors in a shoe manufacturing factory in haiphong city. Vietnam. *International Journal of Occupational Medicine and Environmental Health*, 27, 950-958.

More S., Vyavahare R., (2014). Anthropometric and grip strength data of agricultural workers for Marathwada region of Maharashtra (India). *International Journal of Applied Engineering and Technology*, 4(2), 148- 153.

Naidu Krishnamma (1996). Enterprises Products and Impact of changes in Footwear Industry, Women's Employment in Industry the ease of Indian Footwear. CLRI Chennai.

Nathalie B., Franck Z., 2010. The Impact of Technology on Creativity in Design: An Enhancement? *Creativity and Innovation Management*, 19 (2), 180-191.

Okudan, G. E., & Tauhid, S. (2008). Concept selection methods–a literature review from 1980 to 2008. *International Journal of Design Engineering*, 1(3), 243-277.

Otto, K. N. (2003). Product design: techniques in reverse engineering and new product development. 156-159.

Patil R. B. (2002). Marginal Communities in Leather Industry Informal Sector in India: Challenges and Consequences. LAP Lambert Academic Publishing, Germany. 114-117.

Pheasant, S. (1987). Some anthropometric aspects of workstation design. *International journal of nursing studies*, 24(4), 291-298.

Pheasant, S. (1991). Ergonomics, work and health. Macmillan International Higher Education.

Pugh, S., & Clausing, D. (1996). Creating innovative products using total design: the living legacy of Stuart Pugh. Addison-Wesley Longman Publishing Co., 115-119.

Rafeeq A. (1996). Development Perspectives of Indian Footwear Industry'. A case of Indian footwear CLRI Chennai and Department of Human Geography, University of Amsterdam the Netherlands. pp.53.

Rajkumar Phatate. (2011). Toe-Hold Artisans Collaborative: A Case of transforming Necessity-based entrepreneurs to opportunity-based entrepreneurs, India. *Journal of Management Policy and Practice*, 12, 39-51.

Ramakrishnappa V., PriyaKumari M., Vishwanatha J. (2014). Unorganized Workers in Beedi Industry: A Study on Women Beedi Rollers of Karnataka, India. *International Journal of Social Science*, 3,325-334.

Rao P. (2001). Effective marketing strategies for augmenting footwear exports from India. *Leather Age*, 1, 151-157.

Reid C., Pamela M., Waldemar K., Samiullah K., Durrani J. (2010). Occupational postural activity and lower extremity discomfort: A review. *International Journal of Industrial Ergonomics*, 40, 247–256.

Robertson M., Michael J. (2003). Reducing musculoskeletal discomfort: effects of an office ergonomics workplace and training intervention. *International Journal of Occupational Safety and Ergonomics*, 9 (4), 491-502.

Sanjog, J., Karmakar, S., Agarwal, H., & Patil, C. D. (2012). Designing and ergonomic evaluation of a shoe-rack in a CAD environment. *International Journal of Computer Applications*, 49(20), 38-41.

Sanjog, J., Patnaik, B., Patel, T., & Karmakar, S. (2016). Context-specific design interventions in blending workstation: an ergonomics perspective. *Journal of Industrial and Production Engineering*, 33(1), 32-50.

Sarkar S. (1998). Indian craft technology: Static or Changing- A case study of the Kansari's craft in Bengal, 16th 18th century. *Indian journal of history and sciences*, 33-53.

Sarkar S. (2010). Report of a nationwide survey on leather products; Chennai, Marketing channels published by CLRI, 162-166.

Salve U., Jadhav G. (2018) Analysis of posture adopted by female Kolhapuri Chappal (footwear) manufacturing workers India. *Advances in Intelligent Systems and Computing*. *Springer*, 826, 278-286.

Salve U.R., Jadhav G.S., Shete H.K. (2017). Design solution of shoe sole (base of the footwear) preparation in traditional hand sewn footwear manufacturing: A Case Study on Kolhapuri Chappal. *Advances in Ergonomics in Design*. *Springer*, 588, 995-1013.

Selvakumar and R. Sundar (2007). Leather Industry Scope for Export, Published by Science Tech Entrepreneur magazine, Aug 2007, 103-109.

Sethi, R., Duque C., Vencatachellum I. (2005). Designers Meet Artisans, A Practical Guide, Craft Revival Trust, New Delhi, 2005, 92-94.

Shan Y., Paul M., Carl T., Carlos H. (2013). A comprehensive analysis of project management practices to improve craft productivity. *Construction Specialty Conference*. 95, 1-12.

Shaaz Abulais, (2014). Current research trends in electric discharge machining (EDM): Review. *International journal of scientific & engineering research*, 5(6), 100-118.

Shinde G., Jamadar V., Jadhav G., Yadav V. (2015). Stress Analysis of Connecting Rod using FEA. *International journal of engineering and management research*, 19, 233-238.

Sinha S., Sinha Saurabh. (1994). Indian Leather Industry. The challenge of modernization, Oxford and IBH Publishing Company Pvt. ltd., New Delhi, 41-46.

Sheriff M., Chandramouli D., Das B., 2000. Footwear trade emerging market: India's Opportunities. *Leather Age*, 1, 22 - 24.

Siregar, Suzanna Lamria, Giovanni Battista Dagnino, and Francesco Garraffo (2011). Content Analysis and Social Network Analysis: A Two-Phase Methodology in Obtaining Fundamental Concepts of Competition. *Journal Ilmiah Ekonomi Bisnis*, 14(2), 1-11.

Sturm V., Peter L., Noll R. (2000). Steel analysis with laser-induced breakdown spectrometry in the vacuum ultraviolet. *Applied Spectroscopy*, 54, 1275-1278.

Sumangala D. and Pallavi M. (2008). Leather industry in India' published by centre for education and communication (CEC), New Delhi, 10-13.

Subhrajit Chatterjee (2015). The ancient craft of Dhokra: A case study at Bikna and Dariapur in West Bengal. *International Journal of Interdisciplinary Studies*, 1, 19-23.

Szadkowska S., Woyniak H, Stroszejn M. (2003). Health effects of occupational exposure among shoe workers. A review. *Medycyna pracy*, 54, 67-71.

Szubert Z, Wilczynska U, Sobala W. (2001). Health risk among workers employed in rubber footwear plant. *Medycyna pracy*, 52(6), 409-416.

Taylan A.,ltana B., Lillyb Y., YenaT. (2001.) Manufacturing of dies and molds. *CIRP Annals*, 50 (2), 404-422.

Tiwari R. (2013). Child labor in the footwear industry: Possible occupational health hazards, *Indian Journal of Occupational & Environmental Medicine*, 9, 7-9.

Todd L, Puangthongthub S., Mottus K., Mihlan G., Wing S. (2008). Health survey of workers exposed to mixed solvent and ergonomic hazards in footwear and equipment factory workers in Thailand. *An Occupational Hygiene*, 52, 195-205.

V. B. Bhandari, (1995). Design of machine elements third edition. Tata McGraw hill. 41-43.

Vieira E., Ramos V. , MaysaV., Larissa B., Wilza V., Joao D., Paulo R., Veiga Q. (2015). Symptoms and risks for musculoskeletal disorders among male and female footwear industry workers. *International Journal of Industrial* Ergonomics, 48, 110-116.

Veisi, H., Choobineh, A. R., & Ghaem, H. (2016). Musculoskeletal problems in Iranian hand-woven shoe-sole making operation and developing guidelines for workstation design. *The international journal of occupational and environmental medicine*, 7(2), 83-87.

Venkatachalam R. (2013). Role of SHGs in empowering women through craft revival- A Case Study of KaiKrafts. 130-133.

Vink, P., Koningsveld, E. A., & Molenbroek, J. F. (2006). Positive outcomes of participatory ergonomics in terms of greater comfort and higher productivity. *Applied Ergonomics*, 37(4), 537-546.

White, M. D., & Marsh, E. E. (2006). Content analysis: A flexible methodology. *Library Trends*, 55(1), 22-45.

Zhan X., Stuart W., Ricardo H., Pardo K., Martyn E. (2017). Craft and Sustainability: Potential for Design Intervention in Crafts in the Yangtze River Delta, China. *The Design Journal*, 20(1), 2919-2934.

Xiao Ma, Luximon, A., Zhang Y. (2011). The Application of Toe-deletion and Ankle Deformation Technique in Shoe Fitting Assessment. *Proceedings of the human factors and Ergonomics*, 55(1), 1644-1648.

Indian culture (Kolhapuri footwear), (August 2017). Retrieved from http://www.indianmirror.com/culture/indian-specialties/kolhapurifootwear.html

Chowdhury S., (2016). A festival of footwear with crafts of India. Retrieved from https://www.telegraphindia.com/1160406/jsp/t2/story_78468.jsp

Authentic leather Kolhapuri Chappals, (2016). Retrieved from

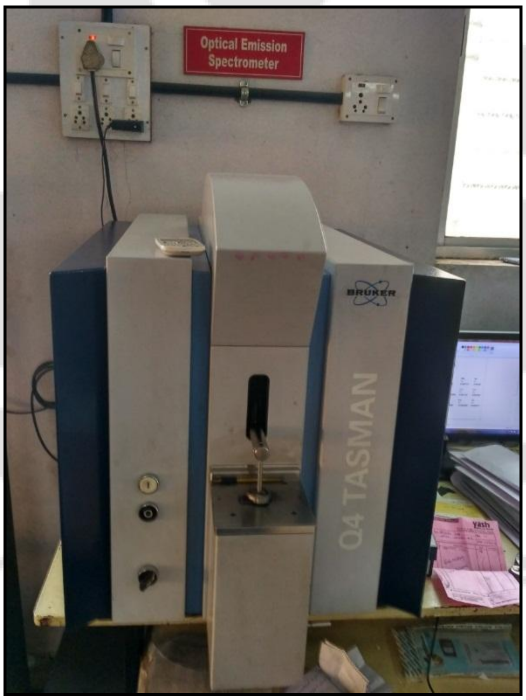
https://kolhapurichappal.co.in/kolhapuri-chappals

Appendices

Appendix I Optical Emission Spectrometer

Optical Emission Spectrometer (OES)

Optical Emission Spectrometer (OES) is usually used for metal analysis. It works on the principle of arc and sparks excitation. In an Atomic Emission Spectroscopy, the concentration of light is released from a flame or arc at a specific wavelength to regulate the quantity of an element in the specimen. This method is used to determine the chemical composition of metallic samples. The application of this process is mainly used in metal manufacturing industries, ferrous foundries and in die casting manufacturing.



Optical Emission Spectrometer (OES)

Appendix II - Time study sheets

Time study sheet of skiving operation

Time Study Sheet			
Time study Engineer:	Ganesh Jadhav	Date:	4-Nov-16
Product:	Kolhapuri footwear	Crew:	1
Product Family:	Chappal	Posture:	Sitting
Machine/Tool:			
Operation:	Skiving		

Sr. No.	**Element Description**	**Basic Time (Min)**	**Allow. (%)**	**Std. Time (Min)**
1	Cutting operation	0.6	9%	0.71
			Total Standard Time (Min):	0.71
			Available Time for Production/Shift (Min):	
			Output/Shift (Units):	

Time study sheet of profile cutting operation

<table>
<tr><th colspan="5">Time Study Sheet</th></tr>
<tr><td colspan="5">Name: Ganesh Jadhav   Date: 4-Nov-16
Product: Kolhapuri footwear   Crew: 1
Product Family: Chappal   Posture: Sitting
Machine/Tool:
Operation: Cutting Profile Pattern</td></tr>
<tr><th>Sr. No.</th><th>Element Description</th><th>Basic Time (Min)</th><th>Allow. (%)</th><th>Std. Time (Min)</th></tr>
<tr><td>1</td><td>Profile Cutting operation (Cutting Profile of the footwear)</td><td>2.1</td><td>9%</td><td>2.33</td></tr>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="4">Total Standard Time (Min):</td><td>2.33</td></tr>
<tr><td colspan="4">Available Time for Production/Shift (Min):</td><td></td></tr>
<tr><td colspan="4">Output/Shift (Units):</td><td></td></tr>
</table>

Time study sheet of grinding operation

Time Study Sheet			
Name:	Ganesh Jadhav	**Date:**	4-Nov-16
Product:	Kolhapuri footwear	**Crew:**	1
Product Family:	Chappal	**Posture:**	Sitting
Machine/Tool:			
Operation:	Grinding		

Sr. No.	**Element Description**	**Basic Time (Min)**	**Allow. (%)**	**Std. Time (Min)**
1	Grinding Operation	0.3	9%	0.38
			Total Standard Time (Min):	0.38
			Available Time for Production/Shift (Min):	
			Output/Shift (Units):	

Time study sheet of polishing operation

Time Study Sheet			
Name:	Ganesh Jadhav	**Date:**	4-Nov-16
Product:	Kolhapuri footwear	**Crew:**	1
Product Family:	Chappal	**Posture:**	Sitting
Machine/Tool:			
Operation:	Polishing		

Sr. No.	Element Description	Basic Time (Min)	Allow. (%)	Std. Time (Min)
1	Polishing operation	1.3	9%	1.40
			Total Standard Time (Min):	1.40
			Available Time for Production/Shift (Min):	
			Output/Shift (Units):	

Time study sheet of punching operation

Time Study Sheet				
Name:	Ganesh Jadhav		**Date:**	4-Nov-16
Product:	Kolhapuri footwear		**Crew:**	1
Product Family:	Chappal		**Posture:**	Sitting
Machine/Tool:				
Operation:	Punching			
Sr. No.	**Element Description**	**Basic Time (Min)**	**Allow. (%)**	**Std. Time (Min)**
1	Punching Operation	0.8	9%	0.89
			Total Standard Time (Min):	0.89
			Available Time for Production/Shift (Min):	
			Output/Shift (Units):	

Time study sheet of pasting operation

Time Study Sheet			
Name:	Ganesh Jadhav	**Date:**	4-Nov-16
Product:	Kolhapuri footwear	**Crew:**	1
Product Family:	Chappal	**Posture:**	Sitting
Machine/Tool:			
Operation:	Pasting		

Sr. No.	Element Description	Basic Time (Min)	Allow. (%)	Std. Time (Min)
1	Take a paper and paste it on the Chappal profile	0.3	9%	0.36
2	Cut paper according to profile	0.5	9%	0.59
3	Paste glue on the cutting profile	0.1	9%	0.13
			Total Standard Time (Min):	1.07
			Available Time for Production/Shift (Min):	
			Output/Shift (Units):	

Time study sheet of stitching operation

Time Study Sheet			
Name:	Ganesh Jadhav	**Date:**	5-Nov-16
Product:	Kolhapuri footwear	**Crew:**	1
Product Family:	Chappal	**Posture:**	Sitting
Machine/Tool:			
Operation:	Stitching		

Sr. No.	**Element Description**	**Basic Time (Min)**	**Allow. (%)**	**Std. Time (Min)**
1	Stitching operation	11.0	9%	12
			Total Standard Time (Min):	12
			Available Time for Production/Shift (Min):	
			Output/Shift (Units):	

Time study sheet of trimming operation

Time Study Sheet			
Name:	Ganesh Jadhav	**Date:**	5-Nov-16
Product:	Kolhapuri footwear	**Crew:**	1
Product Family:	Chappal	**Posture:**	Sitting
Machine/Tool:			
Operation:	Trimming		

Sr. No.	Element Description	Basic Time (Min)	Allow. (%)	Std. Time (Min)
1	Trimming operation	0.2	9%	0.18
			Total Standard Time (Min):	0.18
			Available Time for Production/Shift (Min):	
			Output/Shift (Units):	0

Time study sheet of water dipping operation

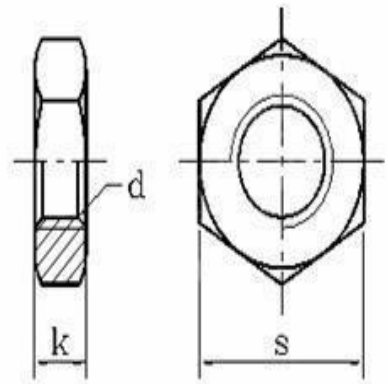
Time Study Sheet			
Name:	Ganesh Jadhav	**Date:**	5-Nov-16
Product:	Kolhapuri footwear	**Crew:**	1
Product Family:	Chappal	**Posture:**	Sitting
Machine/Tool:			
Operation:	Water dipping		

Sr. No.	Element Description	Basic Time (Min)	Allow. (%)	Std. Time (Min)
1	Water dipping operation	0.42	9%	0.46
			Total Standard Time (Min):	0.46
			Available Time for Production/Shift (Min):	
			Output/Shift (Units):	

Appendix III - Standard catalog of hydraulic cylinder

BORE mm	MM ROD	KK THREAD	A	PP BSPP PORT	VD	ΦB	WC, W	WV	ΦE MAX	P (+str)	PA	ZB (+str)	ZP, ZF (+str)	F	ΦFB	FC	UC
40	22	M16 X 1.5	22	3/8	3	50	16	13	55	63.5	40	136	150	16	9	106	125
	28	M20 X 1.5	28														
50	28	M20 X 1.5	28	3/8	4	60	18	14	65	68.5	45	147	165	20	11	126	150
	36	M27 X 2	36														
63	36	M27 X 2	36	1/2	4	70	20	16	75	70	67	171	194	25	13.5	145	175
	45	M33 X 2	45														
80	45	M33 X 2	45	1/2	4	85	22	18	95	78	77	193	223	32	17.5	165	200
	56	M42 X 2	56														
100	56	M42 X 2	56	3/4	5	106	25	20	125	100	98	246	276	32	22	200	245
	70	M48 X 2	63														
125	70	M48 X 2	63	1	5	132	28	23	150	116	138	288	318	32	22	235	280
	90	M64 X 3	85														
160	90	M64 X 3	85	1 1/4	5	160	30	25	195	143	142	354	386	36	22	280	325
	110	M80 X 3	95														
200	110	M80 X 3	95	1 1/2	5	200	35	30	245	160.5	139.5	374	412	40	26	340	395
	140	M100 X 3	112														

Appendix IV -Nut catalog



mm

d	P	k		s		1000pc weight ≈kg	d	P	k		s		1000pc weight ≈kg
		max	min	max	min				max	min	max	min	
M1.6	0.35	1	0.75	3.2	3.02	0.04	M22	2.5	11	9.9	34	33	44.85
M2	0.4	1.2	0.95	4	3.82	0.07	M24	3	12	10.9	36	35	54.26
M2.5	0.45	1.6	1.35	5	4.82	0.16	M27	3	13.5	12.4	41	40	81.19
M3	0.5	1.8	1.55	5.5	5.32	0.22	M30	3.5	15	13.9	46	45	117.4
M3.5	0.6	2	1.75	6	5.82	0.28	M33	3.5	16.5	15.4	50	49	151.1
M4	0.7	2.2	1.95	7	6.78	0.43	M36	4	18	16.9	55	53.8	202.2
M5	0.8	2.7	2.45	8	7.78	0.66	M39	4	19.5	18.2	60	58.8	260.9
M6	1	3.2	2.9	10	9.78	1.29	M42	4.5	21	19.7	65	63.1	325.2
M8	1.25	4	3.7	13	12.73	2.72	M45	4.5	22.5	21.2	70	68.1	408.6
M10	1.5	5	4.7	16	15.73	5.21	M48	5	24	22.7	75	73.1	509.4
M12	1.75	6	5.7	18	17.73	7.51	M52	5	26	24.7	80	78.1	618.9
M14	2	7	6.42	21	20.67	11.46	M56	5.5	28	26.7	85	82.8	739.2
M16	2	8	7.42	24	23.67	17.18	M60	5.5	30	28.7	90	87.8	876.9
M18	2.5	9	8.42	27	26.16	23.59	M64	6	32	30.4	95	92.8	1027
M20	2.5	10	9.1	30	29.16	31.43							

Appendix V – Questionnaire

Section 1: Personal and General Information

---

1. Name:
2. Age (Sex):
3. Gender:
4. Taluka:
5. Education: illiterate/ primary school/ secondary school
6. Marital status: (married or single)
7. Height (cm):
8. Weight (kg):
9. BMI (kg/m^2):
10. Smoking: Yes/No
11. Tobacco: Yes/No
12. Drink: Yes/No
13. Are you right-handed or left-handed?
14. How much amount of time spent on sport and other physical activities each day?____hrs.
15. Job experience: _____________ (years)
16. Daily working hours_______________ (hrs.)
17. On average, How many hours a week do you work? ______hours a week
18. How long have you been employed at your present job? ____________________
19. Number of working days in a week________________
20. Weekly working hours______________ (hrs.)
21. Perceived speed of work: Does your work require you to work very fast? Yes/No

22. How many hours do you usually work without breaks [breaks .10 min]? ______hrs.

23. Do you feel pressure due to work? Yes/No

24. Which workstation is difficult to work? ________________

(more manual effort perceived for a work)

25. How much are you satisfied with your job? Low/Moderate/High

26. Total breaks taken during the working hours in a day_________________

Section 2: Standardized Nordic Musculoskeletal Disorders Questionnaire

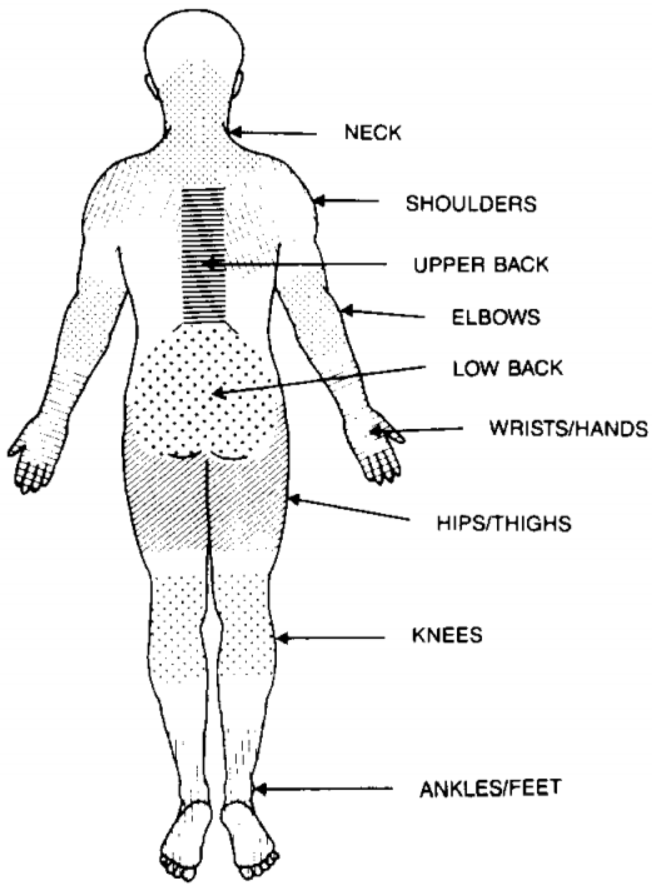
---

Trouble with the locomotive organs		
	To be answered only by those who have had trouble	
Have you at any time during the last 12 months had trouble (ache, pain, discomfort) in:	Have you at any time during the last 12 months been prevented from doing your normal work (at home or away from home) because of the trouble?	Have you had trouble at any time during the last 7 days?
Neck 1. No 2.Yes	1. No 2.Yes	1. No 2.Yes
Shoulders 1. No 2.Yes, in the right shoulder 3. Yes, in the left shoulder 4. yes, in both shoulder	1. No 2.Yes	1. No 2.Yes
Elbows 1. No 2.Yes, in the right elbow	1. No 2.Yes	1. No 2.Yes

3. Yes, in the left elbow 4. yes, in both elbow		
Wrists/hands 1. No 2.Yes, in the right wrist 3. Yes, in the left wrist 4. yes, in both wrist	1. No 2.Yes	1. No 2.Yes
Upper back 1. No 2.Yes	1. No 2.Yes	1. No 2.Yes
Low back (small of the back) 1. No 2.Yes	1. No 2.Yes	1. No 2.Yes
One or both hips/thighs 1. No 2.Yes	1. No 2.Yes	1. No 2.Yes
One or both ankles/feet 1. No 2.Yes	1. No 2.Yes	1. No 2.Yes
One or both knees 1. No 2.Yes	1. No 2.Yes	1. No 2.Yes

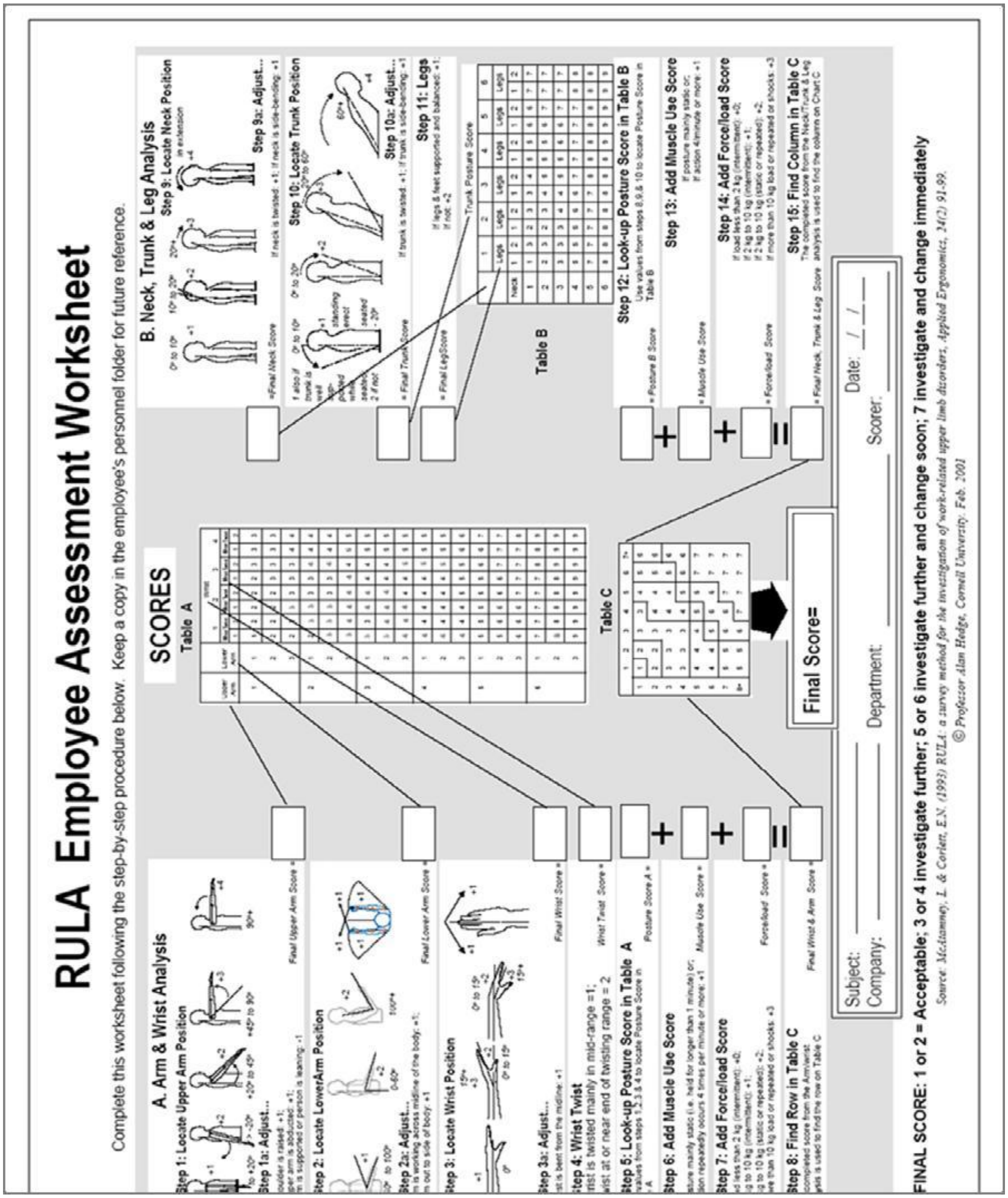
Section 3: Body Map

How much trouble (ache, pain, discomfort) in the following body parts during the last 12 months for each of the above-mentioned body regions.



Body Parts	No pain (0)	Very low pain (1)	Low pain (2)	Moderate pain (3)	High pain (4)	Very high pain (5)
Neck						
Shoulder						
Wrists/Hand						
Elbow						
upper back						
low back						
hips/thighs/buttocks						
Ankles/Feet						
Knee						

Appendix VI - RULA Self Employee Assessment worksheet



RULA Employee Assessment Worksheet

Complete this worksheet following the step-by-step procedure below. Keep a copy in the employee's personnel folder for future reference.

SCORES

A. Arm & Wrist Analysis

Step 1: Locate Upper Arm Position

Step 1a: Adjust...

Step 2: Locate LowerArm Position

Step 2a: Adjust...

Step 3: Locate Wrist Position

Step 3a: Adjust...

Step 4: Wrist Twist

If wrist is twisted mainly in mid-range =1; If wrist is at or near end of twisting range = 2

Step 5: Look-up Posture Score in Table A

Step 6: Add Muscle Use Score

Step 7: Add Force/load Score

Step 8: Find Row in Table C

Table A

Table C

Final Score=

B. Neck, Trunk & Leg Analysis

Step 9: Locate Neck Position

Step 9a: Adjust...

Step 10: Locate Trunk Position

Step 10a: Adjust...

Step 11: Legs

Table B

Step 12: Look-up Posture Score in Table B

Step 13: Add Muscle Use Score

Step 14: Add Force/load Score

Step 15: Find Column in Table C

Subject: Company: Department: Scorer: Date: / /

FINAL SCORE: 1 or 2 = Acceptable; 3 or 4 investigate further; 5 or 6 investigate further and change soon; 7 investigate and change immediately

Source: McAtamney, L. & Corlett, E.N. (1993) RULA: a survey method for the investigation of work-related upper limb disorders, Applied Ergonomics, 24(2) 91-99.

© Professor Alan Hedge, Cornell University. Feb. 2001

Appendix VII - Patent Publications

1. Title of the invention: Cutting dies for Kolhapuri Chappal and automation thereof

Jadhav Ganesh S., Salve U. R., Deshmukh S., Shete H.K., 2018. Patent application No. *201821034508*. India. The Patent Office Journal No. 50/2018, page no.47104, dated 14/12/2018.

(12) PATENT APPLICATION PUBLICATION — (21) Application No.201821034508 A

(19) INDIA

(22) Date of filing of Application :13/09/2018 — (43) Publication Date : 14/12/2018

(54) Title of the invention : CUTTING DIES FOR KOLHAPURI CHAPPAL AND AUTOMATION THEREOF

(51) International classification	:B23G 5/04	(71)**Name of Applicant :**
		1)Ganesh Suresh Jadhav
(31) Priority Document No	:NA	Address of Applicant :Flat No. BF5; Silver Woods; Banawadi
(32) Priority Date	:NA	Corner; Taluka - Karad; District - Satara; Pin 415124 Maharashtra
(33) Name of priority country	:NA	India
(86) International Application No	:NA	**2)Urmi Ravindra Salve**
Filing Date	:NA	**3)Suhas Deshmukh**
(87) International Publication No	: NA	(72)**Name of Inventor :**
(61) Patent of Addition to Application Number	:NA	**1)Ganesh Suresh Jadhav**
Filing Date	:NA	**2)Urmi Ravindra Salve**
(62) Divisional to Application Number	:NA	**3)Suhas Deshmukh**
Filing Date	:NA	**4)Hemant Kallappa Shete**

(57) Abstract :
ABSTRACT Present invention relates to cutting dies for Kolhapuri Chappal manufacturing, consists two parts one is shoe sole (cutting of base of the Chappal) and heel of the Chappal. Die for shoe and heel will together manufacture Kolhapuri Chappal, die further automate the manufacturing process as against traditional manual manufacturing which involves large no of processes and tools such as sharp edged tool (rappi), current invention helps to make the process automate and improves manufacturing speed as well as accuracy along with reduction in artisans effort.

No. of Pages : 7 No. of Claims : 7

The Patent Office Journal No. 50/2018 Dated 14/12/2018

Patent Publications

2. Title of the invention: Adjustable seating-stitching apparatus for hand-woven leather footwear in Kolhapuri

Jadhav Ganesh S., Arunachalam M., Salve U. R., 2019. Patent application No. 201921002204. India. The Patent Office Journal No. 04/2019, page no. 3263, dated 25/01/2019.

(12) PATENT APPLICATION PUBLICATION (21) Application No.201921002204 A

(19) INDIA

(22) Date of filing of Application :18/01/2019 (43) Publication Date : 25/01/2019

---

(54) Title of the invention : ADJUSTABLE SEATING-STITCHING APPARATUS FOR HAND-WOVEN LEATHER FOOTWEAR IN KOLHAPURI

(51) International classification	:A43B 13/00 A43B 3/00	(71)**Name of Applicant :** **1)Ganesh Suresh Jadhav** Address of Applicant :Flat No. BF5; Silver Woods; Banawadi Corner; Taluka - Karad; District - Satara; Pin-415124 Maharashtra India **2)M. Arunachalam** **3)Dr. Urmi Ravindra Salve** (72)**Name of Inventor :** **1)Ganesh Suresh Jadhav** **2)M. Arunachalam** **3)Dr. Urmi Ravindra Salve**
(31) Priority Document No	:NA	
(32) Priority Date	:NA	
(33) Name of priority country	:NA	
(86) International Application No	:NA	
Filing Date	:NA	
(87) International Publication No	: NA	
(61) Patent of Addition to Application Number	:NA	
Filing Date	:NA	
(62) Divisional to Application Number	:NA	
Filing Date	:NA	

(57) Abstract :

Present invention relates to adjustable seating-stitching apparatus for hand-woven leather footwearTMs in Kolhapuri footwear manufacturing. The existing stitching activity of Kolhapuri crafted footwear is carried out by female artisans in seating position. These stitching tasks carried out on floor in an awkward posture which create several ergonomics issues and cause a poor quality of footwear. The current invention helps to reduce ergonomics issues and improve productivity, accuracy of manufacturing without affecting original work flow (main essence of craft) of female artists.

No. of Pages : 10 No. of Claims : 6

The Patent Office Journal No. 04/2019 Dated 25/01/2019

Appendix VIII - Publications

Book Chapter Publications

1. Urmi R. Salve, **Ganesh S. Jadhav**, Hemant K. Shete., (2017). Design Solution of Shoe Sole (Base of the Footwear) Preparation in Traditional Hand Sewn Footwear Manufacturing: A Case Study on Kolhapuri Chappal. International Conference on Applied Human Factors and Ergonomics. Advances in Ergonomics in Design. Springer, 588, pp.995-1003. DOI: 10.1007/978-3-319-60582-1_100.
2. Urmi R. Salve, **Ganesh S. Jadhav**, (2018). Analysis of Posture Adopted by Female Kolhapuri Chappal (Footwear) Manufacturing Workers India. Congress of the International Ergonomics Association. Advances in Intelligent Systems and Computing. Springer, 826, pp. 278-286. DOI: 10.1007/978-3-319-96065-4_31.
3. **Ganesh S. Jadhav**, Arunita Paul, Urmi R. Salve, (2016). Manual Material Handling Trolley: Case Study. 14th International Conference on Humanizing Work and Work Environment HWWE 2016, pp.19-23, ISBN: 978-93-83006-81-6.

Publications in conference proceedings

1. **Ganesh S. Jadhav**, Arunita Paul, Urmi R. Salve, (2016). Design of Manual Material Handling Trolley for Spool Loading and Unloading: Case Study. 6thInternational & 27th All India Manufacturing Technology, Design and Research Conference (AIMTDR-2016), pp.851-855, ISBN: 978-93-86256-27-0.
2. Arunita Paul, **Ganesh S. Jadhav**, Urmi R. Salve, (2016). Risk Factors in Carpal Tunnel Syndrome: A Review. 14th International Conference on Humanizing Work and Work Environment HWWE 2016, pp.61-65, ISBN: 978-93-83006-81-6.
3. Adne Shubham, Patil S.R., **Jadhav Ganesh**, Salve U.R., (2017). Posture evaluation by RULA and introduction to Pugh matrix technique. Proceedings of 2nd National Conference on Recent Trends in Mechanical Engineering (NCRTME - 2017), pp. 26-31. ISBN: 978-81-931546-6-3.
4. Vahid Jamadar, Ganesh Jadhav, Gurunath Shinde, Anant Awasare, (2019). Productivity Improvement in a Manufacturing Industry using Value Stream Mapping Technique.

International Conference on Reliability, Risk maintenance and Engineering Management, Springer, pp. 79-84.

Publications under review in the scientific journal

1. **Ganesh Suresh Jadhav**, Arunachalam M., Urmi Ravindra Salve, (2018). Design proposal and postural evaluation for the workstation of workers in Indian Kolhapuri footwear (traditional hand sewn) manufacturing industry. WORK: A Journal of Prevention, Assessment & Rehabilitation.
2. Urmi Salve, **Ganesh Jadhav**, (2018). Designing an ergonomics workstation to reduce the postural load of female Kolhapuri hand-crafted footwear manufacturing workers in India. Journal: Applied Ergonomics. Manuscript ID- JERG_2018_353.
3. **Ganesh Suresh Jadhav**, Urmi Ravindra Salve., Arunachalam M., (2018). Musculoskeletal problems of hand-sewn crafted footwear manufacturing artisans in Kolhapur, India. WORK: A Journal of Prevention, Assessment & Rehabilitation.
4. **Ganesh Suresh Jadhav** and Urmi Salve, (2019). Ergonomic design intervention for sole cutting operation in crafted hand sewn footwear manufacturing in India. Journal of Industrial and Production Engineering, Taylor and Francis. Manuscript Number: JCI-2019-0031.
5. **Ganesh Suresh Jadhav**, Arunachalam M., and Urmi Ravindra Salve, (2019). An application of a Kolhapuri Hand crafted-footwear stitching station improvement using a virtual digital human modeling method. Journal of Industrial and Production Engineering, Taylor and Francis Manuscript Number: TJCI-2019-0042.