INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI
SHORT ABSTRACT OF THESIS

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Thesis Title: **LASER SURFACE ALLOYING OF ALUMINUM AND SURFACE MELTING OF Al-12Si-4Cu-1.2Mn ALLOY**

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SHORT ABSTRACT

Aluminum alloys are groups of nonferrous metals finding a wide range of applications. They have appreciable properties such as high strength to weight ratio, high thermal conductivity, excellent corrosion resistance and workability. This favors their high demand in many industries. Aluminum is used in many applications—automobile parts, aircraft parts, nuclear plant material and shipbuilding materials. They are also used to fabricate various domestic items like kitchen utensil and packaging. Due to its high conductivity, pure aluminum is used for electrical transmission lines and protective coating on the surface of other metals. Alloying aluminum with different metals enhances its mechanical properties and makes it suitable for structural applications. However, mechanical alloying of aluminum by casting and other techniques may not be cost-effective, when only the properties at the surface need to be changed.

In this thesis, the motivation is implementing the cost-effective method of surface modification of commercially pure aluminum. For this, a continuous wave CO_2 laser was used. Laser surface alloying (LSA) was conducted by adding additional metal and ceramic materials to the aluminum substrate and high energy laser beam was used to melt pre-placed material as well as a portion of substrate aluminum. For LSA, powders of copper, magnesium, manganese, titanium and zinc were used. The average particle size of each powder was about 10 μm. In order to investigate the effect of the material combination on the alloy formed, copper, magnesium and manganese were mixed by a ratio of 2:1:1 and alloyed with aluminum substrate.

Ceramic materials of SiC and TiO_2 were also used for laser surface alloying of aluminum. Alloying powders were pre-placed uniformly on substrate material after mixing with Fevigum binder, which is a cost-effective method due to high laser beam absorptivity and material utilization. The formation of metallurgical bonding of added materials with aluminum substrate played a great role in improving surface properties such as microhardness, wear, and corrosion resistance. Alloy depth and alloy width are highly affected by laser beam parameters such as laser power, laser scan speed and beam diameter. For example, alloy depth increased when laser beam power was increased from 1.7 to 1.9 kW power. Similarly, when laser scan speed was increased from 300 to 500 mm/min, both alloy depth and alloy width got decreased. The effect of beam diameter was also observed; there is an optimum beam diameter for the best performance.

Wear is a major cause of the failure of engineering parts. In this work, after laser surface alloying, a pin on disc wear testing in dry condition was conducted for 20 minutes for AlCu, AlMg, AlMn and Al-CuMgMn alloys. The result was promising since wear resistance after alloying with different metals was achieved. For example, an improvement of 30–50 % was achieved for different alloy. The highest wear resistance was observed for AlCu and Al-CuMgMn alloys. The effect of normal load, sliding speed and sliding time on wear mass loss were investigated. In general, for different alloys, a two-fold increase in normal load had wear mass loss by 1.4–3.2 times.

Both acid and salt immersion tests were conducted for corrosion evaluation for 200 hours at room temperature. Very attractive results were obtained. For example in acid (2.5% H_2SO_4) corrosion immersion test, highest corrosion improvement was achieved for AlTi alloy and AlMg alloys and other materials as well. For different alloys, corrosion resistance was improved by 22% to 55%, where AlTi and AlMg alloy got first and second ranks in improving the acid corrosion resistance. The corrosion attack in the form of pitting that grows faster in the material and microcracks were the major causes of corrosion. Corrosion affects the hardness of the material as confirmed in the experiment. After corrosion about 50% hardness reduction in hardness was observed for AlTi alloy.

The second study for surface modification was laser surface melting (LSM) on Al-12Si-4Cu-1.2Mn alloy. Due to LSM, microhardness increased by about 2.5 and 2.6 times for heat treated and as-cast samples, respectively. There was a considerable improvement in mechanical properties of as-cast samples at low laser specific energy. Although the heat treated samples also showed the improvement in mechanical properties, yet they could not surpass the as-cast samples. The ultimate tensile strength increased by 23% and 70% for heat treated and as-cast samples, respectively. Surface scratch resistances after LSM also increases. The coefficient of friction reduced after LSM.

Overall, this research work established the feasibility of surface modification by alloying and remelting of aluminum on a CO_2 laser machine. There is a scope to model and optimize the process. Surface modification of exotic materials may also be studied.