Surface Modification of Commercial Pure Aluminum by Laser

B.Ramesh Chandra
Assistant Professor,
Department of Metallurgical Engineering,
JNTUH College of Engineering, Hyderabad, India.

Abstract:

The present study concerns to improve hardness on the surface of Al such that the wear resistance property can be improved. A thin layer is melted on Al substrate by using laser with high power continuous wave (CW) CO_2 laser. Irradiation on Al substrate with a high power continuous wave CO_2 laser leads to melting of Al substrate and modification of the surface takes place. Following laser irradiation, a detailed characterization of the melted layer was undertaken in terms of microstructure, composition and phases. Important mechanical properties like microhardness and wear resistance were also evaluated in details and correlated with microstructure. The microstructure of the melted layer consists of fine grains. The microhardness of the surface is marginally improved as compared to that of the as-received Al substrate. A significant improvement in wear resistance in surface melted Al is observed as compared to the as-received substrate.

Keywords:

Laser surface melting, Aluminum.

1. Introduction:

Al and its alloys have a potential scope of application in aerospace and automotive industry because of its low density and high strength to weight ratio [1]. However, a poor resistance to wear and erosion is of serious concern for prolonged use of the component made of Al [2].In this regard, it may however be noted that wear is a surface dependent degradation which may be improved by a suitable modification of surface microstructure and/or composition of the near surface region [3-4]. Hence, surface modification could improve the surface properties like wear and erosion resistance without sacrificing the bulk properties. On the other hand, a high power laser beam may be used as a source of heat to melt the metallic substrate. Ability to deliver a large power/energy density (10^3 to 10^5 W/cm^2), high heating/cooling rate (10^3 to 10^5 K/s) and solidification velocities (1-30 m/s) are the notable advantages associated with laser assisted surface modifications [5-7]

In the presence study, attempts have been made to develop a fine grain structure on the surface of Al substrate to improve its wear resistance property. Laser processing has been carried out using a large number of trials to observe the effect of process parameters on microstructures and defect densities (porosities, macro and micro-cracks) and to optimize the process parameters. A detailed study of the microstructure, phases and composition of the surface layer (processed under optimum conditions) have been undertaken to understand the process. Evaluation of kinetics of wear of the surface Al was undertaken against diamond indenter.

2. Experimental:

In the present investigation, commercially pure Al of dimension: 20 mm x 20 mm x 5 mm was chosen as substrate material. The samples were sand blasted prior to laser processing in order to remove oxide scale from the surface. Laser surface melting was carried out by irradiating the Al substrate using a 10 kW continuous wave (CW) CO_2 laser with a beam diameter of 3.5 mm and Ar as shrouding gas. The specimens were mounted on a CNC controlled X-Y stage which was moved at a speed of 100-500 mm/min. Table I summarizes the laser parameters used for the formation of defect free microstructure. Following laser surface melting, the microstructure of the composite layer (both the top surface and the cross section) was characterized by optical microscopy. A detailed analysis of the phase and composition of the composite layer were carried out by X-ray diffractometer. The microhardness of the composite layer (both at the top surface and along the cross sectional plane) was measured by a Vickers microhardness tester using a 25 g applied load. Finally, the kinetics of wear of the composite surfaced Al was compared with the as-received one by a Friction and Wear monitor unit with the specimen as disc and diamond pyramid indenter (120^0)as pin. During wear testing, the pin was allowed to slide over the disk with 300 rpm wheel speed at an applied load between 500 g to 1 kg.

During wear, the depth of wear was measured as a function of time. Effect of load on the rate of wear was studied in details.

Table I: Summary of laser parameters used for the formation of homogeneous microstructure

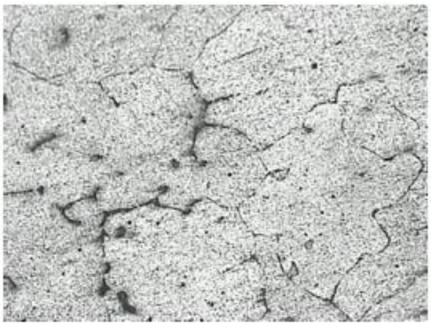
Sample No.	System	Power (kW)	Scan speed (mm/min)
1.	Al (melted)	3	500
2.	Al (melted)	3	300
3.	Al (melted)	3	200
4.	Al (melted)	3	100

3. Results and discussions:

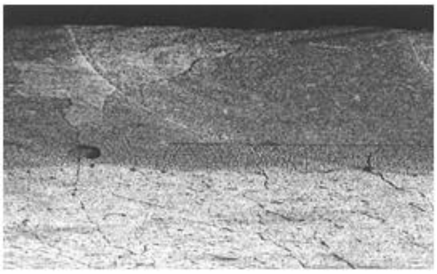
In the present study, a detailed characterization of microstructure, composition and phases of the melted surface Al was undertaken. The results of the characterization and mechanical properties of the layer are discussed in this section.

3.1. Microstructural Evolution:

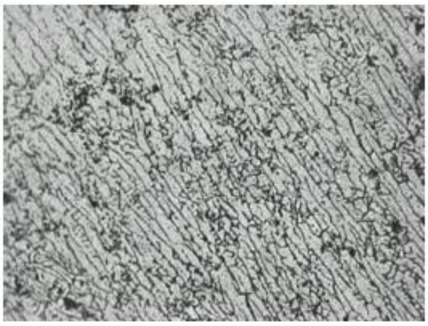
Figures 1(a,b, c) show the microstructures of the cross section of (a) As received Al, (b) laser melted surface and (c) melted surface at high magnification (200x). From Figure 1(b,c) it is relevant that there is a substantial refinement of grains by laser surface melting as compared to that of as-received substrate. Moreover, surface melting causes formation of a defect free and adherent interface.



(a)



(b)



(c)

Figures 1(a, b, c): Shows the microstructures of the cross section of (a) As received Al, (b) laser melted surface and (c) melted surface at high magnification (200x)

3.2.Phase Analysis:

A detailed phase analysis of the laser surface melted and Al was undertaken by X-ray diffraction technique to observe the influence of laser parameters on the phase change. Figure 2 (a,b) shows the X-ray diffraction profile of (a) as received and (b) laser surface melted Al ((lased with a power of 3 kW and scan speed of 500 mm/min). A close comparisons between the X-ray diffraction profiles of as-received and laser surface melted Al reveals the presence of a few alumina (Al_2O_3) peaks in laser surface melted aluminum confirming that though surface melting was carried out using Ar as a shrouding environment oxidation could not be totally avoided.

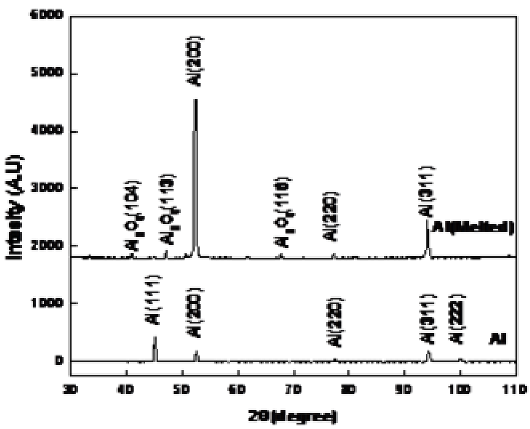


Fig. 2. X-ray diffraction profiles of (a) as received Al and (b) laser surfaced melted Al.

Figure 3 shows the microhardness profile for as received Al and surface melted Al. The microhardness was found to be 50-100 VHN for surface melted Al as compared to the as-received Al (25 VHN)

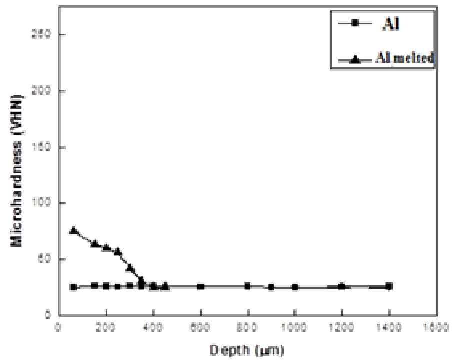


Figure 3 shows the microhardness profile for (a) as received Al and (b) surface melted Al.

Figure 4 compares the kinetics of wear in terms of depth of wear as a function of time measured by friction and wear monitor using specimen as disc and diamond pyramid indenter as a pin material at an applied load of 1 kg and no. of revolution at 300. A close comparison of different graphs in Figure 4 reveals that the wear resistance of laser surface melted Al is marginally improved as compared to the as-received Al, which is attributed to improvement in hardness due to grain refinement.

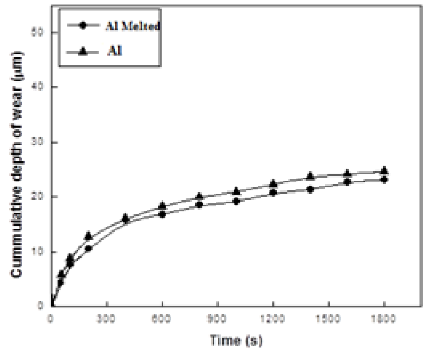


Figure 4Compares the kinetics of wear in terms of depth of wear as a function of time (a) As received Al and (b) Surface melted Al

4. Summary and Conclusions:

In the present investigation laser surface melting of Al have been undertaken. From the detailed characterization and testing of laser surface melted Al the following conclusions may be drawn:

1.Laser surface melting caused significant refinement of grains.

2. X-ray diffraction study confirmed the presence of Al2O3 on the surface.

3.The microhardness is marginally improved (to 60 VHN) by laser surfaced melting due to significant refinement of grains as compared to that of 25 VHN of as-received Al.

4.Wear resistance against a diamond indenter in 1 kg applied load is marginally improved by laser surface melting.

5.References:

[1]P. J. Blau, Trib. Int., 30 (1997) 321-331.

[2]Y. Wan, Q. J. Xue, Tribilogy letters 2 (1996) 37-45.

[3]Rabinowicz E. Friction and Wear of Materials, New York: John Wiley and Sons, 1965.

[4]K. G. Budinski, Surface Engineering for Wear Resistance, New Jersey, Prentice Hall, 1988.

[5]L. E. Rehn, S. T. Picraux and H. Wiedersich, in: L. E. Rehn, S. T. Picraux and H. Wiedersich (Eds.), Surface Alloying by Ion, Electron and Laser Beams, Metals Park, Ohio: ASM, 1987. p. 1-17.

[6]B. L. Mordike, Laser Processing of Materials in: R. W. Cahn, P. Haasan, E. J. Kramer (Eds.), . Materials Science and Technology, vol.15, Weinheim: VCH, 1993, p. 111-136.

[7]J. DuttaMajumdar and I. Manna, Sadhana, 28(2003) 495.