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Improving the Surface Properties of Medium Carbon Steel by Adding Alloying Elements Using Laser

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

Abstract:

Surface engineering is increasingly recognized as a powerful surface modification tool to enhance the wear and corrosion resistance of engineering components. The present work deals with laser alloying of medium carbon steel with silicon using a high-power CO2 laser. A processing regime, identifying an appropriate laser power-scan speed combination for achieving defect-free alloyed layers, has been established during the study. The influence of repetitive scans in different environments on the alloyed layer properties was also subsequently investigated in a comprehensive manner. The microstructure in the LSA layers was also observed to vary significantly.

Keywords:
Medium carbon steel, microhardness, laser surface alloying

1.Introduction:

The need to prolong the service life of engineering components that are exposed to severe environmental conditions during their normal operation has brought about the increasing acceptance of surface engineering in the recent past. Most forms of wear and corrosion and initiated at the part's surface. The improvement of both bulk and surface properties can be achieved by modifying the surface by giving it an appropriate high performance coating. Among the many surface modification techniques available Laser Surface Alloying (LSA) is very popular. It has attracted considerable attention in recent years as an efficient method to improve the chemical and mechanical surface properties of engineering components [1].

The present investigation deals with laser surface alloying of medium carbon steel with Si using a high-power CO_2 laser. It may be emphasized that the objective of the experiments conducted was not to produce a composite, but an alloyed layer, by incorporating Si into the steel substrate. The effect of modification on the microstructure, phase constitution and hardness profile of alloyed layers has been comprehensively studied in this paper.

2.Experimental:

In the present investigation, the medium carbon steel of dimension: 10 mm x 10 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 alloying was carried out by irradiating the medium carbon steel substrate with Silicon as alloying elements 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 100-300 mm/min.Following laser surface alloying, the microstructure of the alloyed layer was characterized by optical microscopy. A detailed analysis of the phase and composition of the alloyed layer were carried out by X-ray diffractometer. The microhardness of the alloyed layer was measured by a Vickers microhardness tester using a 25 g applied load.

2.1 Description of Laser Surface Alloying Process:

Figure 1 describes the process of laser irradiation on the precoated substrate. From figure 1 it describes that the Laser alloying involves adding alloying elements to the melt pool, either as a pre-deposited layer, or by

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feeding powder or wire into the melt pool. Due to the high solidification rates involved, the resulting microstructures are fine and frequently contain non-equilibrium phases and supersaturated solid solutions, leading to high hardness and wear and corrosion resistance. Since the laser energy is applied locally, laser surface treatment is particularly well suited to the treatment of small areas, a possibility that does not exist with most other surface engineering methods.

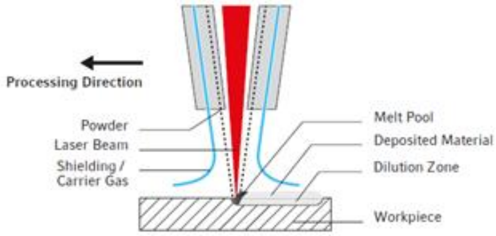


Figure 1The process of laser irradiation on the precoated substrate

Advantages of Lasers Surface Engineering over Conventional Processes:

- Treatment can be localized
- Heat input is low resulting minimum distortion of work piece
- Accurate control of depth is possible
- Complex shapes can be treated and inaccessible areas readily reached by using mirrors
- Processing is rapid so no scale produced and it is suitable for a production line operation.
- Generally no finished grinding is required after treatment
- No quenching oil/water required, for self – quenching occurs.
- No requirement for a special gaseous atmosphere or vacuum.

3. Results and Discussions:

In the present study, a detailed characterization of microstructure, composition and phases of the alloyed surface medium carbon steel was undertaken. The results of the characterization andmechanical properties of the layer are discussed in this section.

3.1.Microstructural Evolution

Figures 2 show the microstructures of the cross section of laser alloyed surface at high magnification (100x). From Figure 2 it is relevant that there is a substantial alloying taken place by laser surface alloying as compared to that of as-received substrate. Moreover, surface alloyingcause’s formation of a defect free and adherent interface.

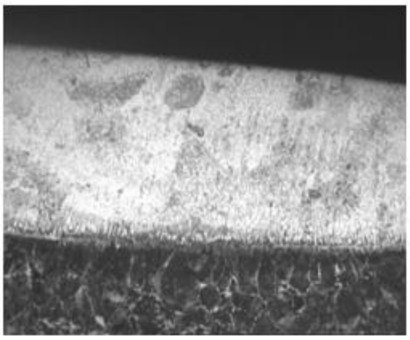
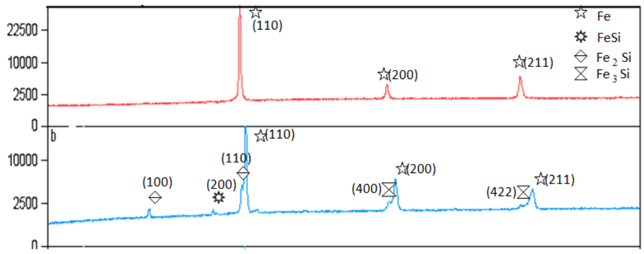


Figure 2.Shows the depth of the alloyed zone of laser surface alloying of medium carbon steel with Si at 100X.

3.2 Phase Analysis:

A detailed analysis of phases of as received medium carbon steel and laser surface alloyed mediucm carbon steel as be studied using x-ray diffraction. Figure 3 shows the X-ray diffraction profile of (a) as received medium carbon steeltop surface and (b) laser surface alloying of medium carbon steel with Si at the bottom. A close comparison of the two plot shows that laser composite surfacing of Si with steel-matrix lead to formation of silicites and some silicon in the matrix. Hence, Si particles was melted and mixed with the Fe particles leading to the formation of Fe_3Si particles.



Position (2Thetha)

Figure3(a,b) shows the X-ray diffraction profile of (a) as received medium carbon steel at top and (b) laser surface alloying of medium carbon steel with Si at bottom.

3.3 Microhardness Study:

Figure 4 Shows the microhardness profiles for laser surface alloyed medium carbon steel with Si particlesas a function of depth from the surface measured on the cross sectional plane.

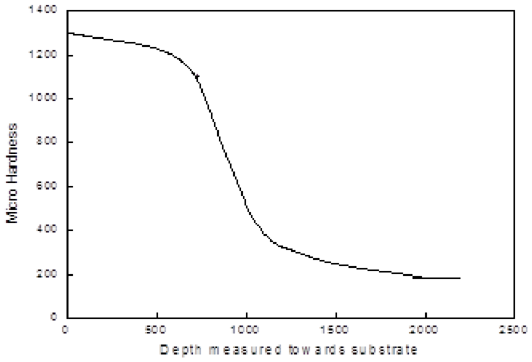


Figure 4 Shows the microhardness profiles for laser surface alloyed medium carbon steel with Si

It is relevant to mention that the microhardness of the alloyed zone has increased significantly to as high as 1300 VHN as compared to 180 VHN of the as-received one. For a particular sample microhardness is maximum at surface and gradually decreases to a value of ~180 VHN at the substrate .In between hardness falls rapidly in the alloyed region. Hence, the improved microhardness is attributed to the presence of silicites(Fe_3Si). Furthermore, it may be noted that the improved microhardness is beneficial to impart better wear properties.

4. Conclusion:

1. The range of process parameters for employed for laser composite surfacing of medium carbon steel with Si was as follows: power = 1-3 kW, scan speed = 250-300 mm/min.
2. The XRD pattern shows that Si dispersed in the substrate and form silicites.
3. Themicrohardness of the composite surfaced layer was significantly enhanced to as high as 1300 VHN as compared to 180 VHN of the substrate metal.

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