Turkish Journal of Physics

Volume 22 | Number 10

Article 5

1-1-1998

Alloying of AISI 1008 Steel Surfaces by 10ms Nd: YAG Laser Pulses

Raid A. İSMAİL

Recommended Citation

İSMAİL, Raid A. (1998) "Alloying of AISI 1008 Steel Surfaces by 10ms Nd: YAG Laser Pulses," *Turkish Journal of Physics*: Vol. 22: No. 10, Article 5. Available at: https://journals.tubitak.gov.tr/physics/vol22/iss10/5

Tr. J. of Physics
22 (1998) , 983 – 988.

Alloying of AISI 1008 Steel Surfaces by 10ms Nd: YAG Laser Pulses

Raid A. İSMAİL
School of Applied Sciences, University of Technology
Baghdad-IRAQ

Received 16.10.1997

Abstract

Hardened surfaces were produced on AISI 1008 steel through a laser surface alloying (LSA) technique. Mixture of pure Boron, Silicon, and Carbon powders of the same grain size were deposited on the substrate. The surface was then melted using pulsed Nd:YAG laser (τ = 10 ms) at an energy of 12 J. The influence of alloying elements on the microstructure and hardness of treated layer was investigated. Dependending on the alloying elements species, different maximum surface hardness, different maximum depth, and different hardness profile could be obtained. The B+Si alloyed zone exhibited maximum hardness to a nominal alloying depth of 350 μm.

1. Introduction

High energy lasers are receiving considerable attension as sources for causing surface modification for improvement in, for instance, wear and corrosion resistance [1-3]. The major advantage of laser surface alloying is that a part can be fabricated from a base metal selected on the basis of cost and mechanical properties. The working surface can be modified, using high energy laser pulses to provide the desired characteristics necessary for military and civilian applications. By using laser surface alloying technique, low cost materials can be made to exhibit high strength and corrosion resistance of more expensive materials. The additional material required for changing the composition of the processed layer may be supplied in form of deposited layer [4-6] or injected into the molten region beneth the laser beam [7].

The first objective of the present work is to investigate the microstructure of alloying layer formed by deposition of alloying elements (painting technique) and subsequently melted by laser pulses. Second, the hardness behaviour of these layers is examined.

Preliminary aspects of this work have been reported eailer [8].

2. Experiment

The experiments reported in the present paper were carried out using Nd:YAG laser pulses under conditions listed in Table 1. Large areas of surface treatment were obtained by overlapping technique, after each pulse the specimen was displaced laterally to give an overlapping ratio about 78 % as shown in Fig. 1.

AISI 1008 steel (0.082 wt % C, 0.29 wt % Mn, 0.022 wt % P, and 0.025 wt % S) samples were used for this study. The sample was mechanically polished to obtain mirror finish surface and then etched in nital solution to reveal the prior microstructure before laser treatment as shown in Fig. 2.

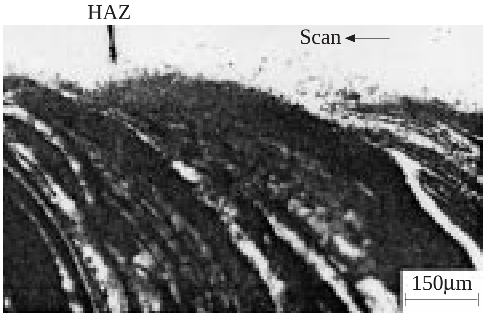


Figure 1. Top view of a laser surface alloyed (B+Si) with the distance between center to center of two successive passes equal to 0.25 mm

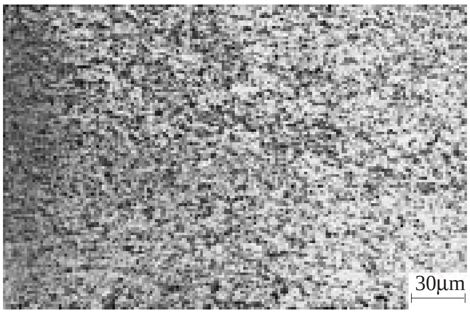


Figure 2. Microstructure of AISI 1008 Steel before laser treatment

Surface alloying experiments were carried out using a painted coating as means to supply the desired elements. The paint used was a strong diluted organic glue with the alloying elements in fine powder (grain size about 75 μm). A paint was composed of 1 ml of glue, 2-3 g of powder, and further diluted with 1 ml of solvent. Painted layers containing (1:1) a mixture of B+C powders have been used here. Paint coatings were applied to ground surfaces by fine brush.

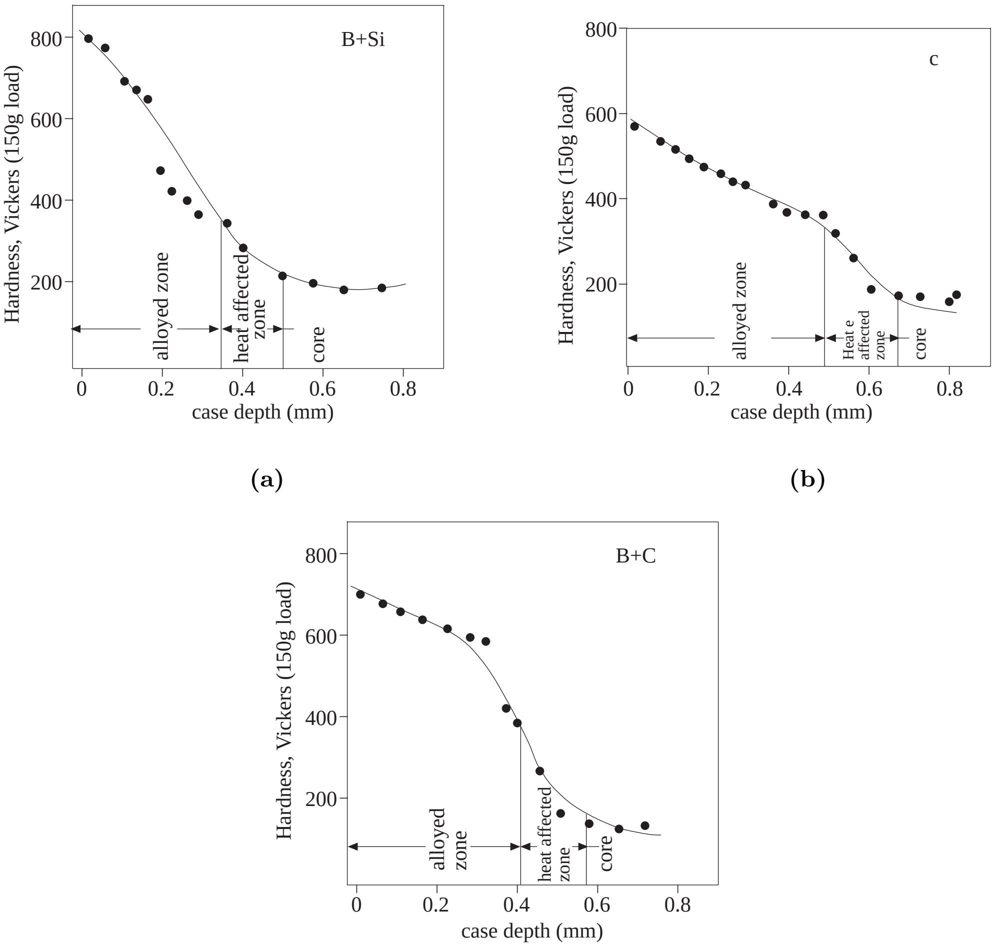
For optical microscopy observation of laser alloyed layer, an etching reagent consisting of 60 ml H_2O, 40 ml HCl, and 10 ml HNO_3 was used. Vickers microhardness (150 g load) measurements were made as function of depth below the surface (on sections normal to treated region).

Table 1. Laser parameters used in alloying technique

Wavelength	1.064 μm
Pulse duration	10ms
Mode	TEM_{00}
Pulse energy	12 J
Beam diameter ($1/e^2$ points	0.6 mm

3. Results and Discussion

Microhardness versus case depth results of laser alloyed region for various alloying elements are presented in Fig. 3.



(a)

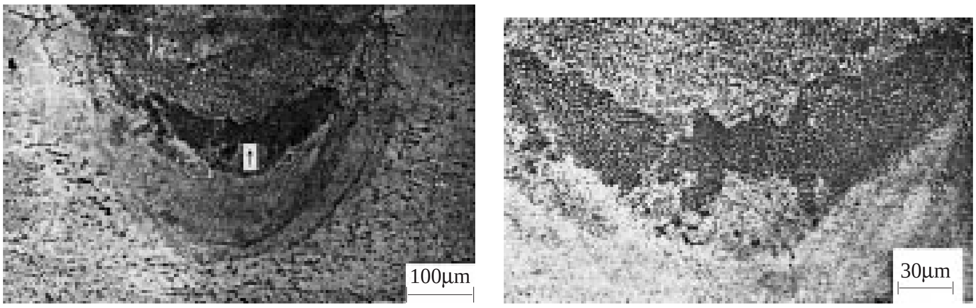
(b)

(c)

Figure 3. Microhardness profile on cross-sectional surface of alloyed region as function of distance. a) B+Si b) C c) B+C

The surface alloying process results in significant increases in hardness compared with values of base metal. The hardness has maximum value near the surface and then drops smoothly across the laser alloyed-heat affected zone (HAZ) interface, and finally reaches the value of the core. In the case of B+Si alloyed layer the surface hardness increased by a factor of 4.4 times over that of the core. This effect can be attributed to the formation of a borided layer up to diffusion depth of about 0.35 mm with a structure of iron borides Fe_2B.

Figure 4 shows the transverse section of laser melted surface alloyed with B+Si, the fusion zone, possesses a semicircular shape with a small aspect ratio (melt depth/melt width).



(a) (b)

Figure 4. Optical micrographs of transverse sections of (B+Si) alloyed zone. a) Laser alloyed zone b) Higher magnification of alloyed zone (indicated by an arrow in a) showing irregularity in microstructure

It is evident from Figure 4 there are microstructure inhomogeneties in fusion zone resulting from a nonuniform composition in the concentration of alloying elements. This is can be explained on the basis of segregation and non-equilibrium melting arising from high quenching rate (cooling rate near 1.1 $\times 10^5$ $°C/S$ was calculated) [2, 8, 9]. The structural heterogeneities observed in both solidified and solid state transformed HAZ (heat affected zone) regions are the regions for the very large fluctuations in the value of microhardness across the surface alloy (Fig. 3).

It is also evident from Fig. 4 that the cracks are concentrated in HAZ. The narrow HAZ is the most vulnerable part of the area surrounding the fusion zone [10], as micro distribution of alloy element occur in this region. A high concentration of vacancies and subsequent coalescing could provide sites for initiation of cracks in this region [11].

When the carbon atoms diffused into the substrate the surface hardness increased 3 times. This is mainly due to formation of hard martensitic phases in the fusion zone. The cross-sectional view of laser alloyed layers containing added C and B+C are shown in Figures 5 and 6, respectively; they show clearly that the fusion zones have triangular shape.

The alloyed layers of Figs. 5 and 6 exhibit good planarity of the external surface and the inhomogeneities in microstructure. The microstructure of the alloyed zone pictured Fig. (6-b) shows the plat of martensites in an austenite matrix. The fine spots in Figs. 5 and 6 are particles that may be Oxides/carbides formed from reaction of the metal with an organic binder rather than micropores. The fusion zones were lack of prosities or cracks; the microcracks are accumulated in the heat affected zone.

4. Conclusions

The present work has shown that the laser treatment of coating paint of B+Si, C, and B+C powders deposition on AISI 1008 steel leads to the formation of a surface alloy by intermixing in laser molten regions.

Laser surface alloying resulted in significant increasing in the hardness of treated region. The hardness profile of alloyed zone shows it has maximum value at the vicinity of the surface and then drops as the case depth increased.

The laser alloyed layer showed good planarity of the external surface and the irregularity of the alloyed thickness and microstructure. On the other hand the alloyed zone were free from prosities and cracking.

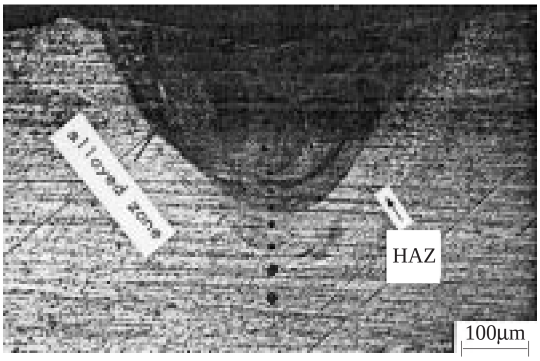
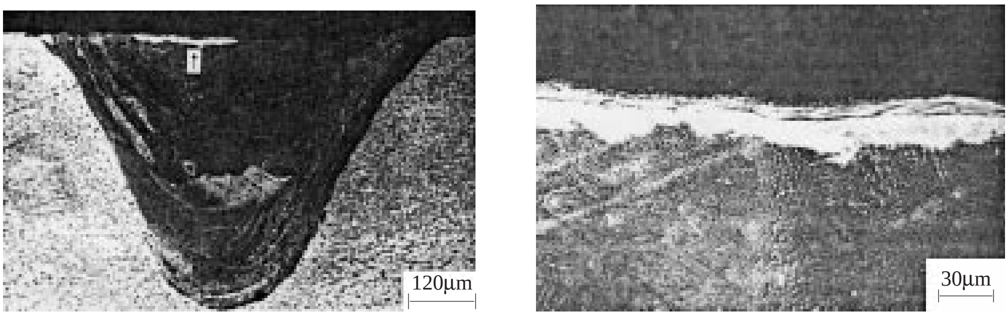


Figure 5. Optical micrograph of Carbon alloyed zone



(a) **(b)**

Figure 6. Optical micrograph of (B+C) alloyed layer a) laser alloyed region b) higher magnification of fusion zone indicated by an arrow in a) showing microstructure inhomogeneities

References

[1] A. Belmondo and M. Castagna, Thin Solid Films, **64** (1979) 249.

[2] N. Rykalin and A. Uglov, "Laser and electron beam material processing hand book", MIR Publishers, 1988, p.277.

[3] P.W. Leech, A.W. Batchelor, and G.W. Stachowiak, *J. Mater. Sci. Lett.*, **11** (1992) 1121.

[4] A. Walker, D.R.F. West, and W.M. Steen, *Met. Technol.*, **11**, 1984, p.399.

[5] M.L. Capp and J.M. Rigsbee, *Mater. Sci. Eng.*, **62** (1984) 49.

[6] P.A. Molian, *J. Mat. Sci.*, **20** (1985) 2903.

[7] J.D. Ayers and T.R. Tucker, Thin Solid Films **73** (1980) 201.

[8] Walid K. Hamoudi and Raid A. Ismail, *Int. J. for Joining of Materials*, **7** (1995) 119.

[9] G. Sepold, "Gas flow and chemical lasers", Chapter Hardning and alloying of steel surfaces by high power laser beams, ed. J.F. Wendt, McGraw-Hill, New York, 1978, p.561.

[10] N.B. Dahotre, A. Hunter, and K. Mukherjee, *J. Mater. Sci.*, **2** (1987) 403.

[11] K. Mukherjee, T.H. Kim, and W.T. Walter, "Laser in metallurgy" (The Metallurgical Society of AIME, Warrendale), 1981, p.137.