Wear Resistance Improvement of A Laser Cladded B_4C – NiCr on Mild Steel

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Abstract

In the present study, an attempt has been made for deposition of B4C-NiCr powder on low carbon steel by laser cladding to improve wear resistant of the substrate. clad powder blends of B4C and NiCr of composition 10%B4C+90%NiCr (80%Ni20%Cr) were deposited by laser cladding using a continuous wave CO2 laser under optimum processing conditions. The result showed that the microstructure of the clad layer consisted of dispersion of B4C particles in the form of nickel borides (NiB, Ni2B). The wear resistance of laser clad low carbon steel was significantly improved as compared to as-received low carbon steel substrate. The wear rate of laser clad low carbon steel (0.1563×10-9 kg/Nm) is much lower than that of as-received substrate (0.1892×10-9 kg/Nm).

Keywords: B4C-NiCr; laser cladding; wear; corrosion; low carbon steel

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I. Introduction

Low carbon steel play an important role in automobile industries and domestic appliances, like truck bed floors, automobile doors and body sides on regular automobiles. However the main disadvantages of this type of steel is very poor wear and corrosion resistance and causes a serious limitation of wide ranging applications. Ceramic coating materials such as boron carbide (B_4C), silicon nitride (SiN), silicon carbide (SiC), titanium carbide (TiC) and titanium oxide have played an important role in wear resisting at either ambient or high temperature. After diamond and cubic boron nitride B_4C is the third hardest substance and it is a covalently bonded compound. The specific properties of B_4C are high melting point, less density and good resistance to chemical agents. The main disadvantages of B_4C has low thermal conductivity and ductility metal, this will causes cracks in the coating during spraying. The mixture of nichrome and boron carbide powder increase the heat transfer rate and improve bonding strength of cladded substrate. Huiying Zhu et al. [6] for instance, have found that the friction coefficient of vacuum

Plasma sprayed B_4C-Ni coating was much lower than that of the pure B_4C and WC-Co coatings. As reported by Jianfeng Li et al. [8] the mechanical property and wear-resistance performance of plasma sprayed Cr_3C_2 based coating using Ni clad Cr_3C_2 powder was outstandingly improved comparing with the coating using mechanical blended Cr_3C_2-NiCr powder. Based on these result, Nichrome metal choose for second phase. Laser cladding is a suitable process to cladding B_4C-NiCr powder with low carbon steel.

II. Experimental

In the present investigation, low carbon steel substrate of dimensions 300mm×300mm×16mm is taken in annealed condition and sand blamed before laser treatment. Elemental powder blends of B_4C and NiCr of compositions $10B_4C90NiCr$ (wt.%) were chosen as clad materials. Laser cladding was carried out by melting the elemental powder blend delivered by optical fiber beam delivery system using a 3 kW continuous wave CO_2 laser (with a beam diameter of 3mm) with argon shrouding environment and subsequently, depositing it on as-received substrate. The powder feed rate was maintained to 14 mg/min as constant feed rate. The specimens were mounted on a CNC controlled *X–Y* sweeping stage which was moved at a speed of 600 mm/min. A relative speed between the laser beam and the specimen was maintained to minimize the substrate and laser beam interaction time and larger area coverage. The laser cladding is done by the optimum process parameters an applied power of 3 kW and scan speed of 600 mm/min to achieve a fine microstructure and compositional homogeneity of the laser treated surface. The optimum parameters have been taken on the basis of surface roughness, minimum crack and fine microstructure so as to ensure a defect free cladding. The microstructure of clad layer was characterized by scanning electron microscopy. A brief analysis of the phase and composition was carried out by X-ray diffractometer. The wear rate is measured by pin on disc apparatus.

Table – 1

Chemical compositions of substrate material

Element	*Content (%)*
C	*0.29*
Cu	*0.20*
Fe	*98*
Mn	*1.03*
P	*0.040*
Si	*0.280*
S	*0.050*

III. RESULT AND DISCUSSIONS

In this study, a briefed analysis of the microstructure and phases present on the surface of cladded low carbon steel with B_4C+NiCr were undertaken. In this section, the microstructure, phase and wear properties of the clad layer would be discussed in details.

A. Microstructure of coating

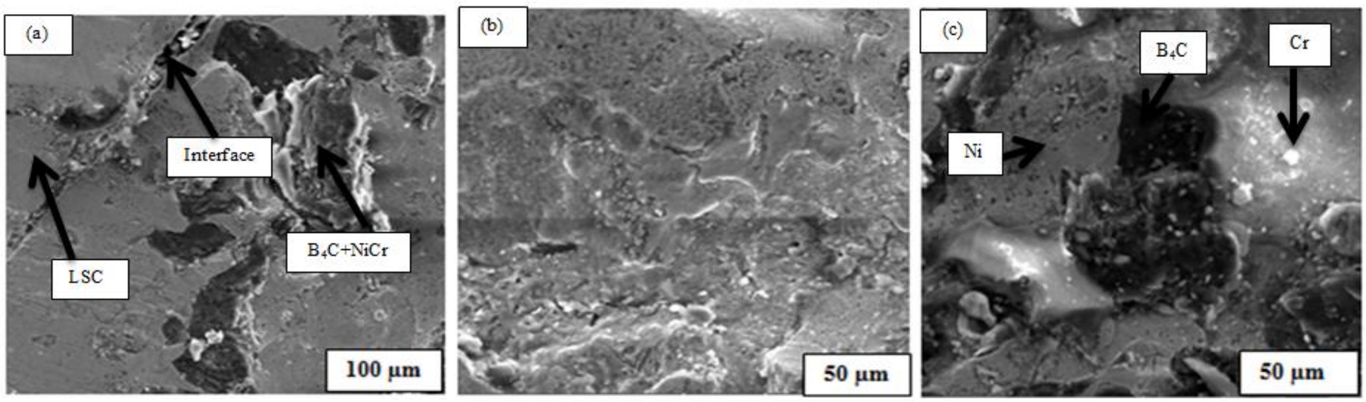

Fig. 1: Scanning electron micrograph of the (a) side view, (b) a higher magnification view of clad layer (a), and (c) top layer of laser composite surfaced low carbon steel with B4C+NiCr

Thickness of the clad layer is most important factor in determining the life of the component for tribological applications. In this study, under the present set of laser parameters, the thickness of the composite layer was 2000 µm. The microstructure of the composite clad layer formed on low carbon steel with a laser power of 3 kW and scan speed of 600 mm/min. From Fig. 1a, it may be concluded that the clad layer and substrate interface are continuous and defect free in nature.

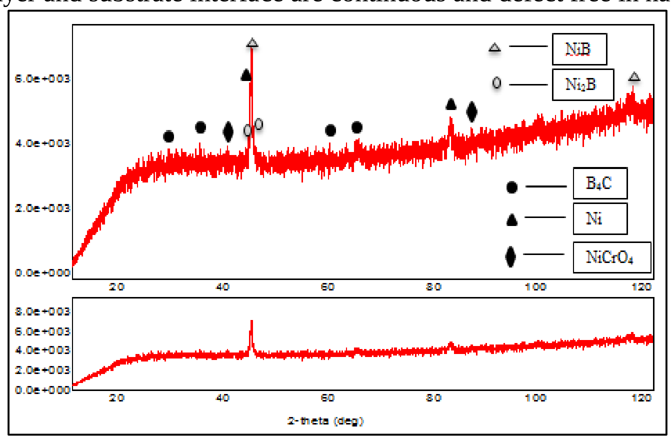

Fig. 2: XRD patterns of the composite coatings

Fig.2 shows the phase compositions of the B_4C-NiCr composite coatings. As can be seen, nickel borides (NiB, Ni_2B) and nichrome oxides ($NiCrO_4$) were obtained during spraying. The X-ray diffraction profile shows that the dispersion of B_4C particles in the presence of NiB and Ni_2B, however the degree of dissociation was too low to be visible from the change of shape of B_4C particles. As a result, there was enrichment of the matrix with NiB and Ni_2B hence, marginal change in composition.With increasing laser power and minimize scan speed, the degree of grain coarsening and dissolution were increased. But the lower applied power led to non-uniform distribution of particles due to inadequate intermixing in the matrix. The graded clad layer and particle distribution was only achieved when lased under an optimum combination of laser parameters (at a power of 3 kW and scan speed of 600 mm/min).

B. Sliding wear behavior

Fig.3 shows the kinetics of wear in terms of depth of wear as a function of time for as received and laser cladded low carbon steel with B_4C+NiCr at 60 and 80 N applied load, respectively. From Fig.3, it may be noted that there is significantly decrement in wear rate on laser cladded low carbon steel with B_4C+NiCr as compared to that of low carbon steel substrate. Then increasing load from 60 to 80 N was found to increase the wear rate though, the rate of increase is higher in as-received low carbon steel as compared to the laser cladded low carbon steel with B_4C+NiCr.

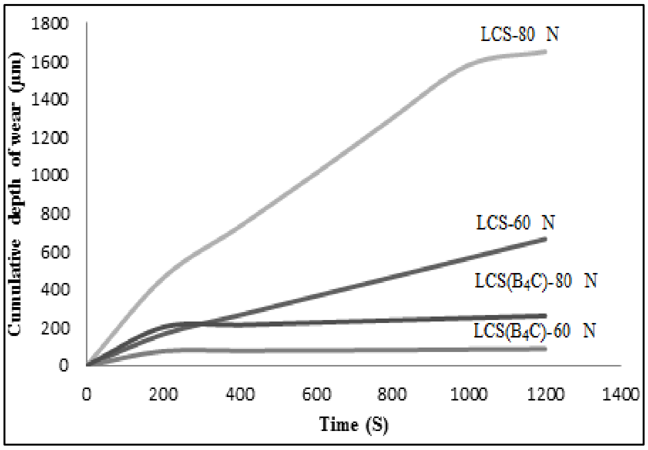

Fig. 3: Cumulative wear of the specimens in terms of depth of wear as a function of time against diamond indenter for low carbon steel (LCS) and the cladded low carbon steel with B4C+NiCr at 60 and 80 N applied load, respectively.

Wear rates of low carbon steel and B_4C+NiCr composite coating at 60 and 80 N applied load after the sliding wear test are shown in Fig. 4. It is observed that wear rates of the composite coating were remarkably lower than that of as-received low carbon steel, and the B_4C+NiCr coating with the minimum wear rate of 0.1563×10^{-9} kg/Nm at 60 N applied load exhibited the best wear resistance properties. Fig. 5a and Fig. 5b show the microstructures of worn out track of cladded low carbon steel by sliding against diamond indenter at an applied load of 60 N. From Fig. 5a and Fig. 5b, it is seen that there are presence of deep scratches, small pits and shear bands. Hence, it may be concluded that the mechanism of wear in laser cladded low carbon steel is initiated by adhesive and abrasive mechanism. However, the degree of damage was much lower. Increased wear resistance due to laser cladding of low carbon steel is predominantly due to an increase hardness of the surface clad zone.

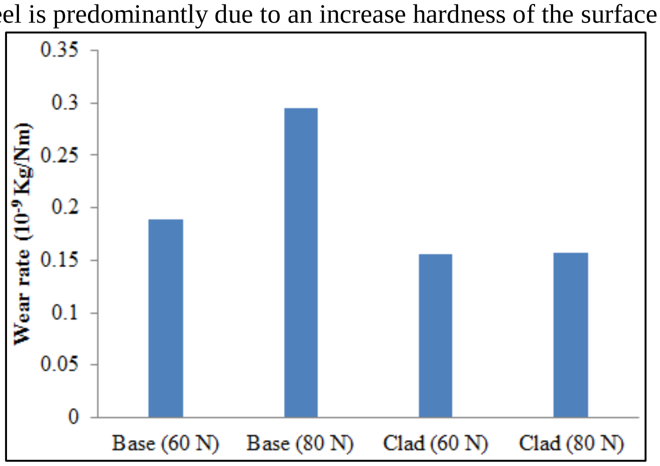

Fig. 4: Wear rates of low carbon steel and the cladded low carbon steel with B4C+NiCr at 60 and 80 N applied load, respectively.

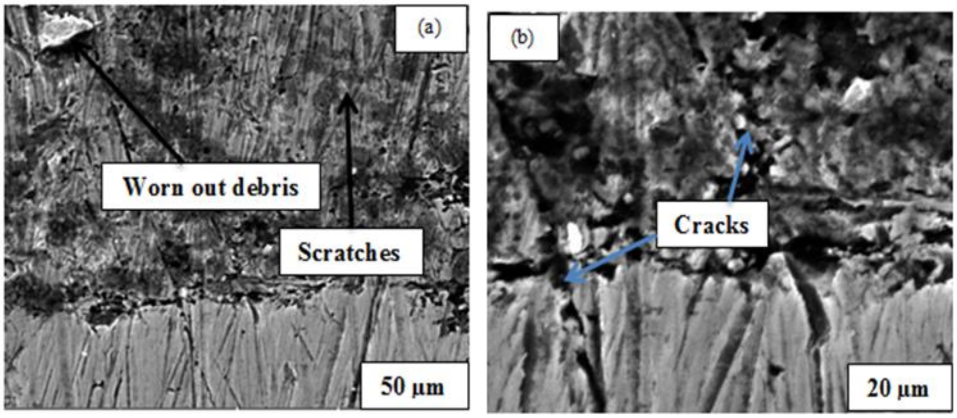

Fig. 5: Scanning electron micrographs showing the (a) worn out tracks, scratches and (b) cracks of cladded low carbon steel by sliding against diamond indenter at an applied load of 60 N

IV. CONCLUSIONS

In the present study, an attempt has been made for laser clad low carbon steel with boron carbide and nichrome powders. From the detailed analysis the following conclusions may be drawn:

1) A defect- free and fine microstructure composite cladded layer is formed under the laser power of 3 kW, scan speed of 600 mm/min and powder feed rate 14 mg/s.
2) The microstructure consists of dispersion of B_4C particles in the grain refined nickel borides (NiB, Ni_2B) and nichrome oxides ($NiCrO_4$).
3) Wear resistance of the cladded substrate was significantly improved as compared to as-received low carbon steel substrate. The wear rate of laser clad low carbon steel (0.1563×10^{-9} kg/Nm) is much lower than that of as-received substrate.

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