Rev. Adv. Mater. Sci. 33 (2013) 102-105

INFLUENCE OF THE TiC CONTENT ON MICROSTRUCTURE AND WEAR RESISTANCE OF LASER SURFACE ALLOYING COATINGS

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Received: October 17, 2011

Abstract :Submicron TiC and WC reinforced metal matrix composite (MMC) coatings on a ductile iron were fabricated by laser surface alloying (LSA) using CO_2 laser. Microstructure and phase of the LSA coatings with different content of TiC were investigated by SEM and XRD. The microhardness and wear resistance of the coatings were tested. The results showed that, when the content of TiC was increased to 30% the white small particles began to appear in the LSA coating and the white particles were ceramic hard phase. While the TiC content increased to 40%, the white particles become even more. The microstructures of the LSA coating with 40% TiC were refine, homogeneous and compact, and the properties of the coating was better than that of low content of TiC. The coating with 40% TiC has a average hardness of 1097 $HV_{0.2}$. The wear mass loss of the coating is just one ninth of that of the ductile iron and the worn surface is relatively smooth, which indicated that the wear resistance of ductile iron was improved by LSA with submicron TiC and WC.

1. INTRODUCTION

Laser surface alloying (LSA) is using a high energy laser beam irradiating over the material coated with a special layer. The coating is mixed up with part of the substrate when heated by the laser beam and then solidify to be a new alloy layer with new chemical and phase composition content with a certain thickness. Adopting LSA processing to prepare wear resistance, corrosion resistance or high temperature coatings on the surface of some materials with a low price and poor surface properties can improve the life of the workpiece with high economic efficiency. Therefore, LSA process has become a hot research and development of laser surface modification [1,2].

In this study, using mixed powers of submicron TiC and WC as hard reinforced phases, high hardness, wear-resistant coatings on the surface of a ductile iron were fabricated by LSA. By variation of the TiC content in the coatings, microstructures and properties were studied to obtain high quality MMC coatings.

2. MATERIALS AND PROCEDURE

2.1. Materials

QT50-5 ductile iron consisted of ferrite and pearlite was adopted as the substrate, with a dimension of 80mm×100mm×40mm. The surface was polished with 240# sand paper and cleaned by acetone. LSA coating material is a kind of alloy powders prepared by ourselves named 302 alloy powders. TiC and WC particles was employed as reinforced hard materials, the content of TiC are 0, 20, 30, 40 (wt.%), respectively, with fixed WC content. The powder size of the 302 alloy powder and (TiC + WC) is less than

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Table 1. Composition of the 302 alloy powder.

Composition	C	Fe	Si	Ti	Cr	Al	Co	Ni
wt.%	30-35	15-20	15-20	10-15	5-10	5-10	5	2

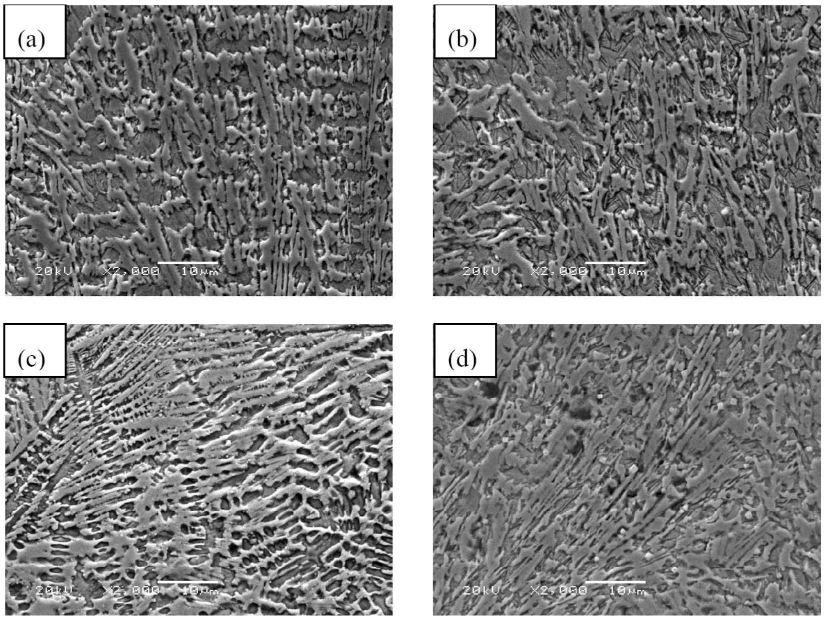

Fig. 1. SEM micrograph of alloyed coatings with different composition of alloying elements (a)302 alloy; (b) 302 alloy+20%TiC; (c) 302 alloy+30%TiC; (d) 302 alloy+40%TiC.

1 mm, and the composition of the 302 alloy powders was shown in Table 1.

2.2. Procedure

The alloying coating was sprayed on the treated surface of ductile iron with a thickness of 0.5 mm. A 5 kW CW CO_2 laser was employed to irradiate the surface of the substrate, then the LSA samples were air-cooled. The LSA parameters are as follows: laser power P = 3 kW, laser scanning speed V = 1000 mm/min, laser spot diameter D = 5 mm.

Metallographic samples were prepared by cutting perpendicular to the scanning direction of laser beam with a dimension of 8 mm ×10 mm ×10 mm. The phase composition, microstructure were analyzed by XRD and JSM-5610LV SEM, respectively. MH-3 microhardness tester was utilized to test the distribution of the microhardness along the across section of the LSA samples, with a load of 200 g and a loading time of 10 s. Wear resistance of the LSA coatings was tested under dry friction by MMS-1G wear/friction tester, the wear loss was measured by an electronic balance whose minimum scale is 0.1 mg. Dimension of the samples is 15.65 mm^2 ×10 mm. GCr15 is the raw material of the abrasive disk with a radius of 80 mm. The parameters of the experiment are: load is 40 N, loading time is 120 s, and running speed of the disk is 70 m/s.

3. RESULTS AND DISCUSSIONS

3.1. Microstructure

Fig. 1 shows the microstructure in upper region of the LSA layers with different contents of TiC in the coating powders. It can be concluded that the microstructures of the four LSA layers are almost the same because of the same laser processing for them, and the microstructures mainly are dendrites. The reason for the formation of the dendrites was that the quick laser scanning speed led to a quick cooling velocity with the big super cooling degree. Then the nucleation rate and growth rate of the grain would also increase. Therefore, the amount of preeutectic precipitation phases was large and their growth rate was fast, but the growth direction was not as close to the grain, when the grain meet each other during the process of growth could not continue to grow, consequently, to form a short-bar dendrites. Compared with Figs. 1a to 1d, the microstructure of the LSA layer with 40%TiC is the most uniform and

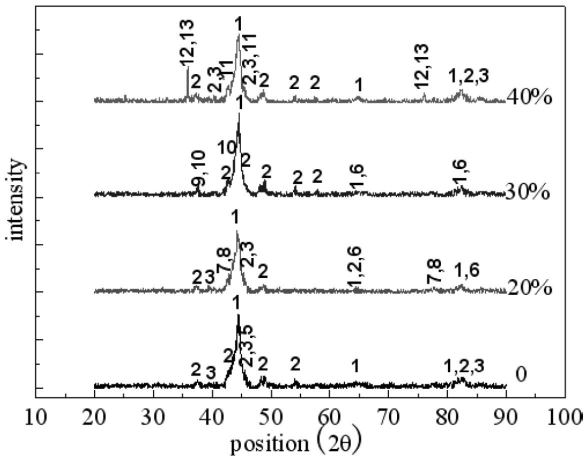

Fig. 2. XRD patterns of alloyed coatings with different composition of alloying elements: 1—g-Fe; 2—Fe_3C; 3—Fe_7C_3; 4—$Fe_{1.34}Si_{0.66}$5—$CrFe_3Si$; 6—$C_{0.055}Fe_{1.945}$; 7—$W_3Cr_{12}Si_5$8—$Cr_{2.2}Ti_{0.8}Si$; 9—Fe_6W_6C; 10—TiC; 11—$C_{0.12}Fe_{1.88}$; 12—WC; 13—Ti_8C_5.

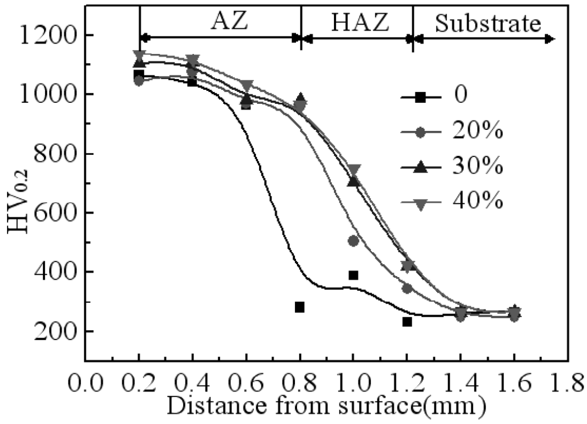

Fig. 3. Microhardness distribution in the cross-section of the alloyed layers.

dense, and white particles dispersed in the gap of the dendrites and inside the dendrites of the alloyed coatings with 30%TiC and 40%TiC in the coating material, the white particles in Fig.1d are more than the others. The white particles in the alloyed coatings play the role of dispersion strengthening, which can effectively improve the wear resistance of the alloyed layers.

3.2. Phase analysis

Fig. 2 shows the XRD patterns of the LSA layers with different contents of TiC. It can be seen that the four LSA layers all containing γ-Fe and Fe_3C, liquid alloy in the molten pool crystallized ledeburite Fe_3C/g-Fe which is the matrix of the LSA layers. In the laser alloying process, the mixed alloy powders melted and formed a pool under the laser beam irradiation, as different TiC content in the alloy powders, the reaction in the alloy molten pool was different, so the phases in the alloyed layers were different. Under the irradiation of the high-energy laser beam, part of TiC and WC were burnt loss or splashed while the other part melted and resolved into elements Ti, W and C which can form composite phases with Fe and present in the dendrites. Elements Ti, W and C also can reform some more fine hard phases, and element C caused by the melting of ceramic hard phases and part of substrate could combine with Fe precipitated in pre eutectic during the solidification process [3]. Because of the low carbide content in the coating material of 0%TiC and 20%TiC, the element C and Fe would together to form FeC compound first which precipitated in pre eutectic, and elements Ti ,W mostly formed intermetallic compounds with Fe, Cr, Si, it is difficult to detect original carbides. But original carbides had been found in the alloyed layers with coating material of 30%TiC and 40%TiC, which greatly increase the hardness of the alloy layers and consist with the hardness test results.

3.3. Microhardness

Fig. 3 illustrates the distribution of micro-hardness along the depth of the laser alloyed layers. Fig. 3 shows that the alloyed layers are consisted of alloyed zone, heat effected transition zone and the substrate. The microhardness curve of the alloyed layer with 40%TiC is higher than the other three microhardness curves, because a large number of Ti_8C_5 dispersed in the alloyed layer. And the micro-hardness of alloyed zone in the alloyed layer is the largest, the micro-hardness range of alloyed zone of the alloyed layer with 40%TiC is 965.4 $HV_{0.2}$~1138.3 $HV_{0.2}$, the average hardness is1097

Table 2. Results of abrasion test.

Sample No	The abrasion loss, (g)	Sample No	The abrasion loss, (g)
TiC 0	0.0994	TiC 30%	0.0902
TiC 20%	0.0978	TiC 40%	0.0885
Substrate	0.7964		

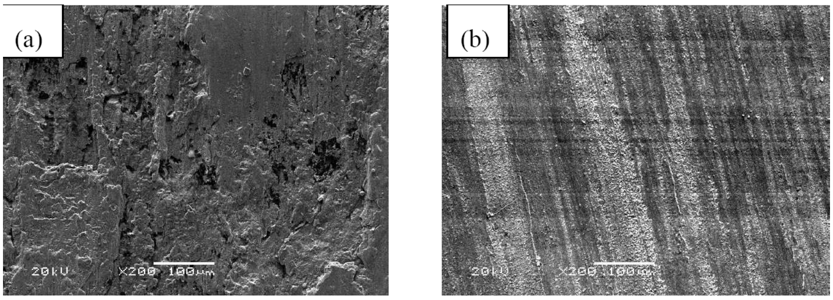

Fig. 4. Wear pattern of the specimens: (a) 302 alloy+40%TiC; (b) Substrate.

$HV_{0.2}$.The heat-affected zone closed to the surface melting zone, which absorbed heat caused the temperature up to the austenitizing temperature but not reached the melting temperature, the microstructure of the heat-affected zone transformed into martensite+retained austenite+graphite pebbles during the rapid cooling process, the micro-hardness of the heat-affected zone decreased gradually. Because of the large volume of the substrate, the energy density of the substrate is not enough to cause a transformation of the microstructure, so the micro-hardness range of the substrate is about 265 $HV_{0.2}$.

3.4. Wear resistance

It can see from Table 2, under the same friction conditions, the abrasion loss of the substrate is about 9 times relative to the laser alloyed sample with coating material of 40%TiC.

Fig. 4a shows the worn surface morphology of the laser alloyed layer with coating material of 40%TiC, there exists many shallow and narrow furrows on the worn surface, which indicate that a light abrasive wear occur on the surface of the alloyed sample. Because of the high hardness of the alloyed layer, the Cr-carbide particles in the GCr15 wheel embedded in the depth of the alloyed layer is relatively low, so the furrows are shallow and narrow [4]. Fig. 4b shows the worn surface morphology of the substrate No. QT50-5, there exsit some large pieces of adhesive spalling pits and a large number of metal transfer on the worn surface, which indicate that the abrasive wear resistance of No. QT50-5 is worse. By comparing Figs. 4a and 4b, it can be seen that the adhesive wear resistance of the alloyed layer has improved significantly relative to the substrate.

4. SUMMARY

(1) The wear resistance, high hardness , good metallurgical bonding LSA MMC layers were prepared on ductile iron by a CO_2 laser, using mixed powders of submicron TiC and WC as reinforced phases.
(2) The influence of TiC content on microstructure and microhardness of LSA layers was investgated by variation of TiC the content from 0 to 40 (wt.%).The microstructure of the LSA layer with 40%TiC is the most uniform and dense.A large number of carbide particles dispersed in interdendritic which made a significant contribution of improving the microhardness. The average hardness of the LSA coating with 40%TiC is about 1097 $HV_{0.2}$.
(3) The wear resistance of the LSA layers with 40%TiC is better than other layers, its worn surface is flat and the mian wear pattern is abrasive wear. the wear resistance of ductile iron was improved by LSA with submicron TiC and WC.

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