

Research on Wear-resisting of Copper- Indium-infiltration on 304 Stainless Steel by Double Glow Plasma Technology

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Abstract. Copper indium element is penetrated into the surface of 304 stainless steel by double glow plasma alloying technology. The microstructure of the sample was analysed by means of SEM and EDS. The friction performance test of the samples is carried out with the wear testing machine, and the relevant parameters are obtained and compared. The results show that the wear resistance of the 304 stainless steel is improved after the infiltration of the copper and indium.

1 Introduction

304 stainless steel is a kind of common stainless steel material, which has the good processing performance and characteristics of high toughness, therefore it has been widely applied in industry , food and medical fields. However, its hardness is low, usually in the case of 200HV below and the surface is easy to produce a scratch. What's more, it may also lead to the corrosion resistance of the product is reduced, so that it is premature to scrap [1-2]. Wear is one of the main failure forms of mechanical materials. The mechanism of failure of the material is the friction of the parts in relative motion, the friction leading to loss of the interaction of metal materials, eventually making the size of the parts change. Therefore, improving wear resistance of 304 stainless steel in order to reduce the loss caused by wear and tear, is of great importance for the development of efficient economy. The double glow plasma alloying technology is that the plasma is produced by the gas ionization , which the plasma is bombard the source, eventually making the workpiece surface to form a layer of alloying layer. The technology has the advantages of low energy consumption, low pollution, low cost, simple operation, strong bonding force, etc[3-7]. In this paper, we study the copper-indium-infiltration layer surface of 304 stainless steel by the double glow plasma alloying technology, then have 304 stainless steel samples and ordinary 304 stainless steel matrix samples to carry on the friction performance test with the wear testing machine, and the comparison analysis.

2 Experimental method

The source material is the quality percentage of 1:1 copper indium alloys. Due to its low melting point , and the experimental process being the melting state, the shape of the size is not strictly

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required and just meets the experimental placed conditions. Cathode material whose size is 40mm * 20mm * 2mm is 304 stainless steel. At the beginning of experiment, polish the surface, and then the source material and 304 stainless steel samples are cleaned with ultrasonic cleaning. The Working medium is Argon. The working pressure is Pa 30~35. The source voltage is 900V~1000V. The cathode voltage is 600V~700V. The temperature of the workpiece is 1100°C, and the insulation is 6h with the furnace cooling. 304 stainless steel samples with Copper- Indium layer are corroded with aqua regia. The Scanning electron microscopy (SEM) was used to observe the microstructure of the infiltration layer. The distribution of elements in the permeability layer is detected by using energy dispersive spectrometer (EDS). The friction performance test was done for the samples with the permeability layer and the common 304 stainless steel by HSR-2M type high speed reciprocating friction and wear testing machine. The key parameters were compared and analyzed. The concrete steps are as follows:
 (1) Use acetone to clean the samples by Ultrasonic cleaning.
 (2) The samples are fixed on the test machine. The load is 10 N, 20N, 30N, respectively. The loading time is 30min. The spindle speed is 500 rpm. The reciprocating length is 5 mm.
 (3) Observe and record the respective coefficient of friction curve.
 (4) Scan samples of the wear scar. The width of the wear scar, the wear depth and the wear amount of each sample are recorded.

Table 1. The element gradient distribution in the infiltration layer

No.	Surface layer depth (μm)	Fe	Cr	Ni	Mn	C	Si	Cu	In	O
1	3	59.15	19.17	8.98	1.13	0.13	0.93	7.13	0.86	0.57
2	18	58.03	25.31	8.33	2.11	0.19	0.99	4.31	0.52	0.21
3	40	65.02	20.12	8.97	3.21	0.95	0.27	1.34	0.09	0.03

3 Experimental results and analysis

The successful preparation of samples is mildly corroded by aqua regia. The microstructure of the coating is observed by the scanning electron microscope (SEM). As shown in figure 1. The content of copper indium with the change of the depth of the layer is analysed by EDS. The results are shown in table 1. From table 1, copper indium element is parabolic gradient distribution in the infiltration layer. The reason is: Firstly, the surface of the workpiece is easy to form the vacancy defect layer. In the surface of the substrate, the iron atoms are bombarded with high energy charged particles, which make the surface layer form the concentration gradient of the vacancy defect. The copper atoms which are emitted by the source of the source are transported and reach the surface of the workpiece to fill the vacancy. Secondly, the diffusion ability of copper indium element is different. The atomic radius of the indium atom is 144 pm. The atomic radius of the iron atom is 126 pm. Both of them are small and mainly exist in the form of interstitial solid solution. The atomic radius of the copper atom is 128 pm, the atomic radius of which is close to the iron atom, and Copper elements exist in the form of displacement solid solution. The Figure 2 is the 1000 times of copper-indium layer surface morphology SEM photo. The surface morphology of the Permeability layer is formed by the granular

structure. Each particle size is about $1\ \mu\text{m}$, which is closely connected with the arrangement.

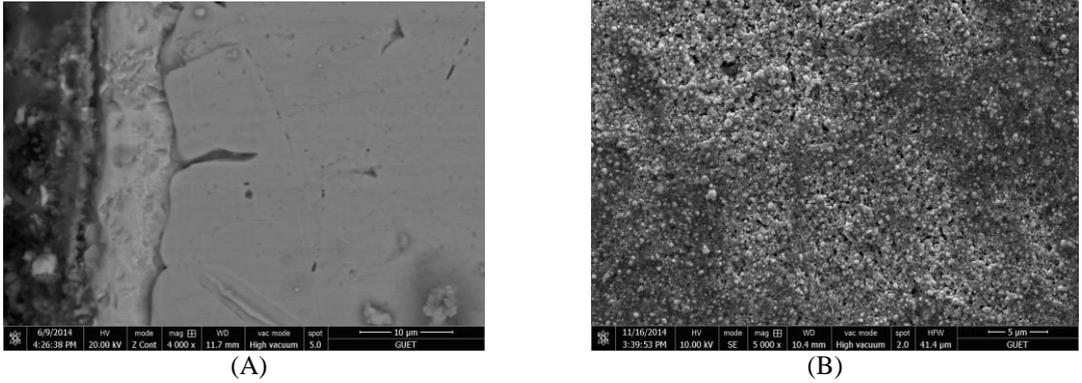


Figure 1. The scanning electron microscopy (SEM) infiltration layer section picture(A)
The copper-indium layer surface morphology SEM photo(B)

The phase of layer permeability mainly include: Fe, Cu, Cu_7In_3 , $\text{Cr}_6\text{Fe}_{18}\text{Mn}_5$, In_2O_3 , CuO , CCuO_3 , etc. The surface of the layer contains a large number of copper ions. The reason is that the copper atoms in the matrix of the solid solution in the matrix of the matrix are constantly accumulating, and the dispersion of the copper ion is precipitated in the process of heat preservation; On the other hand, due to a large amount of active ion from the source, copper ions are not diffused into the matrix, and deposit on the surface. The friction coefficient is one of the main factors that decide material tribology performance. Usually, under equal conditions, the lower friction coefficient is, the wear-resisting performance is better. On the contrary, the wear resistance will be worse. The figure 2 is, respectively, the load on the 10 N, 30N, 20N test conditions, the friction coefficient and time curve of 304 stainless steel samples with a copper indium alloy layer and normal 304 stainless steel.

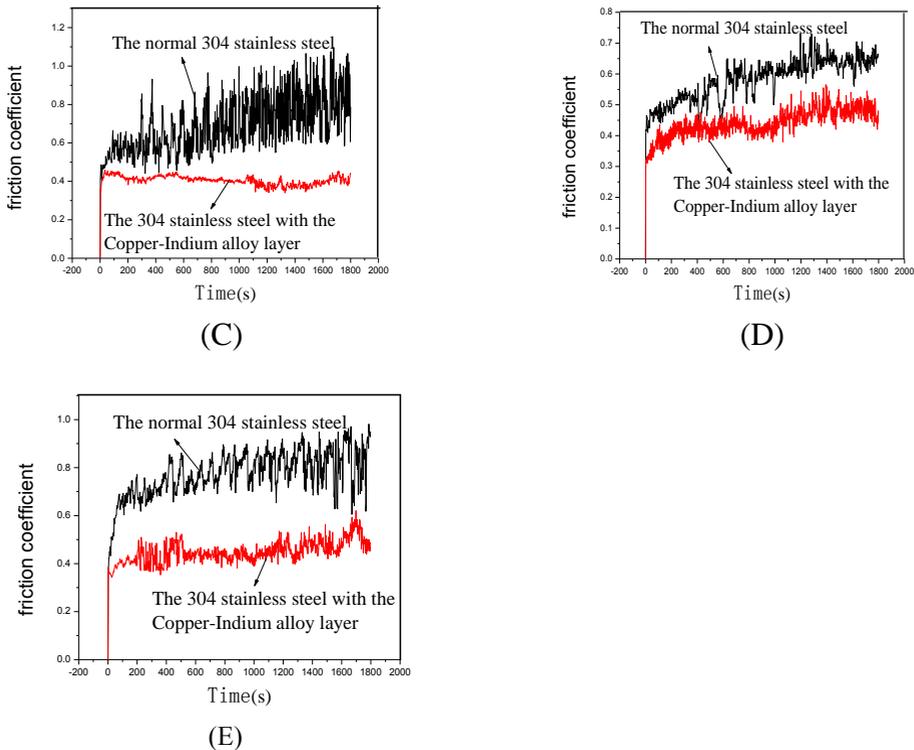


Figure 2. Relationship curves of friction coefficient and time in 10N (C), 20N (D), 30N (E)load

5 Conclusions

In the process of reciprocating friction and wear tests, the friction coefficients of the 304 stainless steel samples with copper-indium layer and the normal 304 stainless steel samples under the condition of 10N, 20N and 30N are respectively stable at 0.38 and 0.63, 0.42 and 0.49, and 0.73 and 0.8.

Under the load of 10N, 20N and 30N, the wear of the 304 stainless steel samples with copper-indium layer and the common 304 stainless steel samples are respectively 0.0429 mm³ and 0.0622 mm³, 0.0569 mm³ and 0.0766 mm³, 0.0693 mm³ and 0.0978 mm³ in the Wear scar profile experiment.

Its wear resistance has been improved, when copper and indium infiltrate the surface of 304 stainless steel.

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