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Coating of AISI 4340 low-alloy steel with austenitic stainless steels and stellite6 cobalt base by tungsten-gas arc welding method and investigation of the microstructure and wear behavior of the resulting layer

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ABSTRACT: In this research, the microstructure and wear behavior of high-strength AISI 4340 low-alloy steel coated using austenitic stainless steels ER309, ER312, and cobalt base steel stellite 6 were investigated by tungsten-gas arc welding method. Microstructural investigations were carried out by optical microscope and scanning electron microscope equipped with X-ray energy diffraction spectroscopy system(EDS). Hardness measurement was done by the Vickers method with a load of 30kgf on the surfaces and Vickers microhardness in the transverse sections of the welds in zigzag form. Also, To evaluate the wear behavior, the wear test of the pin on the disc was used to identify the wear mechanism. the highest hardness was related to stellite 6 by the amount of 565(HV), the reason for this increase in hardness is the presence of carbide phases M23C6 and M7C3 as well as chromium-tungsten complex carbides among bright cobalt dendrites. The results of the wear test showed that the highest friction coefficient was related to ER309 weld metal has an average value of 0.68 and the lowest friction coefficient is related to stellite 6 weld metal with an average value of 0.53.

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1- Introduction

Choosing wear-resistant materials, taking into account the type of wear mechanism, can be effective in terms of cost and increasing the service life of wear parts. Therefore, the type of wear mechanism and the way to deal with this phenomenon is very important for a suitable choice of coating material. The alloys used to create the wear-resistant layer can be of the iron base type, including austenitic alloys with austenitic structure resistant to abrasive wear combined with high impact and resistant to abrasive wear under low forces and economical of these alloys, which is why The characteristics of stainless steels are recommended as coating materials. Another reason for the attention of these alloys is the resulting microstructure, which includes ferrite, austenite, and chromium carbide phases, which show good resistance in metal-to-metal wear conditions at high temperatures (such as rolling rollers) and low temperatures [1]. Another category of cobalt-based non-ferrous alloys is called stellite. One of the important features of these alloys is high wear resistance, corrosion resistance, good stability at high temperature and a combination of these conditions in hostile environments. [2, 3]. Chen et al investigated the wear behavior of stellite 6 laser coating on AISI4340 and AISI4140 steels. The results showed that the thickness of the oxide layer created with the coating of Stellite 6 is in the range of 6 to 12 micrometers. The created oxides are very hard and adhere well to the substrate, these oxide layers do not peel off easily, and therefore the wear rate of Stellite 6 is quite mild [4]. Martin et al. evaluated the additive friction stirrer deposit of 316L to repair surface material loss in AISI4340 steel. The results showed that the wear resistance of 316L coating is as good or better than AISI4340 substrate material. However, there was evidence that intergranular corrosion resistance was compromised due to the formation of carbides or sigma phases [5].

In general, this article Aims to carry out a detailed study on the wear mechanism of Stellite6 alloys and ER312-ER309 austenitic stainless steels with welding coating by gas tungsten arc welding process to discover and compare the wear and mechanical properties of the alloys in question on AISI4340 high strength low alloy steel, is.

2- Research materials and methods

In this research, AISI 4340 high strength low-alloy steel as the substrate and coating metals are made of austenitic stainless steel ER312 and ER309 with diameters of 2.4 mm made by Ama company and cobalt base filler metal Stellite 6 with a diameter of 2.3 mm made by the company Delero UK was used. 3 discs made of AISI 4340 for coating and 1 raw sample to compare the wear surface with coated samples in sizes of 110 and 10 mm in diameter and thickness, respectively.

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Table 1. Welding conditions and parameters of samples

Current (A)	Interpass temperature °C	Speed (mm/s)	Polarity	position	Preheat temperature(°C)
first layer = 150 second layer = 120	140-150	2-2.5	straight	Flat	**150-160**

Table 2. The results of the surface hardness of the samples

samples	AISI 4340AISI	Stellite6	ER309	ER312
Average hardness(HV)	304	565	256	**297**

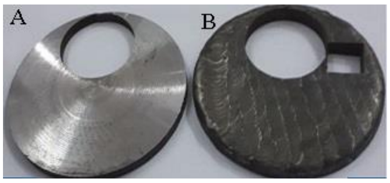

Fig. 1. Discs samples.A:Raw sample, B: Coated sample

Welding conditions and parameters are listed in Table 1. To perform microstructural tests, 50 mm diameter disc samples and other samples of square cross-section according to Figure 1 with dimensions of 20 x 20 mm from coated discs and one uncoated disc sample with a diameter of 50 mm were prepared with a wire cut. After preparing the samples from appropriate sections for microstructural investigations by optical and scanning electron microscopes, the samples were sanded and polished using 60 to 3000-grit sandpaper, then the polished samples, To compare the wear behavior, one sample of each type of coating and one raw sample was prepared to compare with the coated samples, all with a diameter of 50 mm. The conditions of the pin-on-disk test were performed according to the ASTM G99 standard at a temperature of 25 degrees Celsius, a speed of 0.05 m/s, and a humidity of 40%. Also, the applied load on the raw sample and 3 coated samples was set to 100N, and the force-applying pin was selected from 52100 bearing steel. Hardness measurement results of the cross sectional surface of the coatings were done by the vickers method,30kg load in 15 seconds.

3- Results and Discussion

According to Figure 2, a thin martensitic layer has been created at the interface between the substrate and the first layer. The reason for this can be explained by the penetration of carbon from the substrate to the interface, and it was also observed at the interface due to the large difference in the chemical composition of the substrate and the filling metal of the partially uncombined area. Epitaxial growth is due to the similar chemical composition at the interface. The first layer with the second layer is clearly evident that the structure has

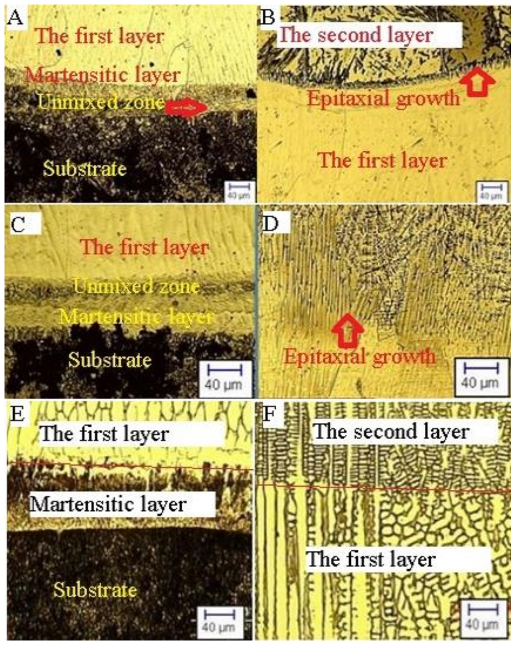

Fig. 2. Optical microscopic images of weld metal interface (A,B: ER312- B,C:ER309- EF:Stellite6)

changed from the interface to the first layer due to the lower cooling and solidification speed and from the interface to the second layer due to the higher cooling and solidification speed and the chemical composition of the weld metal.

4- Conclusions

1. In ER312 weld metal, the hardness is significantly higher than the sample welded by ER309, this problem can be attributed to the presence of more ferrite in the structure of ER312 weld metal due to its relatively different chemical composition and freezing structure, Attributed.

2. The maximum hardness in the austenitic stainless steel samples ER309 and ER312 was observed first in the interface due to the formation of the martensite layer and then in the HAZ region of the AISI4340 substrate steel due to the

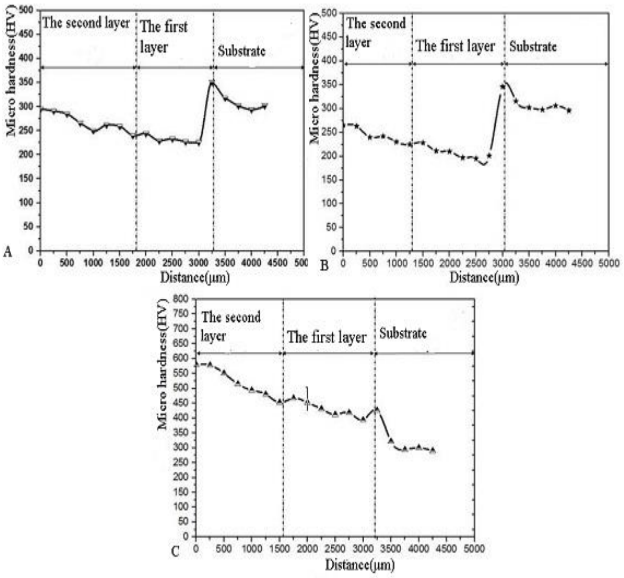

Fig. 3. Microhardness of the cross section of the coating toward s the AISI4340 steel substrate A:ER312-B:ER309-C:Stellite 6

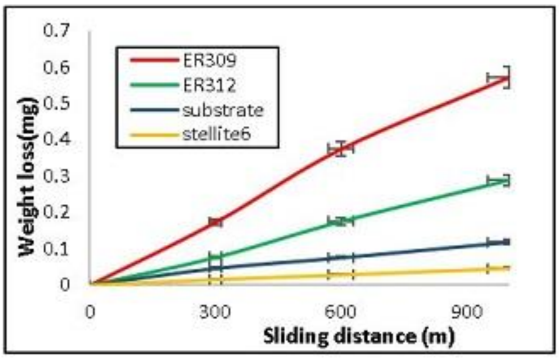

Fig. 4. Graph of weight loss by distance for coating and substrate metals

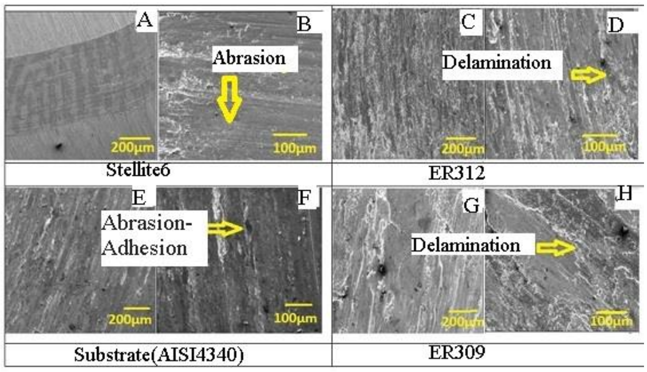

Fig. 5. SEM images of wear surfaces for coating and substrate samples

presence of tempered martensite in the structure.

3. The highest value of hardness, wear resistance, and also the lowest value of friction coefficient was observed in Cobalt Stellite 6 base weld metal, and the lowest value of hardness, wear resistance, and highest friction coefficient was observed in ER309 austenitic weld metal sample.

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