Surface Characterization of Chromized AISI 5115 Steel by Thermo Reactive Diffusion Method

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Abstract

In the present study, effect of the thermo reactive diffusion (TRD) chroming process on characterization properties of AISI 5115 steel has been investigated. AISI 5115 steel was chrome plated at 950 C for 2 and 8h by thermo reactive diffusion method with 40% Al₂O₃, 40% ferro-chromium and 20% NH₄Cl powders. The chromium carbide layer was characterized by optical microscopy, X-ray diffraction technique and the micro-hardness tester. X-ray diffraction analysis of chromium carbide layers on the surface of the steels revealed the existence of Cr₃C₂ and Cr₇C₃ compounds. Depending on the chemical composition of substrates, the chromium layer thickness on the surface of the AISI 5115 steel was found to be 17.35±1.4 µm. The hardness of the chromium carbide compounds formed on the surface of the steels ranged from 1674 to 1758 HK_{0.025}, whereas Vickers hardness values of the untreated the steels was 348 HK_{0.025}.

Keywords: AISI 5115, TRD Process, Chromized, Characterization.

Termo Reaktif Difüzyon Yöntemiyle Kromlanmış AISI 5115 Çeliğinin Yüzey Karakterizasyonu

Öz

Bu çalışmada, termo reaktif difüzyon (TRD) yöntemiyle kromlama işleminin AISI 5115 çeliğinin karakterizasyon özelliklerine etkisi araştırılmıştır. AISI 5115 çeliği, %40 Al₂O₃, %40 ferro-krom ve %20 NH₄Cl tozları ile termo-reaktif difüzyon (TRD) yöntemiyle 950 C'de 2 ve 8 saat süreyle krom kaplanmıştır. Krom karbür tabakası optik mikroskop, X-ışını kırınım tekniği ve mikro sertlik test cihazı ile karakterize edilmiştir. Kromlama sonucunda numune yüzeylerinde Cr₃C₂ ve Cr₇C₃ fazları elde edilmiştir. AISI 5115 çeliğinin kimyasal bileşimine ve sıcaklık süresine bağlı olarak krom karbür kalınlığı 6.82±1.15 µm ile 17.35±1.4 µm olarak elde edilmiştir. Çeliklerin yüzeyinde oluşan krom karbür bileşiklerinin sertliği 1674 ile 1758 HK_{0.025} arasında değişirken, herhangi bir işlem görmemiş çeliğin sertlik değeri 348 HK_{0.025}'dir.

Anahtar Kelimeler: AISI 5115, TRD İşlemi, Krom Kaplama, Karakterizasyon.

1. Introduction

Protection of metals with metal plating is a very common practice as they are more durable, more decorative and provide better protection against corrosion. One of the methods used in coating metal with metal is the thermo reactive diffusion process. Thermo-reactive diffusion process; It is a method in which hard layers with high wear resistance such as carbide, nitride and carbo-nitride are formed on the surface of steel materials. In the TRD process, carbon and nitrogen in steel and base material are diffused with carbide or nitride forming elements such as vanadium, niobium, tantalum, chromium, molybdenum or tungsten to form a deposited layer [1]. Depending on the base carbon content in the hard metallic coating metal layer in the amount of low-carbon (aluminum, chromium, titanium, boron), while the high carbon content depending on the kind of the ferro-alloys used ceramic based layers (chromium carbide, titanium carbide, vanadium carbide) is obtained. Carbon and nitrogen, which diffuse to metals, react intensely with carbide and nitride forming elements to form carbide and nitride coatings that are metallurgically bonded on the substrate surface. The TRD process is unlike conventional surface hardening methods. Because in traditional surface hardening methods, carbon and nitrogen are diffused from outside in order to harden the surface of the base material. Although the TRD Process is not similar to the conventional diffusion method, the coating layer is formed on the surface of the substrate in the TRD process. The coating layer thicknesses obtained in the TRD process can be achieved by using CVD or PVD techniques. By comparison, the thickness of the CVD coatings is close to the thicknesses of the coatings obtained in the TRD process [2,3]. The carbide layer can be formed in four different environments by thermo-reactive diffusion. Solid medium carburizing, fluidized bed carburizing, carburizing by precipitation in the gas phase, carburizing in liquid medium. Solid medium carburizing; It takes place by keeping the material whose surface will be carburized in a powdered carbide-forming medium at temperatures between 850–1050 ° C for 10–30 hours. This method, similar to box cementation, can be performed in an inert gas atmosphere or in tightly sealed boxes in normal atmosphere [4,5]. The components of the carburizing medium consist of a carbon-containing compound, as well as a carbide forming element, activator, and filler material. Carbide forming elements are Cr, Mo, W, Nb, Zr, Ta, Tive Si. The carburizing process in the fluidized bed system is carried out at temperatures between 900–1200 ° C in a fluidized environment with ceramic carbide powders varying in size from 100–200 µm placed in a closed environment and an inert gas mixture fed from the bottom [6]. The TRD Process experimental equipment is simple, low cost, selective carbide coating enables uniform coating in the indented area allows long bath and mold life, easy to clean of the adhering powder, preservative does not require atmosphere, the lack of waste and toxic gas does not harm the environment and labor saving provides.

In this study, chromium carbide phases, coating layer thickness, surface roughness and microhardness were investigated on the surface of AISI 5115 steel, which is Cr coated with TRD method.

2. Material and Method

The AISI 5115 steel essentially contained 0.2 wt.% C, 0.95 wt.% Cr, 1.2 wt.% Mn and 0.35 wt.% Mn. AISI 5115 steel, cut in the dimensions of Ø12 x 10 mm dimensions, ground up to 1000G and polished using diamond solution and are chromized with 40% Al₂O₃, 40% ferro-chromium and 20% NH₄Cl powders in a stainless steel box with thermo-reactive diffusion method (TRD) for 2 and 8 hours at 950 °C. The microstructures of polished and etched cross-sections of the specimens were observed under a Nikon MA200 optical microscope. The presence of borides formed in the coating layer was confirmed by means of X-ray diffraction equipment using Cu K α radiation. The hardness measurements of the boride layer on each steel and untreated steel substrate were made on the cross-sections using a Micro Knoop indenter with a 25 g load.

3. Results and Discussion

3.1. Characterization of coatings

Figure 1 shows the optical microstructures of AISI 5115 steel chromed at 900 °C for 2 and 8 h. As a result of the chroming process with the TRD method, a chromium carbide layer has formed on the steel surfaces. The chromium carbide layer is a very hard phase. Chromium carbide layer thickness increased with increasing TRD process temperature (Table 1). Chromium carbide layer thickness of TRD chromized AISI 5115 steel at 950 °C for 2 and 8h were obtained $6.82 \pm 1.15 \mu\text{m}$ and $17.35 \pm 1.4 \mu\text{m}$, respectively.

The hardness values of the chromided samples increased due to the TRD chromium carbide phases. While the lowest surface hardness value was observed in the sample chromized with 1674 HK_{0.025} for 2h at 950 °C, the highest hardness value was observed in the sample chromized with 1758 HK_{0.025} for 8h at 950 °C. The hardness value of the untreated sample is 348 HK_{0.025}. Chroming process increased the roughness values of the samples. The surface roughness of the sample was obtained after chroming at 950 °C for 2h and 8h, $0.454 \pm 0.08 \mu\text{m}$ and $0.418 \pm 0.07 \mu\text{m}$, respectively.

Figure 1. The cross section microstructure of TRD chromized AISI 5115 steel, a) 950 °C-2h, b) 950 °C-8h

Table 1. Microhardness, coating layer thickness and surface roughness values of TRD chromized AISI 5115 steel

	Layer thickness, (μm)	Microhardness ($\text{HK}_{0.025}$)	Surface roughness, R_a (μm), untreated	Surface roughness, R_a (μm), treated
950 °C - 2h	6.82 $\pm$ 1.15	1674	0,265 $\pm$ 0.04	0.454 $\pm$ 0.08
950 °C - 8h	17.35 $\pm$ 1.4	1758	0.291 $\pm$ 0.02	0.418 $\pm$ 0.07

Figure 2 shows XRD analysis of diffusion coatings formed on steels. As seen in Figure 2, Cr_3C_2 and Cr_7C_3 chromium carbide were obtained in 2 and 8h chrome plated layer at 950 °C. The chromium layer consists of Cr_3C_2 and Cr_7C_3 carbides in samples subjected to chroming surface treatment at 950 °C for 2 and 8 hours. The dominant phase is Cr_3C_2 carbide.

Fig. 2. XRD patterns of TRD chromized AISI 5115 steel) 950 °C - 2h, b) 950 °C - 8h

4. Conclusions

The results obtained from this study are as follows. Depending on the process time, temperature and chemical composition of substrates the depth of the TRD chromium carbide layer ranged from 6.82 $\pm$ 1.15 to 17.35 $\pm$ 1.4 μm . The multiphase TRD chromium coatings that were thermo chemically grown on the steel was constituted by the Cr_3C_2 and Cr_7C_3 phases. Chromium carbide layer thickness increased with increasing chroming temperature. The surface hardness of the TRD chromized steel was in the range of 1674-1758 $\text{HK}_{0.025}$, while for the untreated the steel substrate it was 348 $\text{HK}_{0.025}$. TRD Chroming process increased the roughness values of the samples.

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