Structural Characterization Of Iron Aluminide Coatings On Aisi 4140 Steel By Trd

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Abstract

In the present study, structural characterization of iron aluminide coated AISI 4140 steel by thermo-reactive deposition technique (TRD) in the powder mixture consisting of pure aluminum, ammonium chloride and alumina at the temperatures of 700°C, 800°C and 900ºC for 1-5 h were investigated. The coated samples were characterized by X-ray diffraction, scanning electron microscope and micro-hardness tests. Iron aluminide layer formed on the AISI 4140 steel was smooth, compact and homogeneous. The phases formed in the coating layer deposited on the surface of the steel substrates are Fe2Al5, FeAl2, AlN and Al2O3. The depth of the iron aluminide layer ranged from 37.56±3.46 µm to 280.38±21.58 µm, depending on treatment temperature and time. The higher the treatment temperature and time the thicker the coating layer observed. The hardness of the iron aluminide layer was ranged from 952.4 to 1003.2 HV0.005.

Keywords: Coating, aluminizing, iron aluminide, thermo reactive deposition

1. INTRODUCTION

Protective coatings by pack aluminizing are frequently applied to metals to protect them from high temperature oxidation and hot corrosion attack. Pack aluminizing consists of heating the parts to be coated in a closed or vented pack to a high temperature for a period of time, during which a diffusion coating of desired composition and thickness is produced on the metal (Zhan 2006, Zhan 2007 and Smith 2005). Aluminide coatings were formed at a relatively lower temperature and in a shorter treatment time by combining the pack aluminizing with the ball impact process, compared with the conventional pack aluminizing. The pack processes for simultaneous depositions of Al and Cr, A1 and Si on either steels or super alloys have been studied using a mixture of alloy powder as the pack component. (Lee 2005). Conventional processes for fabricating aluminide coatings, such as pack cementation or chemical vapor deposition (CVD), are typically carried out at elevated temperatures (700-1150°C) (Zhang 2007). Iron aluminide coatings are applied on steels to improve their corrosion resistance in oxidizing, sulphidizing and carburizing environments encountered in coal gasification plants, crude oil refineries and petrochemical industries. In addition, Aluminide-containing surface layers of steel provides high resistance to erosion or low-stress abrasive wear at elevated temperatures, corrosion, and corrosive wear. Iron aluminide-based coatings have demonstrated excellent oxidation resistance in exhaust/steam environments by forming a protective alumina scale. With the push towards ultra-supercritical steam coal-fired power plants, alumina-forming coatings become particularly attractive because at higher operating temperatures the slow growth of alumina and its stability in the presence of water vapor are superior to coatings that form chromium or silica-rich scales. (Jhon 2004, Ahmedi 2003, Pereza 2000 and Zhang 2007).

The main objective of this study was to investigate some structural, morphological and mechanical properties of iron aluminide layers formed on the AISI 4140 steel produced by thermo reactive deposition technique.

2. EXPERIMENTAL PROCEDURES

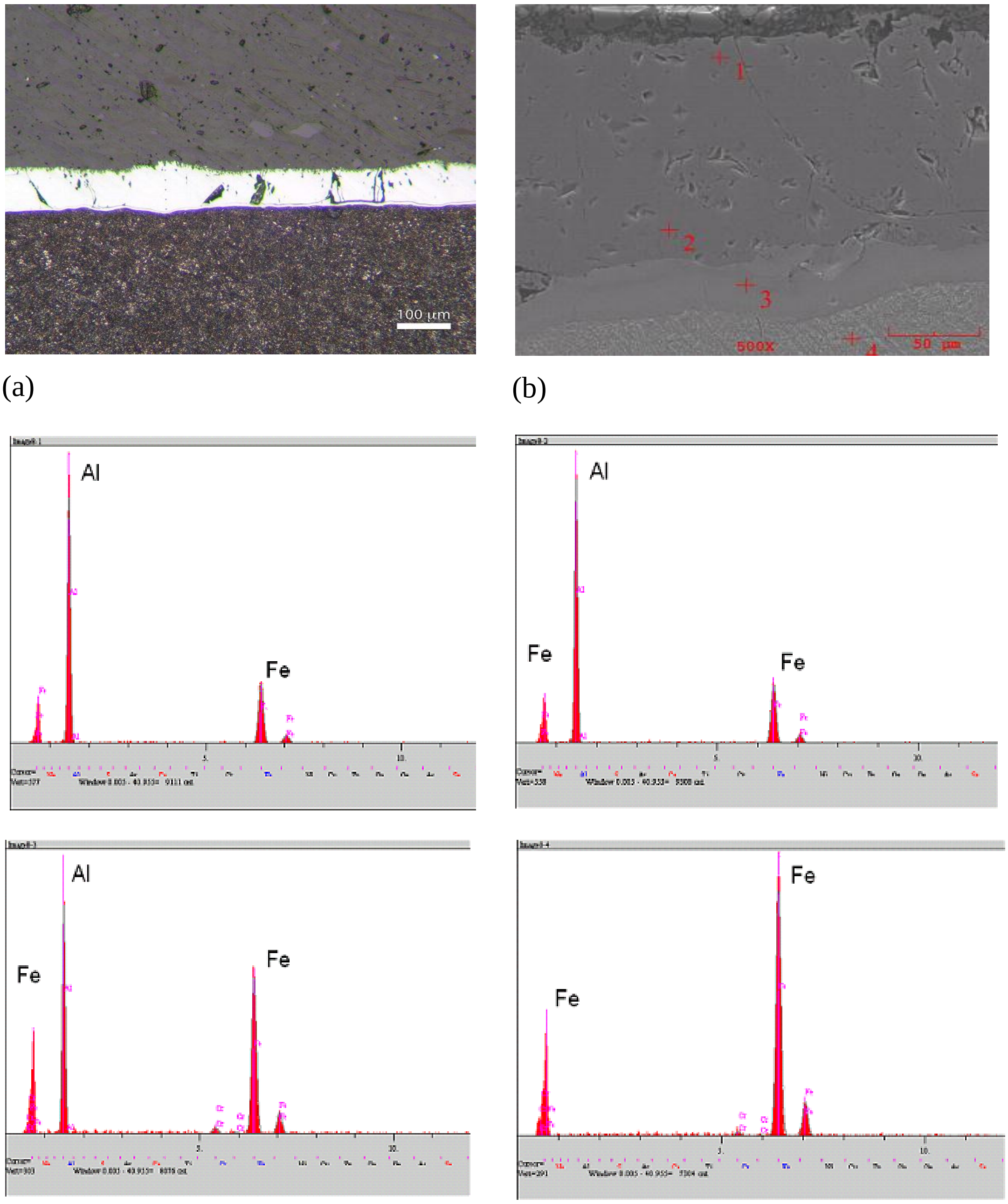
The work-piece material used in this study was AISI 4140 steel containing 0.40wt.% C, 0.25wt.% Si, 0.18wt.% Mo, 0.62wt.% Mn and 1.0wt.% Cr. The substrate samples were in the form of cylindrical coupons that have dimensions of 22 mm in diameter and 5 mm in thickness and polished progressively with 1200 grit emery papers. Then, these samples were cleaned ultrasonically in acetone and dried. Aluminizing was performed on the steel samples by thermo-reactive deposition (TRD) process. The TRD process was performed utilizing a pack box containing pure aluminum, ammonium chloride and alumina powders, in a high temperature tube furnace. Pure aluminum, ammonium chloride and alumina were used as metal supplier (Al), activator and filler materials, respectively. Iron aluminide coated samples were sectioned from one side and prepared metallographically up to 1200 grid emery paper and then polished using 1µm alumina paste. Polished samples were etched by 3% Nital before tests. The thickness of coatings and their morphology were examined using NICKON ECLIPSE L150 optical microscopy and JEOL 6060 LV scanning electron microscopy (SEM) on the cross-sections of the iron aluminide coated samples. The chemical analysis of the coating layers were determined by x-ray diffraction analysis using by RIGAKU XRD D/MAX/2200/PC x-ray diffractometer with Cu Kα radiation. The hardness of the coated steel materials was also measured using a FUTURE TECH FM 700 micro-hardness tester fitted with a Vickers indenter under the loads of 5 gf.

3. RESULTS AND DISCUSSION

Figures 1(a-c) show optical, SEM micrographs and EDS analysis of the iron aluminide coated AISI 4140 steel at 800ºC for 1h and 800ºC for 3h, respectively. Coating layers formed on the AISI 4140 steel were compact homogenous, with significant regularities in their thickness and presenting a smooth interface with the substrate (Figure 1a,b). EDS analysis showed that, the coating layer includes higher aluminum in the coating layer as seen in Figure 1(c). Aluminum concentration of in the outer of the coating layer is much higher than that of inner parts of the coating layer and iron concentration of the inner parts of the coating layer is much higher than that of the in the outer of the coating layer was observed as seen in Figure 1c .

XRD pattern (Figure 2) of the iron aluminide coated sample at 800 ºC for 3 h showed that, the phases formed on the coated steel sample are Fe2Al5, FeAl2, AlN and Al2O3. This result agrees with earlier studies of Zhan et al. (Zhan 2007). The thickness of iron aluminide layer ranged from 37.56±3.46 µm to 280.38±21.58 µm, depending on treatment temperature and time. The higher the treatment temperature and time, the thicker the iron aluminide layer became. Figure 3 shows the iron aluminide layer thickness depending on process temperature and time. For thermo chemical coating processes, the longer the process time and the higher the treatment temperature, the thicker the coating layer becomes. Bath composition, substrate, treatment time and temperature affect the coating layer thickness in the TRD processes (Arai 1989). The hardness of the iron aluminide layer formed on the AISI 4140 steel was ranged from 952.4 to 1003.2 HV0.005 (Figure 4) whereas the hardness of uncoated steel is 390

HV0.005. These results are in good agreement with Zhan et al. (Zhan 2007). These are due to the presence of hard aluminides (Fe2Al5 and FeAl2) in the coating layer as verified by XRD analysis (Figure 2).



(c)

Figure 1. (a) Optical, (b) SEM micrographs and EDS analysis of the iron aluminide coated AISI 4140 steel at 800ºC for 1h and 800ºC for 3h, respectively.

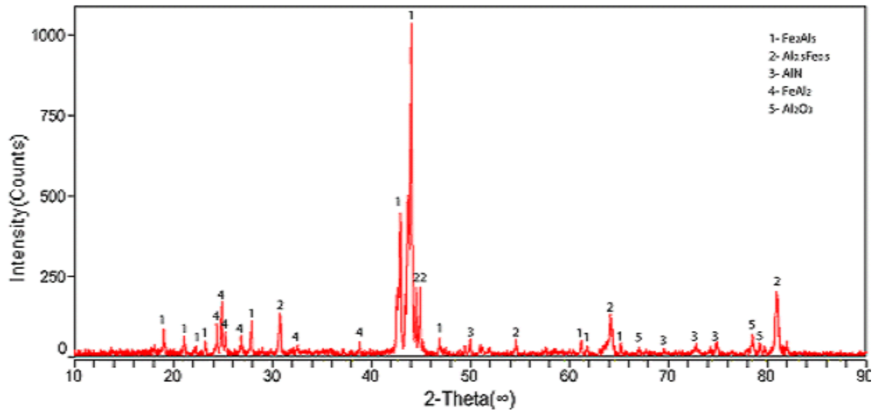
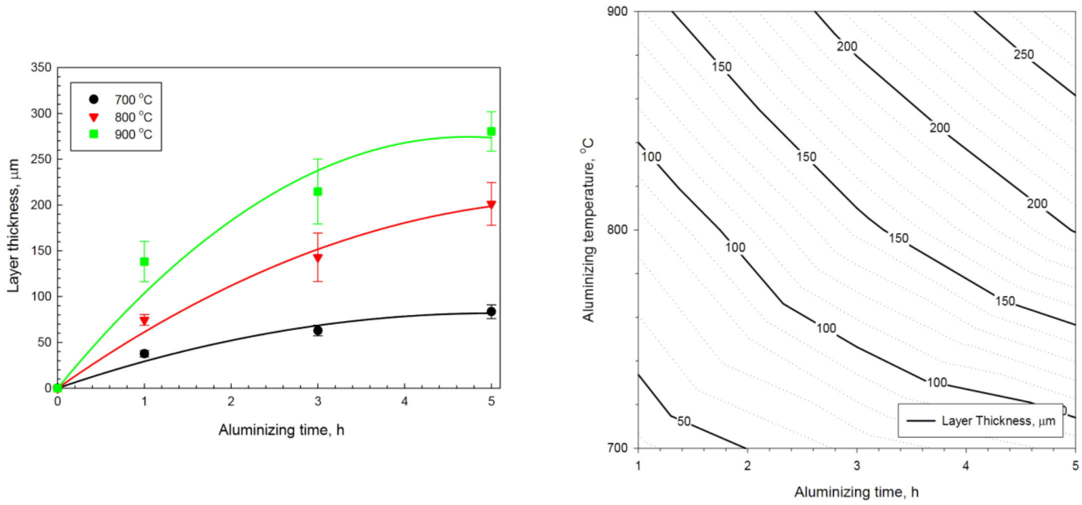


Figure 2. XRD pattern of the iron aluminide coated AISI 4140 steel at 800 ºC for 3 h



(a) (b)

Figure 3. (a) The thickness of iron aluminide layer formed on AISI 4140 steel and (b) contour diagrams of coating layer thickness depending on process parameters

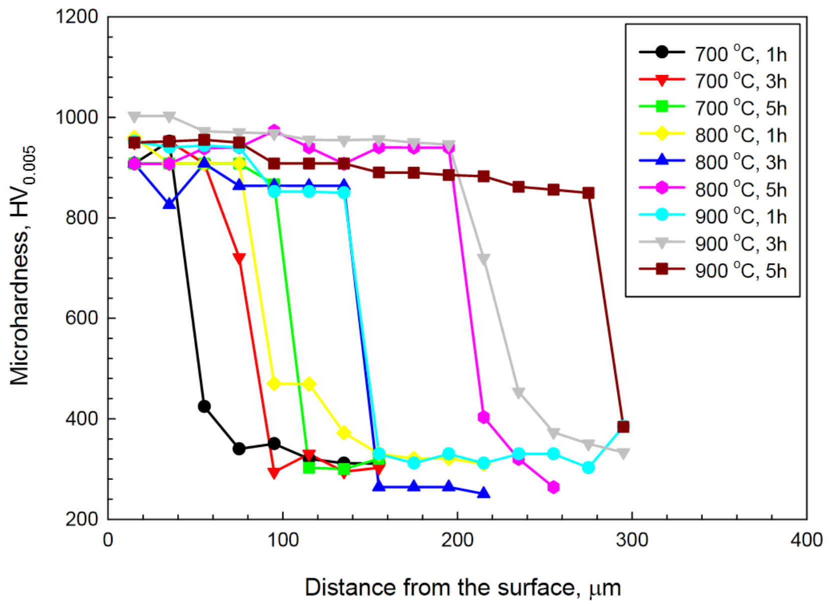


Figure 4. The variation of hardness of iron aluminide layer formed on AISI 4140 steel from surface to interior, depending on process parameters.

4. CONCLUSIONS

AISI 4140 steel was the substrate used for the deposition of iron aluminide coating by thermo-reactive deposition technique and the treatment was proved to be efficient in the production of iron aluminide base coatings.The results obtained from present study can be summarized as follows:

• Coating layers formed on the AISI 4140 steel were compact homogenous, with significant regularities in their thickness and presenting a smooth interface with the substrate.

• EDS analysis show that aluminum concentration of in the outer of the coating layer is much higher than that of inner parts of the coating layer and iron concentration of the inner parts of the coating layer is much higher than that of the in the outer of the coating layer was observed. • XRD analysis showed that the coating layer includes Fe2Al5, FeAl2, AlN and Al2O3 phases.

• The thickness of iron aluminide layer ranged from 37 µm to 280 µm, depending on treatment temperature and time.

• The hardness of the iron aluminide layer formed on the steel samples was changingbetween 952.4 to 1003.2 HV0.005 which was much harder than steel (390 HV0.005).

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