ALUMINIDE COATING ON STAINLESS STEEL FOR NUCLEAR REACTOR APPLICATION: A PRELIMINARY STUDY

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ABSTRACT

Stainless Steels have been used as structural materials in the nuclear reactor since its first generation. Stainless Steel type 304 and 316 are commonly used in structural components. Since the first generation materials, improvements were made on Stainless Steels. This includes addition of stabilizing elements and by modification of metallurgical structure. This study investigates the formation of aluminide coating on Stainless steels by diffusion to help improve corrosion resistance. Stainless Steel type 304 and 316 subtrates were immersed in molten aluminum at 750°C for 5 minutes. Interaction between molten aluminum and solid to form the outer aluminide coating by hot dipped aluminizing is studied.

ABSTRAK

Keluli Tahan Karat telah digunakan sebagai bahan struktur di reaktor nuklear sejakgenerasi pertamanya. Jenis Keluli Tahan Karat 304 dan 316 biasanya digunakan dalam komponen struktur. Sejak bahan-bahan generasi pertama, peningkatan telah dibuat di Stainless Steels. Ini termasuk tambahan menstabilkan unsur dan oleh pengubahsuaian struktur pelogaman. Kajian ini menyiasat pembentukan salutanaluminide di keluli Stainless oleh resapan membantu meningkatkan rintangan kakisan. Jenis Keluli Tahan Karat 304 dan 316 subtrates asyik dengan aluminiumlebur di 750oC selama 5 minit. Interaksi antara aluminium lebur dan padu untuk membentuk salutan aluminide luar dengan panas cecah pengaluminiuman dirancang.

Keywords: Stainless steel, aluminum, aluminide, coating

INTRODUCTION

Steel is the most common materials used as structural materials in industries. In nuclear industries, for instance, there are many items that are made of steel such as vessels, containments, piping systems, pumps, valves, core support structures and storage tanks, including their respective supports (ASTM standards, 2000). Stainless steel type 316 is chosen for structural components of reactor assembly, other than the core components, with operating temperatures above 700K while stainless steel type 304 is chosen for components operating at lower temperatures (Mannan et al., 2004).

Structural components within the reactor core are often the most critical for safe and reliable operation as the failure of a core internal component may have very severe consequences. For advanced future fission reactor systems, structural material performance and integrity are important and likely even more complex (Steven et al., 2009). The first generation materials belonged to 304 and 316 SS grades. These steels quickly reached their limits because of unacceptable swelling at high doses. Many improvements were made by the addition of stabilising elements, by changes in the chemical composition of major and minor elements and by modifications of the metallurgical structure such as by cold working [2].

Aluminide coatings would have potential as one of the solution in protection of steels against degredation. Aluminide coatings have an ability to form a protective and slowly growing oxide (Al2O3) film at higher temperature (above 900°C) (Zielinska et al., 2011). The addition of Al to Stainless steels would increase the oxidation resistance in high temperature and the complex aluminide intermetallic formed exhibit superior resistance to oxidation, carburization and sulfidation (Sharafi et al., 2006). Aluminides exhibit high oxidation resistance owing to a dense and protective alumina layer formed by preferential oxidation of Al. The melting points of aluminides are generally high although that of pure Al is relatively low (660°C) (Shiomi et al., 2011). In preliminary this study, the diffusion of aluminum into steels to form aluminides is investigated.

MATERIALS AND METHOD

Steel plates with 50mm x 10mm x 2mm dimension were used in the experiment as substrate. The oxide surfaces were removed by grinding with SiC abrasive paper prior to cleaning by ultrasonic. Pure aluminum (99.9% from Aldrich Chemical Company Inc) was melted in a graphite crucible at 750°C. Then, the Stainless Steel type 304 (SS304) and 316L (SS316L) substrates were dipped into the molten aluminum for 5 minutes. Finally, the coated samples were cross-sectioned and analyzed by using the Scanning Electron Microscope and EDX.

RESULT AND DISCUSSION

Figure 1 (a-b) show the cross-section of the samples after hot dipping. The thickness of coatings for SS304 and SS316L are measured at 87μm and 91 μm, respectively. Coating thickness for SS316L is higher as compared to SS304 due to lower percentage of carbon in SS316L.

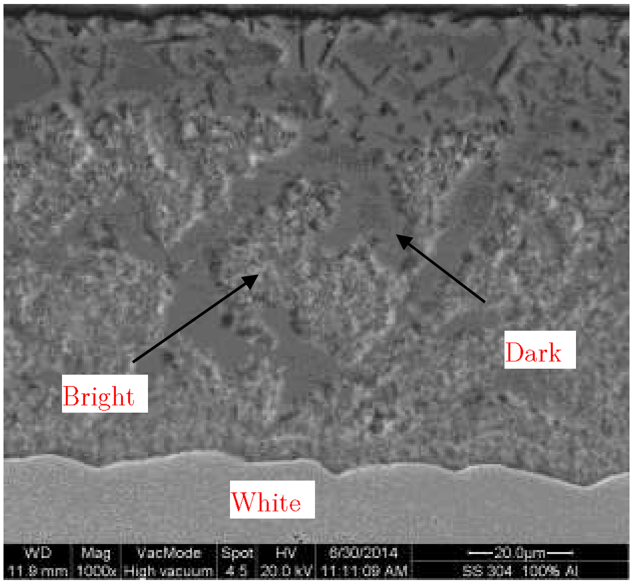

Fig. 1a Microstructure of the aluminized Stainless steel 304 sample

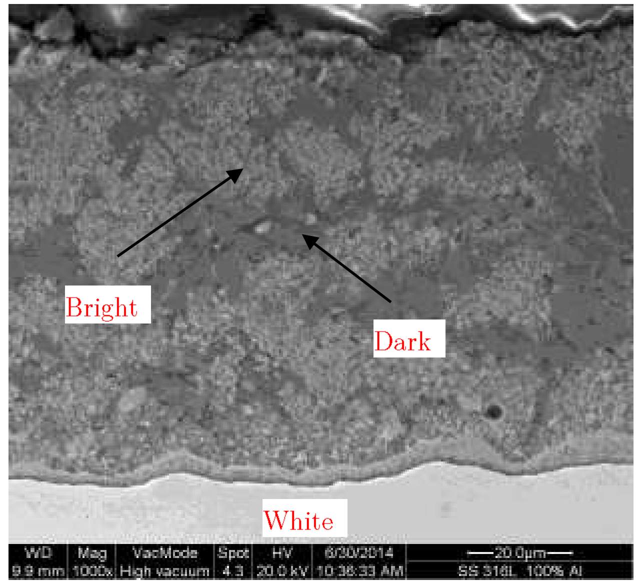

Fig. 1b Microstructure of the aluminized Stainless steel 316L sample

There are three distinct regions that could be recognized which are dark, bright and white areas. Both the dark and bright areas are the coating layer including the intermetallic phases (aluminides), whereas the white area is the steel substrates as reference. Figure 2 (a-d) show the EDX spectrums of all the area of coating. The EDX spectrums show the interaction of aluminum and steel substrate to form the aluminide phases. The dark areas are the aluminum rich area with small amount of elements from steels. The bright areas for aluminized SS304 are the Fe rich areas with small amount of aluminum whereas the bright areas for aluminized SS316L are still the Al rich with higher amount of Fe as compared to the aluminized SS304. Further studies are recommended to be conducted to determine the phases existed inside both coatings by using XRD.

For the aluminized SS304, it was found out that the dark area mostly cover the outer part of coating and grow towards the steel substrate. For the aluminized SS316L, the bright phase dominates the coating with some dark phases distributed randomly in the coatings. This might be due to lower percentage of carbon in S316L to slowdown the diffusion of aluminum into substrate SS316L.

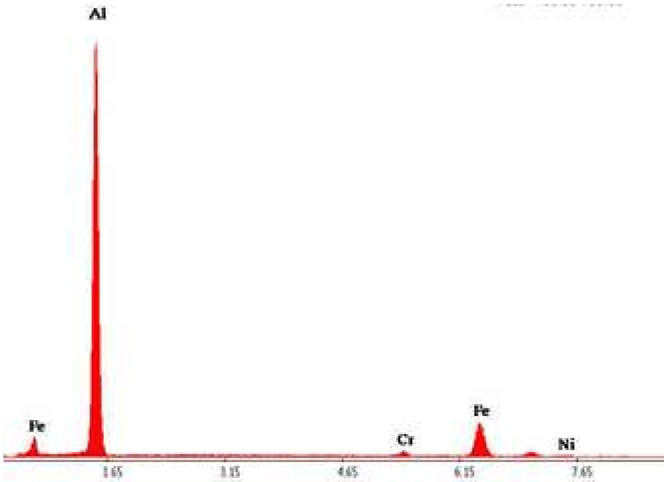

Fig. 2a EDX spectrum of the dark area for aluminized SS304

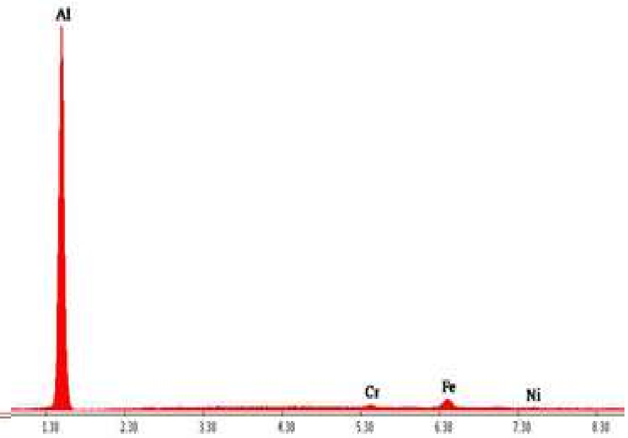

Fig. 2b EDX spectrum of the dark area for aluminized SS316L

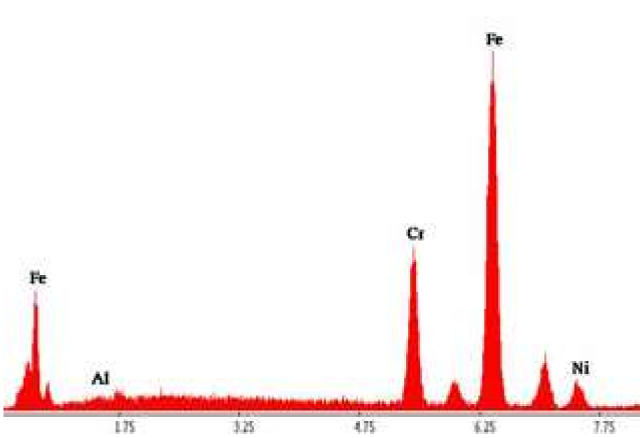

Fig. 2c EDX spectrum of the bright area for aluminized SS304

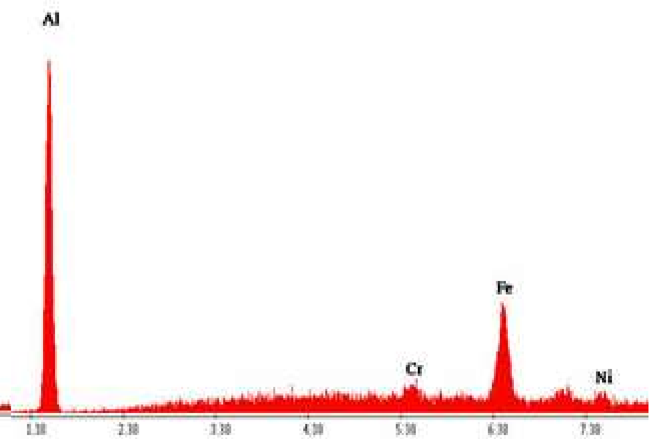

Fig. 2d EDX spectrum of the bright area for aluminized SS316L

CONCLUSION

The interaction of aluminum and steels during hot dipping process was successfully studied. This interaction produces the intermetallic phases. Further studies are recommended to be conducted by using XRD to determine the phases existed inside both coatings and also to determine the mechanical and corrosion properties of the samples.

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