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Investigation of Coatability of NiAl Powder to AISI 304 Stainless Steel Using SHS Process

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ABSTRACT

This study relates to the coatability of the Ni-Al powder to surface of AISI 304 stainless steel substrate using self-propagating high temperature synthesis (SHS) method. Effects of different pressing pressure and sintering after igniting on the microstructure and microhardness of the coating was investigated experimentally. Scanning electron microscope (SEM), X-ray diffraction (XRD) techniques were used to characterize the coatings. The microhardness was measured by microhardness device. Along the depth from the surface towards the substrate coating has been found microhardness variations. Micro hardness of the coating layer increased with increasing of the pressing pressure and the sintering temperature.

Anahtar Kelimeler:
SHS,
Ni-Al,
mikroyapı,
mikrosertlik

ÖZET

Bu çalışma, kendi kendine ilerleyen yüksek sıcaklık sentezlemesi (SHS) yöntemi kullanılarak AISI 304 paslanmaz çelik yüzeyine Ni-Al tozunun kaplanabilirliği ile ilgilidir. Farklı presleme basıncının ve ateşleme sonrası sinterlemenin kaplamanın mikro yapısına ve mikro sertlik değerlerine etkileri deneysel olarak araştırılmıştır. Taramalı elektron mikroskobu (SEM) ve X-ışın difraktogramı (XRD), kaplama tabakasını incelemek için kullanılmıştır. Mikrosertlik, mikrosertlik test cihazı ile ölçülmüştür. Kaplama yüzeyinden alt tabakaya doğru kaplama derinliği boyunca mikrosertlik değişimleri tespit edilmiştir. Kaplama tabasının mikrosertliği, presleme basıncının ve sinterleme sıcaklığının artması ile artmıştır.

1. Introduction

Recently, SHS (Self Propogating High Temperature Synthesis) has been used as a new method. SHS is an advanced technology to produce ceramics, cermets and intermetallic materials. Materials prepared by SHS are reported to be purer and require less energy than conventional methods, which are generally energy-and time-intensive processes (Subrahmanyam and Vijayakumar, 1992; La et al., 1999; Yuan et al., 2011). Austenitic stainless steels are used in the areas such as the medical, kitchen supplies, food, energy and shipping industry. Increasing the wear and corrosion resistance of these steels will expand the application fields. For this purpose, so far paint, polymer coating and ceramic coating and surface modification processes have been used in studies. A potential application to improve high temperature wear and corrosion resistance is to coat the surfaces of this materials with an intermetallic compounds (Jin and Stephenson, 1998; Jimenez et al., 1998; Johnson et al., 1996; B1au and DeVore, 1990). In this study, coatability of Ni-Al powder to AISI 304 stainless steel using SHS was investigated method. The microstructure and phase compositions of the coatings were determined via scanning electron microscope (SEM), energy dispersive spectrometer (EDS) and X-ray diffraction (XRD) analyses.

2. Material and methods

Commercially available Ni (99.9 wt% purity, -325 mesh), Al (99.9 wt% purity, -325 mesh), and B (95-97 wt% purity, diameter <1 μm), powders (purchased from SavKim Chemical Co., Ltd. and Alfa Easer Company) were selected as starting materials. Powders were prepared as 25 wt. % Al and 75 wt.% Ni. 1 wt.% B was added to NiAl mixture, and then mixed. Powder mixture was pressed into cylindrical compacts of 12 mm in diameter using a hydraulic press at a cold compaction pressure of 50 and 100 MPa. Then green compacts were sintered at 700 and 800 °C. The compacted samples were placed in a furnace with the protection of high purity argon gas. Then specimens were ignited. Production operations were performed in the system shown in Fig. 1. Microhardness was measured using a LEICA MHF-10 tester with a load of 100 g and a loading time of 10 s. The microstructure was examined with a scanning electron microscope (SEM) (LEO Evo-40VP) equipped with energy dispersive X-ray spectrometer (EDS). The phase constituents were characterized on an X-ray diffractometer XRD (Rigako Rad-B D-Max 2000 XRD).

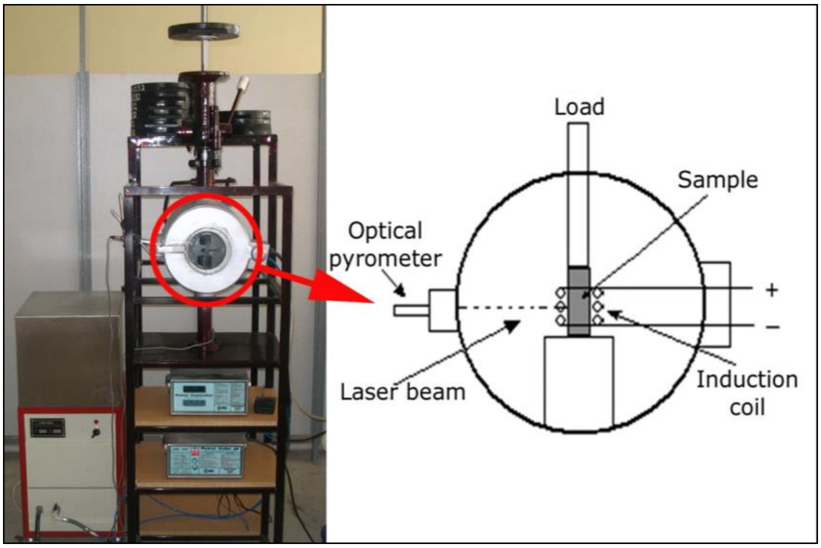


Figure 1. Production system

3. Results and Discussion

3.1. Microstructure

Fig. 2 show SEM images of NiAl coatings produced by SHS. When the microstructure is examined, two different structures draw the attention. Coating layer and the substrate material can't be clearly distinguished by the difference, which at the specimen produced at 700 °C and 50 MPa (Fig. 2a). Any crack or separation was not observed at the interface. As the sintering temperature and pressure increased, in the amount of pores in the coating layers decreased (Fig. 2b and d) (Tosun et al., 2009; Yeh et al., 2004). Moreover, chromium carbide precipitates occurred at the grain boundaries of the material cooled on the air. This situation is because carbides formed in the grain boundaries of austenitic stainless steel a high temperature. It is observed that interface completely disappeared with increasing of pressure (from 50 MPa to 100 MPa) (Fig. 2c and d).

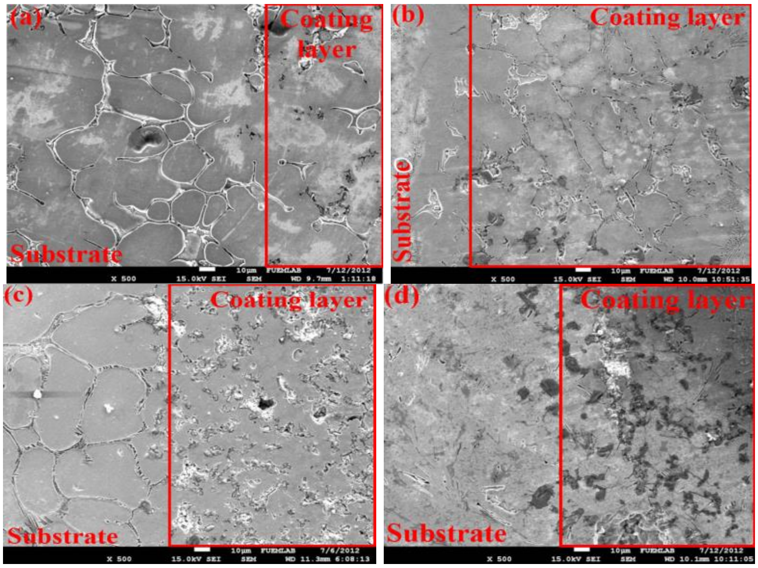
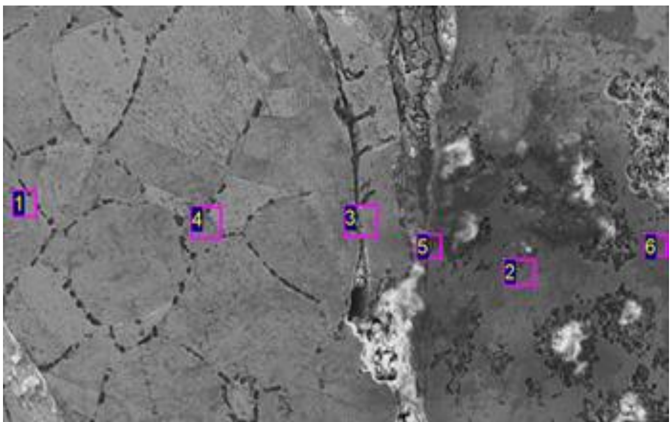


Figure 2. SEM images of NiAl coating, (a) 50 MPa, 700 °C, (b) 50 MPa, 800 °C, (c) 100 MPa, 700 °C and (d) 100 MPa, 800 °C

Fig. 3 illustrates EDS analysis of coating produced at 50 MPa and 700 °C. According to EDS analysis, in the microstructure was identified C, Si, Cr, Fe, Ni, O, Al, and Mn elements. Boron was identified in none of the samples because the EDS analysis was carried out in a very small area. As a small amount of Cr and Fe elements transferred to coating layer from AISI 304L stainless steel, a small amount of Ni and Al elements transferred to AISI 304L stainless steel from coating layer.



Points	Element (wt. %)								
	C	Si	Cr	Fe	Ni	O	Al	Mn	B
1	4	0.61	18	66.3	8.6	-	-	1.6	-
2	4	-	0.43	1.27	64	12	16.5	-	-
3	4	0.59	17.3	63.9	9.34	2.9	0.48	-	-
4	3	0.57	17.4	65.5	8.21	-	-	1.61	-
5	4	-	0.71	2.91	50	28	14	-	-
6	3	-	0.35	0.9	76.5	3.4	14.5	-	-

Figure 3. EDS analysis of coating produced at 50 MPa and 700 °C

The XRD pattern of coating produced at 50 MPa and 700 °C is shown in Fig. 4. The products such as Fe and Ni are the predominant phases. In addition, several second phases, such as Fe_3Ni_2, Cr_2Ni_3, and $Fe_{0.64}Ni_{0.36}$ formed. Finally, a ternary phase, such as $B_2Fe_3Ni_3$. Boron not detected in the EDS analysis was determined by XRD analysis.

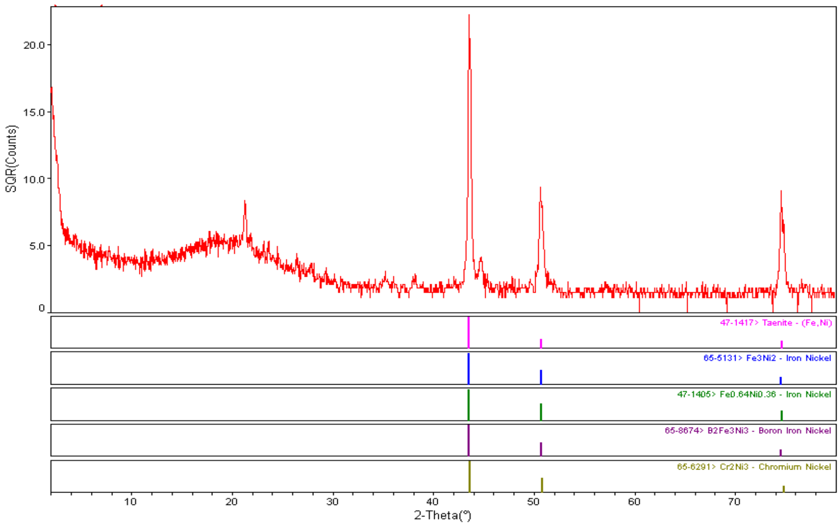


Figure 4. XRD pattern of coating produced at 50 MPa and 700 °C

3.2. Microhardness

Microhardness measurements were conducted throughout a line from the upper region of the coating through AISI 304L stainless steel substrate at intervals of 0.5 mm (Fig. 5a). Fig. 5b shows microhardness change between coating and substrates. Microhardness varied as depending on pressure and sintering temperature. It decreased towards substrate from coating layer. While the highest hardness value taking from S4 sample that was produced at 100 MPa and 800 °C was 280 HV0.1, the lowest hardness value taking from S1 sample that was produced at 50 MPa and 700 °C was 245 HV0.1. Microhardness of substrate was 195 HV0.1. Microhardness of the coating to the substrate are increased by 45%.

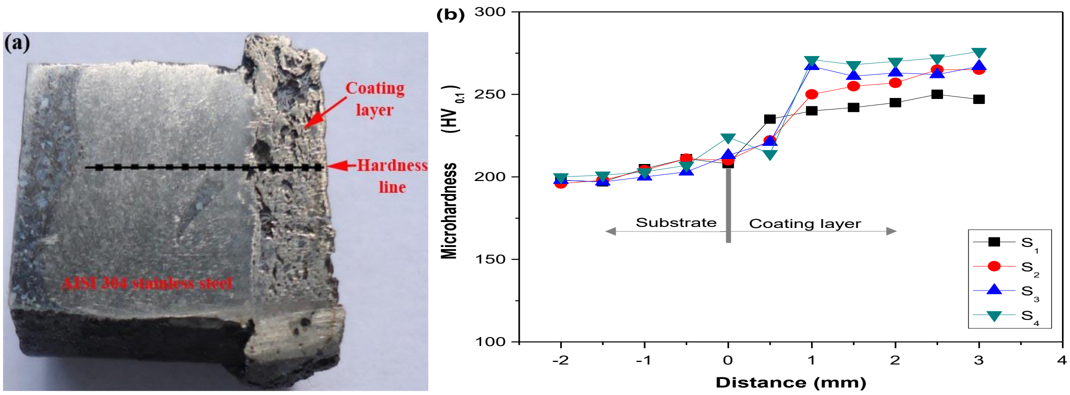


Figure 5. (a) Microhardness taking representative and (b) Microhardness graph (S1: 50 MPa, 700 °C; S2: 50 MPa, 800 °C; S3: 100 MPa, 700 °C; S4: 100 MPa, 800 °C)

4. Conclusions

The NiAl coatings on the surface of AISI 304L stainless steel substrate were produced successfully using self-propagating high temperature synthesis (SHS) method. SEM images showed that any crack or separation was not observed at the interface coating layer and substrate. The amount of pores in the coating layers decreased with increasing sintering temperature and pressure. According to XRD pattern, binary and ternary phases formed in the microstructure. Microhardness of coating layer increased markedly as depending on increasing of pressure and sintering temperature, which it is 45% higher than substrate.

5. Acknowledgment

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