Journal of Materials and Electronic Devices 3 (2020) 26-29

FYTRONIX JOURNAL OF MATERIALS AND ELECTRONIC DEVICES JMED http://dergi-fytronix.com/

PTA coating of austenitic stainless steels with NiAl-Al2O3 + TiB2 powders

A. Imak, M. Kilic, I. Kirik*, Y. Baran Kavak, Z. Balalan

Universty of Bingöl , Technical Sciences Vocational School, Department of Mechanical, 12000, Bingöl, Turkey

Since the occurrence of abrasion in the materials leads to a shorter service life and an increase in operating costs, reinforcers such as carbides, borides and oxides are coated on the surface of metals to increase the wear resistance. In this study, NiAl-Al2O3 + TiB2 composite was coated on AISI 304 stainless steel surface. The effect of current values on coating surface properties was investigated by optical microscope, elemental analysis by scanning electron microscope (SEM-EDX) and microhardness devices. Consequently, NiAl-Al2O3 + TiB2 composite coating on AISI 304 steel surface was successfully performed by Plasma Arc Welding method. From the microstructure analysis after coating, it was determined from the microstructure pictures that the bonding between NiAl-Al2O3 + TiB2 composite coating layer and the substrate 304 stainless steel was good. Four times the hardness of the substrate was reached..

Keywords: NiAl, Al2O3, PTA, AISI 304 stainless steel.

Submission Date: 26 February 2020
Acceptance Date: 05 May 2020

Corresponding author: alihsankirik@gmail.com (B, Turkey), Tel/Fax +905545619115

1. Introduction

For more than a decade, multi-layer coatings made of two different material piles have been developed due to their outstanding mechanical and chemical properties compared to individual coatings [1]. Ceramic matrix coatings have been the focus of interest in many advanced technological applications due to their high hardness values and high wear resistance (2). These coatings are widely used in many fields including aerospace, defence, chemical and machinery [3]. In the case of wear and special use, different reinforcements can be selected or combined into the metal matrix, such as carbides, oxides, borides and nitrides. Al2O3, TiB2 and TiC are of potential interest due to their advantages such as high hardness, ultra-high melting point, good wettability, high thermal stability and excellent wear resistance [4]. Al2O3 has good mechanical properties but it can improve mechanical properties by adding ceramics such as TiB2 as well as grain growth occurring in Al2O3 and spreading of cracks in the matrix can be prevented [5, 6]. Al2O3-TiB2 composites exhibit high hardness and chemical stability at high temperatures compared to others [7], Ceramic materials such as aluminium oxide, zirconium oxide, titanium oxide, chromium oxide, silicon oxide and yttrium oxide, to improve the abrasion, erosion, cavitation and corrosion resistance of materials They are widely used as surface coating materials. Such materials are particularly needed in applications where resistance to corrosion and corrosion is required [8-10].

These methods used in surface coating processes can be made with TIG, MIG / MAG, Oxy-gas technique and Electric arc welding, as well as plasma transfer arc (PTA) welding method and laser welding methods in hard coating materials and composite coatings in recent years to improve abrasion resistance. widely used.

Thanks to the high frequency unit for the start of the arc, the gas present between the material and the electrode is ionized. The current is then transferred by forming an electrode arc. In this type of surface

coating process, fine-grained microstructures are obtained in the material with rapid heating and cooling value [11-13].
PTA coating method is a preferred method because it is cheaper and easier to apply than laser welding method. In addition, the PTA method has higher welding speed, higher penetration depth and good arc stability compared to other methods. [14] The use of plasma transfer arc technique for high performance coatings has been tried by many researchers. producing high, wear-resistant coatings on their surfaces is an effective approach to improve the surface properties of metallic material without significantly affecting the properties of the substrate materials [15-19].
L. Bourithis and G. Papadimitrou [16] used the PTA coating method to coat plain carbon steel with boron and CrB2 powders and obtained successful coatings with both powders. They obtained a hardness of 1000-1300 HV in boron powder coatings, while 900 HV hardness in CrB2 powder coating. Wear rates were low in both coatings.
Q.Y. Hou et al. [17] examined the effects of molybdenum on the microstructure and abrasion resistance of nickel-based alloy coatings by PTA method and found that abrasion resistance increased by 47.2%.
Y. F. Liu et al. [18] investigated the microstructure and non-lubricated slip wear properties of TiC reinforced composite coating made by PTA method and stated that the composite coating provides high surface hardness and non-lubricated wear resistance.
The objective of this study is to coating of AISI 304 stainless steel with NiAl-Al2O3 + TiB2 powders using PTA alloying.

2. Materials and Methods

In this study, NiAl-25% Al2O3 + TiB2 powder mixture was coated with AISI 304 stainless steel surface by using plasma transfer arc (PTA) method. The effects of process parameters on the interface microstructure were investigated. It was mixed by adding 25% Al2O3 + TiB2 by weight to the atomic 50% Ni-50% Al Ni-Al powder mixture. Chemical composition values of powders and litter material are given in Table 1.

Table 1: Properties of powders used in the experimental study

Material	Purity degree by weight (%)	Powder Size(mesh)	Melting Temp. (ºC)	Atomic Mass (g / mol)
Ni	99,5	-325	1453	58.71
Al	99,5	-325	660.4	26.9
TiB2	-	<10 µm	3470	69,49
Al2O3	-	-	2.072	101,96

The process was carried out in the following order. The 304-steel selected as the substrate material was cut to 100 mm x 20 mm x 10 mm. The groove milling process opened 3.5 mm wide and 1.5 mm deep grooves and cleaned before coating. During the PTA surface coating process, the powders were bonded to the sample surface with the aid of sodium silicate in order to prevent the flying powders of NiAl-25% Al2O3+TiB2 from flying. After adhering the powders, the samples were coated in the oven at 40 oC for 20 minutes to completely remove the sodium silicate liquid from the samples. PTA parameters used in coating process are shown in Table 2. After coating, the samples were cut on the cutting disc device for analysis and then polished from 120 mesh to 1200 mesh. After the final polishing process, the samples were etched with prepared chemical etching solution. Surface etched samples were analyzed by optical microscope, while some samples were examined by microhardness.

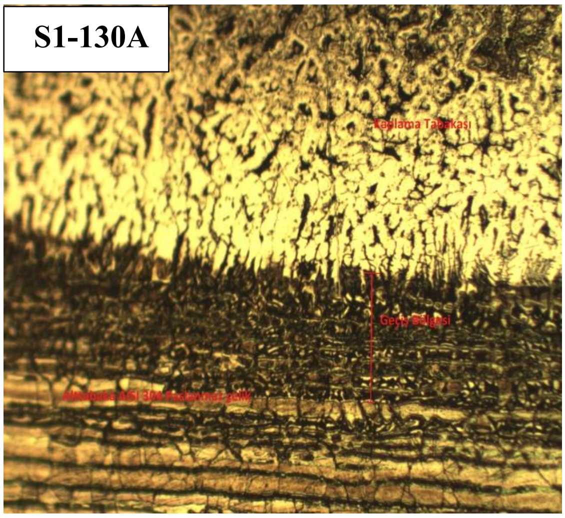
Table 2: Process parameters of PTA coating method

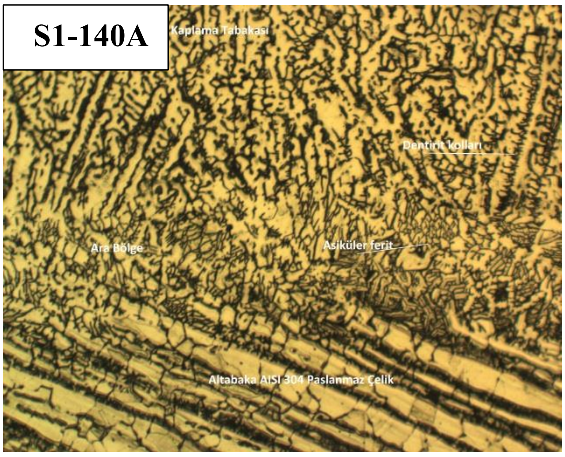
Arc Current (A))	130-140-150-160
Shielding gas flow (Ar, l / min)	25
Plasma gas flow (Ar, l / min)	0,2
Diameter of the electrode (mm)	4,7
Vehicle speed (mm / s)	1,5
Torch clearance (mm)	2

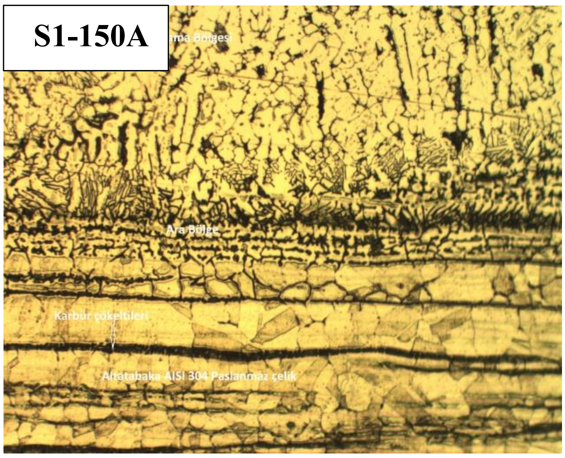
3. Result and discussion

The coating layer and base metal matrix exhibit good metallurgical bonding and there are no defects such as pores and cracks as seen in Figure 1. All samples show partially molten regions extending from the coating layer into the base metal. Immediately next to the region, there are abundant islets of acicular ferrite. Acicular ferrites are mostly formed at the melting margin and on the free surfaces of the material, i.e. at high cooling rates. It is known that acicular ferrite depends on both the cooling rate and the inclusions in the structure and starts from inclusions. However, it is seen that smooth transitions occur with diffusion from the coating layer to the substrate material. No cracks were observed in the transitions between the coating layer and the substrate in the samples. Dense dendritic structures were observed in the pavement area. Furthermore, excess molten Al and solid Ni react with liquid NiAl as the melting point of NiAl is lower than the temperature of the adiabatic reaction system. The sequences of the entire reaction are as follows:

$$Ni+Al \rightarrow NiAl \quad (1)$$
$$2Al+B_2O_3 \rightarrow Al_2O_3+2B \quad (2)$$
$$4Al+3TiO_2 \rightarrow 2Al_2O_3+3Ti \quad (3)$$
$$Ti+2B \rightarrow TiB_2 \quad (4)$$







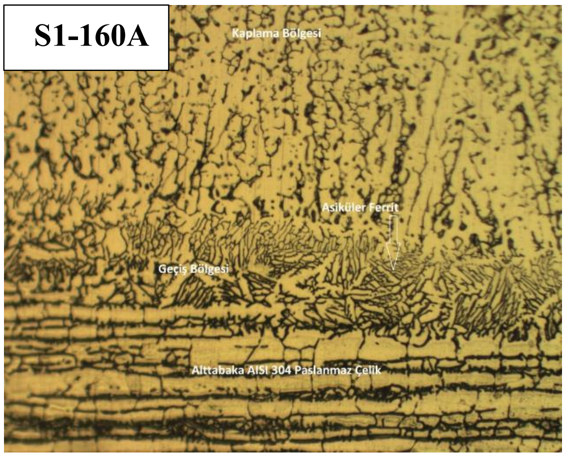


Figure 1: *Microstructure optical pictures of S1, S2, S3 and S4, respectively*.

Li et al. stated that the coating layer had a positive effect on the microhardness of the substrate, and that the microhardness values of the coating layers having Al2O3 content of 10% and 30% were more than 1000 Hv together with the pre-prepared powder. The microhardness values obtained in our study were obtained by AISI 304 stainless steel from the transition zone between the coating layer and the substrate and over the coating layer. When the obtained results were evaluated, it was determined that the highest value was taken from the coating region of the sample no. Hardness values are given in Figure 2.

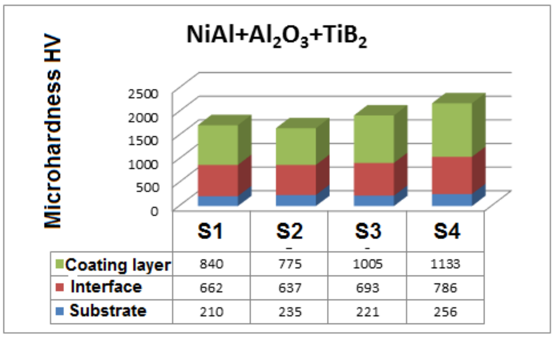


Figure 2. *Microhardness values*

Conclusion

In this study, it is aimed to investigate the usability of NiAl and Al2O3 + TiB2 and coating on AISI 304 steel surface by using Plasma Arc Welding method. For this purpose, the factors affecting the coating process, the examination of the samples after welding and the results obtained after the coating process depending on the parameters are presented below:

- NiAl / Al2O3 + TiB2 composite coating on AISI 304 steel surface by Plasma Arc Welding method was performed successfully.
- From the microstructure analysis after coating, it is determined from the microstructure pictures

that the bonding between NiAl / Al2O3 + TiB2 composite coating layer and the substrate 304 stainless steel is good.

- With the melting of the plasma arc welding, it was seen that some of the coating powder flew away from the coating layer due to the protective gas flowing into the coating region. Therefore, it was determined that some coating layers experienced mass loss.
- It was determined that microhardness values were higher in coating region and intermediate region.
- No microcracking was observed after the solidification period between the coating and the substrate in the macrostructure image taken after coating.

Acknowledgement

This study was supported by TÜBİTAK 2209 A (1919B011601692)

References

[1] X.D. He, L. Dong, J. Wu, D.J. Li, The influence of varied modulation ratios on crystallization and mechanical properties of nanoscale TiB2/Al2O3 multilayers, Surface & Coatings Technology. 365 (2019) 65.

[2] M. Masanta, S.M. Shariff, A. Roy Choudhury, Microstructure and properties of TiB2–TiC–Al2O3 coating prepared by laser assisted SHS and subsequent cladding with micro-/nano-TiO2 as precursor constituent, Materials and Design. 90 (2016) 307.

[3] Z. Li, et al. Microhardness and wear resistance of Al2O3-TiB2-TiC ceramic coatings on carbon steel fabricated by laser cladding, Ceramics International. 45 (2019) 115.

[4] J. Xu, Binglin Zou, S. Tao, M. Zhang, X. Cao, Fabrication and properties of Al2O3-TiB2-TiC/Al metal matrix composite coatings by atmospheric plasma spraying of SHS powders, Journal of Alloys and Compounds. 672 (2016) 251.

[5] F. Sajedi Alvar, M. Heydari, A. Kazemzadeh, M. Vaezi, L. Nikzad, Al2O3-TiB2 nanocomposite coating deposition on Titanium by Air Plasma Spraying, Materials Today: Proceedings 5 (2018) 15739

[6] X. J. Song, H. Z. Cuı, L.L. Cao, P. Y. Gulyaev, Microstructure and evolution of (TiB2+Al2O3)/NiAl composites prepared by self-propagation high-temperature synthesis, Trans. Nonferrous Met. Soc. China. 26 (2016) 1878.

[7] P. Luo, S. Dong, A. Yangli, S. Sun, Z. Zheng, H. Wang, Electrospark deposition of Al2O3–TiB2/Ni composite-phase surfacecoatings on Cu–Cr–Zr alloy electrodes, Journal of Asian Ceramic Societies 3 (2015) 103.

[8] B. Wang, S. W. Lee, Erosion–corrosion behaviour of HVOF NiAl–Al2O3 intermetallic-ceramic coating, Wear. 239 (2000) 83.

[9] Y, Sun, B. Li, D. Yang, T. Wang, Y. Sasaki, K. Ishii, Unlubricated friction and wear behaviour of zirconia ceramics, Wear. 215 (1998) 232.

[10] M. Cadenas, R. Vijande, H.J. Montes, J.M. Sierra, Wear behaviour of laser cladded and plasma sprayed WC–Co coatings, Wear. 212 (1997) 244.

[11] Y.P. Kathuria, Some aspects of laser surface cladding in the turbine industry, Surface Coatings and Technology 132 (2000) 262.

[12] H.J. Kim B.H. Yoon and C. H. Lee, Wear performance of the Fe-based alloy coatings produced by plasma transferred arc weld-surfacing process, Wear, 249 (2002) 846.

[13] J. S. Selvan K. Subramanian and A. K, Nath, Laser alloying of aluminum with electrodepo-sited nickel: optimization of plating thickness and processing parameters, Journal of Materials Processing Technology. 91 (1999) 29.

[14] İ. Çelikyürek, R. Gürler, Some of the compounds regular in Metallarara Vacuum Melting Determination of Terms "Eskişehir Osmangazi University, Institute of Metallurgy (2007) Batımeşelik, Eskisehir, Turkey.

[15] B. Kurt, Microstructure investigation of Ni3Al intermetallic alloy coating on AISI 304 steel by PTA process, Optoelectronics and Advanced Materials – Rapid Communications. 9 (2015) 234.

[16] L. Bourithis and G. Papadimitriou, "Boriding a plain carbon steel with the plasma transferred arc process using boron and chromium diboride powders: microstructure and wear properties." Materials Letters 57.12 (2003) 1835.

[17] Y. Hou, et al., Influence of molybdenum on the microstructure and wear resistance of nickel-based alloy coating obtained by plasma transferred arc process. Materials & design 28.6 (2007) 1982.

[18] Y. F. Liu, J.S, Mu, X. Y., Xu & S. Z. Yang, Microstructure and dry-sliding wear properties of TiC-reinforced composite coating prepared by plasma-transferred arc weld-surfacing process. Materials Science and Engineering: A, 458(1) (2007) 366.

[19] S. Buytoz, the Nitriding of AISI 4340 Steel and GTA Resources Investigation of Surface Modification Method and Mechanical Behavior Operations Post, Ph.D., (2004) Firat University, Elazig, Turkey.