The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM)
ISSN: 2602-3199

The Eurasia Proceedings of Science, Technology, Engineering & Mathematics (EPSTEM), 2020

Volume 11, Pages 64-68

IConTES 2020: International Conference on Technology, Engineering, and Science

Boriding of Ni40Al

Osman TORUN
Afyon Kocatepe University

Ibrahim CELIKYUREK
Eskişehir Osmangazi University

Bedri BAKSAN
Eskişehir Osmangazi University

Abstract: Boriding has been one of the thermochemical processes that have been developed and used recently in industries. The main advantages of this technique are leading to the high strength of abrasion wear and high oxidation resistance compared with other conventional surface treatments Ni-Al alloy is a new material that offers improved high-temperature properties over traditional ferrous and nickel based hot work die materials. In this study, Ni and Ni-40Al alloys were borided. Ni40Al at. % alloy was prepared by vacuum arc melting under argon atmosphere. Boriding of Ni and Ni-Al alloys was carried out with Ekabor–Ni powders at 875 C for 2, 4, and 6 h. The characterization of the boride layer formed on the surface of nickel aluminide substrates was identified by optical microscopy. Microhardness and thickness of boride layers were measured. Its hardness was found to be higher than the cast Ni-40Al alloy. The thickness and of boriding layers were found to be different depending on the boriding time.

Keywords: Hardness, boriding, Ni-Al

Introduction

Excellent high-temperature strength properties of intermetallics, occurring in relatively narrow compositional ranges around simple stoichiometric ratios, have long been recognized and attributed to long-range ordered superlattices. Aluminides are an important group of materials in this class. Alloy design work has been centered primarily on aluminides of nickel, iron, and titanium. Nickel aluminides are an important group of intermetallics have been used for since long as a base for alloy developments for high-temperature applications because of many attractive chemicals (e.g. high resistance to oxidation and corrosion), physical (e.g. high melting point), and mechanical (e.g. positive temperature dependence of flow strength) properties. However, they tend to be brittle, especially at low temperatures. Recently, considerable efforts have been devoted to improving the ductility of nickel aluminides at ambient temperatures by controlling microstructure and alloy additions (Matuschka, 1980; Cahn and Deevi, 1997; Kim, 1998).

Ni_3Al alloy is a new material that offers improved high-temperature properties over traditional ferrous and nickel-based hot-work die materials. Conventional hot-work die steels are based on the family of Cr–Mo–V tool steel, typical grades H1 and H13. The problem with these materials is that they rapidly lose strength and hardness at above 811 K and cannot sustain prolonged die surface contact during the hot forging of metals heated to 1089–1533 K. Nickel aluminide alloys provide improved strength, oxidation resistance, and thermal stability at these temperatures (Orth, 1997).

Boronizing is a thermochemical surface-hardening process in which boron atoms diffuse into a metal surface to form metal borides. The surface hardness of the resulting boride layer can exceed 2000 HV and has good resistance to abrasive and adhesive wear. In particular, surface hardening of steels by boriding treatments has found wide applications in industries (Matuschka, 1980; Tsipas. 1987; Palombariniand. 1993; Kim. 1998).

- Selection and peer-review under responsibility of the Organizing Committee of the Conference

Boronizing can be carried out in numerous ways, including gas boronizing, molten salt boronizing, with and without electrolysis, and pack boronizing (Tsipas,1987). Surface hardening treatments such as carburizing and nitriding of pure nickel is difficult because pure nickel has a very low solubility for carbon and nitrogen in the solid-state. The nickel alloys, which contain the nitride-forming elements such as Cr and Mo, are nitrided but the thickness of the nitrided layer is thin. On the other hand, boriding is appropriate for Ni because Ni can be easily borided and the boride layer is thick. The authors have reported their findings of boriding Ni using the fluidized bed method and powder pack method (Özbek et al., 2000; Ueda et Al., 2000; Anthymidis et al., 2002). Although studies have been done on the boriding of Ni, no investigation has been reported on the boriding of nickel aluminides. Alloying elements such as carbon, silicon, nickel, chromium, and manganese can influence the morphology, thickness, and nature of the boride layers consisting of either Fe2B or FeB or sometimes both formed in iron-based alloys (Keown and Pickering 1977; Tsipas, 1987). All these alloying elements, depending on their amounts, reduce the boride layer thickness and flatten the tooth-like morphology generally observed in ferrous alloys. There is little data available for the effect of alloying with aluminum on the properties of the boride layer. It has been reported that increasing aluminum content in steels decreases the boride layer thickness (Tsipas, 1987).

Method

The alloy Ni-40Al was prepared by electrical arc melting under argon atmosphere from nickel and aluminum of 99.9 and 99.7% purity, respectively (Fig.1). The samples were cast into molds with a nominal diameter of 8 mm. Surfaces of samples were ground with 1200 grit grinding paper and polished with 1 μm diamond paste before boriding process. Boriding was carried out in a solid medium consisting of Ekabor–Ni powders at 875 ^{o}C for periods of 2, 4, and 6 h.

The characterization of the boride layers formed on the Ni-Al substrates was confirmed by optical microscopy. Microhardness measurements of the boride layer were made to the center from surfaces of borided samples utilizing Vickers indenter with a load of 50 g. Averages of ten measurements were taken for each sample.

Figure 1. Vacuum arc melting furnace.

Results and Discussion

Optical microscopy cross-sectional examinations of the borided Ni and Ni-40Al samples showed that boride layers formed on the substrates had smooth morphology (Fig. 2). This morphology is different from the tooth-shaped form of carbon steels and low-alloy steels. In the previous works, it was reported that the tooth-like boride layer has strong bond to the base metal (Üçışık and Bindal, 1997; Yu et Al., 2002). During the boriding process, the majority of aluminum atoms diffused away from the surface into the matrix (Çelikyürek et Al., 2006). According to Ni-Al–B ternary phase diagram, up to 7–8 at. % aluminum dissolves in the boride phases. With increasing the amount of aluminum, Ni-Al–B compounds form (Villars, 995). In this situation, the boride layer and Ni-Al–B compound formed on the surfaces of the borided samples.

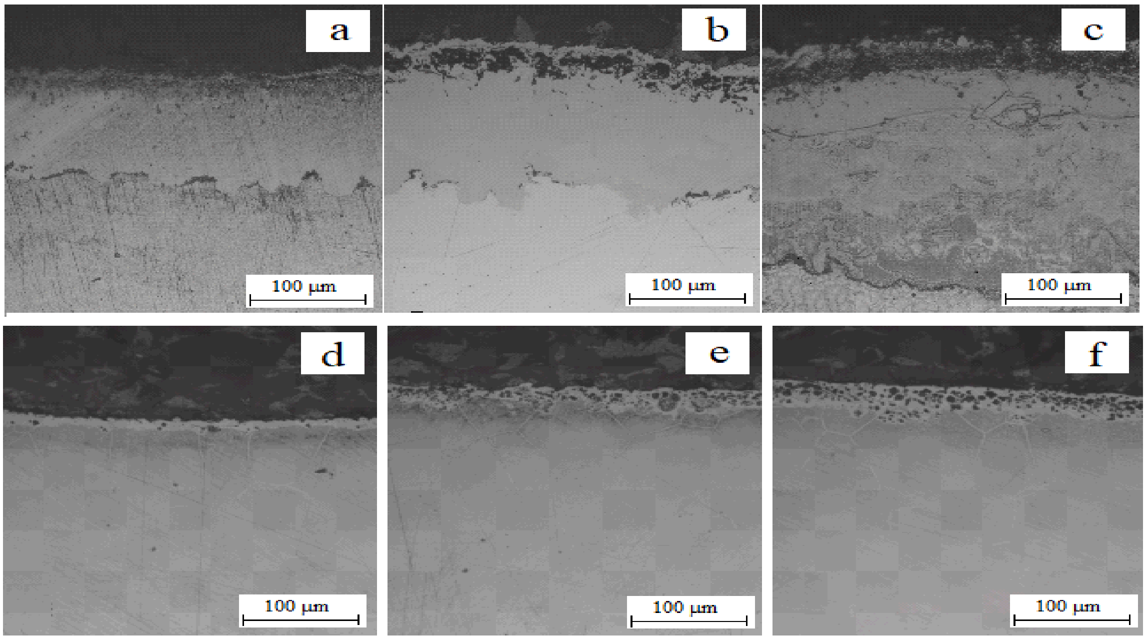


Figure 2. Optical micrographs of borided samples a) Ni-120 min. b) Ni-240 min. c) Ni-360 min. d) Ni40Al-120 min e) Ni40Al-240 min f) Ni40Al-360 min

The boride layer thicknesses of the borided samples were given in Fig 3. The boride layer thickness increased with increasing the boriding time. While the boride layer thickness was 120 µm for Ni at 2 hours, it was 245 µm at 6 hours. While the boride layer thickness was 13 µm for Ni40Al at 2 hours, it was 25 µm at 6 hours. Besides, the increase in boride layer thickness showed a parabolic tendency. The boride layer thicknesses were found to be decreasing sharply with the Al content increasing to 40Al for all boriding times. The diffusion of Boron atoms into Ni was more difficult due to an increase in Al content because Nickel boride has a limited solubility of Al atoms.

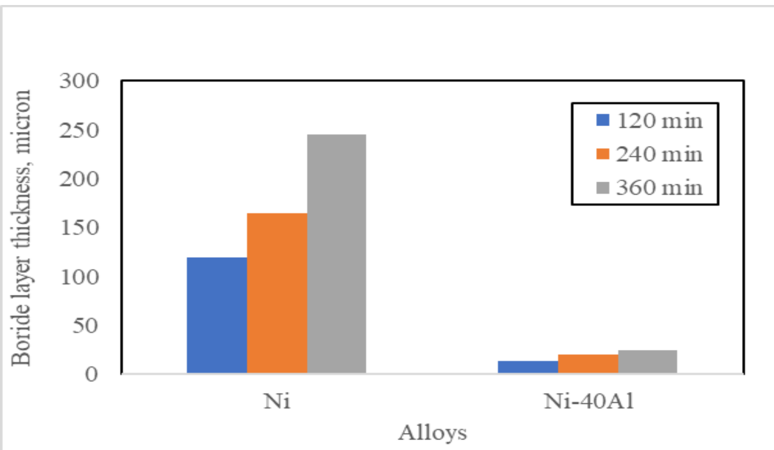
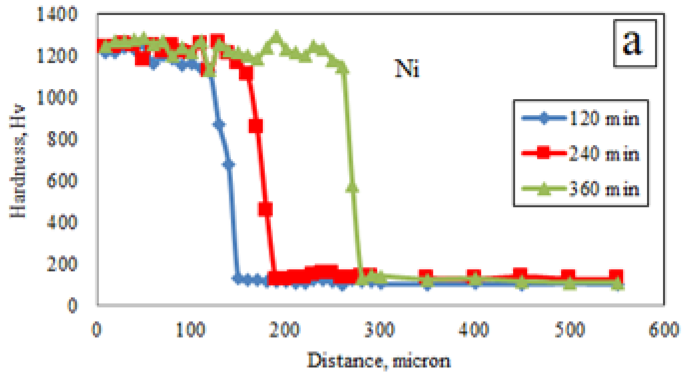


Figure 3. Boride layer thicknesses of the borided samples

In Figure 4a hardness values were shown for Nickel substrate, in Fig.4b the Ni-40Al substrates' microhardness values were given. From the figure it can be clearly seen that the hardness of boride layers formed on the surface of the borided samples was fairly high. The results of microhardness measurements showed that the microhardness values of boride layers were slightly increased with increase boriding time. Higher microhardness values were measured by Ni40Al alloy. The microhardness values were found 1235 HV for Ni and 1315 HV for Ni40Al. The reason for the increase in surface hardness is related to the B content in the Ni-B phase. If the quantity of Boron in Ni-B phases increases, the hardness of boride layer increases.



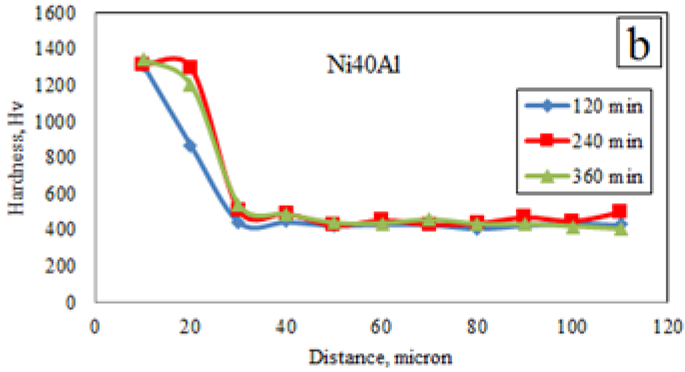


Figure 4. Microhardness values to the center from the borided samples. a) Ni b) Ni40Al

Conclusion

In this study, boriding of pure Ni and various Ni40Al alloys was carried out with Ekabor–Ni powders at 875 ^{o}C for various times. Depending on boriding time and alloy composition, the hardness of borides formed on borided nickel aluminide is between 1070 and 1315 HV while unborided Ni substrate is 380 HV. When the hardness of boride layer is compared with substrates, boride layer hardness is much higher than substrates. Compared with pure nickel, the diffusion of boron atoms into nickel aluminide is more difficult because of by significant migration of aluminum atoms into the substrate. As a result of this situation according to pure nickel, the thickness of boride layer formed on the surface of Ni-40Al alloy is much lower for all boriding times.

References

Anthymidis, K. G., Zinoviadis, P., Roussos, D., & Tsipas, D. N. (2002). Boriding of Nickel in a Fluidized Bed Reactor, *Mater. Res. Bull.*, *37*, 515-522.

Cahn, RW. In: Deevi, SC, S. V., & Maziasz, P.J. (1997). *International Symposium on Nickel and Iron Aluminides: Processing, Properties, and Applications: Proceedings from Materials Week'96*, 7-9 October 1996, Cincinnati Convention Center, Cincinnati, Ohio. ASM International (OH).

Çelikyürek, İ., Baksan, B., Torun, O., & Gürler, R. (2006). Boronizing of iron aluminide Fe72Al28, *Intermetallics 14*, 136-141.

Keown, S.R., & Pickering, F.B. (1977). Some aspects of the occurrence of boron in alloy steels. *Metal Science, 11*(7), 225-234.

Kim, YS, K. Y. (1998). Sliding wear behavior of Fe3Al-based alloys. *Mater Sci Eng A 258*, 319-324.

Matuschka, A.G.V., (1980). *Boronizing.* München, Wien: Hanser, p 100.

Ueda, N.,Mizukoshi, T., Demizu, K., Sone, T., Ikenaga, A., & Kawamoto, M., (2000). Boriding of nickel by the powder-packmethod, *Surface and Coatings Technology126* 25-30.

Orth, J.E., Maddox, C. C., G., Horax, D., Orillion, M.T., & Pyle, J. (1997). *Proceedings of materials week '96 on nickel and iron aluminides: Processing, properties, and applications*, Ohio, 7–9 October 1996, ASM International, USA, 1997, p. 377.

Özbek, I., Akbulut, H., Zeytin, S., & Bindal, C. (2000). The characterization of borided 99.5% purity nickel, *Surface and Coatings Technology*, *126*, 2–3, 166-170.

Palombariniand G, C. M. (1993). Influence of carbon on the chromium redistribution when boriding iron alloys. *J Mater Sci Lett.12*(11), 797-798.

Tsipas, D.N., & Rus, J. (1987). Boronizing of alloy-steels, *J Mater Sci Lett, 6*(1), 118-120.

Ueda, N., Mizukoshi, T., Demizu, K., Sone, T., Ikenaga, A., & Kawamoto, M. (2000). Boriding of nickel by the powder-pack method, *Surface and Coatings Technology, 126*, 25-30.

Üçışık, A.H., Bindal, C. (1997) Fracture Toughness of Boride Formed on Low-. Alloy Steels, *Surface Coatings*, and *Technology*, *94-95*, 561-565.

Villars, P. (1995). *Handbook of ternary alloy phase diagrams*, ASM International, Materials Park, OH. USA.

Yu, L.G, Khor, K.A, & Sundararajan, G. (2006). Boride layer growth kinetics during boriding of molybdenum by the Spark Plasma Sintering (SPS) technology, *Surface and Coatings Technology, 157*, 2849-2853.

Author Information

Osman Torun
Afyon Kocatepe University
Technology Faculty, Department of Mechatronic Engineering
otorun@aku.edu.tr

İbrahim Çelikyürek
Eskişehir Osmangazi University
Department of Metallurgy and Materials Engineering

Bedri Baksan
Eskişehir Osmangazi University
Department of Metallurgy and Materials Engineering