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Effect of Sic_p on the Microstructure and Mechanical Properties of Sintered Distaloy DC Composites

K. Emre Öksüz[a,*], L. Cenk Kumruoğlu[a], O. Tur[a]

[a]*Cumhuriyet University, Metallurgical & Materials Eng. Department, Sivas 58140, Turkey.*

Abstract

Different PM steels have found applications, mainly in the automotive industry for engine and transmission systems. In this paper examined in research on the microstructure and mechanical properties of Distaloy DC + 0.5 %C + %0.6 introlube® with addition the silicon carbide. Specimens were prepared from diffusion alloyed Distaloy DC (Fe-2 wt. % Ni-1.5 wt. % Mo) mixed with graphite. SiCp in proportion to 0.5 and 1 wt % was added to the powder-graphite mixtures. In this work the Distaloy DC+ 1 wt % SiC is the best composition, because it presented the highest wear resistance and good hardness.

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Keywords: Distaloy DC; Mechanical analyses; Powder metallurgy; Sintered steel, SiC.

1. Introduction

Sintered material base on pre-alloyed powders (Fe-Ni-Mo) are expansively applied in the automotive industry and Distaloy is today the most widely used raw material worldwide for the production of complex, precise, high strength PM machine parts, Karwan - Baczewska (1996), Karwan - Baczewska (1997), Karwan - Baczewska (2000), Karwan – Baczewska (2011), Selecka et al. (1995), Per Lindskog (2013). The use of powder metallurgy (P/M) in gearing applications continues to expand with the development of new materials and processing. P/M processing offers raw material savings plus the potential for net shape gearing Bocchini (1998), Rutz and Hanejko (1994).

* Corresponding author. Tel.: +90 544 277 60 88; fax: +0-000-000-0000 .
E-mail address: kerimemreoksuz@gmail.com

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However, their applications are limited by the particular porosity values of those materials. To reduce the porosity and, simultaneously, to increase the consolidation of sintered alloy steels, miscellaneous methods within powder metallurgy technologies are utilized, as well as an activated sintering process, Karwan – Baczewska ans Rosso (2001), Karwan - Baczewska et al. (2010). Recently, the development of new alloys and advanced processing has dramatically increased the strength and density of P/M components enabling P/M gearing to compete in high performance gear applications, Bocchini (1998), Rutz and Hanejko (1994). Distaloy DC powder mixture was also one of the competitors that contains 2.1 %Ni and 1.5%Mo, and is produced by diffusion-bonding 2.1 %Ni-powder to Astaloy Mo, an atomized iron powder homogeneously alloyed with 1.5%Mo. This material is specially designed to achieve very closely restricted dimensional scatter of the sintered components, irrespective of compact density. This makes the material ideal for components of intricate shape with internal density variations. With admixed graphite, this material ensures high strength after sintering as it forms a relatively large amount of bainite, and some martensite at lower cooling rates (0.5 – 0.8°C/s) in the cooling zone of a common belt furnace, Lindberg et al. (1993), Höganäs (2002). The alloying elements such as Ni, Mo and Cu have an influence on the solubility of carbon in the austenite slowing down the rate of cooling at which martensite are formed. Mn, Cr, Mo and Ni are used to increment the hardenability of steels, Seshendra (2000), Öksüz et al. (2014). Mechanical and physical properties of the bonding metals can be improved with the addition of some materials in small and defined proportions Meszaros and Vadasdi (1994). In the current study, an attempt is made to understand the microstructure and mechanical properties of sintered steel Distaloy DC + 0.5 %C + %0.6 introlube® with the addition of SiC_p.

2. Experimental Study

In the experiments a diffusion bonded powder type Distaloy DC (Fe-2 wt. % Ni-1.5 wt. % Mo, *Höganäs*-Sweden) was used. It was alloyed by 0.5, and 1 wt. % silicon carbide with the addition of 0.6 wt. % lubricant in the form of introlube®. Powders were blended for 45 min. with a T_2F turbula mixer. All the powder mixtures were compacted at 600 MPa, and then sintered for 30 min. in argon atmosphere at 1120° C (at a ramp of 5°C/min). The sintered density and relative density of the samples were measured by Archimedes' method. Micro-hardness tests were done with a Vickers micro-hardness testing equipment (Shimadzu micro-hardness tester type M, Japan, load of 9.81 N, the results were the average of ten different indentation measurements). For wear test, a pin-on-disc type of apparatus was employed to evaluate the wear characteristics of composite. Wear test was performed under varied loads such as: 20, 40 and 60 N and at a constant speed of 1 m/s and a constant sliding distance of 60 m with 180 mesh SiC paper for each composite sample. After the test, the wear pin was cleaned in acetone prior to and after the wear tests, and then dried after being weighed on a micro-balance with a 0.1 mg sensitivity. Wear tests were carried out for three samples per composition. Average amount of weight loss was calculated and is presented. An X-ray Diffractometer (Rigaku D/MAX/2200/PC) with a monochromatic Cu-K_α radiation (λ= 1.5408 Å) was used over a 2θ angle from 20° to 80° to characterize the crystal structure of the sintered compacts. The microstructure of the samples was examined by using a Scanning electron microscope (SEM, Model JEOL-JSM 6060-LV, Japan).

3. Results and Discussion

3.1. Density Measurement and Hardness

The experimental results of the densification and mechanical properties (micro-hardness in this case) of the produced Distaloy DC and SiC reinforced composites are shown in fig. 1. In this study, the bulk densities of sintered pure Distaloy DC were found as 6.69 g/cm^3 at 1120°C 2h whereas the bulk densities of Distaloy DC- SiC_p composites varied in the range of 6.65–6.61 g/cm^3 depending on the SiC reinforcement amount. Relative density decreased as the amount of added reinforcement particle increases. This is due to the fact that the increased rate of added SiC ceramic particles has an adverse effect on sinterability. Hardness of the composites increased with increasing reinforcement particle content. This may be explained by the rule of mixture, applied to composite materials Kim (2000), Kumar et al. (2011), Şimşir and Öksüz (2013). Maximum hardness values were measured from Distaloy DC + 1 wt. % SiC composition.

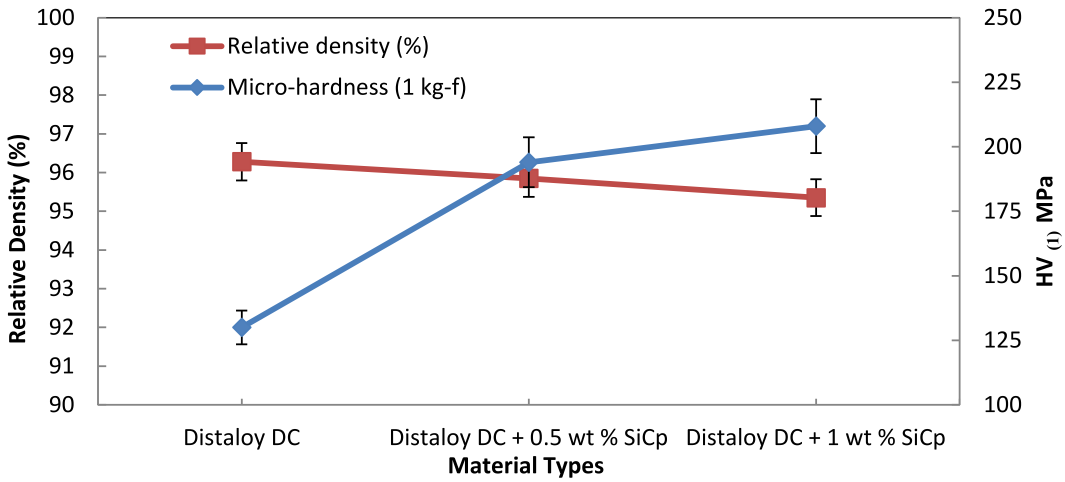

Fig. 1. Variations in relative density and micro-hardness in Distaloy DC + 0.5 %C + %0.6 introlube® composites with different SiC contents.

3.2. *XRD Analysis*

The room temperature x-ray diffraction patterns for Distaloy DC and its composites added with 0.5 wt. % SiC and 1 wt.% SiC sintered at 1120° are shown in Fig.2. All the peaks are indexed according to the PDF files No 87-0721, and no second phase is observed.

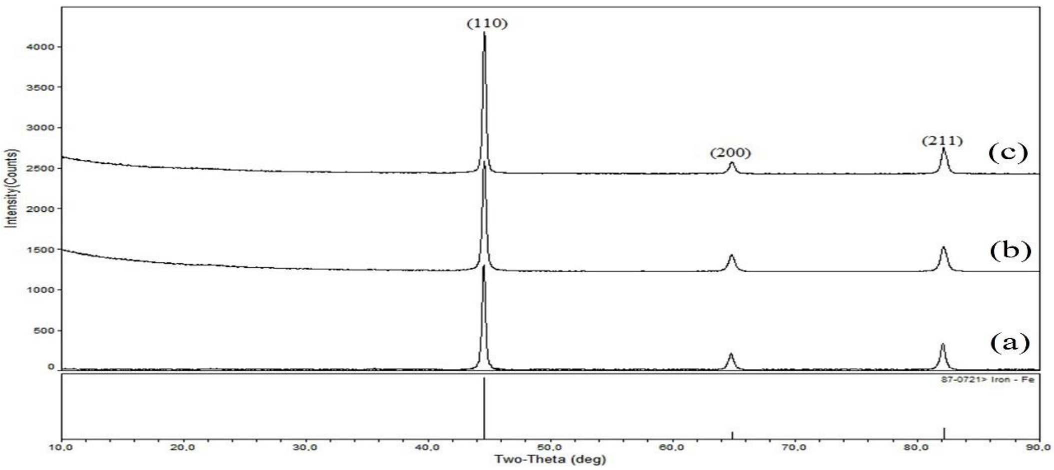

Fig. 2. (a) XRD patterns of Distaloy DC samples at RT; (b) Distaloy DC+ 0.5 wt. % SiC (c) Distaloy DC+ 1 wt.% SiC.

3.3. Wear Resistance

Figure 3 Shows the results of wear resistance for the Distaloy DC samples. The wear rate increased more or less linearly with increasing load for all tested samples. The wear rate was slightly higher for the Distaloy DC composites due to decreased hardness and its microstructure. It can be seen that the smallest weight loss value found is related to samples with Distaloy DC+ 1 wt. % SiC. It suggests that in this study, Distaloy DC+ 1 wt. % SiC is the best composition, because it presented the highest wear resistance and good hardness.

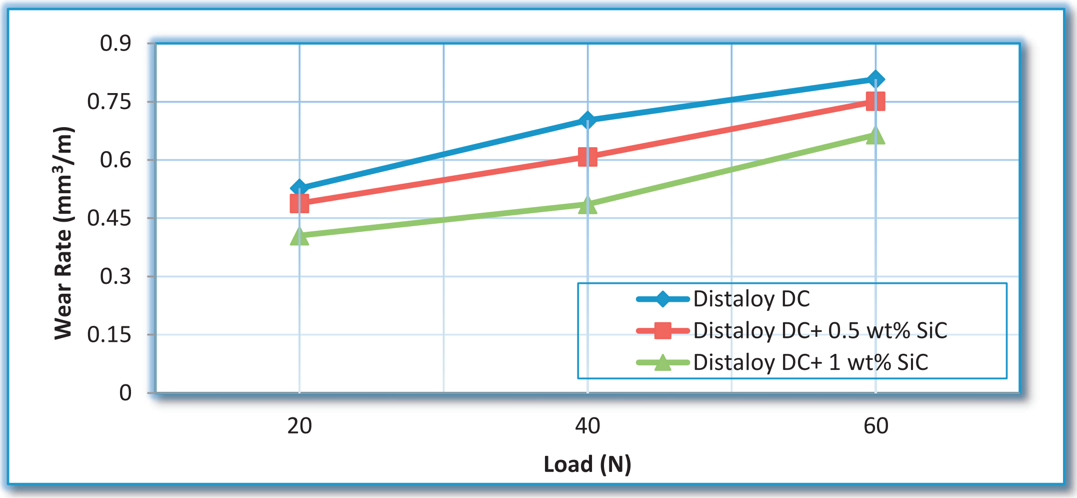

Fig. 3. Results of wear resistance for the Distaloy DC samples.

3.4. Microstructural Analyses

Microstructure of the Distaloy DC samples was examined using SEM. All samples were embedded in *Polyfast* mounting resin from *Struers*. They were subjected to grinding down with 220μm grinding paper and a subsequent polishing with 9, 3 and 1μm diamond paste. Distaloy DC samples were etched with nital (3 volume% HNO_3 in ethanol). Fig. 3 shows the microstructural aspects of the Distaloy DC sinters with SiC_p contents.

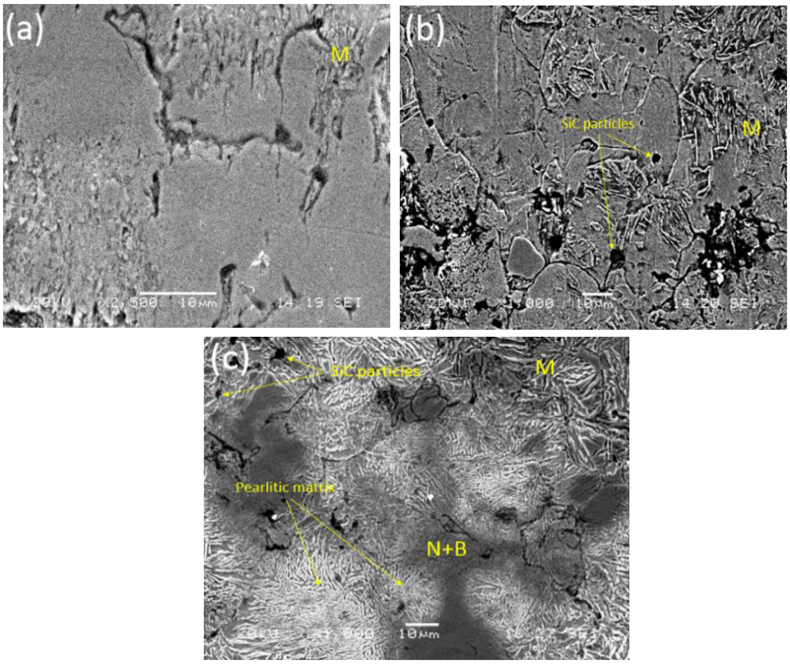

Fig. 4. Microstructures of Distaloy DC sinters with SiCp contents. (a) 0 wt. % SiC; (b) 0.5 wt. % SiC; (c) 1 wt. % SiC.

Throughout the sample, the microstructure was homogeneous, typical of prealloyed materials. No evidence of microstructural gradient between the surface and the center of the specimen was seen. Microstructural investigation of Distaloy DC, fig. 4(a-c), suggests a microstructure, with regions of martensite (indicated by M in the figure)-etched light white and black, nickel and bainite region (indicated by N+B in the figure)-etched black. Similar regions were identified at both sintered samples. SiC particles distributed into Distaloy DC matrix, which confirms homogenous structure formation (figs. 4b and 4c). Distaloy DC sintered composite containing sub-micrometric SiC-particles and the dissolution of particle/metallic matrix composite in the interface between the Distalloy DC matrix and SiC particles. This microstructural features were responsible for the satisfactory values for the hardness and wear resistance for the contents of SiC particles.

4. Conclusions

In the present work the influence of silicon carbide additions on mechanical properties and microstructure homogeneity was studied.

- With an increase in SiC content (from 0.5 wt. % to 1 wt. %) the density decreased for both Distaloy DC. The amount of phases obtained was approximately similar for both materials.
- The microstructures of Distaloy DC and its composite sinters with silicon carbide are characterized by a lathe martensite structure with bainite. Microstructure for Distaloy DC also consisted of Ni-rich areas due to lower diffusivity of Ni in Fe.
- With the increasing of silicon carbide particles (from 0.5 up to 1 wt. %) micro-hardness and wear rate values of Distaloy DC specimens improved. For comparison the properties of Distaloy DC sintered samples without SiCp were presented. It was stated that the highest values of properties were attained for Distaloy DC+ 1 wt. % SiC sinters.

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