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Heat Flow Behaviours of Distaloy AE Alloys Produced by Powder Metallurgy

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Abstract

The alloying techniques are classified with pre-alloyed, pre-mixed and diffusion-bonded powders. Distaloy AE alloy used in this study is type of diffusion-bonded alloy including of Fe, Ni and Mo alloying elements and has high strengthening microstructures. In this study; hardness, density and heat flows distaloy AE samples prepared by powder metallurgy method performed. As hardness and density measurements of these samples, Brinell hardness measurements and Archimedes water displacement technique performed and heat flows of these alloys determined using Differential Scanning Calorimetry (DSC) device. These results supported by SEM images, EDS spectrums of alloys and also, crystal structures of these alloys determined by XRD patterns.

Keywords: Distaloy AE, Powder metallurgy, Heat flow, Surface characterization

Toz Metalurjisi Metoduyla Üretilen Distaloy AE Alaşımlarının Isı Akışı Davranışları

Öz

Alaşımları teknikleri ön alaşımlı, önkarışımlı ve difüzyon-bağlı tozla olmak üzere sınıflandırılır. Bu çalışmada kullanılan Distaloy AE alaşımı Fe, Ni ve Mo alaşım elementleri içeren bir difüzyon-bağlı alaşım çeşididir ve yüksek dayanımlı mikroyapıya sahiptir. Bu çalışmada toz metalürjisi metoduyla üretilen Distaloy AE alaşımlarının sertlik, yoğunluk ve ısıl akışları çalışılmıştır. Bu malzemelerin sertlik ve yoğunluk ölçümleri Brinell sertlik ölçümleri ve Archimedes suyun kaldırma tekniği kullanılmıştır ve Diferansiyel Taramalı Kalorimetre (DSC) cihazı kullanılarak alaşımların ısıl akışları saptanmıştır. Sonuçlar alaşımların SEM fotoğrafları, EDS spektrumlarıyla desteklenmiştir ve ayrıca alaşımların kristal yapıları XRD desenleriyle saptanmıştır.

Anahtar Kelimeler: Distaloy AE, Toz metalürjisi, Isıl akışı, Yüzey karekterizasyonu

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1. INTRODUCTION

Powder metallurgy method that is one of producing of iron and iron derived alloys includes of three main stages powder/powder mixture preparation, shaping of prepared powder mixture in order to obtain green bulk product and densifying of shaping of green bulk products for acquiring densely bulk products from green products. This sintered product has more more densely structure compared to green bulk products [1-5].

Pre-alloyed or diffusion bonded alloys includes of Fe, Ni alloying elements and shows high strengthening structure [6-8]. Distaloy AE alloy used in this study has a diffusion bonding powder structure and on the structure of Distaloy AE alloy, between Fe and dispersed alloying element into Fe-matrix, metallurgical binding structure happens. This situation provides high strengthening to structure [8-10].

Heat flow occurs always from a region having high temperature to a region having lower temperature and happens by conduction, convection and radiation [11,12]. On the solids, heat flow comes true via conduction. In this study; heat flows and hardness of distaloy AE produced by powder metallurgy method have been investigated and relationship between heat flow and mechanical property of these alloys has been determined.

2. MATERIAL AND METHOD

In this study; Distaloy AE alloy powder that is obtained from Höganas in Sweden utilized. The chemical composition of this powder includes of 0.01 of C%, 4.00 of Ni%, 1.50 of %Cu 0.50 of Mo% and Fe in balance.

Distaloy AE powder mixed with lubricant pressed on the 400 and 600 MPa pressures using traditional pressing technique on the 10×15×70 mm molds. Pressed these green bulk products annealed at 600 and 600 °C temperature for 30 min in order to debond of grains in the alloy and provide uniform temperature distribution according to literature [13-15]. After then, samples sintered at 1200 °C, for 2 hours under N_2 atmosphere. Heating and cooling rate selected as 5 °C/min. In this work; as hardness test. Brinell hardness measurements of these alloys performed and calculated following Equation (1).

$$HB=\frac{2P}{\pi D\left(D-\sqrt{D^2-d^2}\right)} \quad (N/mm^2) \qquad (1)$$

In this Equation (1) P and d are referred as ball load and ball diameter of indentator that is contacted to surface of alloys. D is referred as diameter of indentation on the surfaces of these alloys. HB gives Brinell hardness values of these alloys. Ball load and ball diameter have been given as 31.25N and 2.5 mm, respectively. Brinell hardness test performed using BMS Digirock Hardness Tester.

The density measurements of Distaloy AE samples prepared on the 400 and 600 MPa pressures performed via Archimedes water displacement technique; pure water as medium was utilized. Samples cut to small prismatic samples in order to put chamber of assay balance with with 0.0001 sensitivity and Samples firstly dry weighted on assay balance, after, weighted samples were taken in pure water and were boiled to boiling point of water (100 °C) and also waited for 4 hours at this temperature due to homogeneous dispersing of water into pores in the microstructures of samples. After then, samples cooled in water to room temperature and cooled samples dried with clear dishtowel and were individually weighted in air and suspended in pure water. Density and porosity measurements of Distaloy AE alloy samples were calculated with acquiring weighting values of these samples. Equations (2-5) of density and porosity measurements of these samples were given in below,

$$\text{Bulk Density } (\rho_{bulk}) \ (g/cm^3) = \frac{W_K}{W_D-W_A}\times\rho_{liquid} \qquad (2)$$

$$\text{Apparent solid density } (\rho_{apparent}) \ (g/cm^3) = \frac{W_K}{W_K-W_A}\times\rho_{liquid} \qquad (3)$$

$$\text{Apparent porosity (\%)} = \frac{W_D - W_K}{W_D - W_A} \times 100 \quad (4)$$

$$\text{Water adsorption (\%)} = \frac{W_D - W_K}{W_K} \times 100 \quad (5)$$

From equations; W_K,W_A and W_D are defined as dried weight, suspended weight in pure water, weighted in air, respectively. Density measurements performed using Scaltec Sec31 with precision of 0.0001g

Heat flows of sintered Distaloy AE samples and powder Distaloy AE have been investigated using DSC (Differential Scanning Calorimetry). These heat flows of alloys supported via SEM images, EDS spectrums and XRD patterns of alloys.

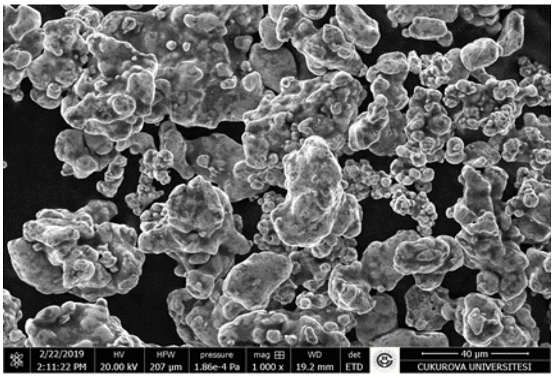

Figure 1. The SEM image of Distaloy AE powder (40 µm)

3. RESULTS AND DISCUSSION

For Brinell hardness values of Distaloy AE alloys, it was obtained that distaloy AE prepared on the low pressure has 106.25 N/mm^2, whereas other Distaloy AE sample has 177.32 N/mm^2. When pressure increased, Brinell hardness values of these samples increased. With pressure increasing, porosity closed, grain bonding occurred and Distaloy AE samples have more strengthening microstructure.

On the Table 2; bulk and apparent solid density (g/cm^3), apparent solid porosity (%) and also water adsorption (%) values of Distaloy AE alloy samples prepared on the 400 and 600 MPa pressures were given. It was observed that bulk and apparent solid density of samples increased when pressure increased. Apparent porosity and water adsorption (%) of samples decreased. With increasing of pressure; pores closes, grain bonding occurs, therefore microstructures of samples gain dense and strenghtening structures. Maximum bulk and apparents solid density are obtained on the sample prepared on the high pressure (6.38 and 6.55 g/cm^3, respectively) and Minimum apparent and water adsorption are recorded as 2.60 and 0.41 %, respectively.

Table 1. The density measurements of Distaloy AE samples prepared on the 400 and 600 MPa pressures

	400 MPa	600 MPa
Bulk density (g/cm^3)	6.18	6.38
Apparent solid density (g/cm^3)	6.41	6.55
Apparent porosity (%)	3.67	2.60
Water adsorption (%)	2.2	0.41

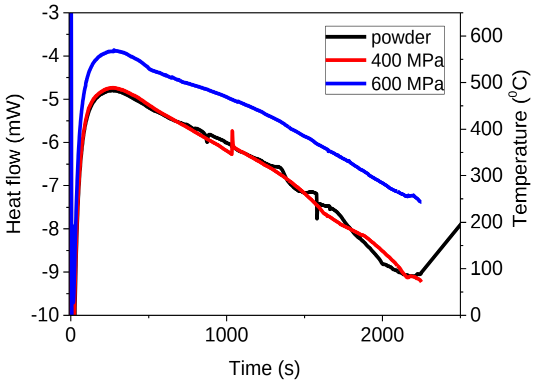

Figure 2. The heat flows of powder and sintered Distaloy AE alloys

In Figure 2; the heat flows of powder and sintered Distaloy AE alloys are given. The heat flows of powder and Distaloy AE prepared on the 400 MPa pressure were recorded close to each other. On the austenitic stainless steel prepared on the 600 MPa pressure; heat flow has higher values than that of Distaloy AE powder and prepared on the 400 MPa pressure. Heat values of these alloys were given according to literature [16]. In this study; for all samples; first, all heat flow plates were arranged to at temperature of approximately 25 °C, after, at the temperature range of approximately 550-450 °C, values of all heat flow plates decreased at time range from 15 to 40 sec, after then, at medium temperature of approximately 450 °C for Distaloy AE powder and prepared on the 400 MPa pressure and at temperature range from 550 to 450 °C for distaloy AE prepared on the 600 MPa pressure; on the values of heat flows decreasing occur at time of 275 sec. On the heat flow of Distaloy AE powder; values of heat flows firstly decreases at temperature of 350 °C and then, increases at temperature of 325 °C, at temperature range from 300°C to 200°C and at time range from 1265 to 1690 sec, on the values of heat flow, frustating occurred. For Distaloy AE alloy prepared on 400MPa pressure; at temperature range from 205 to 108 °C and at time range from approximately 990 to 1065 sec., values of heat flow of this sample, decreasing occurs.Maximum heat flow was recorded on the distaloy AE alloy prepared on the 600MPa pressure. (-3.86279 mW at 277 sec at temperature of 57.667 °C)

In Figure 3 and Table 2, the SEM images and EDS spectrums of sintered Distaloy AE alloys are given. Surface appearances of both of distaloy AE samples have smooth. With pressure effect and heat treatment, porosity into alloy structure closes and more grain binding happens. Via heat treatment; increasing of atomic vibration causes to diffusion and more atoms acts in the contact area and hence, bonding surface happens. Occurred bonding surface extends, therefore, sintering necks occurs [17,18]. this situation observed that surface of Distaloy AE alloy prepared on the 600 MPa pressure has smoother appearance than that of other alloy sample and recommended that this situation has a role on the higher heat flows of this samples according to the other samples.

From EDS spectrums in Table 2; ratios of C, Ni, Cu alloying elements decreased, but ratios of Fe and Mo alloying elements increased. This situation is observed o the XRD patterns. Sintering at high temperature, liquid phase that is caused to densification occurs between alloying elements and carbon atoms [6,19]. More carbon atoms on the structure of alloys lead to transformation martensite structure that is Cu-rich network. In addition, Ni–rich causes to austenitic structure. Cu melts down at almost 1085 °C temperature. Diffusion of Ni atoms happens into the melting of Cu. Martensitic structure having of both of Cu and Ni rich have a significant a role on the reinforcing of alloys [6].

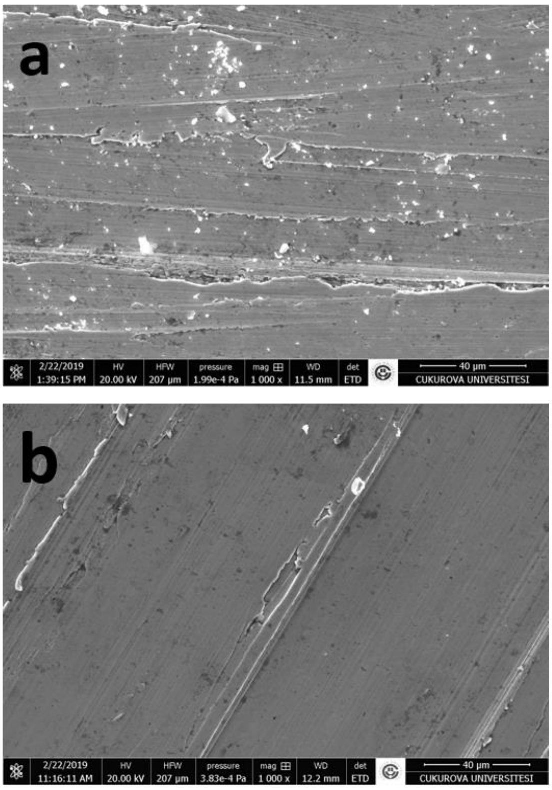

Figure 3. The SEM images of Distaloy AE prepared on the 400 and 600 mPa pressures (40 µm)

Table 2. EDS spectrums of Distaloy AE prepared on the 400 and 600 mPa pressures (all surface of both of samples)

	400 MPa	**600 MPa**
C	4.11	3.7
Ni	4.21	4.09
Cu	1.56	1.28
Mo	0.3	0.34
Fe	89.82	90.59

In Figure 4, the XRD patterns of powder and sintered Distaloy AE samples are observed. On the all XRD patterns of these alloy; it was seen that Fe and Ni alloying elements in microstructures of alloys were preponterated to Cu alloying element. XRD pattern of this alloy powder; (111) cubic crystal structure (at 43.4°) varied to (011) crystal structure on the both of sintered Distaloy AE alloys and at 50.59-51.85° range. It was also observed that (020) cubic crystal structure (Cu, Ni) on the distaloy powder was not seen on both sintered Distaloy AE alloys [20,21].

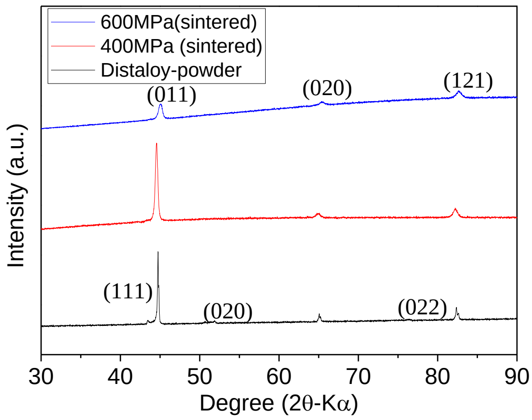

Figure 4. The XRD patterns of powder and Distaloy AE alloy samples

4. CONCLUSION

In this study; the Brinell Hardness values and Heat flows of Distaloy Ae alloys prepared by powder metallurgy method have been examined. Following experimental results are given;

- As pressure increases; Brinell hardness, bulk and apparent solid density values of these values increased. Water adsorption and apparent porosity of these alloys decreased.

- As pressure increased, increasing of heat flows of these alloys occurred.

- Maximum heat flow occurred on the distaloy AE alloy prepared on the high pressure.

- On the SEM images of these alloys; decreasing porosity and therefore grain bonding occurs with increasing of pressures and XRD patterns of of these alloys; Fe and Ni alloying elements in the structures of samples were dominated according to Cu alloying element.

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