PRODUCTION OF NI_3AL-FE COMPOSITE AND INVESTIGATION OF MECHANICAL PROPERTIES

[1]Ayhan Erol, [1]İsmail Yıldız, [2]Ahmet Yonetken

[1]Afyon Kocatepe University, Technology Faculty, 03200, Afyonkarahisar/ Turkey
[2]Afyon Kocatepe University, Engineering Faculty, 03200, Afyonkarahisar/ Turkey
aerol@aku.edu.tr, iyildiz@aku.edu.tr, yonetken@aku.edu.tr

ABSTRACT

In intermetallics high resistance to creep and oxidation, high strenght, low density are desired properties. Sintering process was used in this study by adding different amounts of Fe powder to Ni-Al powder mixture. When the properties of the sample after sintering were examined 40% weight Fe added composition was found as the most suitable ratio in terms of mechanical properties. Analyses were conducted metallographically on the samples after sintering, the densities were calculated, hardness and shear strengths were determined. According to the data 40% Fe added composition had 5,82 gr/cm^3 of density, 92,8 HB hardness values and displayed 221 MPa shear strength.

Keywords: Sintering, intermetallic, powder, composition

1. INTRODUCTION

The intermetallic compound, Ni_3A1, has many advantages such as high melting point, low densities, high strength, as well as good corrosion and oxidation resistance, which make it an attractive candidate for high-temperature structural use [1-4]. Furthermore, the high strength and work hardening ability of these alloys mean that they can perform well in a variety of wear environments [5]. Because of the potential use of nickel aluminides at high temperatures, it is imperative to understand and study their oxidation behaviour [6]. However, low ductility, brittle fracture and processing problems seriously handicapped its application [7]. Its indicated that high temperature alloys should resist to corrosive affect of service atmosphere, should have enough strength in addition should protect its microstructure at elevated temperatures and stay durable [8]. Al–Fe–Ni alloys have been employed as the basis of the Ni-Al-Co permanent magnets because of their good magnetic properties and as high-temperature materials due to high melting points and excellent oxidation resistance [9-11]. Due to their good magnetic properties, Ni-Al-Fe alloys have been employed as the basis of the Alnico permanent magnets. Later on, they were improved by major additions of Co and minor additions of Cu, Ti and traces of other elements [12,13].

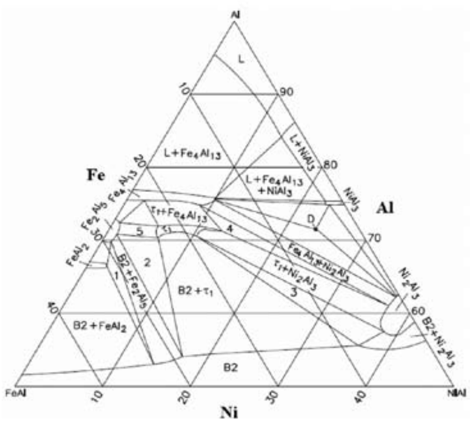

Figure 1. Ni-Al-Fe ternary phase diagram [13].

The purpose of this study is to obtain Ni_3Al-Fe composite by heat threatening at 600 C. It is known that the intermetallics obtained with addition of Fe have low density, high hardness, and high shear strength. In the light of this information the mechanic properties of obtained Ni_3Al-Fe will be investigated.

2. EXPERIMENTAL METHOD

In this study properties of raw materials are; the nickel is in 99.8% purity and has particle size lower than 40 µ, the aluminum is in 99.95% purity and has particle size lower than 75 µ and Fe is in 99.9% purity and has particle size lower than 150µ. For obtaining 11 gr rectangle sample according to the formula $(Ni_xAl_y)(Fe)_{100-(x+y)}$ (x+y= %80, 70, 60 weight) Al and Fe as well as Ni material were mixed homogenously for 24 hours in certain proportions in order to produce a Ni based intermetallic. For this process the raw material powders mixed in mixer has single phased electric motor. This mixer is a mixer that circular motion.

The mixture was shaped by one axis cold hydraulic pressing in a suitable container. In shaping process the pressing pressure was 300 bar. Pressed samples have undergone sintering for 2 hours at 600 °C in a tube oven within Argon gas atmosphere. They were left to free cooling after sintering, their hardness, density and shear strengths were measured. Also XRD and SEM were applied to samples after sintering.

The XRD analyses carried out in Shimadzu XRD-6000 the radiation chosen is Cu k-alfa the scan range is 2 teta and scanning rate is 2degree/minute. The SEM microanalyses performed in Leo 1430 VP secondary electron detector and the W used as filament of electron gun.

3. EMPIRIC RESULTS

3.1. Density: The densities of the samples obtained after sintering were calculated by using (d=m/V) calculation formula (Figure 2). Here m is the mass of sintered sample; v is the volume of sintered sample, calculated geometrically. When Figure 2 is examined highest density is in 40% Fe added mixture as 5.82 gr/cm^3 and the lowest density has 5.57 gr/cm^3 values in 20% Fe added mixture.

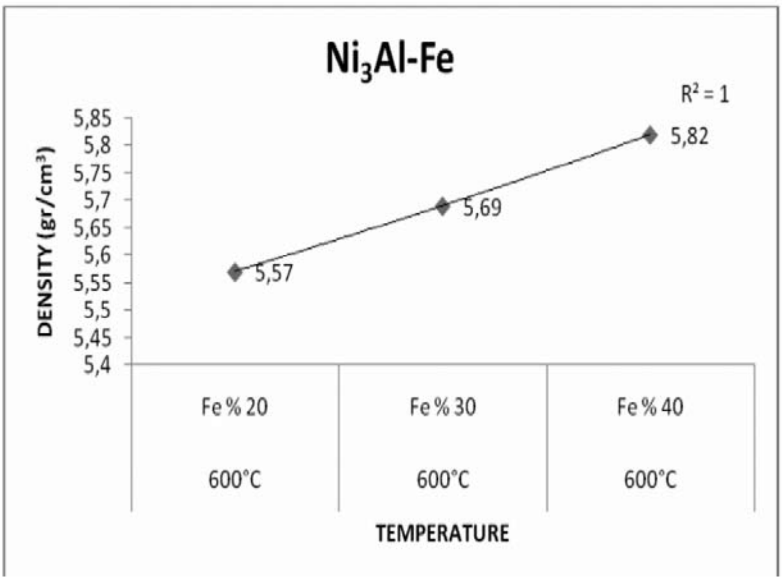

Figure 2. Density graphic of Ni_3Al-Fe composite materials

3.2. Hardness: Hardness values of samples which were obtained in connection with sintering effect were measured as Brinell (Figure 3). In Brinell hardness measurement method 10 mm spherical ball tip used. The approximate data has taken that performed any 3 places on rectangle sample. The reason is obtaining the exact hardness data.

When Figure 3 is examined while the highest hardness was obtained in 40% Fe added mixture as 92.8 HB, the lowest hardness was obtained in 20% Fe added mixture as 86.2 HB.

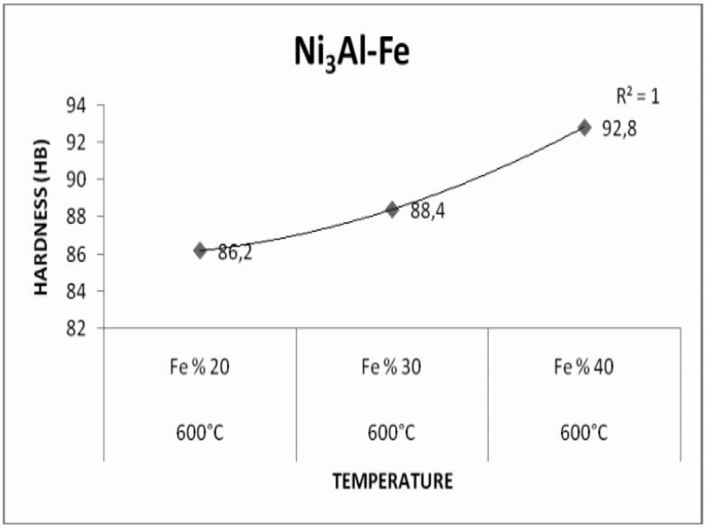

Figure 3. Hardness graphic of Ni_3Al-Fe composite materials

3.3. Volumetric Change: The volumetric changes of Ni_3Al-Fe composite material after sintering were calculated by using (d=m/V) calculation formula (Figure 4). The volume of pre-sintered and post-sintered samples was measured with Archimedes principle that volume changing in liquid.

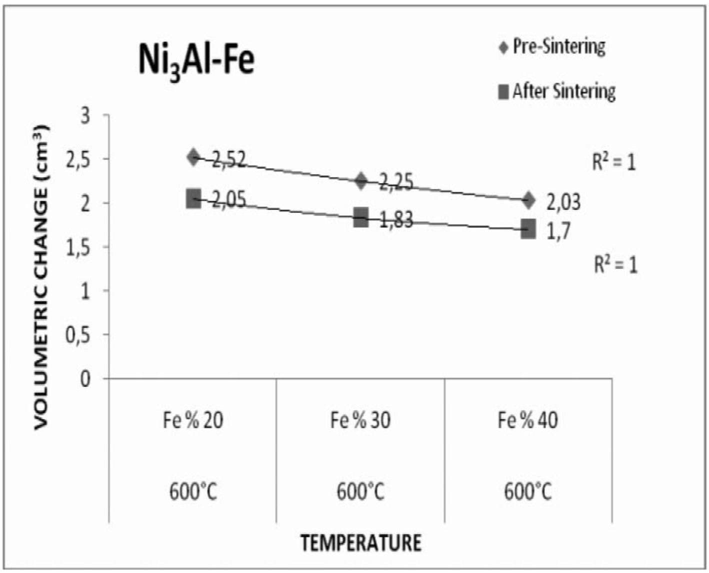

Figure 4. Volumetric change graphic of Ni_3Al-Fe composite materials

When Figure 4 is examined it can be seen that decreases in volumetric changes of composite materials occur inversely proportional to increases in density values when compared to pre-sintering.

While the highest volumetric change was obtained in 40% Fe added mixture with 1.75 cm^3, the lowest volumetric change was 2.06 cm^3 in 20% Fe added mixture. The increasing in density is changing diametrically with decreasing in volume change. This situation shows that the desired sintering occurred.

3.4 Shear Strength: Shear strength values (Figure 5) for the samples obtained after sintering were measured by Shimadzu AG-IS 100KN device. Shear strength performed via connecting shear apparatus to jaw of tensile testing device and the rectangle samples placed in this apparatus and testing performed.

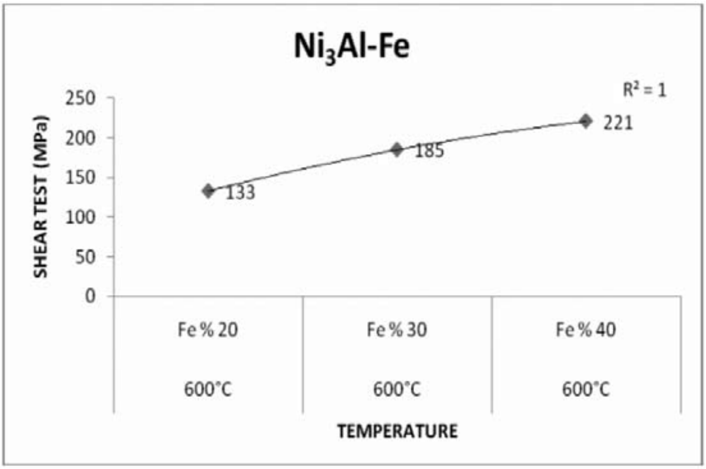

Figure 5. Shear strength graphic of Ni_3Al-Co composite materials

While the highest shear strength value was obtained as 221 MPa in 40% Fe added mixture, the lowest shear strength value was 133 MPa in 20% Fe added mixture.

3.5 Xrd Analysis: After sintering, XRD analysis was performed upon the samples (Figure 6 and Figure 7). When the analysis results were examined, the highest peak value was observed in Ni_3Fe phase among the sintered composite materials. Following this phase, FeAl phase has the second highest peak value. It is anticipated that Ni_3AlFe peak value indicates the reaction of Ni with Al within the composite material.

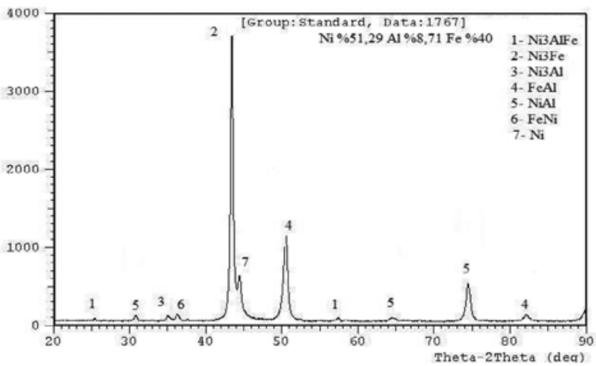

Figure 6. XRD graphic of Ni-Al-20% Fe composite material

The XRD analysis result of 40% Fe added mixture is seen in Figure 7. As it is seen in the Figure as well, Ni_3Fe phase has the highest peak value. It is anticipated that this case indicates that Ni element may be formed within the composite material.

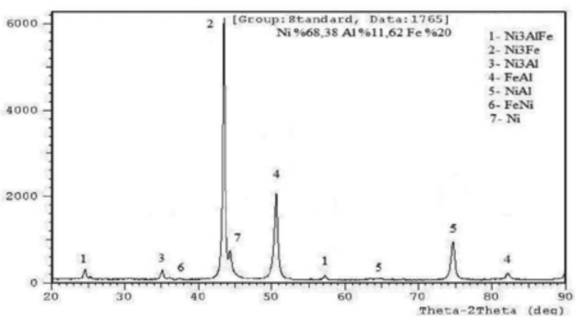

Figure 7. XRD graphic of Ni-Al-40% Fe composite material

When Figure 6 and 7 are examined it is seen that intermetallic phase formed in Ni_3Al-Fe composition after sintering is Ni_3Al, Ni_3AlFe, Ni_3Fe, NiAl, FeAl, Ni, FeNi.

3.6 Sem Analysis: SEM analysis of the composite materials obtained depending upon sintering effect was performed (Figure 8). When SEM images were examined, it is observed that more homogenous and less porous structure 20, 30 and 40% Fe added materials. The reason of obtaining less-porous structure is more sintering. It is thought that this situation indicates that Fe material in the composite material could increase the sintering temperature by reacting with other materials.

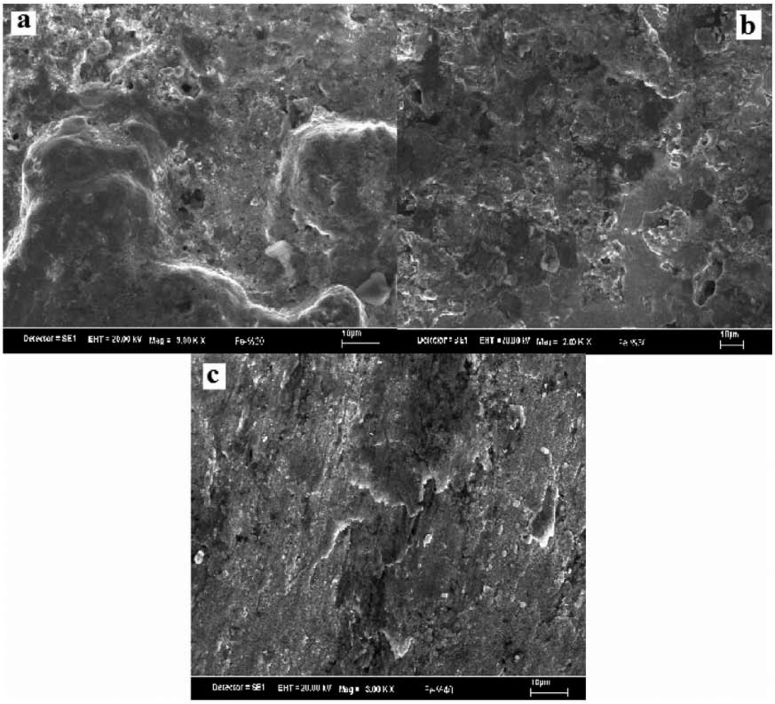

Figure 8. SEM images of Ni_3Al-Fe composite materials, a) SEM image of Ni-Al-20% Fe added composite material, b) SEM image of Ni-Al-30% Fe added composite material, c) SEM image of Ni-Al-40% Fe added composite material

4. RESULTS AND DISCUSSION

The following results were obtained from the experimental findings;

- The highest density value was calculated in 40% Fe added composite material as 5.82gr/cm^3 (Figure 2).
- The highest hardness value was measured as 92.8 HB hardness in 40% Fe added composite material among the sintered composite materials.
- The highest shear strength was measured in 40% Fe added composite material as 221MPa.
- When SEM analysis were examined, it was seen that 20, 30 and 40% Fe added composite material has a more spaceless and homogenous structure.
- While the flow charted followed in empiric studies is similar to the one used by Yonetken et al. in their studies, there are some differences in the values [14].
- Decreasing in volume change is changing diametrically with the increasing in density, by the way the desired sintering quality occurred.

5. ACKNOWLEDGEMENT:

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