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Production of Ni_3Al-Cr Composite and Investigation of Mechanical Properties

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ABSTRACT

Nickel aluminide intermetallic compounds possess attractive properties that make them good candidates for high temperature structural applications. It is known that Ni_3Al intermetallics are commonly used in various application fields with the addition of Cr, in particular as well as elements such as Ti, Co, Mo and Fe which are related to this group for improving properties thereof. Given this information, sintering process was used in this study by adding different amounts of Cr powder to Ni_3Al powder mixture. When the properties of the sample after sintering were examined we were able to reveal the effects of Cr on Ni_3Al and consider 3% Cr added compositions 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 3% Cr added composition had 5,23 gr/cm^3 of density, 153,9 HB hardness values and displayed 307 MPa shear strength.

Keywords: Sintering, intermetallic, density, hardness, structural

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]. The precipitation process of Ni-Al-Cr alloys has been widely investigated by many scholars, however, which mainly focused on the modulation structure and pattern at the late stage of precipitation. The macroscopic performance and behavior of alloy depend almost entirely on its microstructure [9]. The size and distribution of precipitated phase particles can be controlled by the reasonable aging thermal treatment, thus, the better performance can be acquired for precipitation-strengthened alloys [10]. Most of the work on Cr-containing Ni Al alloys has been addressed to the study of the microstructure, mechanical properties and the effect of chromium on the suppression of dynamic embrittlement at intermediate temperatures [11].

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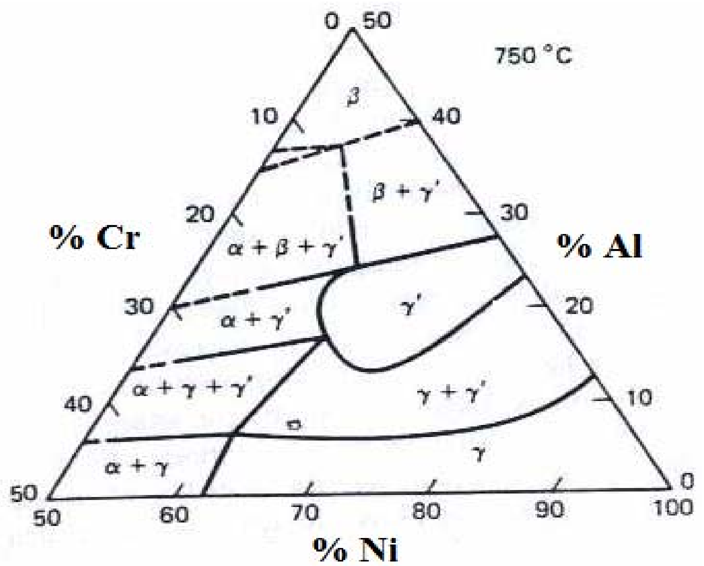

Figure 1. Ni-Al-Cr ternary phase diagram [12].

The purpose of this study is to obtain Ni_3Al-Cr composite by heat threatening at 600 C. It is known that the intermetallics obtained with addition of Cr have low density, high hardness, and high shear strength. In the light of this information the mechanic properties of obtained Ni_3Al-Cr 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 Cr is in 99% purity and has particle size lower than 40μ. For obtaining 11 gr rectangle sample according to the formula $(Ni_xAl_y)(Cr)_{100-(x+y)}$ (x+y= 97, 94, 91, 88) Al and Cr 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. The mixture was shaped by one axis cold hydraulic pressing in a suitable container. In shaping process the pressing pressure is 300 bar. Pressed samples have undergone sintering for 2 hours 600 °C in a tube oven within Argon gas atmosphere. The aim of sintering process is packaging the particle of raw materials by the way increasing the hardness of samples by heat treating. 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 was used 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 12% Cr added mixture as 5.42 gr/cm^3 and the lowest density has 5.23 gr/cm^3 values in 3% Cr added mixture. According to these values density and porosity changing inversely proportional.

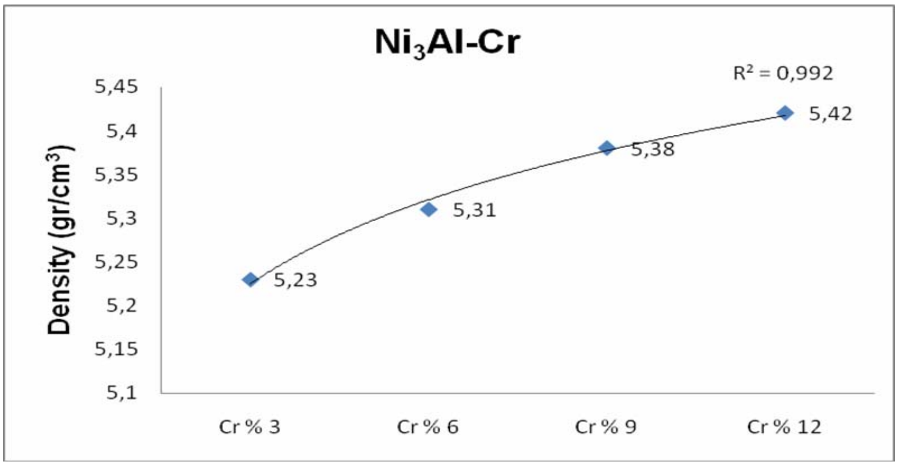

Figure 2: Density graphic of Ni_3Al-Cr composite materials

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 3% Cr added mixture as 153.9 HB, the lowest hardness was obtained in 6% Cr added mixture as 119.1 HB. In accordance to this datas reason of high hardness in 3% Cr sample is high Al content by the way liquid phase sintering consisted.

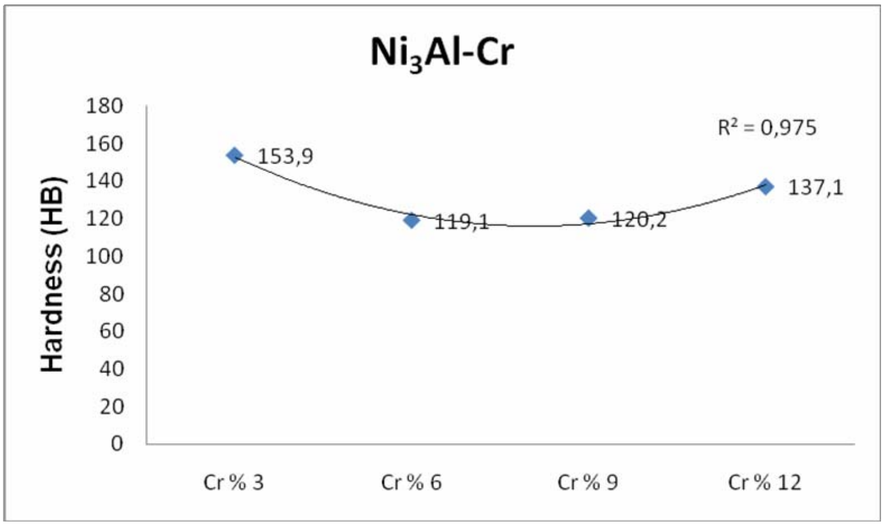

Figure 3: Hardness graphic of Ni_3Al-Cr composite materials

3.3. *Volumetric Change*

The volumetric changes of Ni_3Al-Cr 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.

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 12% Cr added mixture with 2.2 cm^3, the lowest volumetric change was 1.89 cm^3 in 3% Cr added mixture. The increasing in density is changing diametrically with decreasing in volume change. This situation shows that the desired sintering occurred.

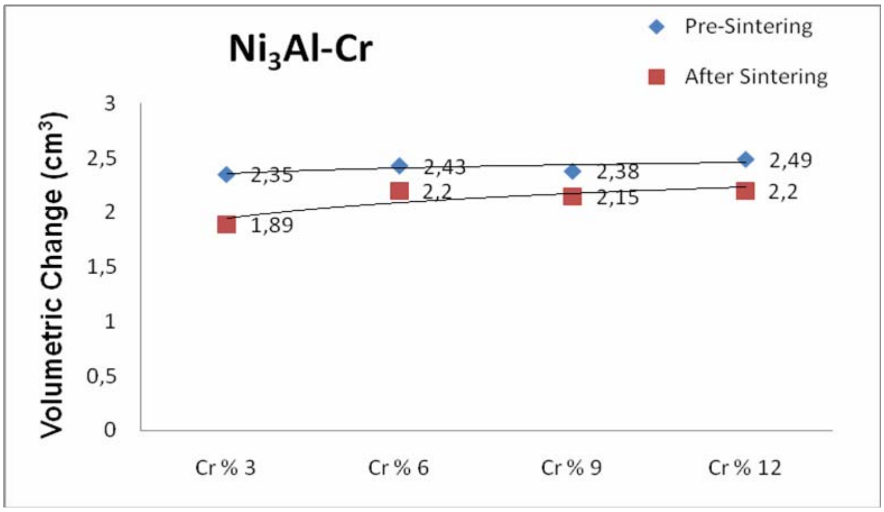

Figure 4: Volumetric change graphic of Ni_3Al-Cr composite materials

3.4. *Shear Strength*

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

While the highest shear strength value was obtained as 307 Mpa in 3% Cr added mixture, the lowest shear strength value was 189 Mpa in 9% Cr added mixture.

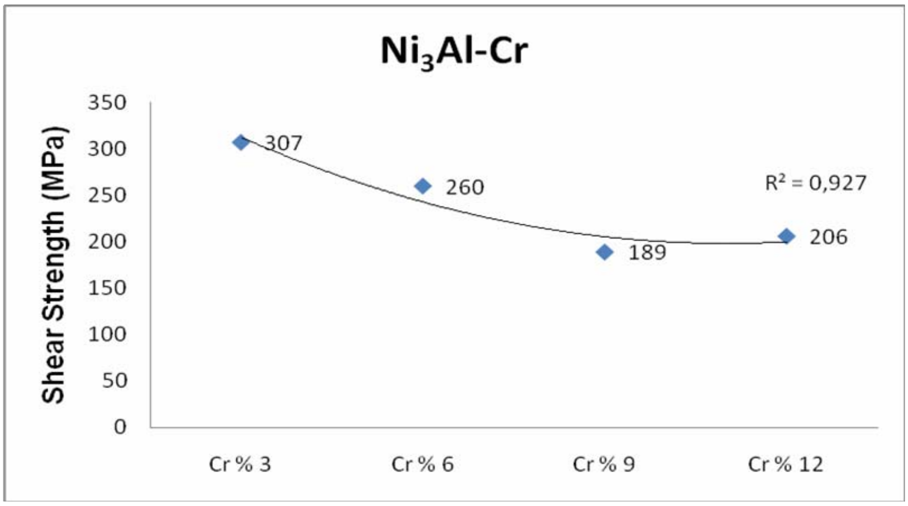

Figure 5: Shear strength graphic of Ni_3Al-Cr composite materials

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_3Cr phase among the sintered composite materials. Following this phase, Ni_3Al phase has the second highest peak value. It is anticipated that Ni_3AlCr peak value indicates the reaction of Ni with Al within the composite material.

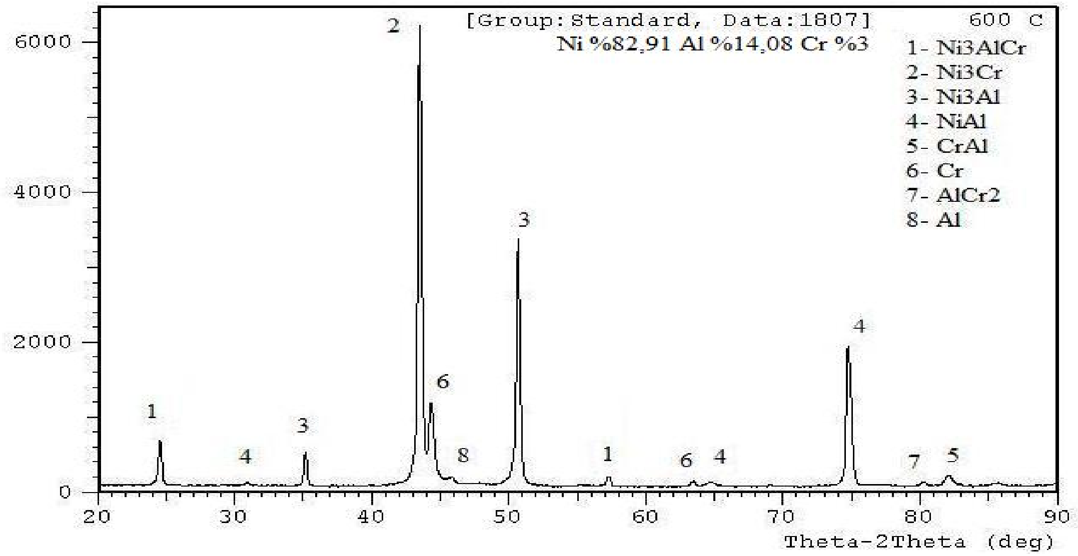

Figure 6: XRD graphic of Ni-Al-3% Cr composite material

The XRD analysis result of 12% Cr added mixture is seen in Figure 7. As it is seen in the Figure as well, Ni phase has the highest peak value. It is seen that Ni phase follows this phase. It is anticipated that this case indicates that Ni element may be formed within the composite material. When Figure 6 and 7 are examined it is seen that intermetallic phase formed in Ni_3Al-Cr composition after sintering is Ni_3Al, Ni_3AlCr, Ni_3Cr, NiAl, CrAl, Cr, Ni, NiCr, $AlCr_2$.

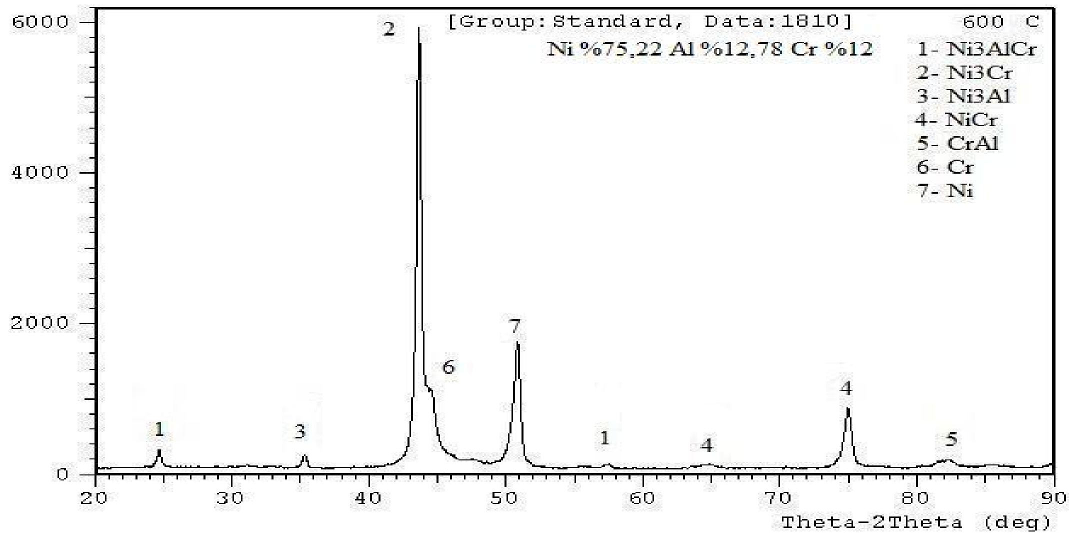

Figure 7: XRD graphic of Ni-Al-12% Cr composite material

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 less porous structures and a more homogenous exist in 3% Cr added materials and porous structure was formed in 6, 9 and 12% Cr added material. The reason of obtaining less-porous structure is more sintering.

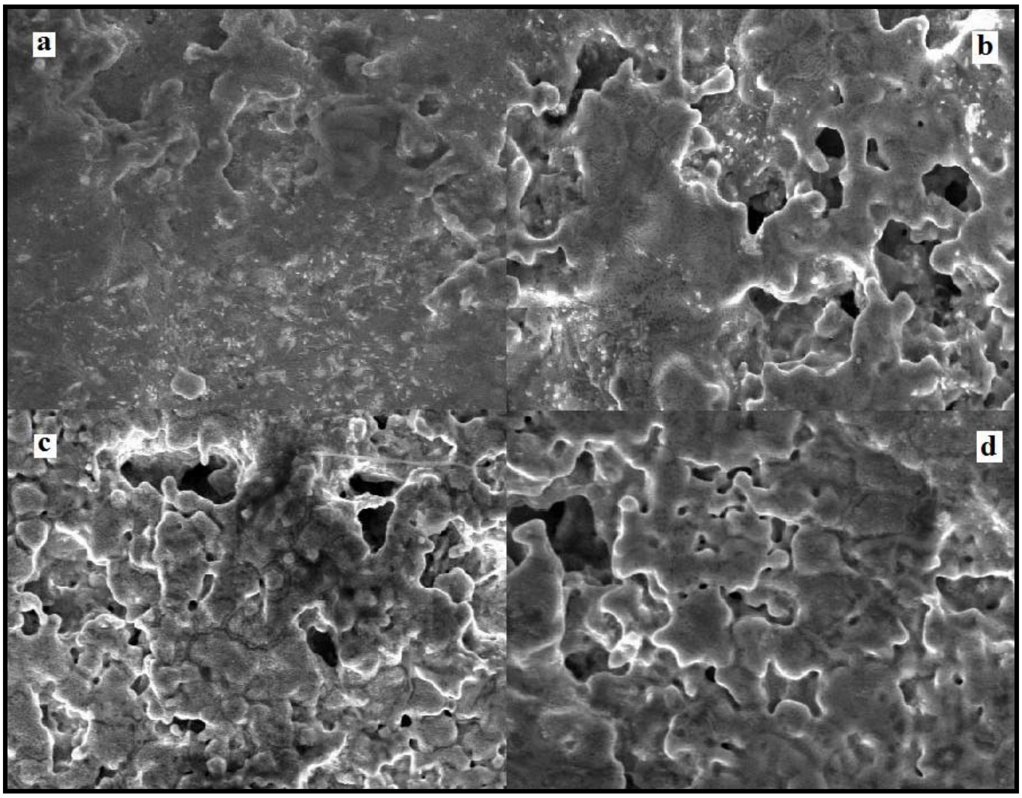

Figure 8: SEM images of Ni_3Al-Cr composite materials, a) SEM image of Ni-Al-3% Cr added composite material, b) SEM image of Ni-Al-6% Cr added composite material, c) SEM image of Ni-Al-9% Cr added composite material, d) SEM image of Ni-Al-12% Cr added composite material.

4. CONCLUSIONS

The following results were obtained from the experimental findings;

- The highest density value was calculated in 12% Cr added composite material as 5.42gr/cm^3 (Figure 2).
- The highest hardness value was measured as 153.9 HB hardness in 3% Cr added composite material among the sintered composite materials.
- The highest shear strength was measured in 3% Cr added composite material as 307MPa.
- The highest hardness value in respect to density is inspected in 3% Cr composite material. The reason creates this hardness value is liquid phase in sintering media causing by high aluminum content.
- Hardness values have also changed in proportion to the shear strength values. It is estimated that The highest shear strength value of the Cr composite caused by high hardness of sample.
- When SEM analysis were examined, it was seen that 3% Cr 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 [13].
- 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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