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The effect of heat treatment on the physical and mechanical properties of the (Alnico-5) alloy prepared by powder metallurgy method

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ABSTRACT

The aim of this work is studying the (Alnico 5) alloy by using powder metallurgy method. Containing after testing by device of atomic absorption (5% Al, 13% Ni, 17% Co, 2% Cu, 63% Fe) Physical properties have been studied at different heat treatment temperatures (Apparent Density, Porosity, Water Absorption) and mechanical (Vickers Hardness). The real density and apparent density results show that the ratios of the apparent density less than real density. The mechanical hardness measurement show the increasing in this value corresponding to the decreasing of porosity and water absorption after heat treatment because of grain growth and alloy homogenization.

Key words: Heat treatment, Physical properties, Mechanical properties, (Alnico 5) alloy, Powder metallurgy

INTRODUCTION

Alnico alloys are very important group of Permanent magnetic alloys which are used in wide range of electrical devices [1,2]. Such as mini-transducer for Mossbuar [3],Gint Magneto Resistance(GMR)[4] and recently as Alnico bonded magnet [3,4,5,6].

They contain Fe, Co, Ni and Al with minor addition of Cu and Ti [7, 8]. These alloys have attracted considerable work, both theoretical and experimental because of their magnetic properties, good corrosion resistance, heat treatment, high Curie temperature and the highest saturation magnetization [9]. More recently the structure of some titanium and niobium adding to the Alnico composition has been examined in an attempt to find the reason for their high coercivity and saturation magnetization [10,11].

These Alnico alloys can be divided into more than nine types, depending on atypical nominal composition and improvement in magnetic properties during a suitable method of preparing [7, 9].

The magnetic hardness of Alnico magnets results from the shape anisotropy of magnetic precipitates which are formed when cast Alnico alloys are subjected to a special heat treatment. The homogenized alloy consists of a single BCC structure (α -phase) which with heat treatment undergoes spinodal decomposition into two BCC phases (α 1 and α 2 phases). The α 1 phase is an Al(Ni)-rich weakly magnetic phase (matrix phase) and the α 2 phase is an Fe(Co)-rich strongly magnetic phase (in the form of rod shaped precipitates) [12].

There are only few studies exist on the behavior of Alnico in confined geometries [13,14]. Most of the studies and all attention in the literature have been focused on magnetic and structural properties of Alnico-5 is still insufficient. In the present work the correlation between the variations of the magnetic and structure properties at different annealing temperature has been studied.

MATERIALS AND METHODS

Metallic powder with high purity has been used . That has purity more than (99.96 %) . An these powders are mixed according to standard percents of Alnico 5 alloy. A mould of steel with geometrical dimensional has been built . The samples has been form often mixing of powder by hydraulic press under (6 Ton) pressure for cylindrical samples with (L = 1.6 cm, r = 0.5 cm). Figure (1) shows technology rout of preparation of Alnico 5 alloy by powder metallurgy method. Then thermal treatment of samples by German furnace of type : (Renfert) model (Magma no.2300-0000) at room temperature and degrees (700,800,900) °C with heating range (5 °C/m) with fixing of samples at thermal degrees mentioned for (1 hour) with slow cooling . Then physical examination (Apparent density, Porosity, Water Absorption) are done by Archimedes method where samples are dried for (1 hour) by using electric drying furnace . At (100 °C). The sample has been weighed after taking it out from the furnace . This weight called dried weight (W_d).

An then the sample been bathed for (24 hour) and after that took out of water and dried from water drops by a cotton cloth without pressing the sample. So as not to pulling water found in external vacancies of samples. After that the sample been weighed and this weight called saturated weight (W_s) .

Then sample measured its weight while hanging . This step done by simple system shown in figure (2) . The saturated water sample so as to weight while it's hanging in the water and this weight called hang weight(W_i).

Then apparent density calculated (A.D), apparent density (A.P) and water absorption (W.7A) according to equations below [15,16,17]:

$$A. D = \frac{Wd}{Wd-Wi} \times \rho \qquad -----(1)$$
Where ρ : water density (1gm/cm³)

$$A. P = \frac{Ws-Wd}{Ws-Wi} \times 100\% \qquad -----(2)$$

$$W. A = \frac{Ws-Wd}{Wd} \times 100\% \qquad -----(3)$$

For the mechanical properties represented by calculating values of hardness (Vickers hardness test) for all samples with load (500 gm). Taking five values in order to show surface's homogeneity and free of defects. Then calculation of average by unit (gm/cm³) from digital screen of device directly.

RESULTSAND DISCUSSION

Figure (3) shows values of apparent density to the samples increased with increase of sintering temperature . Because of reduce in porosities and increase of alloys homogeneity, this agree with the studies [18, 19, 20]. Either figures (4) and (5) it shows values of apparent density and water absorption for sample of project. It's observed that values of porosity and water absorption reduce it values with increase sintering temperature , where increase of sintering temperature leads to increasing in correlation of grains powder where reduce of porosities took place and change in its shape . This reduce of values porosity and water absorption confirm that they have inverse relation with apparent density .

Figure (6) shows hardness values by Vickers method for alloys samples with different sintering temperatures. Where show as hardness values of samples increasing with increasing of sintering temperature and so because decrease of its porosity mention. This agree too with the study [21]. Table (1) show values of apparent density, porosity, water absorption and hardness values with change sintering temperature.

Table 1. Values of apparent density, porosity, water absorption and hardness with change of sintering temperature

Sintering Temp.($^{\circ}$ C)	Apparent Density (g/cm ³)	Water Absorption	Porosity %	Hardness (g/mm ²)
<i>R.T.</i> (25° <i>C</i>)	4.87	6.4	12.65	534.54
700• C	5.1	2.95	4.35	554.22
800• C	5.22	1.65	2.85	605.39
900 • C	5.35	0.7	1.8	691.62



Fig. 1: Preparing of (Alnico 5) alloy by powder metallurgy method



Fig. 2: Digital balance



Fig.3 : Change of apparent density with sintering temperature



Fig.4 : Change of apparent porosity with sintering temperature



Fig.5: Change of water absorption with sintering temperature



Fig.6: Change of hardness values with sintering temperature

CONCLUSION

Throughout preparation alloy (Alnico 5) and studying its physical and mechanical properties are summarized as follows:

1- There is clear effect of used thermal treatment and chosen time of the physical and mechanical properties.

2- The studied samples showed linear relation between apparent density and hardness values with sintering temperature.

3- Studied samples indicated inverse relation of a apparent porosity and water absorption with sintering temperature.

4- The studied samples showed apparent density and hardness values increased with increasing of sintering temperature.

5- The studied samples showed inverse relation of apparent porosity and water absorption with apparent density

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