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The Effect of Adding Zinc on the Mechanical and Microscopic Properties of the Al-Ni Composite Prepared using Powder Technology

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Abstract

Aluminum and its compounds are important materials due to their availability and properties, which has enhanced their applications in many fields. This study aims to detect the effect of strengthening with zinc particles on the mechanical and microscopic properties and adding it to the composite (Al_Ni). The composite (aluminum_nickel_zinc) is prepared by powder metallurgy with the volumetric proportions of aluminum (97, 94, 91, 88, 85%) and nickel at a fixed percentage (3%) with zinc reinforcement at volumetric percentages of (12, 9, 6, 3, 0)%. The metal powders are grounded for an hour and then pressed at a pressure of 6 tons for a minute for all samples in order to achieve good harmony between its components, Then, the samples are annealed at a temperature of 600 °C for a period of two hours. After that, the mechanical properties (hardness, compressive strength) are studied. The results show an increase in both Vickers hardness and compressive strength values with increasing zinc particle content before and after sintering. The morphological (microscopic) properties show dispersion and dissolution of zinc particles in aluminum and the replacement of dark phases with bright ones with increasing zinc concentration.

Keywords: *aluminum, microscopic properties, zinc, powder metallurgy.*

Introduction

Interest in composite materials has increased in recent years due to their distinctive properties, such as light weight and high resistance. They have proven successful in industrial uses (space, agricultural, medical) and various transportation tools (1).

Aluminum-based composite products produced by powder metallurgy are ranked second in the world after steel products (2). Powder technology is one of the most important techniques in preparing alloys, through which various parts and compositions are produced by mixing metal powders, pressing them with special molds, then annealing them at an appropriate temperature to obtain the required shapes and desired characteristics (3). Aluminum powder sintering technology is considered a low-cost and lightweight process thanks to the mechanical properties of aluminum alloys prepared by the powder method (4).

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Aluminum alloys have gained great industrial importance from the beginning of the nineteenth century until today. Aluminum and its alloys are used in many industrial and engineering applications due to their good physical and chemical properties, such as the ability to conduct heat and electricity, being ductile, easy to form, plumb, and extrude, and their ability to be hammered, drawn, and light in weight. Its density is 2.74 gm/cm3, in addition to the high strength of the alloy, which contributes to the design and construction of strong and lightweight structures important for the manufacture of spacecraft and aircraft structures (5).

Applications on ground metals found in aluminum alloys have shown more interest in using thin metals and adding them to alloys to obtain high-quality properties such as zinc and nickel (6). Aluminum-nickel-zinc alloys prepared by the powder method are widely used in the mechanical field, especially the field of vehicle manufacturing and applications that need to withstand shocks and vibrations (7).

Practical Part

Materials used

In the current study, three metal powders for the composite are used, namely aluminum, nickel, and zinc, with a purity of (99)%. They are supplied by The Thomas Baker Company and prepared in the following proportions, as shown in Table (1).

Table (1): Volumetric proportions of the alloy components

	S_1 %	S_2 %	S_3 %	S_4 %	S_5 %
Al	97	94	91	88	85
Ni	3	3	3	3	3
Zn	0	3	6	9	12

Samples Preparation

The powders are weighed with a sensitive electric scale. They are placed in a homemade grinding machine for an hour with steel balls. The process of mixing and grinding is done well, leading to homogeneity of the powders. Then, the forming process is carried out using a hydraulic press with a capacity of (15 tons) and a cylindrical mold. Cold pressing is conducted with a force of pressure (6 Ton) for one minute to ensure the consistency of the compresses. The compresses are then baked using an electric oven at a temperature of (600°C) for two hours in a vacuum atmosphere to prevent oxidation of the samples. The samples are left to cool well at room temperature, after which smoothing and polishing are carried out in order to prepare them for examinations.

Results and Discussion

The Vickers Hardness

Figure (1) shows the relationship between the change in the percentages of zinc content and the Vickers micro-hardness before and after sintering. The hardness values increase before sintering from (44.1_50) Hv at the zinc content of (6_0)%. The values decrease afterward from (12_6)%. After sintering, it is noticed that there is an increase in Vickers hardness from(28.9-41.7) Hv by an increase in zinc reinforcement particles (12_0)%. The increase in hardness before and after sintering as a result of adding zinc particles is attributed to increased resistance to plastic deformation and increased internal stresses. Zinc particles act as barriers to deformation of the base material, as indicated by Joseph et al (8).

After sintering, it is found that there is an increase in the hardness percentage with an increase in the percentage of zinc reinforcement (0-12%). This increase is due to the role of temperature in recrystallization, granular growth, and the removal of stresses in the composite. Moreover, zinc contains a strong flat cubic structure in the form of austenite that increases the strength of the metal (9, 8).

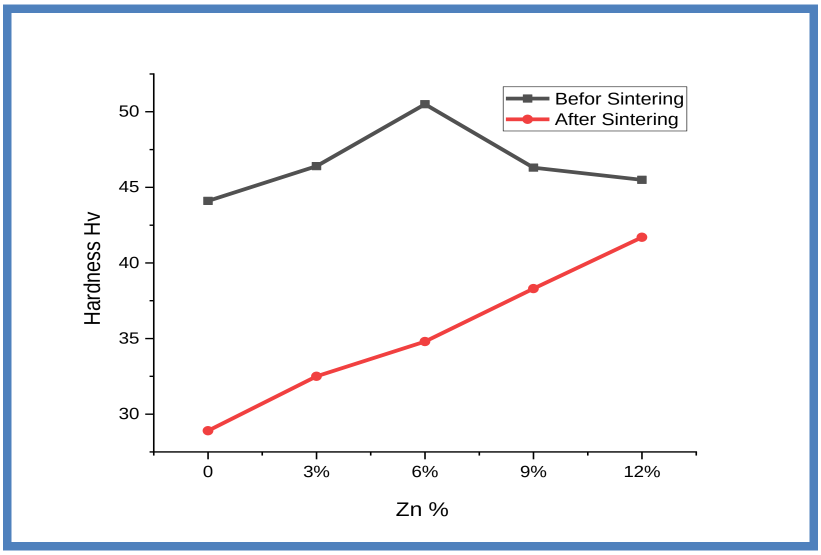


Figure (1): The relationship between the change in volumetric percentages of zinc content and Vickers hardness before and after the sintering process

Compressive strength

Figure (2) shows the relationship between changing zinc percentages and compressive strength. It is noted from the figure that the compressive strength values increase from (20_25) Mpa to the level of zinc concentration (6_0)%, then decrease after that before sintering. This is due to the spread of the basic components of the compound in a homogeneous manner and the formation of compounds rich in zinc, among the metals, giving compressive strength to the compound (6).

After sintering, it is found that there is find an increase in compressive strength from (32_43) Mpa with an increase in the percentage of zinc reinforcement from (12_0)%. This is due to the fact that the sintering temperature (600°C) for two hours contributes to increasing the bonding between the reinforcement particles and the base material through increasing the spread and good distribution of the particles, and the dissolution of the zinc particles in the aluminum base material, causing intense compression of the particles and improving the compressive strength, as indicated in studies by (9.10).

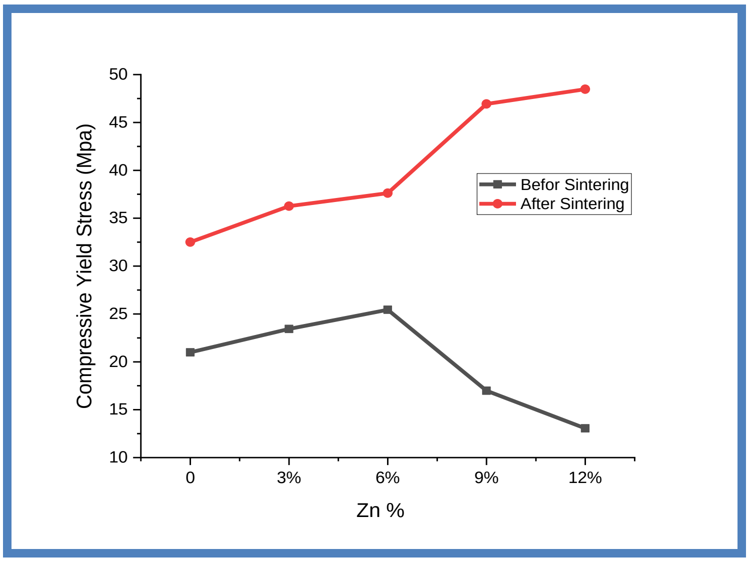
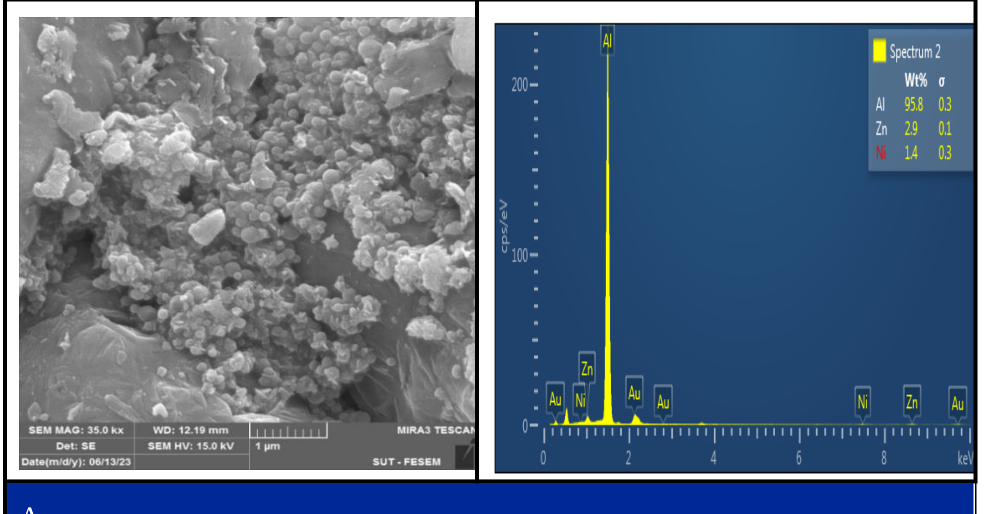


Figure (2): The relationship between the change in volumetric percentages of zinc content and the compressive strength before and after the sintering process

Scanning Electron Microscope

Figure (3) shows scanning electron microscope images at a depth of (1µm) for all samples before and after the sintering procedure. It is noticed that there is a homogeneous distribution and strong correlation of the reinforcement content of zinc with aluminum and nickel. The recrystallization and diffusion of particles in the samples also supports an increase in the hardness of the samples. The shapes also show that increasing the reinforcement ratio contributes to increasing the bonding and homogeneity between the components and improving the characteristics of the composite. The image has also revealed how the zinc particles are dispersed and dissolved in the aluminum, where dark areas appear to be replaced by bright ones, which is consistent with (9).



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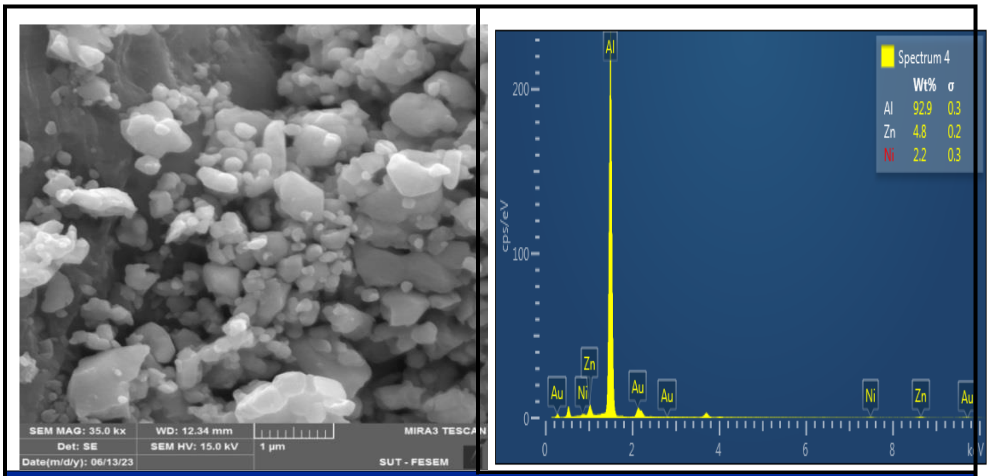

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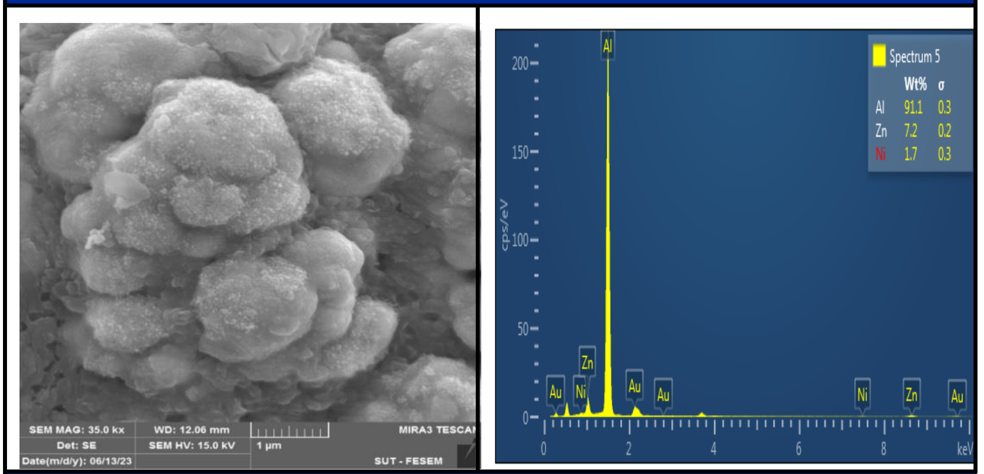

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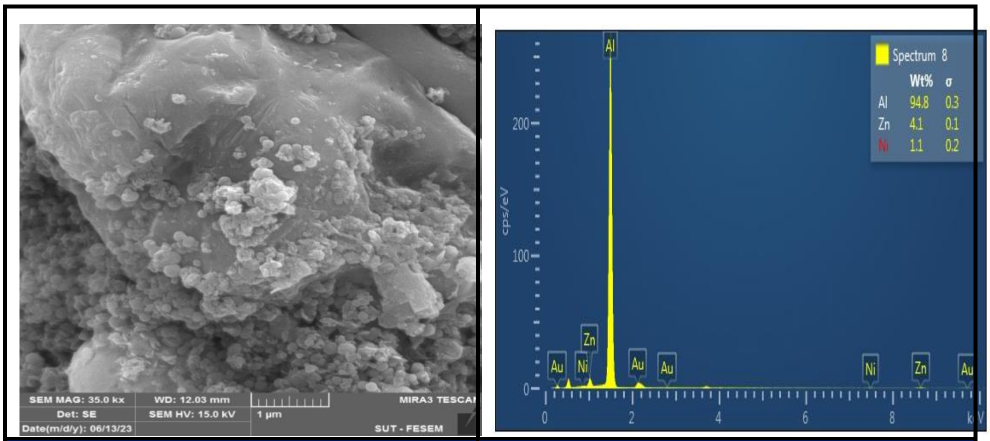
Before the sintering



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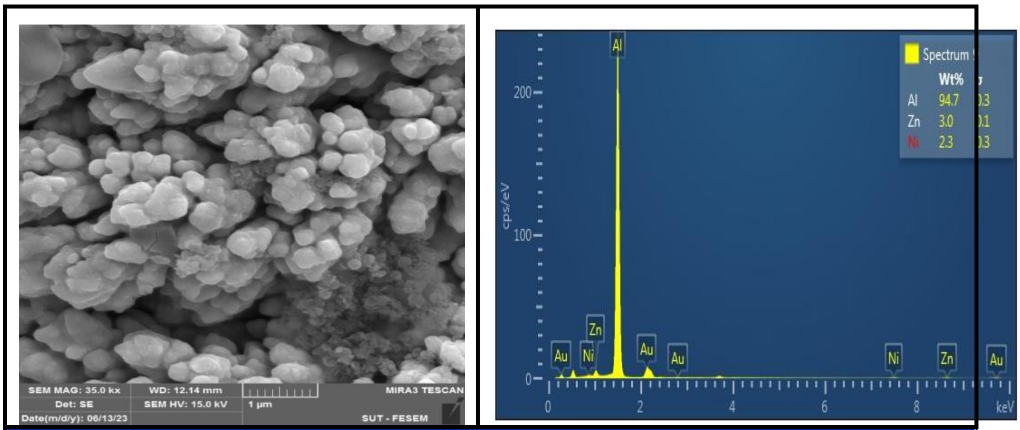

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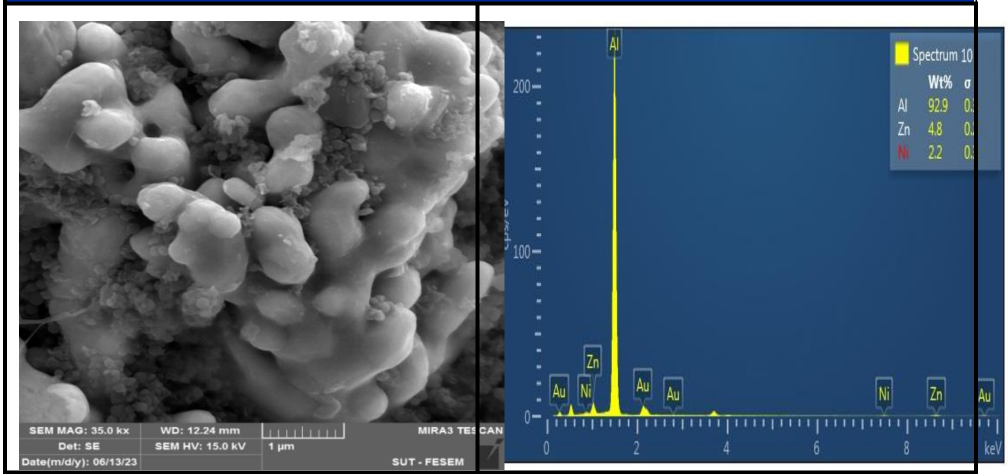

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After the sintering

Conclusions

Aluminum composites reinforced with zinc particles prepared by powder metallurgy are developed and the morphological and mechanical properties of the composites are examined. The results in the microstructure show that there is a distribution and dissolution of zinc particles in the aluminum base material, with the presence of bright phases and homogeneity between the particles of the compound. As for the mechanical properties, there is an increase in hardness before and after sintering with an increase in the concentration of (6-0)% and a decrease in hardness at a weight of (10)% reinforcement, meaning that increasing the concentration of zinc enhances the hardness. As for the compressive strength, there is an increase in the compressive strength before and after sintering.

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