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EFFECTS OF NI ADDITION ON MECHANICAL PROPERTIES OF LOCALLY MANUFACTURED 7022 ALUMINUM ALLOY

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Abstract

Aerospace sector uses 7022, a wrought aluminum-zinc alloy, extensively. In this work, aluminum alloy 7022 was made locally, and the effects of "Ni" reinforcement on mechanical properties were investigated. Stir casting is a commonly used process for the production of Metal Matrix Composites, when combined with Sand Molding. By adding Ni, the mechanical properties of the Al-7022 alloy are enhanced. Initially, the AA-7022 was created using a sand mold. Three specimens were created utilizing the stir casting method with different weight percentages of Ni, i.e., 1wt% and 3wt%. The manufactured samples' density, tensile strength, and hardness were measured. The test findings reveal a 38.744% improvement in the tensile strength of the 3wt% specimen compared to the unfiltered Al-7022. The hardness value was likewise most promising for the 3wt% specimen, increasing by 9.9% compared to the unfiltered variant. 94.16% density was achieved by specimen C1 with a 3wt% Ni. The material behaves brittle and fractures without warning. Further heat treatment is necessary to make it commercially viable.

INTRODUCTION

The alloy 7022 aluminum alloy is part of the wrought aluminum-zinc family. Zinc is the main alloying component of 7022 aluminum, a 7000-series aluminum alloy. It is used in the aerospace industry and was designed for primary shaping into wrought products. The Aluminum Association (AA) assigned this alloy the number 7022 and designated it as EN AW-7022. The European Union's chemical nomenclature is AlZn5Mg3Cu. The AFNOR also uses the designation A-Z4GU (French military). In addition, A97022 is the (UNS) Unified Numbering System number. Originally released in 1979 and classified as a standard. Experts believe it has the lowest electrical conductivity of all the 7000-series alloys in the database.

In terms of physical qualities, there are four main types of 7022 aluminum. It is one of the most demanding categories in the 7000 series of alloys, including at least 87.85% aluminum by weight, making it one of the most demanding grades. Alloy 7022, like many other aluminum alloys, has a high yield strength of 370 MPa, which is similar to the strength of the majority of highly alloyed alloys. It has good corrosion and oxidation resistance, comparable to 7075 aluminum alloy but less than 7039 aluminum alloy and is resistant to stressed corrosion cracking. It's also tiny and lightweight, with excellent heat resistance. 7022 alloy is a popular material for plastic injection molds due to its excellent machinability, thermal conductivity, and mechanical stability, among other properties. The most common grade is T651, which represents the most difficult work. Alloy 7722 can be thermally heat-treated to improve tensile strength at the expense of flexibility. Laczankis (2009).

In this work by adding soft reinforcements to rigid reinforcements reduces composite brittleness. Incorporating solid lubricants into these composites encourages the creation of a protective tri-layer at the interface, which reduces wear and plastic deformation. Using agro/industrial waste materials for reinforcement, such as fly ash, red mud, and rice husk ash, reduces composite density while maintaining mechanical and wear qualities.

Aluminum alloys incorporating nickel and titanium produce alloys with superior mechanical characteristics. Nickel's restricted solubility in aluminum has a reinforcing effect, significantly increasing the alloy's mechanical characteristics by forming intermetallic phases in the aluminum matrix. Furthermore, adding nickel into an aluminum alloy create a novel kind with enormous research and application potential, as well as numerous advantages over typical aluminum alloys.

Despite its high strength, AA-7022 aluminum alloy is prohibitively expensive to import. Our goal was to make 7022 aluminum alloy locally and improve its mechanical properties at a reduced cost.

Literature Review:

Aluminum alloys in the 7000 family, such as AA-7022, are well known for their excellent strength-to-weight ratio, machinability, and corrosion resistance, making them popular in aerospace, automotive, and tooling applications. Mechanical qualities are primarily determined by precipitation hardening, with η ($MgZn_2$) phases contributing significantly to strength. Alloying additives such as Cu, Cr, and Mn improve thermal stability and hardness [7, 13].

Much research has concentrated on enhancing aluminum alloys through reinforcing or mild alloying additions. Several reinforcements, including as fly ash, red mud, rice husk ash, graphene, and TiO_2, improve hardness, wear resistance, and tensile strength, with varying impacts on density [1, 10, 11, 18]. These investigations show that adding relatively small amounts of reinforcing materials or particles can dramatically improve the performance of aluminum alloys.

Nickel has garnered special attention due to its low solubility in aluminum and propensity to produce stable intermetallic complexes. These chemicals are known to limit grain development and act as barriers to dislocation motion, resulting in increased strength and hardness. Studies on Al-Ni and Al-Zn-Ni alloys show that Ni additions improve tensile strength, hardness, and thermal stability [5, 6, 7, 19]. For example, Naeem et al. [5] found that small Ni additions increased the homogeneity and strength of Al-Zn-Mg-Cu alloys, whereas Hernández-Méndez et al. [7] discovered improved hardness and tensile behavior in Ni-reinforced aluminum-based systems.

The alloy's performance is heavily influenced by its processing route. Sand casting, while widely utilized for its simplicity and cost-effectiveness, frequently produces porosity, coarse grains, and segregation. Previous research has demonstrated that Ni additions can help to overcome these limits by refining the structure and fostering stable intermetallic phases, resulting in better mechanical outcomes even without sophisticated processing methods [10, 15]. Comparisons of sand casting to procedures such as cooling slope casting or friction stir processing show that mechanical qualities are controlled by both reinforcing content and processing route [3, 14, 17].

Although there is a large body of literature on 7000-series alloys, the effect of Ni on AA-7022 has received little attention. The majority of studies have concentrated on alloys such as AA-7075 or AA-7079 [2, 16, 19], leaving a vacuum in our understanding of Ni's involvement in AA-7022. To close this gap, the current work investigates the effects of 1% and 3% Ni additions on the tensile strength, hardness, and density of locally manufactured AA-7022 produced via sand casting, providing fresh insights into the practical strengthening of this alloy.

Materials and methods:

The raw materials needed to manufacture aluminum alloy 7022 were bought from FS Corporation (Lahore, Pakistan) in master alloy form.

Three samples were created. A1, B1, and C1 have 0%, 1%, and 3% Ni reinforcement, respectively. Their composition is as follows:

Composites	Standard AA-7022	Formulation	Formulation	Formulation

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		A1	B1	C1
Zinc, Zn	4.3 - 5.5 %	4.5 %	4.5 %	4.5 %
Chromium, Cr	0.10 - 0.30 %	0.15 %	0.15 %	0.15 %
Copper, Cu	0.50 - 1.5 %	0.5 %	0.5 %	0.5 %
Magnesium, Mg	2.4- 3.7 %	2.5 %	2.5 %	2.5 %
Manganese, Mn	0.10 - 0.40 %	0.10 %	0.10 %	0.10 %
Silicon, Si	<= 0.50 %	0.25 %	0.25 %	0.25 %
Aluminum, Al	88 - 92.4 %	92 %	91 %	89 %
Nickel	0 %	0 %	1 %	3 %

We first determined the element composition needed to produce Aluminium Alloy 7022 and the addition of nickel as an impurity. Three samples with varying compositions, A1, B1, and C1, were also made using sand casting.

A substance can be moulded into a certain shape using a mold. In order to give it shape, an empty compartment is used while a liquid or hot fluid material cools and solidifies in the mold. We used a sand mold with a clay and water glue for our project. The following are the measurements for our mold. Length = 6.5 in; Diameter = 1.5 in

Figure 1: Sand Mold

Figure 2: Binder used for Mold

For melting the composites, firstly a grinder was used to chop the composites into the required small bits.

Figure 3: Material Cutting Process

In a furnace, our materials were melted. A blower was used to increase the furnace's temperature. The furnace's temperature was kept at 700 degrees Celsius. It melted the components in the following decreasing order:

We melted the components in descending sequence because doing so in an irregular or ascending order would have resulted in squandered or evaporated materials due to temperature variances. If it was added in ascending order, for example, the lower melting temperature of one element in comparison to the element with a higher melting temperature may result in the first element being squandered in order to reach the second element's melting temperature. As a result, we melted the components in a decreasing order. After melting the composites in descending order, the slag was removed. For the samples B1 and C1. Nickel was added to the solution in varying percentages; sample B1 received 1 percent Ni, while sample C1 received 3 percent Ni. Following the introduction of Ni reinforcement into a molten solution. It was mixed with other composites to ensure that Nickel was evenly distributed throughout the molten AA-7022.

Figure 4: Furnace used for Casting

The molten solution was poured into the mold once it had melted and was allowed to cool after being exposed to air.

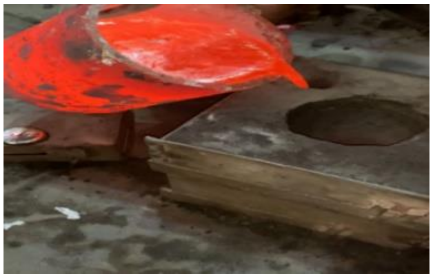

Figure 5: Pouring Molten Metal in to mold

After whole process, 7022 Aluminum alloy was successfully manufactured. Following compositions were produced.

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Figure 6: Specimen A1 with 0% of Nickel Impurity

Figure 7: Specimen B1 with 1% of Nickel Impurity

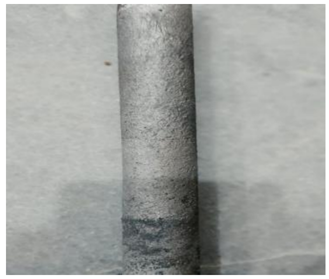

Figure 8: Specimen C1 with 3% of Nickel impurity

Testing and Experimentation:

Density test was performed using Digital electronic weighing scale. To conduct the density test, the specimen was cut into small pieces of 6 cm in length and 1 cm in thickness. The specimen's weight was first measured in air. Water was poured into a beaker as a solution, and the weight was removed before placing the specimen in it. The weight of the specimen in water was then estimated using Archimedes' method.

$$\boldsymbol{Density} = \frac{\boldsymbol{A}}{\boldsymbol{A}-\boldsymbol{B}}(\boldsymbol{\rho_o} - \boldsymbol{\rho_L}) + \boldsymbol{\rho_L}$$

Where

$\boldsymbol{\rho_o}$=Density of Auxiliary Liquid

$\boldsymbol{\rho_L}$= Density of air

A= Weight of sample in air

B= Weight of sample in Auxiliary Liquid

For tensile Strength test, a universal testing machine (UTM), often called a universal tester, materials testing machine, or materials test frame, measures the tensile and compressive strength of materials. Tensile testing was done on the Walter w+b LFT machine. For Tensile testing specimen were made according to ASTM E8.

For Hardness Test, Brinell Hardness Testing was used, it is a nondestructive method of testing a metal's hardness by measuring the size of an imprint made by an indenter. At a particular ball diameter and test force, the Brinell Hardness Testing Machine produces larger indents on the surface, indicating a softer material. ASTM E10 was used to make Brinell test specimens. The specimen was placed in the device, and a 2.5 mm diameter ball intender was used to imprint it with a force of 250 Kgf.

The imprint was studied under a microscope, and Brinell hardness was calculated using an equation.

$$\boldsymbol{BHN} = \boldsymbol{2P} / [\, \boldsymbol{\pi D}(\boldsymbol{D} - \sqrt{(\boldsymbol{D2} - \boldsymbol{d2})})\,]$$

Results:

Aluminum 7022 Alloy 7022 was cast successfully. A1, B1, and C1 are the names of the three compositions. The A1 sample was pure AA-7022 with no Ni reinforcement, the B1 sample had 1% Ni reinforcement, and the C1 sample had 3% Ni reinforcement.

The results based on testing are as follows:

Density Test Results:

After calculating experimental density, theoretical density was estimated. This test resulted in the following:

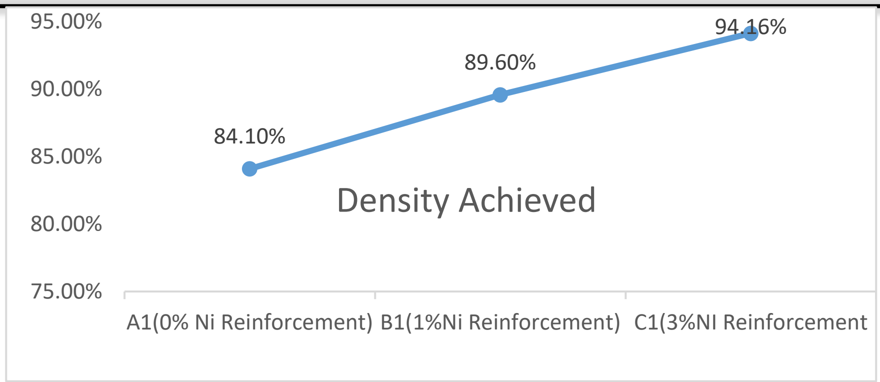

Figure 9: Density Graph

Results of Nickel Addition on density of Aluminium Alloy 7022:

Specimen	Actual Density g/ cm^3	Theoretical Density g/ cm^3	Density achieved
A1(pure AA-7022)	1.8223	2.1608	81.4%
B1(AA-7022 with 1% Ni reinforcement)	2.3682	2.614	89.6%
C1(AA-7022 with 3% Ni reinforcement)	2.588	2.739	94.16%

The graph and table above show the various findings from the density test. According to the above results, sample C1 with 3% Ni Reinforcement yields the best performance. The density was raised by 94.16 percent compared to the theoretical values. Sample A1 has a density of 1.8223 grams per cubic centimeter, whereas Sample C1 has a density of 2.588 grams per cubic centimeter. The addition of Ni increased the density by 12.76%.

Tensile Test Results:

Tensile strength test specimens were cut according to ASTM E8 and placed between circular jaws to provide a force. The following results were acquired via UTM.

Figure 10: Specimen A1, B1 and C1 after UTM Test

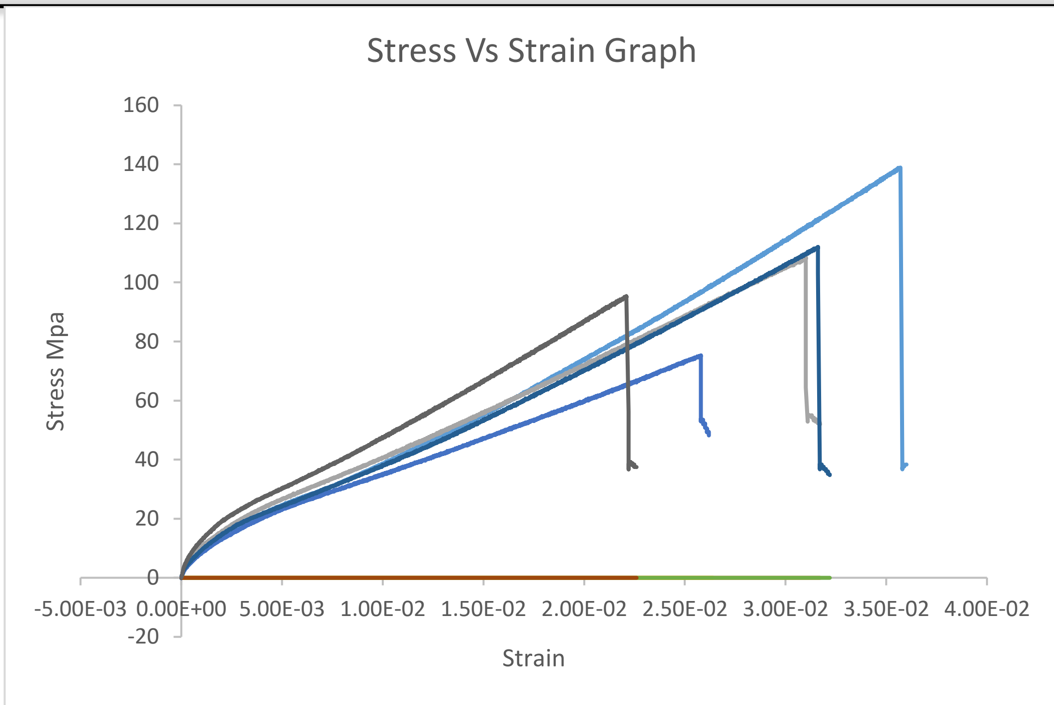

Figure 11: Stress-Strain Graphs showing UTM Results

After finishing the test, the average Stress and Strain values were determined. The results show that the pure AA-7022 specimen A1 was broken with a force of 85.09MPa. At this number, the strain was 2.431E-02. The stress and strain values of the B1 sample with 1% Ni reinforcement are 110.2676MPa and 0.031422, respectively. The sample C1 with 3% Ni impurities was shattered with a force of 138.9097MPa, yielding a strain of 3.57E-02. Respectively. The results showed that the best AA-7022 composition was 3 percent nickel reinforcement. The introduction of Ni impurity increased tensile strength by 38.744%.

Brinell Test Results:

As told earlier, the Brinell test was conducted in line with ASTM E10. To create an impression, the specimen was placed in the machine and subjected to a force of 250KgF. The imprint was studied using a microscope, and the Brinell hardness number was calculated.

Results Nickel reinforcement on hardness of 7022 Aluminum Alloy:

Specimen	Intendant Diameter (mm)	Indentation Diameter (mm)	BHN $\left(\frac{\mathbf{kgf}}{\mathbf{mm^2}}\right)$
A1(pure AA-7022)	2.5	2.395	35.703
B1(AA-7022 with 1% Ni reinforcement)	2.5	2.355	38.34
C1(AA-7022 with 3% Ni reinforcement)	2.5	2.35	39.66

Sample A1 has a BHN of 35.703 based on the available data. However, when the NI reinforcement fraction grows, so does the alloy's BHN. The best result is 39.66 for Sample C1, which has 3% Ni enforcement. This shows that the addition of 3% Ni reinforcement raises the alloy's hardness by 9.9%.

When we compared our findings to the literature, we discovered that our Brinell hardness rating was higher than the literature. Our density was also 94.16 percent; however, the tensile strength was not as planned. According to the literature, the tensile strength of 7022 Aluminum alloy is 150-194 MPa, but we measured 138.909 MPa. It is probable that this is caused to micro pours. The reason for this can be established via XRD and SEM investigation. Due to time constraints, I was unable to run these experiments. However, these tests may be conducted to understand more about our Project's characteristics.

Conclusion:

Aluminum Alloy 7022 was made using sand casting, and Ni enforcement was added to improve its mechanical properties. Three cast samples with different compositions were machined into separate specimens for mechanical testing. Sample A1 was 100% pure AA-7022, with no Ni reinforcement. B1 included 1% Ni reinforcement, while C1 included 3% Ni impurity. The tensile test findings show that specimen A1 of pure AA-7022 was shattered with a force of 85.09MPa. At this number, the strain was 2.431E-02. The B1 sample's stress and strain measurements are 110.2676MPa and 0.031422, respectively. The sample C1 with 3% Ni impurities was shattered with a force of 138.9097MPa, yielding a strain of 3.57E-02. Respectively. The results showed that the best AA-7022 composition was 3 percent nickel reinforcement. The introduction of Ni impurity increased tensile strength by 38.744%. Sample A1 has a Brinell hardness of 35.703. However, increasing the percentage of NI reinforcement raises the alloy's BHN. The best result was 39.66 in a sample with 3% Ni enforcement. This shows that 3% Ni reinforcement raises the alloy's hardness by 9.9%. The density test yielded the best density result for Sample C1 with 3% Ni Reinforcement. The density was raised by 94.16 percent compared to the theoretical results. When Ni was added to sample A1, the density was 1.8223 g/ cm3, but sample C1 had a density of 2.588 g/ cm3. The addition of nickel increased the density by 12.76 percent. According to the findings, adding Ni significantly improved the mechanical properties of AA-7022. The most delicate AA-7022 formulation has 3 percent nickel reinforcing.

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