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Analysis of tensile and hardness properties of Aluminium7075 based Metal Matrix Composite

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Abstract: -- Aluminum 7075 alloys have been proposed for extensive use in automotive engine applications and there have been discrete cases of experimental implementation. In order to enhance the usability of this material, it has been investigated in composite forms with various ceramic reinforcements. Viability of the different constituents depends on the compatibility of their physical and chemical properties. The service conditions are characterized by extreme stress and temperature conditions very close to failure. Hence thermal stresses play an important role in success of these materials.

In this present investigation efforts are made to study the mechanical properties of as cast and heat treatment aluminium nitride particulates reinforced Al7075 composites, containing aluminium nitride particulate of 2-3 microns in different compositions. The vortex method of stir casting was employed, in which the reinforcements were introduced into the vortex created by the molten metal by means of mechanical stirrer. Castings were machined to the ASTM standards on a highly sophisticated lathe. The degree of improvement of mechanical properties of MMCs is strongly depending on percentage composition of aluminium nitride particulate reinforcements. An improved mechanical properties are occurs on reinforced compared to unreinforced MMCs.

Keywords: Al7075-Aluminium Nitride, UTS, percentage elongation, Hardness

1. INTRODUCTION

Composite materials have successfully substituted the traditional materials in several light weight and high strength applications. The reasons why composites are selected for such applications are mainly their high strength-to-weight ratio, high tensile strength at elevated temperatures, high creep resistance and high toughness. Typically, in a composite, the reinforcing materials are strong with low densities while the matrix is usually a ductile or tough material. If the composite is designed and fabricated correctly it combines the strength of the reinforcement with the toughness of the matrix to achieve a combination of desirable properties not available in any single conventional material. The strength of the composites depends primarily on the amount, arrangement and type of reinforcement in the resin.

Metal is a chemical element that is a good conductor of both electricity and heat forms cat-ions and ionic bonds with non-metals. In chemistry, a metal is an element, compound, or alloy characterized by high electrical conductivity. An alloy is a mixture of two or more element in solid solution in which the major component is a metal. Most of pure metals are either too soft, brittle or chemically reactive for practical use. Combining different ratios of metal as alloys modifies the pure metals to produce desirable characteristics. Metals are used because of desirable properties such as low weight, higher conductivity, and resistance to corrosion. Example: Aluminium, Copper, Brass, Silver, Lead.

2. OBJECTIVES OF PRESENT WORK

Composites were prepared by using die-casting method for four different weight percentage of reinforcement namely Aluminium nitride (AN) 1%, 3%, 5% and 7%. Effect of AN on the hardness and Tensile properties of Al 7075 MMCs studied.

3. EXPERIMENTAL DETAILS

3.1 Material selection

In the present investigation base matrix material are selected i.e, Al 7075 and tensile properties and hardness properties are studied.

The Al 7075 alloy (matrix material), 5 microns size AN particles (reinforcement) are used for fabrication of MMCs. The chemical composition of Al7075 is given in the Table 1.

Table 1: Chemical Composition of Al 7075

elements	composition
Zn	5.6
Fe	0.5
Mg	2.5

Mn	0.3
Cu	1.6
Si	0.4
Cr	0.23
Ti	0.2

3.2 Casting (Gravity die casting)

Al 7075 ingots are melted in electrical resistance furnace and different weight percents silicon carbide reinforcement is added to get following composition composite specimens.

3.2.1 Composites preparation

The Al-7075 and Aluminium nitride composite is prepared by using stir-casting technique. The crucibles were made of graphite. This approach involves mixing of the reinforcement particulate into a molten metal bath and transferring the mixture directly into a cylindrical shaped die to complete solidification. In this technique aluminum alloy 7075 ingot pieces are to be heated in the furnace to its molten state. When the temperature is maintained between 700-7500C, a vortex will be created using a mechanical stirrer. Aluminium nitride particles are to be preheated in the furnace. The temperature of the furnace is maintained between 700-7500C. Preheated Aluminium nitride particles are added with different percentage to melt when the stirring is in progress which is shown in below. Stirring is continued for about 15 min after addition of Aluminium nitride particles for uniform distribution in the melt. Castings are prepared by pouring the melt into preheated molds of cylindrical shapes.

Table 2 chemical composition of aluminium 7075

Models	Reinforcements	
	Al 7075	Aluminium nitride
1	100%	0%
2	99%	1%
3	97%	3%
4	95%	5%
5	93%	7%

3.3 BRINELL'S HARDNESS TEST

Brinell hardness is determined by forcing a hard steel or carbide sphere of a specified diameter under a specified load into the surface of a material and measuring the diameter of the indentation left after the test. The Brinell hardness number, or simply the Brinell number, is obtained by dividing the load used, in kilograms, by the actual surface area of the indentation, in square millimeters. The result is a pressure measurement, but the units are rarely stated.
The BHN is calculated according to the following formula:

$$BHN = \frac{F}{\frac{\pi}{2} D * \left(D - \sqrt{D^2 - Di^2}\right)}$$

where ,BHN = the Brinell hardness number
F = the imposed load in kg
D = the diameter of the spherical indenter in mm
Di = diameter of the resulting indenter impression in mm

3.3 Tensile test

The tensile test was conducted using a computerized universal testing machine as per the ASTM E8standard. The test uses specimens of 20 mm grip diameter, 30 mm grip length, 62.5 mm gauge length, 75 mm length of reduced cross section, inner diameter of 12.5 mm and total length 155 mm machined from the cast specimens of various compositions mentioned earlier. From this test ultimate tensile strength, yield strength and percentage of elongation were determined.
The main objective of heat treatment is to make the material system structurally and physically fit for engineering application. Solution heat treatment of aluminium alloys allows the maximum concentration of hardening solute to dissolve into solution. This process is carefully carried out by heat treatment of an alloy to a temperature at which one single, solid phase exists.

3.4 Heat treatment process

Ageing heat treatment Process is carried out. In this process specimens are heated to 5200C and hold it for 8Hr followed by water quench.
Again specimens are raised for 1750C and holding it for different ageing durations like 1hr, 3hr, 5hr and 7hr, which is followed by air cooling.

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4. RESULTS AND DISCUSSION

4.1: Effect of AlN and ageing duration on UTS of Al 7075 alloy:

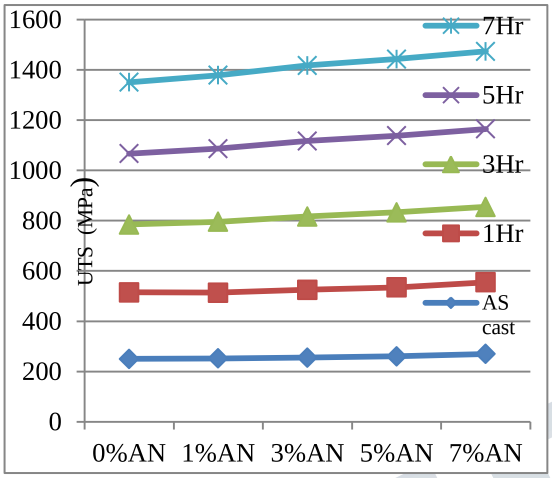

Figure 4.1: Variation UTS of Al 7075 alloy with respect to aluminium nitride and ageing heat treatment duration

From the Fig.4.1 it is observed that the tensile strength of the composites increases slightly with increasing the percentages of Aluminium nitride particles. This could be due the Al7075 aluminum alloy and aluminum nitride has different thermal expansion coefficients. The strain fields piles up dislocation. The propagation cracks during tensile loading encounters resistance due to the interaction between dislocations and the AlN particles. The detachment of AlN particles is delayed due to the presence of a clean and sharp interface and better interfacial bonding. The almost homogeneous distribution of AlN particles provides Orowan strengthening. Therefore, ultimate tensile strength of the composites is improved [3]. Fig4.1.1it is seen that the UTS increases with increase in the ageing duration by keeping percentage of AN constant.

5.1.2: Effect of AIN and ageing duration on YS of Al 7075 alloy:

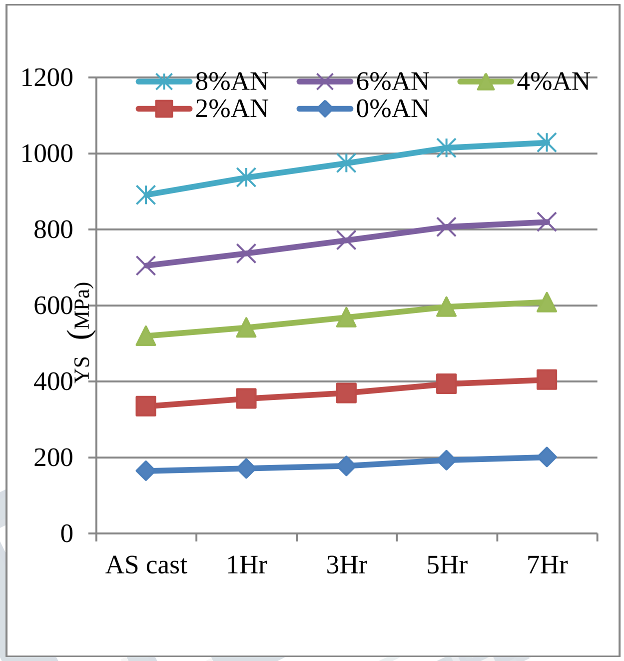

Figure 4.2: Variation YS of Al 7075 alloy with respect to aluminium nitride and ageing heat treatment duration

The Fig. 4.2 shows the yield strength of Al 7075 with varying compositions of Aluminium Nitride and ageing duration. Aluminium nitride is very hard material which makes base matrix more harder and stronger Kennedy & Wyatt[24], obtained similar results in particulate reinforced Al alloy composites and observed an increase in yield strength with addition of particulate regardless of the type of reinforcement used. The Fig. 4.2 shows the yield strength of Al 7075 with varying ageing duration and explains that, ageing duration increases, leading to better yield strength. With increase in ageing duration the porosity of matrix materials also decreases hence the mechanical properties increases.

5.1.3: Effect of AN and ageing duration on % of elongation of Al 7075 alloy:

The figures in the form of graphs (Fig.4.3) shows the comparisons of the percentage of elongation properties between the base metal (Al7075) and base metal with reinforcements in the increments of 1, 3, 5, and 7% respectively. It is seen that the percentage of elongation

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decreases with increases in percentage of AN and ageing duration. There is good bonding between the matrix and the reinforcement particulates resulting in better load transfer from the matrix to reinforcement material.

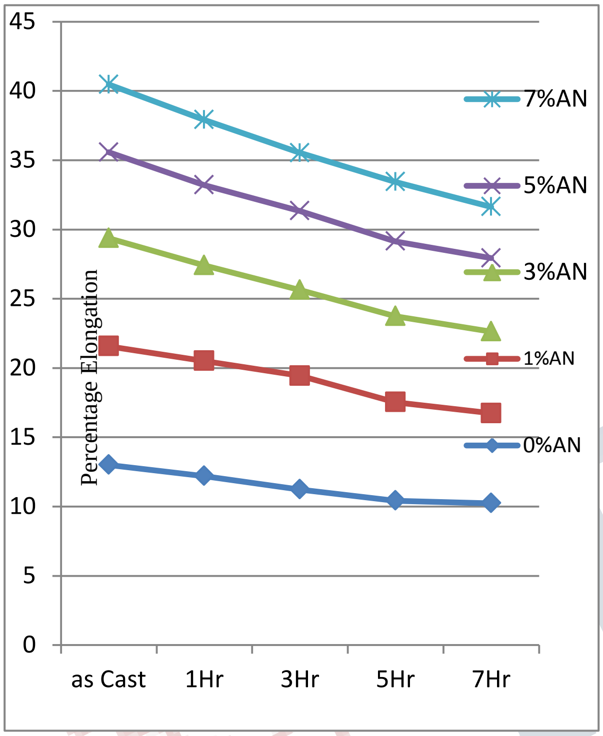

Figure 4.3: Variation % of elongation of Al 7075 alloy with respect to aluminium nitride and ageing heat treatment duration

5.2: EVALUATION OF BHN TEST

5.2.1 Effect of AN and ageing duration on BHN of Al 7075 alloy:

The figure (Fig.4.4) shows the comparisons of the hardness properties between the base metal (Al7075) and base metal with reinforcements in the increments of 1, 3, 5, and 7% respectively. It is also reported that higher hardness is always associated with lower porosity of the MMCs. It can be observed that there is good bonding between the matrix and the reinforcement particulates resulting in better load transfer from the matrix to reinforcement material.
From the above fig. 4.4 we can see that as we increase the ageing duration the hardness properties increases. [3] The hard AN particles was added, it can refine the grain structure of the matrix and also act as the obstacles to the movement of dislocation. Therefore, hardness is improved.
We can also see that the hardness properties of base metal with reinforcements are higher or greater than the hardness properties of base metal without any addition of reinforcements. The ductility decreases with the increase in AN content by a significant amount. The reduction in ductility was about 30% as the AN content was increased from 0 to 5 wt. %.

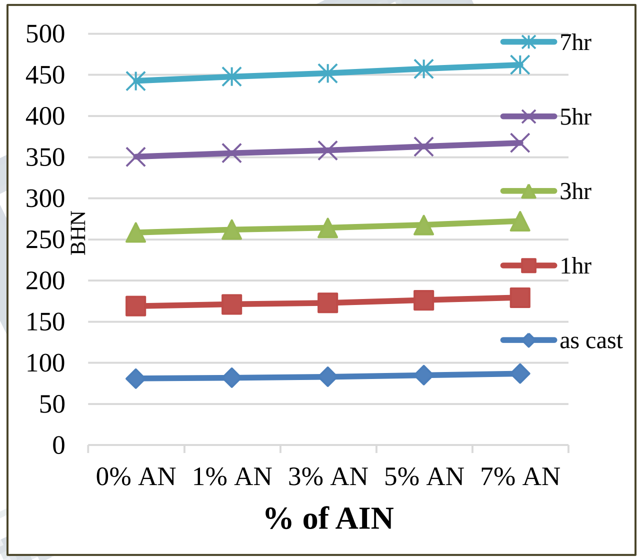

Figure 4.4: Variation BHN of Al 7075 alloy with respect to aluminium nitride and ageing heat treatment duration

CONCLUSION

Based on the analysis of experimental results and findings, the following conclusions can be drawn. This work shows that successful fabrication of a multi component hybrid metal matrix composite (using Al-7075 as matrix, Aluminium nitride as reinforcement) was possible by stir casting method. Cast aluminium 7075-aluminium nitride composites have been prepared satisfactory by liquid metallurgy process.

- Hardness increases with increasing percentage of reinforcement.

- Yield stress increases with increasing percentage of reinforcement.
- The ultimate tensile stress increases with increasing percentage of reinforcement.
- Hardness increases with ageing duration.
- Percentage of elongation decreases with increasing of reinforcement.
- Heat treatment has significant effect on above properties studied.

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