

## **INVESTIGATION OF MICROSTRUCTURE AND MECHANICAL PROPERTIES OF SILICON NITRIDE REINFORCED AMMC USING STIR CASTING METHOD**

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**ABSTRACT:** The aluminum alloys are important in many industrial applications and space applications because of their light weight and good mechanical properties. For this reason many researches had been done to enhance their properties. In this study, particles of aluminium oxide and silicon nitride are used as reinforcement in aluminium matrix alloy to fabricate AMMC through stir casting. Investigation of mechanical properties such as tensile strength and hardness is made. And the wear and surface roughness in machining of these composites with different cutting speed and feed with constant depth of cut is studied. And also the microstructure of the composites is analyzed.

**Keywords** -Aluminium oxides, silicon nitride, stir casting.

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### **I. INTRODUCTION**

Composite materials are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical or chemical properties which remain separate and distinct at the macroscopic or microscopic scale within the finished structure. A common example of a composite would be disc brake pads, which consist of hard ceramic particles embedded in soft metal matrix. The most advanced examples perform routinely on spacecraft in demanding environments. Composites are made up of individual materials referred to as constituent materials.

Aluminium is the most popular matrix for the metal matrix composites (MMCs). The Al alloys are quite attractive due to their low density, their capability to be strengthened by precipitation, their good corrosion resistance, high thermal and electrical conductivity, and their high damping capacity. Aluminium matrix composites (AMCs) have been widely studied since the 1920s and are now used in sporting goods, electronic packaging, armours and automotive industries. They offer a large variety of mechanical properties depending on the chemical composition of the Al-matrix. They are usually reinforced by Al<sub>2</sub>O<sub>3</sub>, SiC, C but SiO<sub>2</sub>, B, BN, B<sub>4</sub>C, AlN may also be considered. The aluminium matrices are in general Al-Si, Al-Cu, 2xxx or 6xxx alloys. As proposed by the American Aluminium Association the AMCs should be designated by their constituents: accepted designation of the matrix / abbreviation of the reinforcement's designation / arrangement and volume fraction in % with symbol of type (shape) of reinforcement.

### **II. Experimental Procedure**

AMMC rods are fabricated by stir casting process. The rods with different weight percentage of silicon nitride (2.5g and 7.5g) and aluminium oxide 20% of aluminium alloy (Al-7075-T6) are made and the tests to determine the mechanical properties such as tensile test to find yield strength, hardness test to find the hardness property, surface roughness test to find surface roughness of the material, wear resistance test to find the best tool for this composite that has high tool life and optimum speed, feed and depth of cut for the material were conducted. And also the microstructure analysis is done using metallurgical microscope.

Stir casting method is to be used to fabricate the composites. It is to be done with a desired pattern. Here we are going to use a simple cylindrical die. The pouring temperature is above 650°C. With the different volume fraction of silicon nitride two different components are to be casted. The powder with different compositions is to be melted in a separate crucible for each rod. The stir speed will gradually be increased to an

optimum speed to get the particles to be dispersed homogeneously. It is to be done for a certain period of time say 30 minutes.



**figure 1.** stir casting machine



**figure 2.** crucible with molten materials of composite

Al-7075-aluminium alloy is used as matrix material. In this aluminium alloy zinc (5.6%) is the major alloying element and 99.75% pure aluminium is present. The other alloying elements are magnesium (2.5%), copper (1.6%) and chromium (0.3%). This alloy is used for operations at lower temperatures of highly loaded parts and for parts with high resistance to corrosion under stress. It is more sensitive to notches and has a higher fatigue-crack propagation rate. However, structures designed and fabricated in 7075 have somewhat less weight than is possible in a 2024-T3 or 2024-T4 structure for equivalent performance.

Al<sub>2</sub>O<sub>3</sub>-aluminium oxide is a type of ceramic material. It has low density, so low weight. It has higher hardness property with low weight of material. It has high thermal conductivity. Its price is lower than silicon nitride. Si<sub>3</sub>N<sub>4</sub>-silicon nitride is also a type of ceramic with higher hardness than aluminium oxide ceramic. Since nitrides are harder than oxides. Its density is low. It has the property of hot hardness; higher fracture toughness; greater resistance to thermal shock and gradients; higher thermal stability; resistance to wear and they are also chemically inert.

**Table 1. different volume fraction of the composites**

ROD	Al <sub>2</sub> O <sub>3</sub> (Wt. %)	Si <sub>3</sub> N <sub>4</sub> (gms)
1	20	0.25
2	20	0.75

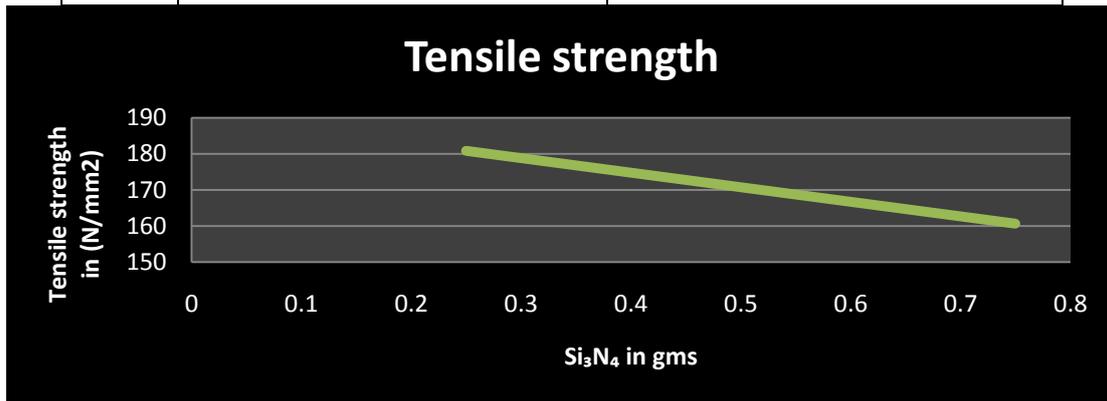
Tensile test is to be done using universal testing machine to find its tensile strength and compressive strength of the rods. Rockwell hardness test is to be conducted using Rockwell hardness machine. Lathe tool dynamometer is used to find out the optimum speed, feed and depth of cut of the material. Surface roughness test is conducted. Microstructural analysis is done using metallurgical microscope.

### III. Results and Discussions

#### a. TENSILE TEST

**Table 2. tensile strength**

S.NO.	Silicon Nitride Wt. (gms)	Tensile Strength In (N/mm <sup>2</sup> )
1	0.25	180.80
2	0.75	160.62



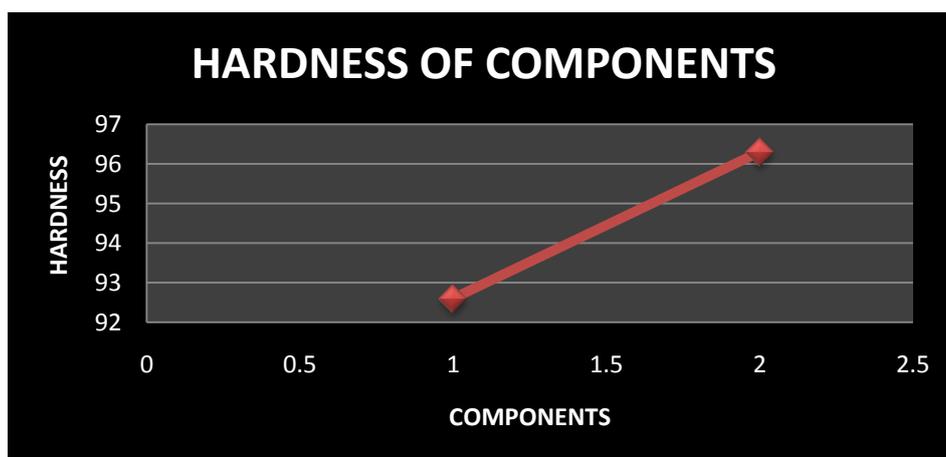
**graph 1. tensile strength vs. silicon nitride different wt.**

Tensile strength value goes on decreasing with the increase in silicon nitride weight (shown in graph no.1). Even though the Tensile strength goes on decreasing with respect to silicon nitride weight the Tensile strength obtained is in considerable amount.

#### 3.2 HARDNESS

**Table 3. hardness**

Component	Hardness (HBW, 10mm dia ball/500kgf load)
1	92.6
2	96.3



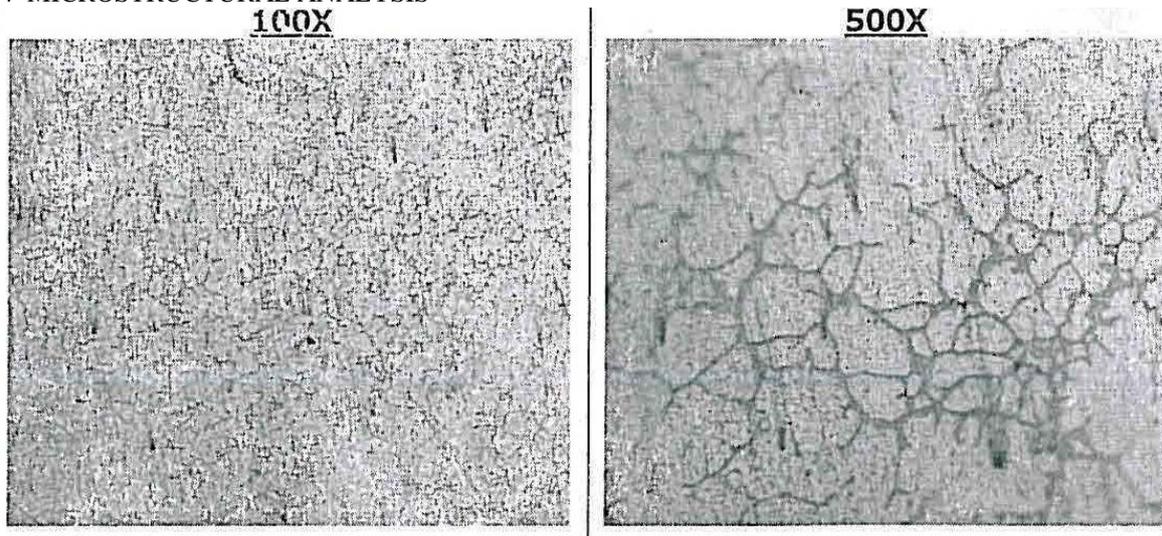
**Graph 2. hardness vs. components**

The hardness value goes on increasing with increase in Si<sub>3</sub>N<sub>4</sub> weight (shown in graph no.2). This further leads to increase of corrosion and wear resistance.

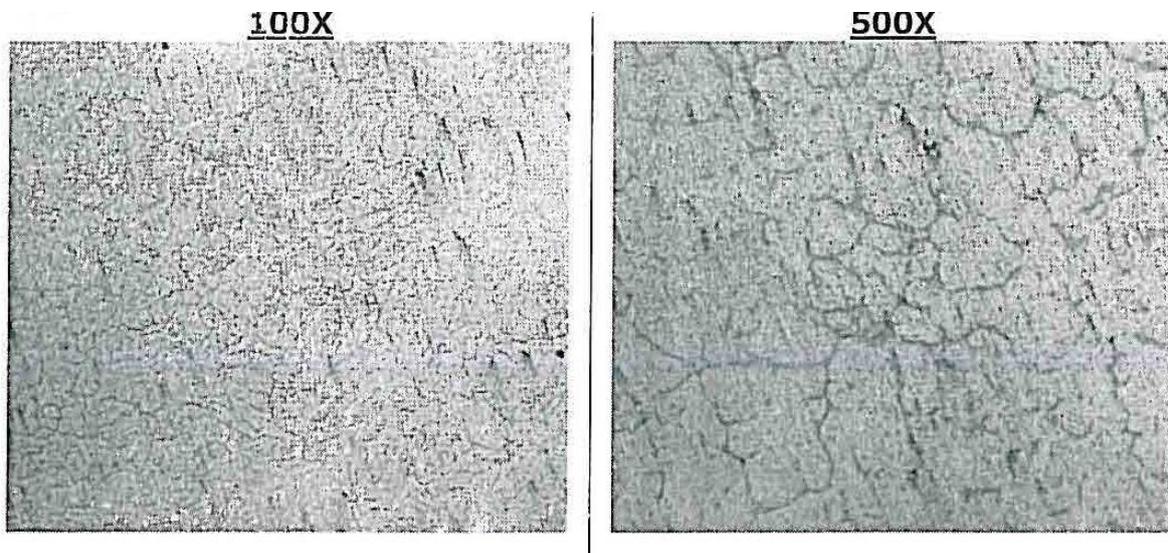
#### 3.3 Optimum Speed, Feed and Depth of Cut with Surface Roughness

By using lath tool dynamometer we have obtained cutting forces at X, Y and Z at varying speed, feed and depth of cut for two rods. The surface roughness values for each speed, fed and depth of cut is found. The optimum speed as 270 rpm, feed as 0.110mm/min and depth as 0.5mm is obtained at low surface roughness value. With this we come to know that at these optimum values the machining can be made accurately with lower surface roughness.

### 3.4 MICROSTRUCTURAL ANALYSIS



**figure 3. microstructure of the AMMC 1**



**Figure 4. Microstructure of the AMMC 2**

For both the composite rods, the microstructure shows the grain boundaries, interdendritic network of aluminium oxide and silicon nitride particles distributed in a matrix of aluminium solid solution throughout the structure.

### IV. CONCLUSION

The AMMC with different volume fraction of silicon nitride is fabricated and various investigations were made.

- Hardness values of the components were found and the hardness of the component increases with the increase in Si<sub>3</sub>N<sub>4</sub> percentage.
- Tensile strength of the component has been decreased when the percentage of Si<sub>3</sub>N<sub>4</sub> is increased.
- The microstructure shows the grain boundaries, interdendritic network of aluminium oxide and silicon nitride particles distributed in a matrix of aluminium solid solution throughout the structure.
- The optimum speed as 270 rpm, feed as 0.110mm/min and depth as 0.5mm is obtained at low surface roughness value. With this we come to know that at these optimum values the machining can be made accurately with lower surface roughness.

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