Analyzing the mechanical properties of aluminium (SiC, B\textsubscript{4}C) hybrid Composite

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Abstract. Aluminium MMCs is play the major role in the industrial sectors. The aluminium MMCs are providing superior properties which cannot achieved by existing monolithic material. Now a days the more research is involves to the development of aluminium MMCs. Here we are choosing Al 7475 is a base metal and reinforced with SiC, B\textsubscript{4}C by stir casting method. The different combinations of composition in volume fraction were chosen like 85\%Al 7.5\%SiC 7.5\%B\textsubscript{4}C, 85\%Al 5\%SiC 10\%B\textsubscript{4}C, 85\%Al 10\%SiC 5\%B\textsubscript{4}C. The stir casted composite is machined carefully to prepare specimens of micro hardness. The mechanical properties are including the micro hardness. The stir casted composite is machined carefully to prepare specimens of micro hardness (Vickers test), tensile test, impact test (Charpy test) and micro structure as per the ASTM standards. The composition of 85\%Al 7.5\%SiC 7.5\%B\textsubscript{4}C, was given more hardness, tensile strength and impact strength has 126.33VHN, 196.79N/mm\textsuperscript{2} and 2 Joule. As increased the percentage of SiC is increase the mechanical properties of the Al MMC.

1. Introduction
A Composite material consist of at least two materials which will combine together to give the better properties to that of the individual constituents. There are many processes that are available to make composite materials which are extremely versatile and efficient. The end produce of the composite results in lighter, more durable and stronger solution compared to the traditional materials. In the field of design and manufacturing, the development of Composite materials is one of the most important advancement in the history of materials. The primary reason composite materials are chosen for components is because of weight for its relative stiffness and strength. Composites also exhibit greater resistance to high temperature corrosion, oxidation and wear. The composites have permeated our everyday lives such as construction medical applications, transportation, aerospace, ships and rockets, probably would not get off the ground with conventional monolithic (unreinforced) materials. The composite technology also makes the use of an entire class of solid materials is possible in application for which monolithic version are unsuited because of their great strength scalar, poor resistance to mechanical and thermal shock. Further many manufacturing processes the composite are well adapted because of its complex structures and also it reduces the manufacturing cost. Those composites are closest to our personal hygiene from our shower stalls and bath tubs made of fibre glass. Solid surface, imitation granite and cultured Marble sinks and counter tops are widely used to enhance our way of livelihood.
The two constituent materials can be broken down into two categories:

1. Matrix (binder)
2. Reinforcement

Table 1. Aluminium 7475 Composition

| ELEMENT | Al   | Zn  | Mg  | Si  | Cr  |
|---------|------|-----|-----|-----|-----|
| PERCENT | 90.3 | 5.7 | 2.3 | 1.50| 0.22|

2. Literature survey

Boopathiraman (2019) Aluminium is widely used for various mechanical applications and also have excellent castability properties. But it has some limitations of pure aluminium alloys due to stiffness, wear resistance and lower strength. This limitation can be eradicated by producing hybrid metal matrix aluminium composites with the addition of reinforcement particle. This paper deals with an attempt to study the mechanical behavior of aluminium hybrid metal matrix composite. The Aluminium 7075 Metal Matrix Composite (MMC) is reinforced (5, 10, 15 Vol. %) with equal amount of Boron Carbide (B4C) and Titanium Carbide (TiC), fabricated by using stir casting method. Here the micro hardness and the ultimate tensile test is obtained at 15% like 46.10BHN & 220 Mpa[1].

T.S.A. Suryakumari (2016) In the fabrication of Al7075 metal matrix composite (MMC), stir casting method is used. In the experimental study it is revealed that the mechanical properties such as micro hardness, tensile strength and micro structure are enhanced by means of heat treatment process. The micro hardness improved by adding reinforcements to the base alloy. The addition of SiC particles improved wear properties results by the addition of AL2O3. Further the mechanical properties enriched by heat treatment. Micro hardness and tensile strength improved by 34% and 7% by the heat treatment process.

Anil Kumar Bodukuri (2016) Powder metallurgy process is used in the preparation of aluminium, SiC, B4C metal matrix composite. The different combination of composition in volume fraction were chosen like 90%Al 8% SiC 2%B4C, 90%Al 5% SiC 5%B4C, and 90%Al 3% SiC 7%B4C. From the above combination the tap density is higher in 90%Al 5% SiC 5%B4C, the Green density is higher in 90%Al 8% SiC 2%B4C and the Sintered density and Hardness is higher in 90%Al 3% SiC 7%B4C. As the percentage of boron carbide is decreasing the hardness value is also decreasing [3].

Malek Ali (2020) In this review of stir casting technique and technical challenges for ceramic reinforcement particulate and aluminium matrix composites were studied. In this process, powder form as reinforcing phases are usually distributed into mechanical stirring. Non uniform distribution and porosity in casted CMMCs are consider as the main disadvantages for stir casting process. With increasing reinforcement weight percentage, and decreasing particles size a significant improvement in the mechanical properties were observed [4].

Pradeep.P [2017] The aluminium 7075 and the reinforced material T2B are the composites made by stir casting method. In this review the value of T2B is 4%, 6%, 8%. Here the 8% wt of T2B is cause maximum hardness 126 VHN [5].

Miss Laxmi [2017]. In aluminium 6061 SiC is used as the reinforcement material. SiC is added in 3 different composition 10%, 15%, 20%. The hardness is increased in 10% and 15%. Increase the composition of SiC increases the hardness [6].

Boopathiram C [2019] The aluminium 7075 is the reinforcement of B4C and TiC. The B4C and TiC is added with aluminium in 3 different composition like 5%, 10%, 15% in equal volume. The 15% of composite is results high micro hardness 46.10 VHN and ultimate tensile 220.41 Mpa [7].

Gopal Krishna U.B [2013] The aluminium with B4C. The boron carbide is used to increase the strength. B4C is used in 37, 44, 63, 105, 250-micron sizes separately. The 250 micron is discovered greatest for 12% wt [8].

3. Experiment

3.1. Stir Casting

The matrix material Al 7475 obtained in the form of ingots. The ingots are cleaned to remove the impurity, dust and heated in graphite crucible in induction furnace. The quantity of aluminium and the
reinforcement are shown in table 2. The melting temperature was held at 780°C and the reinforcement are added in that crucible. The constant stirring of the melt carried out with alumina stirrer to get uniform distribution of the ceramic particles. The stirring was carried out for 15 minutes and the melt was poured in to the graphite mould. The stir casting process is shown in the figure 1.

The composition is chosen from the literature and the most common percentage of base metal is different. So, we are chosen the base metal is equal in all 3 compositions.

| Specimen Code | Al 7475 | B$_4$C | SiC |
|---------------|---------|--------|-----|
| 1             | 85%     | 7.5%   | 7.5%|
| 2             | 85%     | 10%    | 5%  |
| 3             | 85%     | 5%     | 10% |

Figure 1. Stir Casting

Figure 2. Composite Material

Figure 3. Before Casting
3.2. Wire cut EDM
Wire EDM machining is an electro thermal production process where a thin single strand metal wire, along with de ionized water allows the wire to cut through metal by the use of heat from electrical sparks, while preventing rust. Virtually any conductive material can be cut using Wire EDM. This would include all metals, including steel, aluminum, brass, titanium, and alloys and super alloys of all types.

Principle of EDM: Electrical discharge machining process works on the basic principle of spark generation and metal removed by spark erosion. EDM spark erosion is same as electric spark which burn a small hole in a piece of metal through which it contacts. The spark generated by this process produces heat, which remove metal by erosion and evaporation. In this machining process both the work piece and tool must be made by conductive material. We are cutting the material for the ASTM value by using Wire cut EDM.

3.3. Micro structure Analysis
Micro structural analysis is used widely in industry to evaluate products and materials. Performance, response to environment and failure mechanisms are just some of the areas in which microstructural analysis can be utilized to assess and develop products.
4. Testing method

4.1. Vickers hardness test

Mechanical properties of stir casted material samples are determined by hardness measurement. Here we are conducting the hardness test by using micro hardness test machine.
Table 3. Vickers Hardness Test Result

| S.NO | SAMPLE ID | OBSERVED VALUE |     |     |     |
|------|-----------|----------------|-----|-----|-----|
|      |           | 1   | 2   | 3   | AVERAGE |
| 1    | 01        | 129 | 124 | 126 | 126    |
| 2    | 02        | 117 | 121 | 119 | 119    |
| 3    | 03        | 122 | 119 | 126 | 122.33 |

4.2. Tensile test

Table 4. Tensile Test Result

| Sample ID | Yield Stress(N/mm²) | Tensile Strength(N/mm²) | Percentage of Elongation |
|-----------|---------------------|-------------------------|--------------------------|
| 01        | 93.761              | 196.796                 | 2.08                     |
| 02        | 119.708             | 169.876                 | 1.80                     |
| 03        | 115.365             | 150.902                 | 2.88                     |

Figure 11. Tensile Test before Testing

Tensile test was performed to determine tensile properties of Aluminium Hybrid composite including yield stress and tensile strength of the specimens.

Figure 12. Tensile Test after Testing
**Stress Vs Strain**

1. 85%Al 7.5%SiC 7.5%B4C

![Stress Vs Strain Graph 1](image1)

2. 85%Al 5%SiC 10%B4C

![Stress Vs Strain Graph 2](image2)

3. 85%Al 10%SiC 5%B4C

![Stress Vs Strain Graph 3](image3)

4.3. Charpy test

A Charpy test apparatus consists of a weighted pendulum, which is dropped from a specified height to make contact with the specimen. The energy transferred to the material can be inferred by comparing the difference in the height of the pendulum before and after the fracture. The test specimens were prepared for 55 x 10 x 10mm. Impact values obtained by the Charpy. The Charpy test was one of the types of impact test.
Wear occurs as a natural consequence when two surfaces with a relative motion interact with each other. Wear may be defined as the progressive loss of material from contacting surfaces in relative motion. Here we are finding the wear rate in Microns.

### Table 6. Wear Test Result

| SAMPLE | TIME (SECONDS) | WEAR RATE (MICRONS) |
|--------|----------------|---------------------|
|        | 300            | 600                 | 900                 |
| 1      | 259.39         | 478.4               | 770.84              |
| 2      | 791.67         | 1063.13             | 2187.56             |
| 3      | 474.11         | 552.03              | 4835.71             |
5. Results and discussions

A - Tensile Strength Values of the samples

B - Charpy Test values of the samples

C - Vickers Hardness values of the samples

D - Elongation Values of the samples

E - Wear Test values of the samples

Figure 15. Results and Discussions
6. Conclusion
The important conclusion is inferred from the studies carried out on SiC, B$_4$C with Al7475 composite are as follows:

- The stir casting is the effective technique to produce hybrid metal matrix composites with good miscibility.
- Tensile test, Hardness test, Charpy test and Wear test have been carried out using the samples.
- With the addition of SiC increases the hardness is increases and tensile test value is decreases.
- With the addition of B$_4$C increases the tensile test value is increases and hardness test value is decreases
- The sample is containing 85% Al 7.5% SiC 7.5%B4C is exhibited high tensile strength 196.796N/mm$^2$ high hardness 126 VHN and the charpy test value is 2 joules in all samples. The less wear is occurred at the 85% Al 7.5% SiC 7.5%B4C combination.

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