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# Study of Mechanical Behaviour of LM25/$TiB_2$/SiC Metal Matrix Composite

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***Abstract: This paper is about the study of metal matrix composite reinforced with $TiB_2$ and SiC. This paper presents an overview of Al-$TiB_2$-SiC MMC on aspects relating to the mechanical characteristics such as hardness, wear, tensile and microstructure characteristics and also its applications. Aluminium alloys are widely used for commercial applications in the transportation, construction and in many other industrial areas. Nowadays main focus is given to Aluminium as matrix material because of its unique combination of corrosion resistance, low electrical resistance due to these properties they find good application in naval vessels manufacturing. Al-$TiB_2$-SiC Metal matrix composite is formed by stir casting method. With $TiB_2$ as reinforcement addition, the properties of LM25 aluminium can be greatly improved. It improves the strength of the aluminium. This combination of metal matrix composite is widely used in manufacturing cylinder heads, liners, pistons, brake rotors and in many automobile applications due to its improved properties. Comparative study for all the said composites is done with respect to yield strength, tensile strength, hardness, impact strength and compressive strength.***

## I. INTRODUCTION

Metal matrix composites are a group of materials that are incorpated with various reinforcing phases which may in the form of particulates, whiskers or continuous fibers. Over the last few years researchers and manufacturers have greater interests in Metal matrix composites due to their unique mechanical and physical properties. Metal matrix composites has higher strength, high stiffness, high thermal conductivity, low density, high strength to density ratio etc.,

Aluminium matrix composites is becoming a good base material in many applications since they possesses higher resistance to wear and improved strength. While considering the reinforcement type ceramics such as SiC, $Al_2O_3$, TiC, $TiB_2$, $B_4C$, Graphite are more commonly preferred. Many methods are available for fabricating Aluminium matrix composites with ceramic reinforcements. Two such important methods are stir casting and powder metallurgy. The simpler and easier method is liquid state processing i.e Stir casting. Stir casting is of two types namely Ex Situ and In situ methods. In insitu method the particles are synthesized within the melt and in the ex situ method the particles are added externally.

## II. MATERIAL SELECTION

Aluminium is a predominant metal with typical alloying elements namely Copper, Magnesium, Manganese, Silicon, Strontium and zinc. The two main classes of Aluminium are Casting alloys and Wrought alloys. Other main classes of Aluminium alloys are 1XXX, 2XXX, 3XXX, 4XXX, 5XXX, 6XXX, 7XXX, 8XXX series. In this present work LM25 alloy is selected and the elemental composition is given in Table 1.

Table 1: Chemical Composition of LM25

| Chemicals | Contribution % |
|---|---|
| Copper | 0.1 max. |
| Magnesium | 0.20 to 0.60 |
| Silicon | 6.5 to 7.5 |
| Iron | 0.5 max. |
| Manganese | 0.3 max. |
| Nickel | 0.1 max. |
| Zinc | 0.1 max. |
| Lead | 0.1 max. |
| Tin | 0.05 max. |
| Titanium | 0.2 max. |
| Aluminium | 90.45 |

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LM 25 Aluminium alloy belongs to 4XXX series. It is widely used in casting and as filler materials. LM25 has excellent fluidity, is good for castings that has to be leak tight, LM25 can avoid problems due to hot tearing. LM25 is mostly used in the manufacture of wheels, cylinder blocks, heads and other engine body castings. Castings of LM25 aluminium alloy are standardized in the as cast (M) condition, the precipitation treated condition, the solution treated condition, stabilized condition and in fully treated condition.
Titanium Di boride ($TiB_2$) is chosen as the ceramic reinforcement, which is a hard material, has high strength, has high wear resistance at elevated temperatures, has high elastic modulus and high compressive strength. $TiB_2$ is more commonly used in armour weapons such as ballistic armours and in aluminium smelting process.
Silicon Carbide at constant 5% level in powder form is used. It is used in various chemical, industrial and commercial applications. Here LM 25 aluminium alloy metal matrix composite reinforced with weight fractions of 0, 3, 4, 5 % of $TiB_2$ and 5% of SiC were produced using stir casting and the experimental plan for this paper is as shown in Table 2

TABLE 2: Experimental Plan

| Sample No. | Melting temperature (°C) | Reinforcement preheat Temperature (°C) | Reinforcement (%) | |
|---|---|---|---|---|
| | | | SiC | $TiB_2$ |
| 1. | 600 | 200 | - | - |
| 2. | 675 | 250 | 5 | 2 |
| 3. | 700 | 300 | 5 | 3 |
| 4 | 750 | 350 | 5 | 4 |

FABRICATION OF LM25 / $TiB_2$ / SiC:

For preparing metal matrix composite LM25 / $TiB_2$ / SiC liquid state processing of stir casting process is selected. Stir casting equipment is shown in figure 1. Initially 2000 gm of LM25 (Brick shaped) Aluminium is melted in a graphite crucible at 900◦C near to its liquid temperature in an electric furnace under argon gas atmosphere. This composite synthesis is done in 10Kg capacity furnace. LM25 is melt and for each casted sample about 474gm of LM25 (may vary in each sample) in which 3,4,5% of $TiB_2$ at constant 5% level of SiC is added and stirred mechanically using an impeller driven by an motor. $TiB_2$ and $Al_2O_3$ reinforcement powders are heated in reinforcement preheater. These powder reinforcement particles are added into the furnace by manual powder addition. For uniform mixture of the reinforcements and molten LM25 stirring is done for 15mins. Then the molten mixture is poured into pre heated die with 250mm and radius 15mm as shown in figure 2.

Figure 1: Stir Casting Equipment

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Figure 2: Preheated Die

The casted samples of 250mm height of different proportions are then machined separately for testing tensile strength, hardness, wear rates and microstructure analysis. The weight proportions of the four samples are as shown in the table 3.

Table 3: Reinforcement Proportions of 4 Samples

| Sample No. | LM25 (gm) | SiC (gm) | $TiB_2$ (gm) |
|---|---|---|---|
| 1 | 474 | - | - |
| 2 | 474 | 28.35 | 23.85 |
| 3 | 474 | 28.35 | 31.80 |
| 4 | 474 | 28.35 | 39.75 |

## III. MECHANICAL TESTS

### *A. Tensile Test*

The important properties that can be measured when a sample is tensile test are elongation at yield, Yield stress, Load at break, elongation at break, load at peak in an universal tensile testing machine as shown in figure 3. The specifications of the standard tensile test sample is shown in the figure 4(a), and the samples machined according to the tensile test standards are shown in the figure 4(b).

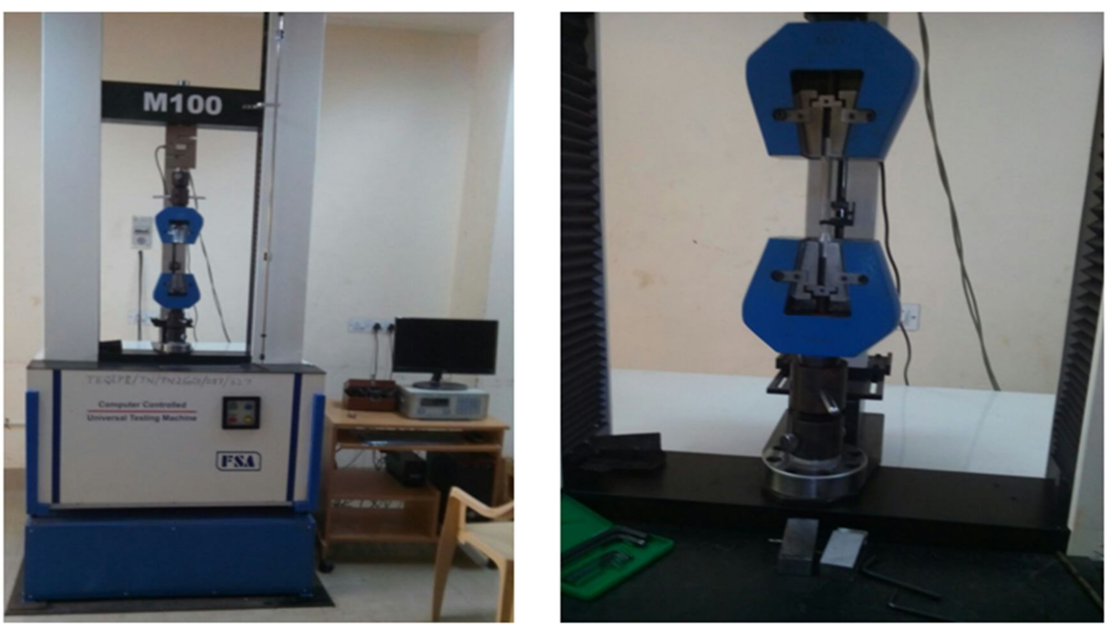
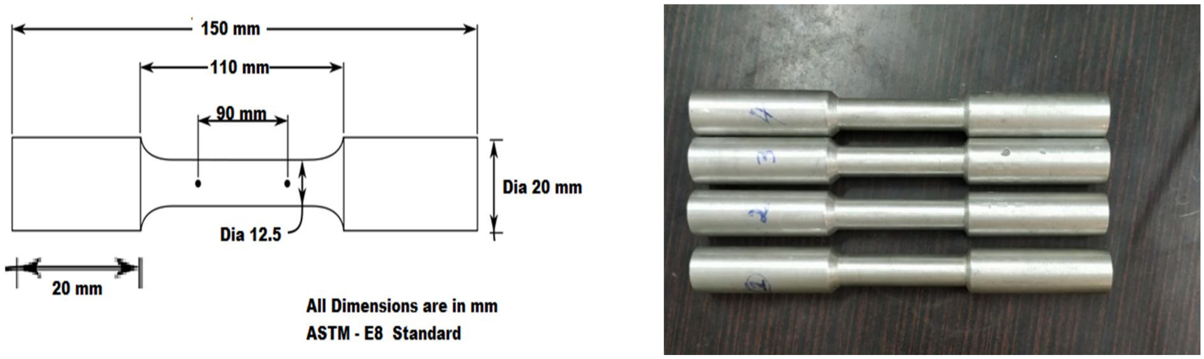



FIGURE 3: Tensile Test machine holding the sample




(a) (b)

Figure 4. (a) Specifications of the standard tensile test sample (b) Machined Samples

It has been observed that the addition of $TiB_2$ particles improved the tensile strength of the composites. Tensile test results of the samples (1,2,3,4) are as shown in table 4 below:

TABLE 4. Tensile test results

| Sample No | Samples | Tensile Strength (Mpa) |
|---|---|---|
| 01 | LM25 | 227.820 |
| 02 | LM25 + SiC(5%) + $TiB_2$(3%) | 232.452 |
| 03 | LM25 + SiC (5%) + $TiB_2$(4%) | 240.556 |
| 04 | LM25 + SiC (5%) + $TiB_2$(5%) | 270.105 |

*B. Dry Sliding Wear Test*

Wear rates of the samples machined as per ASTM G99 05 as shown in Figure 5 standards were calculated using weight loss method tested on Pin On disc apparatus. An approximately strain gauged friction detecting arm holds and loads the specimen vertically on a rotating steel disc as shown in Figure6. After running through a fixed sliding distance at specific time, the specimen was removed, cleaned with acetone, dried and weighed to determine the wear rate. Table 5 shows the wear loss rate of the samples. Figure 7 shows the graph between Wear rate Vs Time.

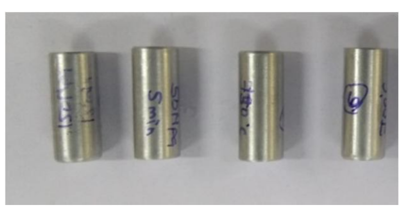


Figure 5: Wear Test Samples

Figure 6: Pin-On-Disc Apparatus

TABLE 5. Wear test results

| Sample No | Load (kg) | Speed (rpm) | Time (min) | Initial weight (gm) | Final weight (gm) | Change in weight (gm) |
|---|---|---|---|---|---|---|
| 01 | 2 | 500 | 5 | 6.115 | 6.103 | 0.014 |
| 02 | 2 | 500 | 5 | 6.847 | 6.838 | 0.009 |
| 03 | 2 | 500 | 5 | 6.956 | 6.948 | 0.008 |
| 04 | 2 | 500 | 5 | 6.232 | 6.227 | 0.003 |

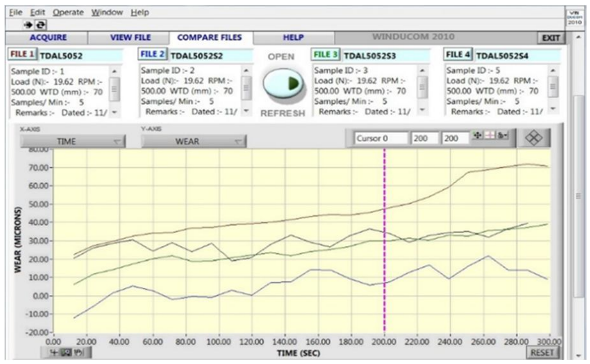


Figure 7. Wear Rate Vs Time

It can be seen that addition of reinforcements such as SiC and $TiB_2$ into LM25 matrix resulted in lesser wear rate. The hybrid composite exhibited superior wear resistance when compared with base alloy.

### *C. Microhardness Test*

Microhardness tests were carried out using Vicker's microhardness test on the polished samples of ASTM G99 05 standards using a 1/16 inch diameter diamond indentor pressed on the sample for a specific period of time as shown in Figure 8. Table 6 shows the Vicker's microhardness test values.

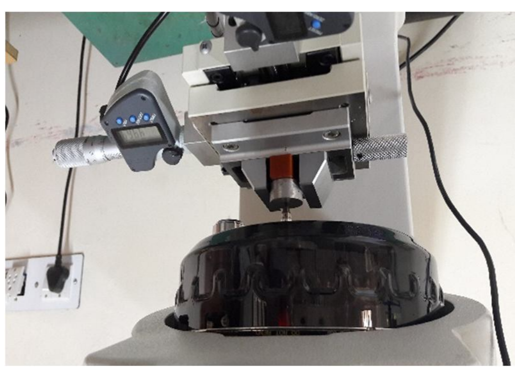


Figure 8: Vicker's MicroHardness Tester

TABLE 6. Vicker's Microhardness Test Results

| Sample No. | Trial 1 [HV] | Trial 2 [HV] | Trial 3 [HV] | Indentation Depth | Average [HV] |
|---|---|---|---|---|---|
| 1 | 122.4 | 121.8 | 132.6 | 3.7mm | 125.6 |
| 2 | 152.3 | 147.8 | 145.8 | 3.9mm | 148.6 |
| 3 | 165.4 | 163.7 | 159.8 | 4.3mm | 162.9 |
| 4 | 179.2 | 181.8 | 186.6 | 4.7mm | 182.5 |

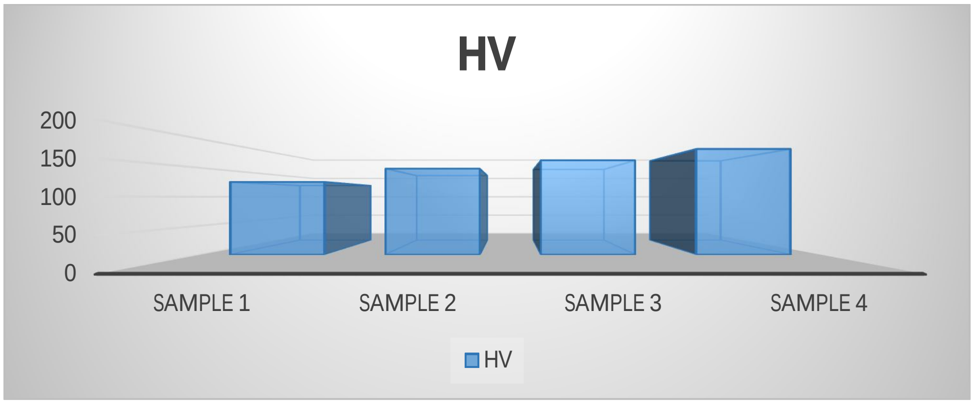



Figure 9: Hardness test Results

Hardness test results compared in Figure 9 indicate that the variation of hardness in the locations due to the uncertainty of reinforcement particles presence at the indentation location. The sample 4 with combination of 5% Silicon Carbide and 5% Titanium diboride with remaining LM25 is having higher hardness and base alloy has the lower hardness because of the absence of the reinforcement particulates.

## IV. CONCLUSION

In this current study, development and characterization of LM25 alloy based metal matrix composite reinforced with titanium diboride and Silicon Carbide is carried out. The following conclusions were drawn from the experimental results:

*A.* With increase in $TiB_2$ levels, the tensile strength of base LM25 alloy had greatly improved.
*B.* From wear analysis carried out on Pin on disc apparatus, it is evident that wear rate of the fabricated Metal matrix composite decreases with increasing levels of $TiB_2$ tested at 2kg load levels.
*C.* Micro hardness test results revealed the improvement in hardness levels due to increase in Titanium Di Boride levels.

Composite having 5% SiC and 5% $TiB_2$ and 90% LM25, combination fabricated at melting temperature 700°C and reinforcement pre-heat temperature 900°C has higher hardness and superior wear resistance compared to other combinations. This hybrid composite can be explored for use in applications where higher wear resistance is required.

## V. FUTURE SCOPE

This project is focused in increasing the hardness and wear resistance of the aluminium alloys. The following may be adopted in future to explore further possibilities to improve the above properties.

*A.* The process parameters like stirring speed, stirring time, die pre-heat temperature, can be varied and can be optimized by any optimization technique.
*B.* The percentage of reinforcements can be varied.
*C.* The same process parameters and percentage of reinforcements can be carried out using squeeze casting or vacuum casting method.

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