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Fabrication and Tensile, Compressive, Flexural Mechanical Testing of Aluminium Metal Matrix Composites Reinforcement with TiO_2

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ABSTRACT:

To enhance the mechanical properties of aluminium alloy we prepared the aluminium metal matrix composite with varying weight percentages of 0%, 3%, 6% and 9% of titanium dioxide and testing their strength limits with all combinations. This work includes the fabrication of pure aluminium with three different weight percentages of titanium dioxide preparing four samples of each weighing 1000gms by using the stir casting process. From each sample three combinations of tensile, compression, flexural, impact, hardness and wear testing specimens were prepared. In this section, this work restricted to tensile, compression and flexural testing to check the mechanical properties of prepared specimens. This work found favourable results of these Al-TiO_2 composites compared with the pure aluminium composite specimens.

Keywords: Aluminium, Titanium dioxide (TiO_2), Mechanical Properties, Tensile Strength, Compression Strength, Flexural Strength.

I. INTRODUCTION:

The increasing demands on innovative light in weight designs in transportation promote the marketplace of personalized components such as complex and also multi-phase products. An appealing product combo is actually aluminium and also titanium. While titanium alloys present high mechanical durability and good deterioration protection, aluminium alloys provide lesser density, and subsequently, greater possibility for weight discounts [1] The current job is actually an attempt to study the mechanical behaviour of Aluminium and Titanium compounds made utilizing the rouse casting method [2].

Aluminium matrix composites have formed tremendous rate of interest in assorted applications featuring aerospace and also car elements due to their light-weight, higher strength to body weight ratio, higher rigidity, affordable as well as higher perspective security [4, 6, 9, 11-14].

New developed aluminium based alloys, specifically with titanium, are obtaining even more level of popularity as a result of their excellent homes. The combination of light in weight as well as high strength makes Ti-based alloys really eye-catching for aerospace and also motor vehicle fields [5]. The planning of metal matrix composites fabricated is actually by the stir directing procedure. Stir substance does not produce a poor make-up in the metallic matrix support. Stir fabricated composites which are reduced in price through quick and easy for construction [7].

Composites deliver the adaptability in opting for the constituent materials as per the expense and also the need associated with processing the same [8] The developing demands on stylish lightweight styles in transit advertise the marketplace of individualized materials, like composites as well as material products. For the last one attractive product combo constitutes aluminium as well as titanium. While aluminium alloys supply a higher specific bending over rigidity, titanium alloys show higher flexible durability combined with a superior rust protection [10].

Aluminium alloys premium physical and mechanical residential properties like lower density, reduced weight, and also low coefficient of thermal expansion, superb corrosion resistance, superior tensile stamina, high hardness, significant firmness as well as use protection contrasted to the other alloys as well as metals [15].

II. FABRICATION:

Fig.1 shows a stir casting setup, casting the aluminium alloy in four different sessions and each session requires 1000 grams of pure Aluminium powder with variable weight percentages of titanium dioxide. Fig.2. shows the stir casting process, we did the casting process in four sessions, in the first session 1000 grams of pure aluminium powder fed into the clay-graphite crucible of stir furnace and heating the metal matrix composite material, around 650°C-700°C aluminium reached to melting state, just after reaching 750ºC applying the stirring action by the motor-operated stirrer at a speed of 200rpm up to the period of 5 to 10 minutes then pour the molten metal in required shapes of dies for testing of mechanical properties.

In second session 970grams of pure aluminium powder heated in the crucible of stir casting machine. Continuing the process until the molten metal reaches to 850ºC and then adding the 3% (30 grams) weight of titanium dioxide, stirring at a speed of 300 rpm up to period of 10 minutes. At 1000ºC pouring molten metal of Al-TiO_2 in to the cavities of dies for the preparation of specimens of tensile, compression and flexural tastings. The same process is to be continued in third session 940 grams of pure aluminium mixed with 6% (60 grams) weight of titanium dioxide and forth session 910 grams of pure aluminium mixed with 9% (90 grams) weight of titanium dioxide and completing the process after pouring the molten metal in to the required shapes of dies.

Fig.1. Stir casting setup

(a) (b) (c)

Fig. 2. Stir casting process (a) Molten metal of pure aluminum, (b) Mixing Titanium dioxide, (c) Stirring the molten metal of Al-TiO_2

III. SPECIMEN PREPARATION:

Fig. 3 shows molten metal pouring in to the die cavity, after the solidification of Al-O_2 composites, quench it and remove it from the die cavity, figure 4 shows the raw specimens after removing from die cavity.

Fig.3. Pouring molten Al-TiO_2 in to the die cavity

Fig.4. Raw specimens

For preparing the Al-TiO_2 specimens based on ASTM standards, we machined the specimens using a lathe machine as shown in figure 5. Figure 6 shows the machined Al-TiO_2 specimens.

Figure 8 shows the standard ASTM B 557 specimen with dimensions for the preparation of the metal composite tensile specimen.

Fig.6. Machining of raw specimens

Fig.7. Machined Specimens

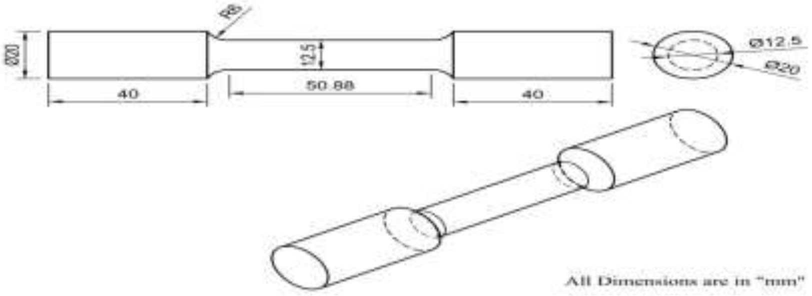


Fig.8. ASTM B 557 standard tensile specimen

Figure 9 shows the standard compression specimen with dimensions and figure 10 shows the standard flexural specimen along with dimensions.

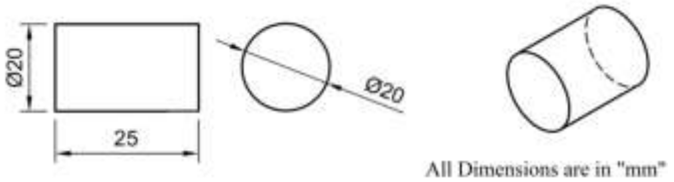


Fig.9. Standard size compression specimen

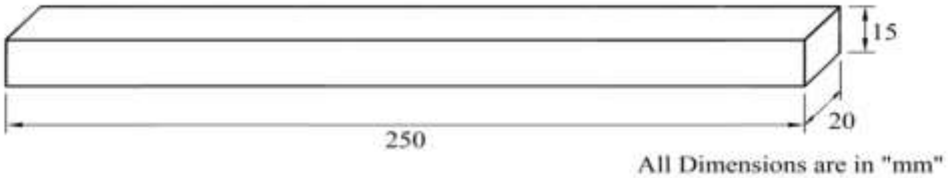


Fig.10. Standard size flexural specimen

Machining of tensile test specimen based on ASTM B 577 standard by using the lathe machine as shown in figure 11.

Fig.11. Cutting in to the standard ASTM B 557 specimen

To conduct the tensile and compression tests, we prepared 6 specimens for MCS, 6 specimens for Al-TiO_2 0% of TiO_2, 6 specimens for Al-3% of TiO_2**,** 6 specimens for Al-6% of TiO_2**,** and 6 specimens for Al-9% of TiO_2**.** To conduct the flexural test, we prepared 3 specimens for Al-0% of TiO_2, 3 specimens for Al-3% of TiO_2**,** 3 specimens for Al-6% of TiO_2**,** and 3 specimens for Al-9% of TiO_2**.**

Total 42 specimens were prepared for these tests, figure 11 shows tensile and compressive test specimens of MCS and 0, 3, 6 and 9 weight percentages of Al-TiO_2 metal composite materials.

Fig.12. ASTM B 557 tensile and standard compression specimens of aluminium with varying 0%, 3%, 6% and 9% of titanium dioxide

IV. TENSILE TEST:

Universal testing machine used for tensile testing and the process of testing is as follows:

- Fix the specimen firmly in between the table and upper movable clamp.
- Apply the load and gradually increasing it by using the speed control, at that time pulling force applied by the upper movable clamp and it moves in an upward direction.
- At a certain load, the specimen lost retaining its withstanding limit against the applied load and tends to fail.
- At that time Ultimate load, ultimate strength, elongation, yield load and yield stress were written onto the memory of the computer system connected to the machine as shown in figure 13 and the failure of tensile specimens as shown in figure 14.

Fig.13. Universal Testing Machine

Fig.14. Tensile tested specimens after failure

V.COMPRESSION TEST:

Compression tests performed by using the universal testing machine, the process of testing are as follows:

- Fix the specimen firmly in between the table and upper movable clamp.
- Apply the load and gradually increasing it by using the speed control, at that time pushing load applied by the upper movable clamp and it moves in down ward direction.
- At a certain load, the specimen lost retaining its withstanding limit against the applied load and tends to fail.
- At that time Ultimate load and strength were written onto the memory of the computer system connected to the machine. Figure 15 shows the compression tested specimens after failure.

Fig.15. Compression tested specimens after failure

VI. FLEXURAL TEST:

A universal testing machine has used to conduct the flexural tests and the process of testing is as follows:

- Locate the specimen on the two-point holder of the table and movable clamp faces on its mid points for application of three-point load.
- Apply the load and gradually increasing it by using the speed control, the movable clamp applying load on the midpoint of the specimen.
- At a certain load, the specimen lost retaining its withstanding limit against the applied load and tends to fail.
- At that time Ultimate load, strength, yield load and yield stress were written onto the memory of the computer system connected to the machine. Figure 16 shows the compression tested specimens after failure.

After conducting the tests we tabulated the results and analysing mechanical properties of 3, 6, 9 weight percentages of Al-TiO_2 with respect to pure aluminium.

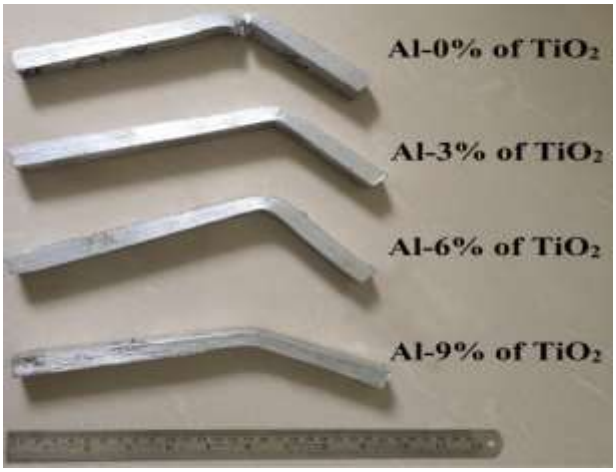


Fig.16. Flexural tested specimens after failure

VII. RESULTS AND DISCUSSIONS:

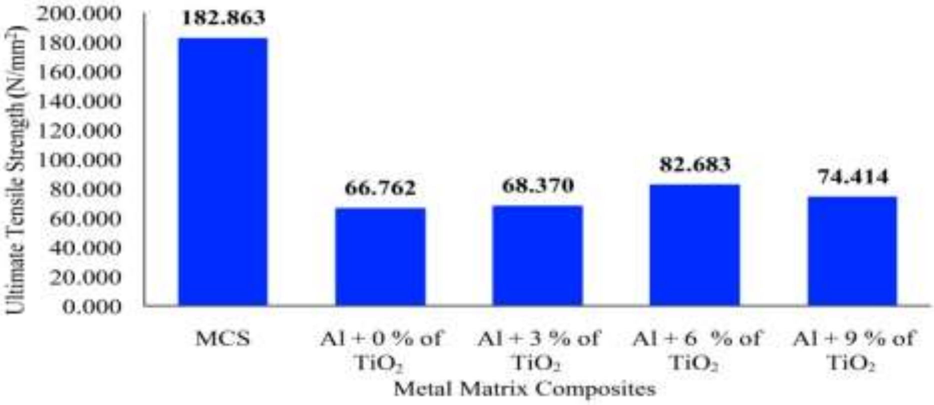
This work consider the pure aluminium results are the base readings and compared with weight percentages of Al-TiO_2 results to know whether there is any use of using titanium dioxide as reinforcement and we found favourable results. We just refer to the results of medium carbon steel because it is a conventionally used material for connecting rods of IC engines, due to the good mechanical properties of aluminium, nowadays aluminium extensively used in automobiles, for example, aluminium connecting rods. In our study, we examined how many mechanical strengths will be improved by adding varying 3, 6, 9, weight percentages of TiO_2 in pure aluminium, so we can able to replace the aluminium connecting rod with Al-TiO_2 connecting rod.

For each material combination, we conducted three tests and had taken the average value as a standard value. The ultimate tensile strength of medium carbon steel and 0, 3, 6, 9 weight percentages of Al-TiO_2 are shown in Table 1 and Graph 1.

Table1. Ultimate Tensile Strength

Metal Matrix Composite Specification	Average of Ultimate Load (KN)	Average of Ultimate Tensile Strength (N/mm^2)
MCS	22.027	182.863
Al + 0 % of TiO_2	8.040	66.762
Al + 3 % of TiO_2	8.227	68.370
Al + 6 % of TiO_2	9.995	82.683
Al + 9 % of TiO_2	9.420	74.414

The average ultimate tensile strength of pure aluminium is 66.76 N/mm^2 and we found 6 weight percentages of Al-TiO_2 having good results. The ultimate tensile strength of 6 weight percentage of Al-TiO_2 is 82.68 N/mm^2. The ultimate tensile strength limits were improved to 24%. The tensile yield strength of medium carbon steel and 0, 3, 6, 9 weight percentages of Al-TiO2 are shown in Table 2 and Graph 2.

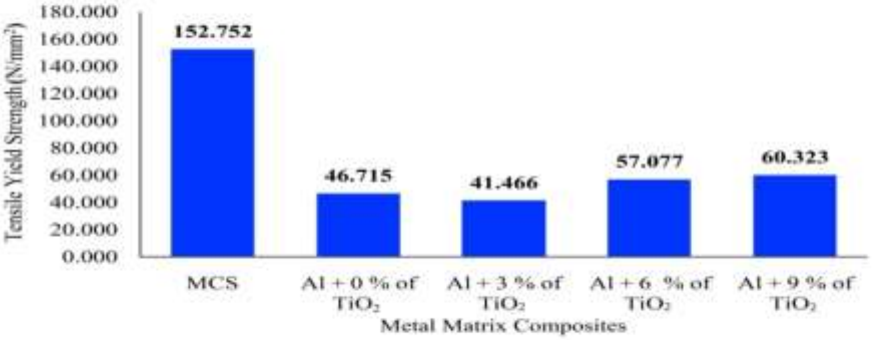


Graph1. Ultimate Tensile Strength

The average tensile yield strength of pure aluminium is 46.71 N/mm^2 and we observed 9 weight percentages of Al-TiO_2 having better results. The ultimate tensile strength of 6 weight percentage of Al-TiO_2 is 57.07 N/mm^2. The ultimate tensile strength of 9 weight percentage of Al-TiO_2 is 60.323 N/mm^2. The tensile yield strength limits were improved to 29%.

Table 2. Tensile Yield Strength

Metal Matrix Composite Specification	Average of Yield Load (KN)	Average of Yield Strength (N/mm^2)
MCS	18.533	152.752
Al + 0 % of TiO_2	5.620	46.715
Al + 3 % of TiO_2	4.990	41.466
Al + 6 % of TiO_2	6.902	57.077
Al + 9 % of TiO_2	7.837	60.323

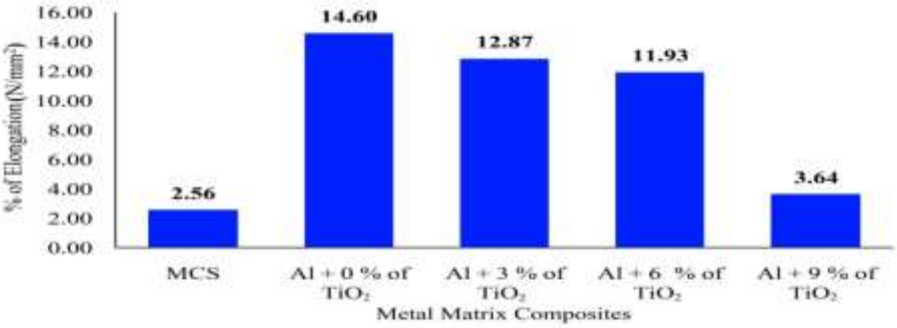


Graph 2. Tensile Yield Strength

The Elongation due to tensile load of medium carbon steel and 0, 3, 6, 9 weight percentages of Al-TiO_2 are shown in Table 3 and Graph 3.

Table 3. Elongation due to tensile load

Metal Matrix Composite Specification	Average % of Elongation
MCS	2.56
Al + 0 % of TiO_2	14.600
Al + 3 % of TiO_2	12.867
Al + 6 % of TiO_2	11.933
Al + 9 % of TiO_2	3.64



Graph 3. Elongation due to tensile load

The average elongation of pure aluminium is 14.6%, 3% of Al-TiO_2 is 12.87%, 6% of Al-TiO_2 is 11.93 and 95 of Al-TiO_2 is 3.41%. The elongation of pure aluminium is 1.73% slightly better than the 3 weight percentages of Al-TiO_2. All metal matrix composites better elongation properties compared to standard medium carbon steel.

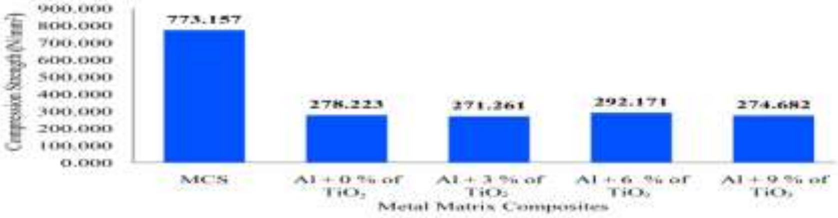
The compression strength of medium carbon steel and 0, 3, 6, 9 weight percentages of Al-TiO_2 are shown in Table 4 and Graph 4.

Table 4. Compression Strength

Metal Matrix Composite Specification	Average of Ultimate Load (KN)	Average of Compression Strength (N/mm²)
MCS	238.590	773.157
Al + 0 % of TiO_2	85.653	278.223
Al + 3 % of TiO_2	85.49	271.26
Al + 6 % of TiO_2	91.88	292.17
Al + 9 % of TiO_2	89.47	274.68

The average compression strength of pure aluminium is 278.22 N/mm^2 and we found 6 weight percentages of Al-TiO_2 having slightly good results. The compression strength of 6 weight percentage of Al-TiO_2 is 292.17 N/mm^2. The compression strength limits were improved to 5%.

The flexural strength of medium carbon steel and 0, 3, 6, 9 weight percentages of Al-TiO_2 are shown in Table 5 and Graph 5.



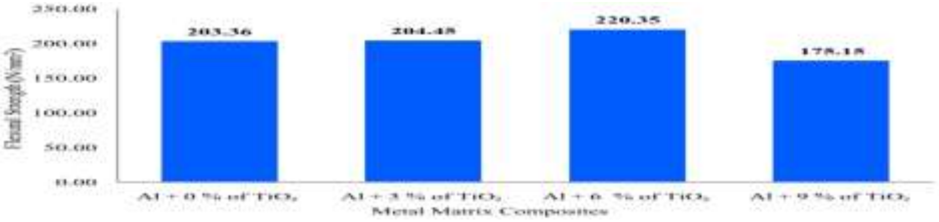
Graph 4. Compression Strength

Table 5. Flexural Strength

Metal Matrix Composite Specification	Average of Ultimate Load (KN)	Average of Flexural Strength (N/mm²)
Al + 0 % of TiO_2	5.08	203.36
Al + 3 % of TiO_2	5.70	204.45
Al + 6 % of TiO_2	5.98	220.35
Al + 9 % of TiO_2	4.85	175.15

The average flexural strength of pure aluminium is 203.36 N/mm^2 and we found 6 weight percentages of Al-TiO_2 having considerable better results. The flexural strength of 6 weight percentage of Al-TiO_2 is 220.35 N/mm^2. The flexural strength limits were improved to 8.35%.

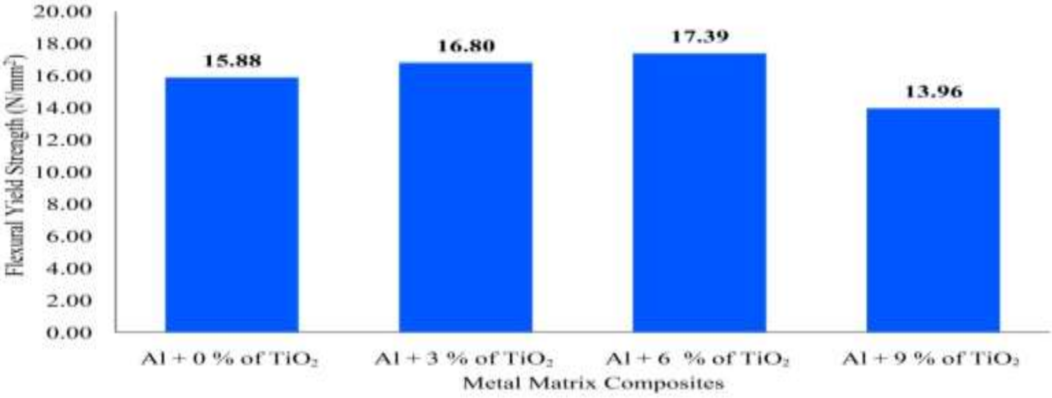
The flexural yield strength of medium carbon steel and 0, 3, 6, 9 weight percentages of Al-TiO_2 are shown in Table 6 and Graph 6.



Graph 5. Flexural Strength

Table 6. Flexural Yield Strength

Metal Matrix Composite Specification	Average of Yield Load (KN)	Average of Yield Strength (N/mm^2)
Al + 0 % of TiO_2	3.94	15.88
Al + 3 % of TiO_2	4.38	16.80
Al + 6 % of TiO_2	4.50	17.39
Al + 9 % of TiO_2	3.65	13.96



Graph 6. Flexural Yield Strength

The average flexural yield strength of pure aluminium is 15.88 N/mm^2 and we found 6 weight percentages of Al-TiO_2 having considerable good results. The compression strength of 6 weight percentage of Al-TiO_2 is 17.39 N/mm^2. The flexural yield strength limits were improved to 9.5%.

VIII.CONCLUSION:

The mechanical properties of 6 weight percentage of Al-TiO_2 showed overall better results against pure aluminium. Its strength limits against pure aluminium as follows:

- The average ultimate tensile strength was 82.683 N/mm^2 and 24% strength limits were increased.
- The average compression strength was 292.17 N/mm^2 and 5% strength limits were increased.
- The average flexural strength was 220.35 N/mm^2 and 8.35% strength limits were increased.
- The average flexural yield strength was 17.39 N/mm^2 and 8.35% strength limits were increased.

The average tensile yield strength of 9% of Titanium Dioxide 60.32 N/mm2 and 29% strength limits were increased compared to pure aluminium.

The tensile elongation of pure aluminium showed a slightly good percentage with respect to 3% of Al-TiO_2 and it has 1.73% more elongation as compared to 3% of Al-TiO_2.

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