Retraction

Retraction: Investigation on mechanical properties of aluminium alloy A356 by reinforcing with TiB₂ & WC composites (*IOP Conf. Ser.: Mater. Sci. Eng. 1145 012110*)

Published 23 February 2022

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IOP Publishing regrets that our usual quality checks did not identify these issues before publication, and have since put additional measures in place to try to prevent these issues from reoccurring. IOP Publishing wishes to credit anonymous whistleblowers and the Problematic Paper Screener [1] for bringing some of the above issues to our attention, prompting us to investigate further.

[1] Cabanac G, Labbé C and Magazinov A 2021 arXiv:2107.06751v1

Retraction published: 23 February 2022
Investigation on mechanical properties of aluminium alloy A356 by reinforcing with TiB₂ & WC composites

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Abstract. In this project, Aluminium metal matrix hybrid composites are processed through stir casting methodology. A356 is reinforced with ceramic particle-like Titanium diboride (TiB₂) and Tungsten carbide (WC) in varying weight percentages of 92.5% A356 and TiB₂ 5% WC 2.5% of Sample 1, A356 90% TiB₂ 5% WC 5% of Sample 2, A356 100% of Sample 3 through stir casting technique. Under the Vickers hardness test, the Sample consisting of 90% A356+ 5% TiB₂+ 5% WC exhibited superior results. Under the Tensile test, the Sample of 90% A356+ 5% TiB₂+ 5% WC exhibited higher tensile strength when compared with the remaining two Samples. It is because the ceramic reinforcement particulates are harder than the A356 matrix material. Then the fractured Samples were examined under SEM and fracture mechanisms were studied.

Keywords: A356, Titanium diboride, Tungsten carbide, Aluminium metal matrix, composites, Tensile test, Hardness test, Impact test, SEM

1. Introduction
Aluminium metal matrix is extensively used in applications like airplane parts, flywheel casing, automobile brakes, engine parts at elevated temperature owing to their mechanical properties such as high strength, good resistance to corrosion, thermal conductivity, etc. From several researchers work it is evident that, A356 is an adaptable material which can be used owing to its greater elongation, high strength, high ductility. At higher temperature the tensile properties of A356 are predisposed by the heat treatment process of the castings and at high-temperature. A356 also has good corrosion resistance. Aluminium matrix composites are made by combining aluminium and ceramic and they are the new generation materials which can be used in various engineering applications. To improve the mechanical properties, reinforcement materials like SiC, graphite, Al₂O₃, TiO₂ are used in numerous studies. Titanium diboride (TiB₂) was used in the recent trend for high strength, high corrosion resistance and high melting point [1,2]. Researchers in [3] examined the tensile properties of tungsten at elevated temperature and the hardness of the tungsten is compared with hot-rolled (HR) and hot forged (HF), HR piece has a slightly greater hardness than HF. Researchers in [4] explored the magnesium matrix composites samples reinforced with SiC micro particles fabricated through stir casting and identify properties that are increasing by ultrasonic treatment processing. Researchers in [5] prepare aluminium (LM-25) metal matrix and reinforcing SiC particles to enhance the properties by precipitation hardening heat-treatment process. Researchers in [6] It has been shown that by reinforcing the micro-SiC particles
with cast aluminium and with magnesium matrix, the elastic modulus, hardness and tensile strength increase noticeably with the increase in reinforcing particles. Researchers in [7] reinforce B₄C with 6061 Al metal matrix to lead enhancements 6061 Al alloy mechanical properties. Researchers in [8] inspected the mechanical properties of 2024 Al- B₄C. Addition of B₄C with different wt% increases tensile strength and hardness. Researchers in [9] studies the effect of B₄C reinforcement on an aluminium metal matrix that improves the mechanical properties by different wt%. Researchers in [10] studies clear the boron carbide particles improves well properties. Researchers in [11] investigated the SiCp and graphite that contributed to improving the hardness and tensile strength while reinforced with A356 at different wt%. Researchers in [12] studied mechanical properties of A356 reinforced with Al₂O₃ and ZrO₂, this increasing the reinforcement content, density decrease while tensile and compressive strength increases and also hardness increases.

From the above literature review, it proves that the mechanical property like tensile strength, hardness, the impact strength of the materials was enhanced by reinforcing the hard ceramic particles. But a smaller amount of investigation was observed by reinforcing TiB₂ & WC particles. So, we attempt in this paper to reinforcing TiB₂ and WC with aluminium A356 alloy by changing the weight percentage of TiB₂ and WC (7.5%, 10%) the composites are fabricated by stir casting and analyse the mechanical properties, SEM image for the automobile application like brakes, casings etc.

2. Materials and Experimental Procedure

2.1 Materials used

In the present study, A356 is selected as matrix metal and is shown in figure 1(a). The chemical compositions of an alloy A356 are tabulated in Table 1. There are many strengthening materials are available. From that materials in this study Titanium diboride (TiB₂) were used as reinforcement material that has high corrosion resistance, high melting point (>2900°C), and it is shown in figure 1(b). The chemical compositions of TiB₂ are shown in Table 2 and also Tungsten carbide is a reinforcement particle along with TiB₂ is shown in figure 1(c). According to the weight percentage selection the samples are fabricated.

| A356 alloy Chemical composition |
|--------------------------------|
| Si  | Fe  | Cu  | Mn  | Mg  | Ni  | Zn  | Ti  | Al |
|-----|-----|-----|-----|-----|-----|-----|-----|----|
| 6.58| 0.16| 0.06| 0.06| 0.57| 0.01| 0.01| 0.14| Max|
|     |     |     |     |     |     |     |     | 92.41|

| Chemical composition of TiB₂ |
|-----------------------------|
| TITANIUM  | BORIDE |
| 67-69    | 29-32  |
2.2 Sample compositions

The samples were fabricated using stir casting by varying the composition. Three Samples were created by changing the weight percentages and tabulated in Table 3. Sample 1 of 100% A356 alloy, Sample 2 of compositions 92.5% A356, 5% TiB$_2$ and 2.5% WC, Sample 3 of composition 90% A356, 5% TiB$_2$, 5% WC. The fabricated Samples were shown in Figure 2.

| S. No | Name of sample | Composition                  |
|-------|----------------|------------------------------|
| 1     | Sample 1       | 100% A356                   |
| 2     | Sample 2       | 92.5% A356, 5% TiB$_2$, 2.5% WC |
| 3     | Sample 3       | 90% A356, 5% TiB$_2$, 5% WC  |

2.3 Processing

Stir casting is one of the oldest manufacturing processes, in which both matrix and reinforcement phase is made to pour in a furnace and heated is shown in Figure 3(a) and 3(b). A356 alloy with TiB$_2$ (wt of
5% and WC (wt of 2.5%) and A356 alloy with TiB$_2$ (wt of 5%) and WC (wt of 5%) Reinforced Composite has existed with determined properties. The production of A356 composite by Liquid phase fabrication (stir casting) is the most convenient method. The A356 alloy was weighted for making sample for required weight percentage (92.5,90). To get good mechanical properties reinforcement particles TiB$_2$ and WC are reinforced into A356 alloy with different weight percentages. A356 alloy was liquefied in a stir casting furnace at 850°C. The mixed TiB$_2$ and WC particles was preheated at 450°C in preheating furnace. The melted A356 was stirred with preheated TiB$_2$ & WC at a speed of 500 rpm in stir casting furnace at 930°C to make a good bonding between base metal. Finally, stirred mixture of metal was poured into cylindrical metal mould to get solidified. Two samples are fabricated with wt% (7.5 wt%, 10 wt%) and one sample pure A356 alloy.

![Stir casting furnace setup](image1)
![Preheating furnace](image2)

**Figure 3.** (a) Stir casting furnace set up (b) Preheating furnace

### 3. Results and Discussions

#### 3.1 Microhardness Test

According to ASTM standards the microhardness test was observed to analyse the grain reinforcement and morphological behaviour of the samples. Vickers microhardness machine was used for testing the microhardness of samples at different places by Vickers pyramid number (HV). At 0.5 Kg average values of microhardness were plotted. The test results are shown in table 4. Since sample 3 (90% A356, 5% TiB$_2$, 5% WC) has a greater of reinforced material compared to other samples, it showed greater hardness value. HV of sample 3 is 75. Sample 1 experienced 68 HV, Sample 2 experienced 72 HV. Therefore, from this test it is found that while increasing wt% of reinforcement of samples increasing microhardness. Figure 4 and Table 4 shows the Microhardness test values and Variation of Vickers hardness number for 0.5kg of the Samples.

| S. No | Material  | HV @ 0.5 Kg (Average) |
|-------|-----------|-----------------------|
| 1     | Sample 1  | 68                    |
| 2     | Sample 2  | 72                    |
| 3     | Sample 3  | 75                    |
3.2 Tensile Strength Test

According to ASTM E8-16a standards the fabricated samples was machined. Figure 5a shows the fractured tensile Sample. The tensile strength values are noted in table 5 and figure 5b. Due to the addition of reinforcement particles the strength of the sample 2 and 3 increases progressively. The results shows that the strength improves in Sample 3 (90% A356, 5% TiB₂, 5% WC) while compared to parent alloy A356 and another sample. Figure 5c and Table 5 shows the percentage elongation of the Samples. Sample 2 & Sample 3 are best while comparing Sample 1 because they have lower elongation percentages.

Table 5. Tensile strength values of Samples

| S. No | Material | Tensile strength MPa | Yield stress MPa | Elongation in % |
|-------|----------|-----------------------|------------------|-----------------|
| 1     | Sample 1 | 142                   | 120              | 4               |
| 2     | Sample 2 | 148                   | 127              | 3.5             |
| 3     | Sample 3 | 152                   | 132              | 3.56            |
3.3 Impact Strength Test

According to ASTM E8-96 standards the Samples are machined with the dimensions of 10 × 10× 55 mm with 2×45° of V-notch. From results, the sample 1 (100% A356) shows increase in impact strength than other reinforced samples. The drop in the energy of reinforced sample 2 (92.5% A356, 5% TiB\(_2\), 2.5% WC) and sample 3 (90% A356, 5% TiB\(_2\), 5% WC) are due to the accumulation of particles are shown in table 6 and figure 6.

**Table 6.** Values of Impact energy of Samples

| Material   | Impact strength (J) |
|------------|---------------------|
| Sample 1   | 5                   |
| Sample 2   | 4                   |
| Sample 3   | 3.5                 |

3.4 Sem Test

Scanning Electron Microscope (SEM) is a microscope that can create an image of a surface over a focused electron beam to analyse the surfaces of fractured, worn. It produces high-resolution images and measures unit in Micrometre (µm) for small objects.
3.4.1 SEM TEST on tensile test

![Figure 7](image1.png)

**Figure 7.** Sem image on Fractured surface (a) Pure A356 100% (b) 92.5% A356, 5% TiB$_2$, 2.5% WC (c) 90% A356, 5% TiB$_2$, 5% WC

Figure 7(a) displays the SEM image of Pure A356. The figure shows the accumulation of dimples and voids on fractured surface aluminium combination confirming bendable crack. Figure 7(b) shows the SEM image of 92.5% A356, 5% TiB$_2$, 2.5% WC composites tensile tested fractured surface. and Figure 7(c) shows the SEM image of 90% A356, 5% TiB$_2$, 5% WC. Due to the less formation of agglomeration in few places improves the tensile strength comparatively from Figure 7 (b) to Figure 7(c). Therefore, the Sample 3 gets high tensile strength in testing.

3.4.2 SEM TEST on impact test

![Figure 8](image2.png)

**Figure 8.** Sem image on Fractured surface (a) Pure A356 100% (b) 92.5% A356, 5% TiB2, 2.5% WC (c) 90% A356, 5% TiB2, 5% WC

Figure 8 (a)(b)(c) displays the SEM image of A356/TiB2 & WC. The figure shows that the fractured surface has perfect bonding between A356 alloy with TiB$_2$ and WC particles. There was a decrease in the impact energy of the materials due to some accumulation in some places.
4. Conclusion

In this study work, A356 reinforced by TiB$_2$ and WC with a weight percentage of Sample 1 (100% A356), Sample 2 (5% TiB$_2$, 2.5% WC) and Sample 3 (5% TiB$_2$, 5% WC) were fabricated through the stir casting method. The results of Microhardness, Impact strength, Tensile strength for Three samples were observed. From this experimental result we conclude that:

- Under the Vickers hardness test, there are progressive increases in hardness values (Vickers pyramid number HV) for the composites when compared to parent A356 alloy.
- From the tensile strength test, it is clear that the 90% A356, 5% TiB$_2$, 5% WC composites samples offer good tensile strength than the remaining samples.
- The impact strength of the pure 100% A356 is greater than composites samples because reinforcement particles were brittle, it shows less toughness.
- Finally, we knew that Sample 3 (90% A356, 5% TiB$_2$, 5% WC) was good in results than parent pure 100% A356. So, it was a good metal matrix composites than other samples.
- After the test accomplished, an SEM image was taken for the fractured Samples (tensile, impact). SEM image shows differences and bonding in fractured surfaces due to reinforcement particles in A356.

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