TO ANALYSE THE MECHANICAL BEHAVIOUR OF ALUMINIUM BASED METAL MATRIX COMPOSITES REINFORCED WITH SIC & TIO$_2$

Aisha Karim[*1] **& Dr. Jonathan Reed**[2]
[*1&2]**Department of Digital and Communication, Imperial Institute of Technology, London, United Kingdom**

ABSTRACT

An analysis has been made on the mechanical behavior of aluminum metal matrix composite reinforced with 10 wt% SiC and 2 wt % of TiO$_2$. Stir casting route has been adopted to fabricate these composites. Different mechanical tests have been carried out on these MMC's and base alloy, to study the mechanical properties. Furthermore, the effects of reinforced particles sizes on the microstructure of the composites were observed by using SEM. These MMCs are to be used for automobile, aircraft and space industries. Hence a solution is needed to solve the issues like selection of material on the basis their mechanical properties.

KEYWORDS: Stir Casting, Aluminum Metal Matrix Composites, SEM.

1. INTRODUCTION

Metal composite materials have found application in many areas of daily life for quite some time. These are combination of metal matrix and stiff and hard reinforcing phase. These materials are producedfrom the conventional production and processing of metals.Materials like cast iron with graphite or steel with high carbide content, as well as tungsten carbides, consisting of carbides and metallic binders i.e., cobalt, also belong to this group of composite materials. For many researchers the term metal matrix composites (MMCs) is often equated with the term light metal matrix composites (LMCs). Substantial progress in the development of light metal matrix composites has been achieved in recent decades, so that they could be introduced into the most important applications. In engineering, especially in the automotive industry, LMCs have been used commercially in fiber reinforced pistons and aluminum crank cases with strengthened cylinder surfaces as well as particle-strengthened brake disks The study of composite materials has become a very important subject of research in the materials engineering area. These materials are heterogeneous man-made mixtures of two or more homogeneous phases that have been bonded together. The first phase is called the matrix and is usually a light metal (e.g. aluminium, steel or titanium) while the other is the reinforcement and is commonly either particles or fibres, the former being the more widely used. In general, the second-phase substance has much higher stiffness than the matrix. It is expected that by combining two types of materials one will obtain the best properties of both substances. This material, the so-called composite material, has then considerably better mechanical properties and higher performance than any single material from which it is formed.

2. MATERIAL PREPARATION METHODOLOGY

The matrix material used in this study is AA1100 (Figure 1). Table 1 shows the chemical composition of AA1100. The reinforcement material added was Sic and TiO$_2$ (Figure 2 and 3). The addition of SiC and TiO$_2$ particles improves high fracture toughness, wear resistance, hardness, strength, and stiffness. The composite was prepared using stir casting process. AA1100 is kept in graphite crucible inside the muffle furnace. The alloy was melted to the desired heating temperature of 645°C. The preheated reinforcement particles with an amount of 10 wt% of SiC and 2 wt% of TiO$_2$ particles and size of 20 µm to 40 µm were introduced into the vortex of the molten alloy after effective heating.

Figure 1 Aluminum Alloy 1100

Figure 2 Silicon Carbide Powder

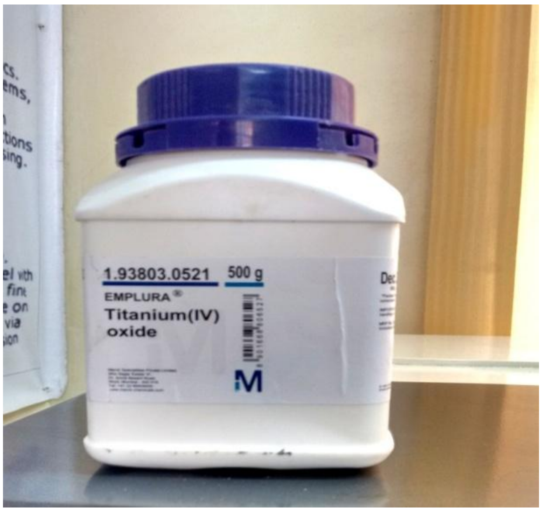


Figure 3 Titanium Dioxide Powder

Table 1 Chemical composition of AA 1100

Alloy	Si+ Fe	Cu	Mn	Be	Zn	Al
1100	0.80 Si+Fe	0.05	0.09	0.00070	0.05	Remainder

Then the stirring was carried out for about 10 minutes at stirring rate of 300 RPM. At this stage, the SiC particles was added manually to the vortex. In the final mixing processes the furnace temperature was controlled within 700 ± 10oC. After stirring process the mixture was pour in the other mould to get desired shape of specimen. Same process was used for specimens with Titanium dioxide particles. Compositions of samples are shown in Table 2 and 3

Table 2 Chemical composition of AA1100/Sic MMC

AA1100/ TiO_2 MMC	**Weight of AA1100**	**Weight of TiO_2**	**Melting Temp. (AA1050) (60mins)**	**Stirrer Speed (RPM)**
10wt% SiC	900 grams	100 grams	646-657 ^{0}C	300

Table 3 Chemical composition of AA1100/ TiO_2 MMC

AA1100/Sic MMC	**Weight of AA1100**	**Weight of Sic**	**Melting Temp. (AA1100) (60mins)**	**Stirrer Speed (RPM)**
2wt% TiO_2	1000 grams	20 grams	646-657 ^{0}C	300

3. EXPERIMENTAL WORK

Tensile tests were used to assess the mechanical behavior of the composites and matrix alloy. The composite and matrix alloy rods were machined to tensile specimens with a diameter of 6mm and gauge length of 30 mm

Table 3.1: Tensile Strength Results

Serial No	**Composite**	**Yield Strength N/mm2**	**UTS N/mm2**	**Elongation (%)**
1	Al 1100	104	112	9
2	10% Sic	148	305	1.98
3	2% TiO_2	169	326	1.60

During tensile testing of a material sample, the stress–strain curve is a graphical representation of the relationship between stress, derived from measuring the load applied on the sample, and strain, derived from measuring the deformation of the sample, i.e. elongation, compression, or distortion. The slope of stress-strain curve at any point is called the tangent modulus; the slope of the elastic (linear) portion of the curve is a property used to characterize materials and is known as the Young's modulus. The area under the elastic portion of the curve is known as the modulus of resilience.

Yield Strength Comparison

As shown in Figure number 5.3 results predict that as the reinforcement wt.% Yield Strength is increases. This happens may be due to dispersion of Sic & TiO_2 which create hinderance to dislocation motion. To move this defect (plastically deforming or yielding the material), a larger stress must be applied. This may results increase in tensile strength of reinforced LM6 alloy.

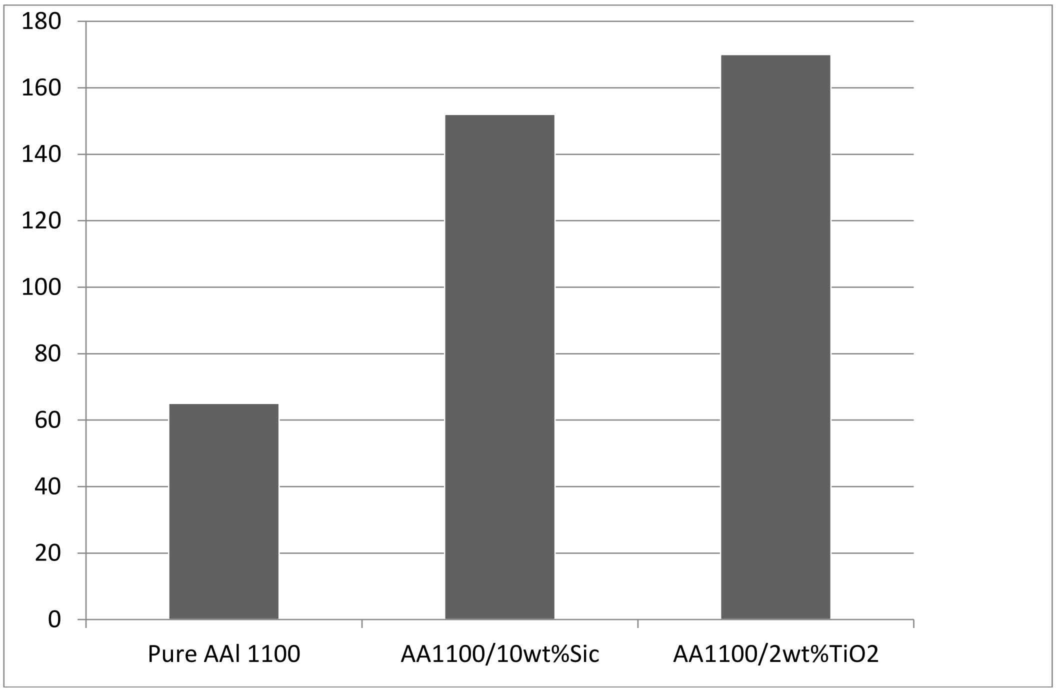


Figure 3.3 Comparison the Yield Strength with AA1100/10wt% Sic & AA1100/2wt% TiO_2.

mate Tensile Strength Result

As shown in Chart Figure number 3.4 results predict that as the reinforcement wt.% UTS is also increases. This happens may be due to dispersion of Sic & TiO_2 particulates which create hinderance to dislocation motion. This may results increase in tensile strength of Al1100 alloy.

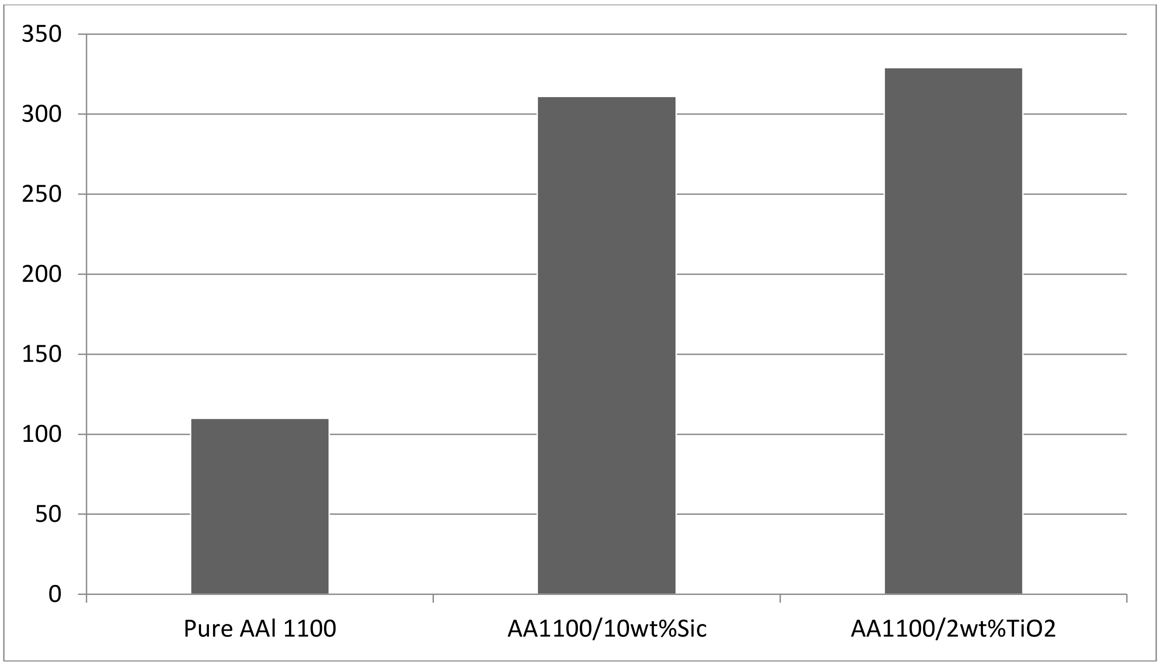


Figure 3.4 Comparison Ultimate Tensile Strength With AA1100/10wt% Sic & AA110/2wt% TiO_2

Hardness test

A Rockwell hardness tester machine used for the hardness measurement. The surface being tested generally requires a metallographic finish and it was done with the help of 100, 220, 400, 600 and 1000 grit size emery paper. Load used on Rockwell's hardness tester was 250 grams at dwell time 25 seconds for each sample. The result of Rockwell's hardness test wt.% variation different reinforcements such as SiC/ TiO_2 are shown in Table number 3.2.

Table 3.2 shows Hardness test results

Serial No	Composites	Trial			Total force Nm	Average Force Nm
		1	2	3		
1	Al 1100					5.9
2	10% Sic	8.4	9.4	8.7	26.5	8.8
3	2 % TiO_2	10	10.1	9.9	30	10

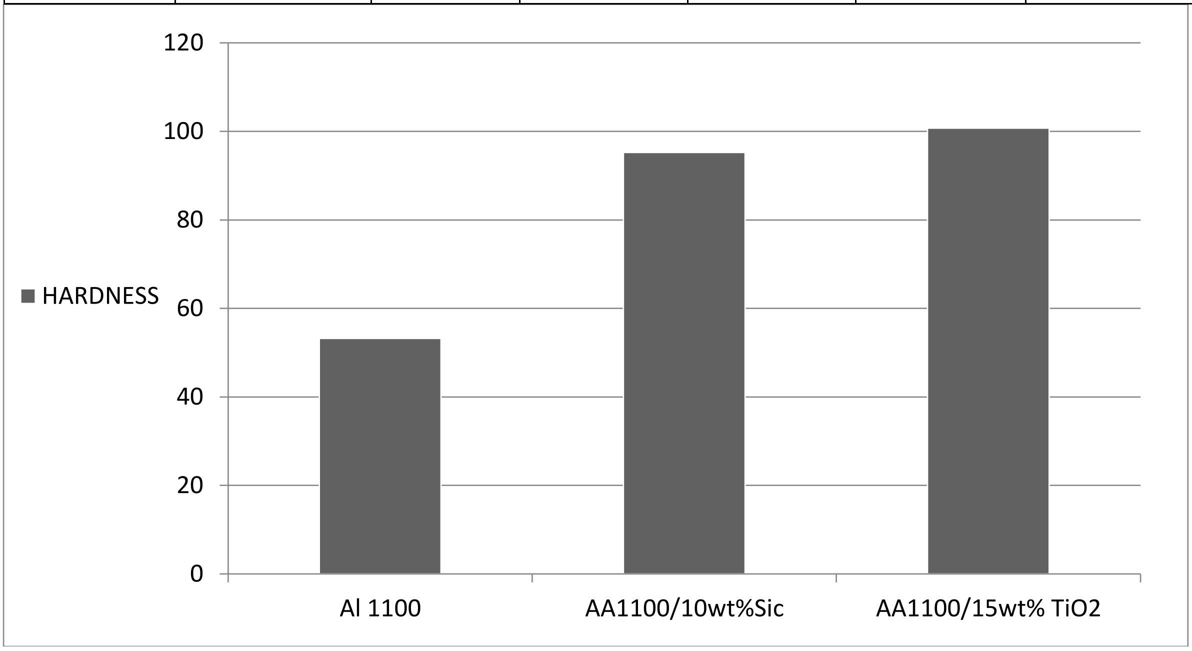
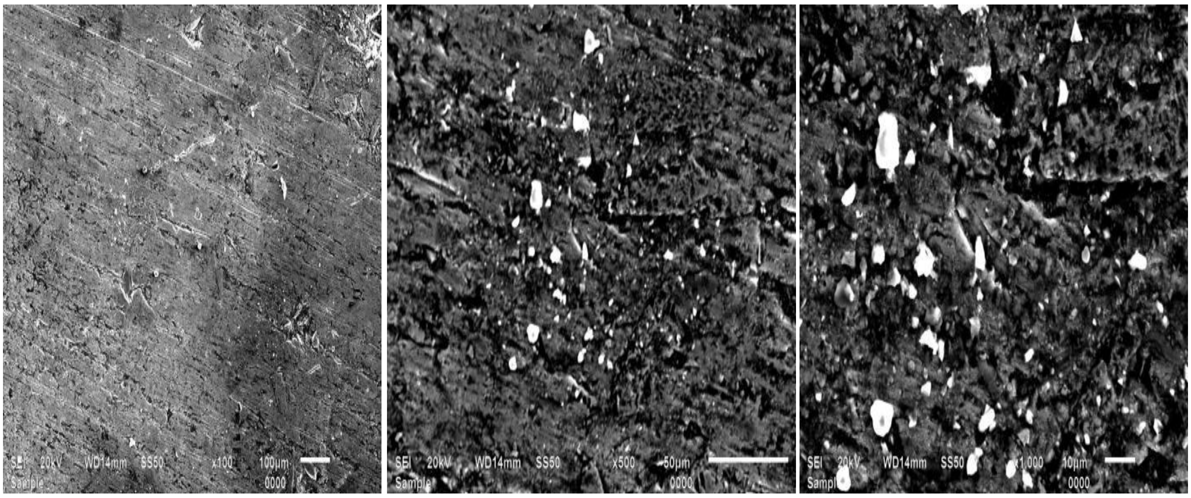


Figure 3.5 Comparison the Hardness of Al1100,AA1100/10wt% Sic & AA1100/2wt% TiO_2

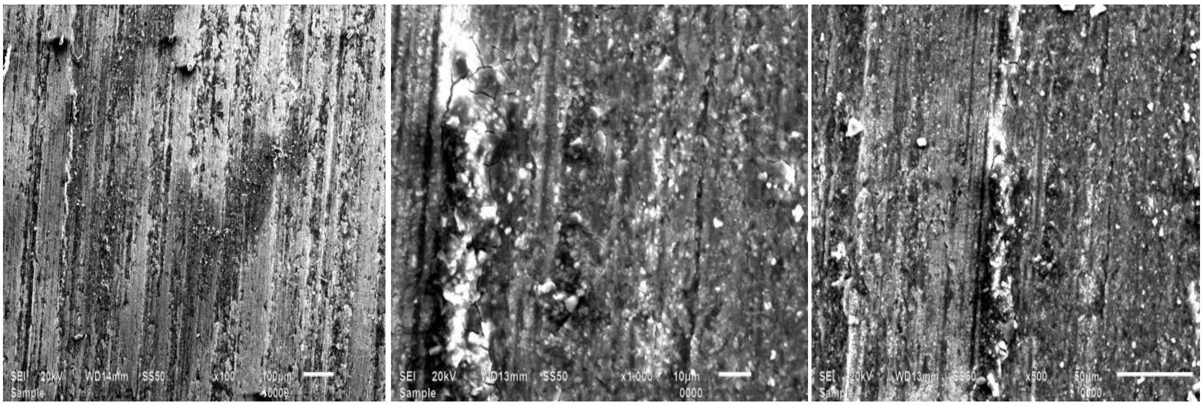
In Figure number 3.5 results predict that uniform increase in hardness is also seen. This is due to increase in resistance to deformation by adding SiC and TiO_2 as reinforcement in Al1100

Results of SEM



100X **500X** **1000X**

Figure 3.6: Microscopic View of 10 % SiC Reinforced in Al 1100 100 X, 500 X, 1000X



100X **500X** **1000X**

Figure 3.7: Microscopic View of 2 % TiO_2 Reinforced in Al 1100, 100 X, 500 X, 1000 X

Figures 3.6 & 3.7 presented with the microphotographs of Cast Al 1100 Sic and TiO_2 composite respectively. From figures it can be observed that, the distributions of reinforcements in the respective matrix are fairly uniform. Further these figures reveal the homogeneity of the cast composites. The microphotograph also clearly revels the increased filler contents in the composites. Cracks are also seen in the microstructure

Impact test results

The Charpy impact test, also known as the Charpy v-notch test, is a standardized high strainratetest which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness.

Table 3.3: Impact Test Results

Serial No	Composites	Trial			Total force Nm	Average Force Nm
		1	2	3		
1	Al 1100					5.9
2	10% Sic	8.4	9.4	8.7	26.5	8.8
3	2 % TiO_2	9.9	9.6	10.1	29.6	9.8

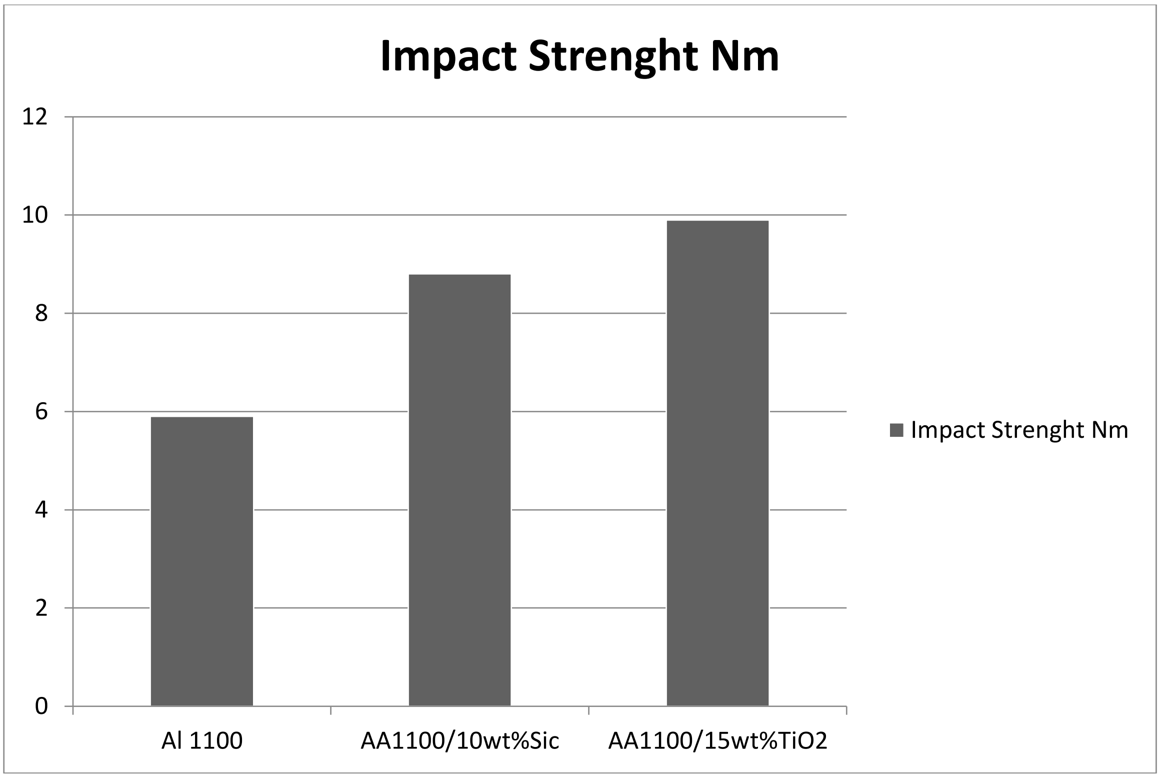


Figure 3.8: Comparison of Impact Strength Al100 ,AA1100/10wt% Sic & AA1100/2wt% TiO_2.

Figure 3.8 shows that with the increase in Sic & TiO_2 constituent Impact strength is increases with respect to base metal. This is due to proper dispersion of Sic & TiO_2 into the matrix or strong interfacial bonding in between the Al alloy and Sic & TiO_2 interface.

Compression test results

Compression tests were used to assess the mechanical behavior of the composites and matrix alloy. The composite and matrix alloy rods were machined to tensile specimens with a diameter of 19mm gauge length of 22 mm. Universal testing machine used for the Compressive Strength measurement. The result of test wt.% variation of reinforcement such as TiO_2 are shown in Table number 3.4.

Table 3.4: Compression Test Results

Serial No	Composites	Trial			Total	Average Compressive Strength in Mpa
		1	2	3		
1	Al 1100					159
2	10% Sic	423.62	424.16	2	10% Sic	423.62
3	15 % TiO_2	446.5	449.16	3	15 % TiO_2	446.5

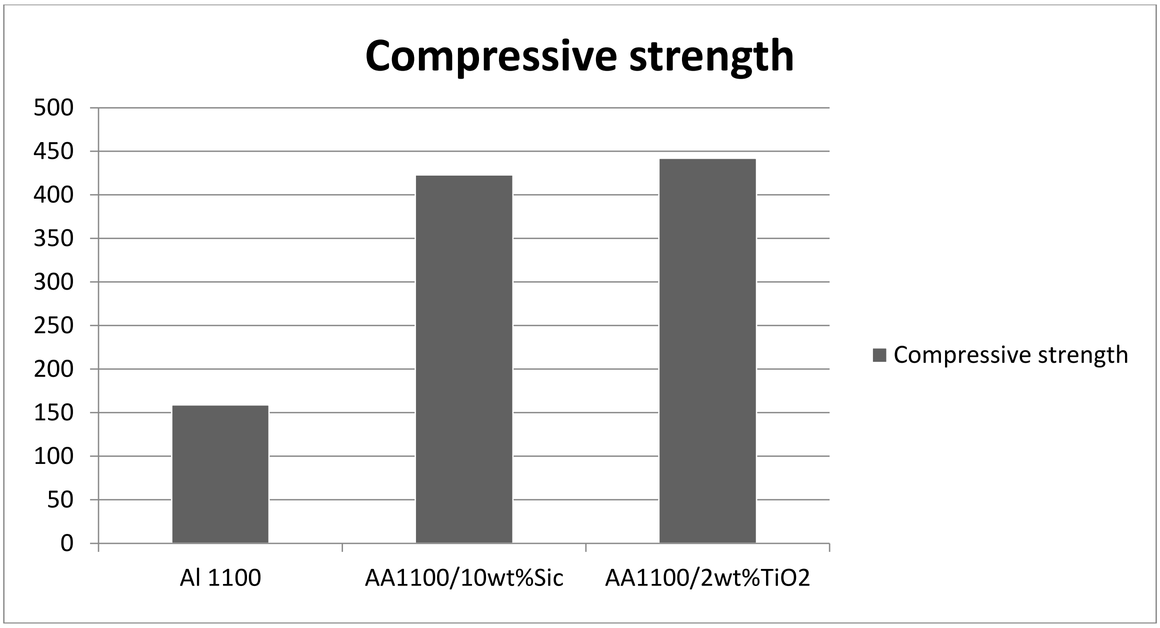


Figure 3.9: Comparison of Compressive Strength Al1100 ,AA1100/10wt% Sic & AA1100/2wt% TiO_2

Figure 3.9 shows that with the increase in Sic & TiO_2 constituent Impact strength is increased with respect to base metal. This is due to proper dispersion of Sic & TiO_2 into the matrix or strong interfacial bonding in between the Al alloy and Sic & TiO_2 interfaces.

Shear test results

Shear tests were used to assess the mechanical behavior of the composites and matrix alloy. The composite and matrix alloy rods were machined to tensile specimens with a diameter of 19mm. Universal testing machine used for the Shear Strength measurement The result of test wt.% variation of reinforcements such as TiO_2 are shown in Table number 3.5.

Table 3.5: Shear Test Results

Serial No	Composites	Trial			Total	Average Shear Strength
		1	2	3		
1	Al 1100					72 MPa
2	10% Sic	133.19	134.95	2	10% Sic	133.19
3	15 % TiO_2	146.44	148.72	3	15 % TiO_2	146.44

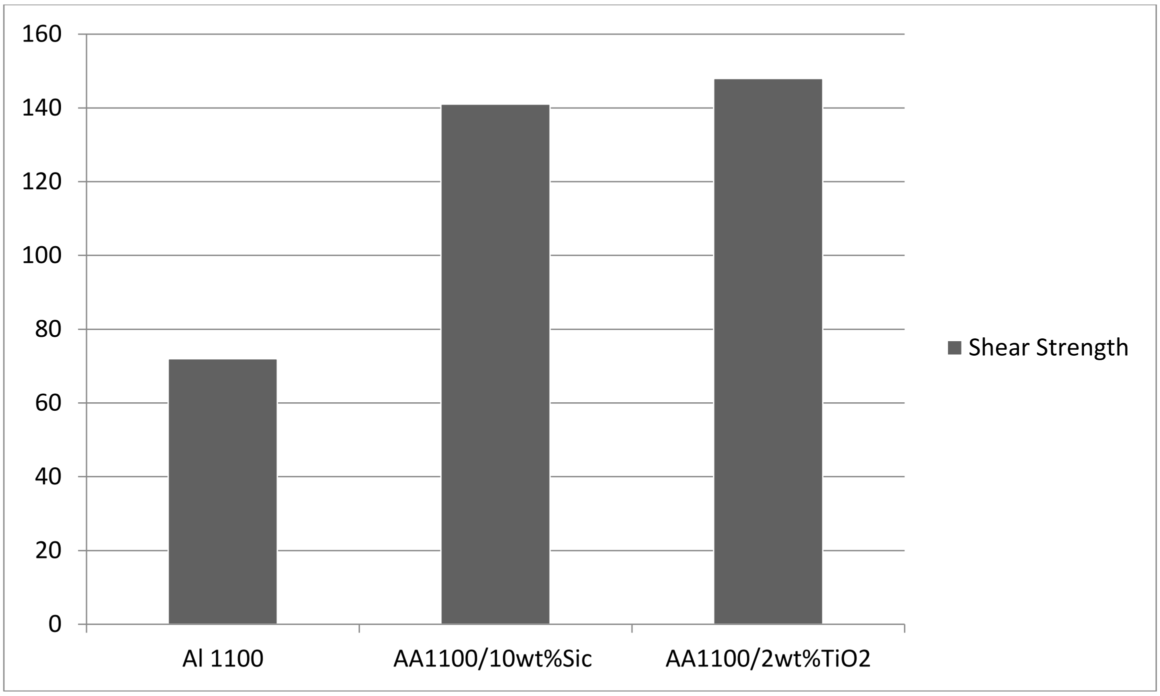


Figure 3.10: Comparison of Shear Strength Al1100, AA1100/10wt% Sic & AA1100/2wt% TiO_2

As shown in Figure number 3.10 results predict that as the reinforcement wt.% Shear Strength is increases. This happens may be due to dispersion of Sic & TiO_2 into the matrix

4. CONCLUSIONS

The conclusions drawn from the present investigation are as follows:

- The results confirmed that stir formed Al 1100 with SiC/ TiO_2 reinforced composites is clearly superior to base Al 1100 in the comparison of tensile strength, Impact strength as well as Hardness.
- Dispersion of SiC/ TiO_2 particles in Al 1100 improves the hardness of the matrix material. It appears from this study AA1100/2 wt% TiO_2 is more harder AA1100/10wt% SiC.
- Impact strength is increase by adding SiC & $TiO_{2.}$
- It appears from this study that UTS and Yield strength increases with 10% weight percentage of SiC and 2 wt% of TiO_2 in the matrix.
- Dispersion of SiC & TiO_2 into the base matrix Al 1100 increases the shear strength.
- It appears from this study that strong interfacial bonding of Al 1100 with SiC & TiO_2 increases the compressive strength.

REFERENCES

[1] K.Singh, M.Kumar "Analysis on Mechanical Behaviour of AA 1050/ SiC and AA 1050/Al2O3 Composites" International Journal of Science and Research (IJSR) Vol 6 Issue 6, June (2017), ISSN (Online): 2319-7064.
[2] K.Singh, S.Choudhary "To Compare & Analyse the Mechanical Behaviour of AA 1100/ SiC and AA 1100/ ZrO2 Composites" IJRMET Vol. 8, Issue 2, May - October 2018, ISSN : 2249-5770.
[3] L.Ceschini, "Tensile and fatigue properties of the AA6061/20% volume Al2O3p and AA7005/10% volume Al2O3p composites", Composites Science and Technology 66 (2006) 333–342.
[4] Divecha, "Silicon carbide reinforced aluminum - A formable composite" Journal of Metals. Vol. 33, pp. 12-17. Sept. 1981.
[5] Hashim, "Metal matrix composites: production by the stir casting method", Journal of Materials Processing Technology 92-93 (1999) 1-7
[6] Joseph Goldstein, Scanning electron microscopy and x-ray microanalysis, Plenum Publishers, 2001.
[7] Manoj Singla, "Development of Aluminium Based Silicon Carbide Particulate Metal Matrix Composite", Journal of Minerals & Materials Characterization & Engineering, Vol. 8, No.6, pp 455-467, 2009.
[8] S. Balasivanandha Prabu, "Influence of stirring speed and stirring time on distribution of particles in cast metal matrix composite", Journal of Materials Processing Technology 171 (2006) 268–273.

[9] G.B.Veeresh Kumar, “Studies on Al6061-SiC and Al7075-Al2O3 Metal Matrix Composites”, Journal of Minerals & Materials Characterization & Engineering, Vol. 9, No.1, pp.43-55, 2010

[10] Sudipt Kumar, “production and characterisation of Aluminium-Fly Composites using Stir Casting Method”, Department of Metallurgical & Materials Engineering National Institute of Technology Rourkela, 2008

[11] M. Kok, “Production and mechanical properties of Al2O3 particle-reinforced 2024 aluminium alloy composites”, Journal of Materials Processing Technology 161 (2005) 381– 387.

[12] D.J.Lloyd, “Particle reinforced aluminium and magnesium matrix composites”, International Materials Reviews 1994 Vol. 39 No.1.