Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 44 No. 3 (2023)

Study of the Mechanical Properties of Composite Materials AA6063 Reinforced with B_4C &TiO_2 for Engineering Application

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Abstract
Composite materials were fabricated at different volume fractions of B_4C & TiO_2 particles, ranging from 1%, 3%, & 5% to evaluate the impact of reinforcements on the mechanical properties of the composite materials. MMC's can be reinforced with various oxides, carbides, nitrides and borides in particulates, whiskers or fiber form such as SiC, Al_2O_3 , B_4C, TiC, TiB_2, TiO_2. B_4C is an attractive reinforcement for aluminum and its alloys showing many of the mechanical and physical properties required of an effective reinforcement, in particular high stiffness and hardness. In this study the Al6063 metal composites are fabricated using stir casting route. Today trend has been changed that the advanced materials are used for vast number of structural as well as engineering applications, an investigation of Aluminium alloy (AA6063), Boron carbide (B_4C) and Titanium oxide (TiO_2) metal matrix composites. Aluminium is the matrix metal having properties like light weight, high strength and ease of machinability. Boron carbide which has excellent hardness and fracture toughness is added as reinforcements with TiO_2 and B_4C. Here, the fabrication is done by stir casting which involves mixing the required quantities of additives into stirred molten Aluminium. The present work deals with the finding of mechanical properties TiO_2, B_4C. Particulate reinforced Al-6063 matrix-based MMC composite. The MMCs are produced from AA6063 matrix and TiO_2 and B_4C. The present study is concentrated on the mechanical properties of Al-6063 metal matrix composites reinforced with micro sized titanium oxide (TiO_2) and Boron carbide (B_4C) particle in different weight percentage of 1,3 and 5% by using stir casting process. Hardness is tested using Micro Vicker Hardness Testing Machine .The behavior of materials is obtained by the compression test of the materials.

Keywords— Metal Matrix Composites, Engineering, Mechanical Properties, Hardness& Compression Test.

I. Introduction

Development of composite materials is a major step in the development of materials. Current engineering applications require materials that are stronger, lighter and less expensive. Standard monolithic materials have limitations with respect to composite material. Development of hybrid metal matrix composites has become an important area of research interest in Material Science. Aluminium metal matrix and hybrid composites (AMMHCs) are invincible used composites in the areas like aerospace, ballistic, electrical, aviation, tribological, space and air vehicle, automotive, thermal, structure, defense, industries, military, transportation, engineering and mineral processing applications because of their excellent and unbeatable combination of composites properties such as high strength-to-weight ratio, good corrosion, oxidation and wear resistance, high fatigue strength, low coefficient thermal expansion, high thermal and electrical conductivity, superior damping capacities, high specific stiffness and strength, creep resistance, and high plastic flow strength.

Aluminium metal matrix and hybrid composites (AMMHCs) are trending materials used in recent time that have the capacity to meet the demand of advancement in processing applications. Several types of reinforcement have been used since the inception of friction stir processing (FSP). The most widely used reinforcing material is inorganic (metallic) powders such as silicon carbide, titanium alloy, graphene, iron , stainless steel, nitrides, oxides etc. and fewer works have been reported on organic powders (i.e. bioprocessing using agro-wastes powders) such as fly ash, palm kernel shell ash, coconut shell ash, rice husk ash etc. Many researchers have established the roles of reinforcements in the modification of surface and texture of the reinforced metal matrix or hybrid composite material and how it enhanced the mechanical and metallurgical properties of the materials via intense.

A composite material is a combination of two materials with different physical and chemical properties.In the present work, Al6063 has been chosen as the matrix material for preparing the hybrid metal matrix composite as it finds enormous application in the construction, automotive, marine, etc. industries due to characteristics such as moderate strength, good corrosion resistance, and toughness compared to other aluminum alloys. Reinforcement Materials In this work, with particulates, namely B_4C, TiO_2, have been employed as reinforcement materials to make the proposed hybrid metal matrix composite materials.

1.2 Problem definition:

Development of hybrid metal matrix composites has become an important area of research interest in Material Science. So it is important to have a materials which shows higher performance in various applications with lower cost. So we have decided to produce a material (hybrid metal matrix), which can shows the high mechanical properties and wide range of applications.We have seen most of the Metal Matrix Composites fail due to the incorrect selection or old methods of its making process. For a good Metal Matrix Composites the Matrix material and reinforced material should be equally distributed over its area. Due to these issues in consideration, we fabricated Metal Matrix composites by using stir casting.

1.3 Objective of the project:

- Study and prepare the ASTM standard test specimens made of Aluminium alloy based hybrid composite material ($AA6063+B_4C+TiO_2$) through stir casting process.
- Prepare the ASTM standard specimens to evaluate mechanical properties (Tensile, Compressive, hardness and Impact properties) .
- Closure of the final report

II. LITERATURE SURVEY

1. A.A cerit , M.B.karamis et al.,(2008), Examined the wear behavior of the Al 6063 combination composites fortified with alumina of diverse compositions, which are casted by stir casting method keeping a constant load of 2kg and varying the velocities and he concluded that with increase in percentage of alumina wear rate decreases. In his research he concluded that Al 6063 alloy reinforced with 8% alumina is showing higher wear resistance for all velocities tested than the 0%.
2. D.N. Sun , Apelian et al.,(2011),Revels that his consider on aluminium based composites recommends that with increment in composition of silicon carbide (SiC) comes about within the increment of hardness, affect quality. He inspected that homogeneous dispersion of SiC particles within the Al framework appears an expanding nature within the tests arranged by

without applying blending handle, with manual mixing and with 2-step strategy of blend casting separately.

3. Omolayo M, Ikumapayi et al.,(2019), Has successfully developed Al 7075 alloy and Short Basalt Fiber composite through blending casting method. The expansion of brief basalt fibre altogether increments the hardness, surrender quality and extreme malleable quality. The composite containing 6% volume division of brief basalt fiber appears higher hardness esteem of 97.1Mpa when compare to base network, 92Mpa. The extreme pliable quality of Al-7075 basalt fiber when fortified 6 vol% is expanded by 65.51%. The conveyance of fortification in metal lattice is decently uniform.
4. K.N Chethan,A.pai et al.,(2018), Explored on the enhancement of mechanical properties of E-glass brief filaments and fly ash strengthened Al7075 crossbreed MMCs. He measured extreme malleable quality and compressive quality. They concluded that due to nearness of E-glass strands and fly ash debris the extreme malleable quality is expanded compare to base metal and due to nearness of these fortifications needed the compressive quality is expanded.
5. MVKrishna ,A.M Xaviour et al., (2014),In this investigation, the Aluminium based composites with the addition of SiC and CSA was successfully achieved with stir casting process. It has been observed that stir formed Al alloy Al6063 with SiC/CSA reinforced composites is superior to base Al alloy Al6063 in terms of tensile strength, Impact strength and Hardness.The investigations have revealed the presence SiC, CSA particles in alloy matrix in a uniformly distributed manner. The phases like CSA and SiC etc. have dispersed uniformly throughout in the MMC thus strengthening the resulting composite.
6. M.A. Xaviour , J.P.A Kumar et al**., (**2017**)**The fundamental aim of this research work is to develop unique composite material to with stand real time wear loading condition. Aluminium 6063 matrix material has been reinforced with two key solid lubricants namely graphite and Molybdenum di sulfide (MoS2).
7. This experimental work, Al6063 metal matrix composites of TiB2 and ZrSiO4 with a weight percentage of (3,5)and (5,8) respectively were fabricated through stir casting technique. Hardness, Impact strength and corrosion behavior of the prepared composites were studied.. From the corrosion test, it is clear that the 87% Al6063, 8% ZrSiO4 and 5% TiB2 composite specimen offers better corrosion resistance when compared with the remaining specimens. Finally, it is known that 92 % Al6063, 5% ZrSiO4 and 3% TiB2is observed to be the better metal matrix composite due to its optimum performance in the present work when compared with other composite and pure alloy.
8. SURABHI LATAA ET AL. Every engineering field is treading the path of technology in search of new smart materials possessing the best of all properties needed by the today's manufacturing world. This paper conducted a research in fabricating an aluminum based composite where AA 5051 was used as matrix alloy and titanium dioxide (TiO2) was the reinforcing material. Three compositions were made with three different percentages of TiO2 particles viz. 5%, 10% and 15%.
9. N.LOKESH ET AL**.** Based on the experimental evaluation, following conclusions can be drawn: Marginal improvement in hardness is observed in the composites with increase in weight percentage of Cu reinforcement. Tensile strength of the composite material increases with increase in weight percentage of Cu. Maximum tensile strength of 119.576 MPa is found for Al 6063-15wt% Cu composite. The ductility decreases as the weight % of reinforcement increases. Impact strength of the material decreases with the addition of Cu reinforcement. Maximum impact strength (28.0J) is observed for Al 6063-5% Cu composite. The microstructure shows better dispersion of reinforcement in the matrix and there is no indication of clustering or agglomeration of reinforcement in the matrix.
10. A.V. POZDNIAKOV ET AL. The composites of 6063+5%B4C and 1545K+5%B4C were successfully produced by two stir casting techniques. The first involved incorporation of reinforcement's particles in pure form. Stir casting technique was novel, in which the particles incorporated to the melt using by powder master alloy. The incorporation of B4C particles in pure form is more effective than using a powder master alloy. A good interface reaction

between the matrix and the B4C reinforcements was observed by the formation of Al3BC and AlB2 phases on the matrix/B4C interface.1545K+5%B4C alloy showed YS=425 MPa and UTS=455 MPa and, also high resistance to inter crystalline corrosion.

III. EXPERIMENTAL PROCEDURE

Preparation of composites:

Experimental procedure for investigation was manufactured by Using Stir Casting Process & Conducting mechanical tests to know the mechanical properties of composites.

Specimens are prepared with the method of stir casting process. For the aluminum materials stir casting is best in the view of cost and preparation process. There are lot of advantages of stir casting such as simplicity, flexibility, applicability to huge quantity, closer net shaping, less cost of processing & easier control of matrix structure. In this preparation, stir-casting method is used for making Aluminium matrix composite. This whirlpool method provides more strength and homogeneous set of Aluminium composite materials. Stir casting is a primary process of composite making in which constant stirring of molten base metal is done followed by addition of reinforcements. The final mixture is poured into the die and allowed to solidify. In stir-casting, the elements often tends to form agglomerates, those can be only dissolved by strong stirring at high temperature. The experimental setup contains the main furnace and parts along with 3 mild steel stirring blades. The 1st process in the fabrication process is preheating, where the empty crucible and the reinforcement powders, namely boron carbide & titanium dioxide powders are heated individually to a temperature close to that of the main process temperature. The melting of the Aluminium alloy ingot is carried out in the crucible inside the furnace. Initially, the ingot was preheated for 3 –4hr at 550°C. At the same time boron carbide and titanium dioxide powders are also preheated to 400°C in the respective containers. Then, the crucible with Aluminium alloy is heated to 800°C while the preheated powders are mechanically mixed with each other below their melting points. This metal–matrix is then kept into the furnace at the same temperature. The furnace completely melts the pieces of Aluminium alloy and the powders of titanium and boron carbide. The stirring mechanism is lowered into the crucible inside the furnace and set at the required depth. The vigorous automatic stirring of the material takes place for 10 min with 550 rpm of stirring rate, thereby uniformly dispersing the additive powders in the Aluminium alloy matrix. The temperature rate of the furnace should be controlled at 830 ± 10°C in final mixing process. The degasser removes all the trapped gases from the mixture in the crucible and ensures that the temperature of the mixture in the crucible does not get transferred easily to the atmosphere. This experiment is repeatedly done by varying the compositions of the composite powder.

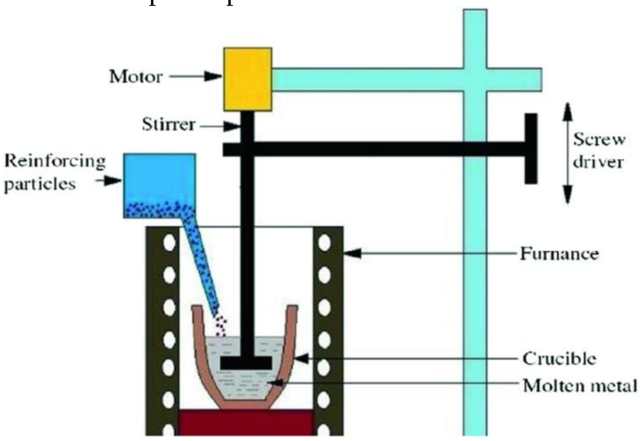


FIGURE 3.1 STIR CASTING

Table :1. Chemical composition of the composite samples.

Sample number	AA6063 (weight %)	B4C (weight %)	TiO_2 (weight %)	Sample name
1	100	0	0	AI 6063
2	98	1	1	98Al-1B4C-1TiO_2
3	96	1	3	96Al-1B4C-3TiO_2
4	94	1	5	94Al-1B4C-5TiO_2
5	96	3	1	96Al-3B4C-1TiO_2
6	94	3	3	94Al-3B4C-3TiO_2
7	92	3	5	92Al-3B4C-5TiO_2
8	94	5	1	94Al-5B4C-1TiO_2
9	92	5	3	92Al-5B4C-3TiO_2
10	90	5	5	90Al-5B4C-5TiO_2

IV. TESTING

Compression test:

- Compression test machines are universal testing machines specially configured to evaluate static compressive strength characteristics of materials, products, and components. Choose from a wide variety of compression test machines that measure characteristics such as ultimate compression strength, yield strength, deflection and modulus.
- Each compression tester is configured to your test requirements by our application engineers with the correct controller, grips, and accessories. Due to our modular machine design, your compression test machine can also be equipped to perform other applications such as tensile, cyclic, shear, flexure, bend, peel, tear by adding appropriate fixtures.
- That means you get the exact system that matches the specifications you need and fits within your budget. More choices mean fewer compromises.

FIGURE 4.1-COMPRESSION TEST MACHINE

V. HARDNESS TEST

Vickers hardness test:

The Vickers hardness test method, also referred to as a microhardness test method, is mostly used for small parts, thin sections, or case depth work. The Vickers test is often easier to use than other hardness tests since the required calculations are independent of the size of the indenter, and the indenter can be used for all materials irrespective of hardness. The basic principle, as with all common measures of hardness, is to observe a material's ability to resist plastic deformation from a standard source. The Vickers test can be used for all METALS and has one of the widest scales among hardness tests. The unit of hardness given by the test is known as the Vickers Pyramid Number (HV) or Diamond Pyramid Hardness (DPH).

FIGURE 5.1-VICKERS HARDNESS MACHINE

VI. RESULTS AND DISCUSSION

In this research work, an investigation on the enhancement of mechanical properties and the machinability of the composites by the application of mechanical tests is done through the Vickers hardness test & compression test.

MACHINING AND SPECIMEN PREPARATION:

After the fabricating of alloy by using stir casting the composite bars are Machined and Produced as per the American Society for Testing and Materials (ASTM) Standards. The whole Machining Process has been done using the Computer Numeric Control (CNC) Lathe Machine. The specimen diameters are 30 mm length and 10mm diameter.The Specimens which are prepared after the machining as given below.

Figure 6.1 composite specimen

Testing the Specimen:

The testing of specimen is done by Vickers hardness test and compression test. TheVickers hardness test is performed to measure the hardness of material. The compression testing determines the material behavior and measure the plastic flow behavior of a material.

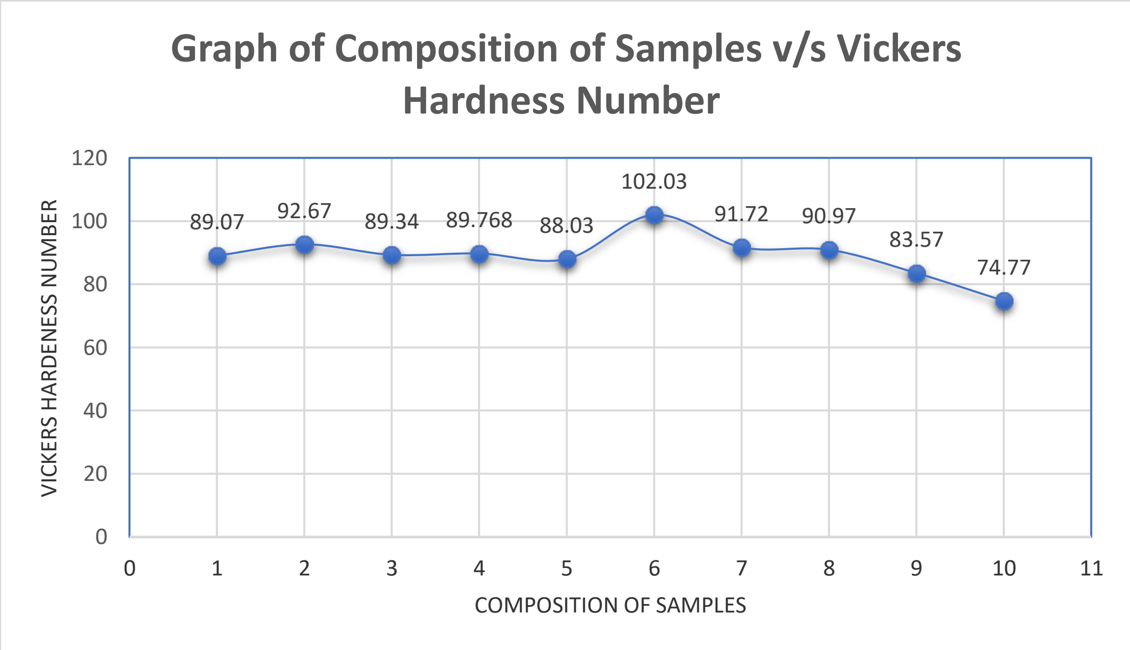
Figure 6.2 UTM machine

VICKERS HARDNESS TEST:

The Vickers hardness test for the specimen is done to measure hardness of material .The hardness values of different specimens are arranged in below table-2.

Sample number	Sample name	Test 1	Test 2	Test 3	Test 4	Test 5	Average
1	AI 6063	89.77	87.66	87.31	85.75	94.72	89.07
2	$98Al\text{-}1B_4C\text{-}1TiO_2$	84.22	99.79	93.59	93.33	92.44	92.67
3	$96Al\text{-}1B_4C\text{-}3TiO_2$	87.1	90.27	85.02	85.99	98.36	89.34
4	$94Al\text{-}1B_4C\text{-}5TiO_2$	94.2	82.89	87.62	86.97	97.16	89.768
5	$96Al\text{-}3B_4C\text{-}1TiO_2$	91.5	98.41	81.59	75.O5	93.62	88.03
6	$94Al\text{-}3B_4C\text{-}3TiO_2$	111.7	98.6	103.2	92.77	103.9	102.03
7	$92Al\text{-}3B_4C\text{-}5TiO_2$	98.25	96.17	85.19	84.71	94.3	91.72
8	$94Al\text{-}5B_4C\text{-}1TiO_2$	85.19	114.7	82.8	93.27	78.9	90.97
9	$92Al\text{-}5B_4C\text{-}3TiO_2$	76.49	102.4	78.88	82.25	77.86	83.57
10	$90Al\text{-}5B_4C\text{-}5TiO_2$	79.27	71.03	74.03	77.04	72.48	74.77

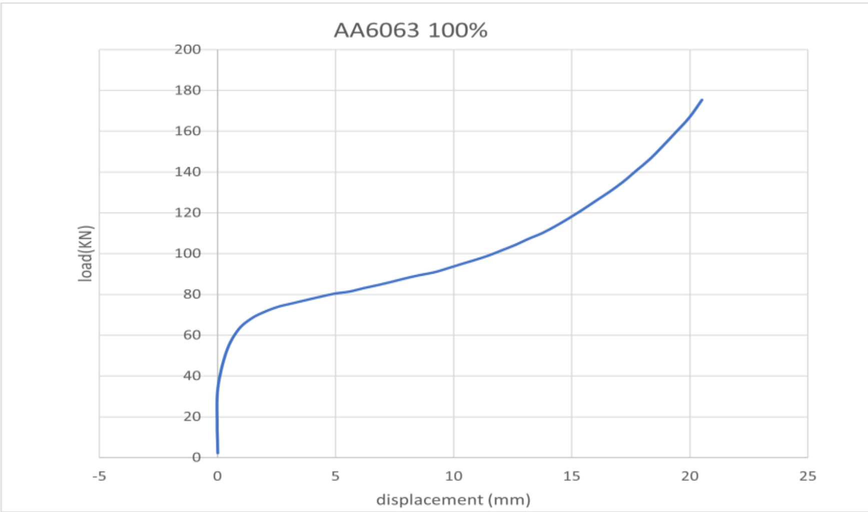
VII. GRAPH ANALYSED FROM VICKERS HARDNESS TEST:



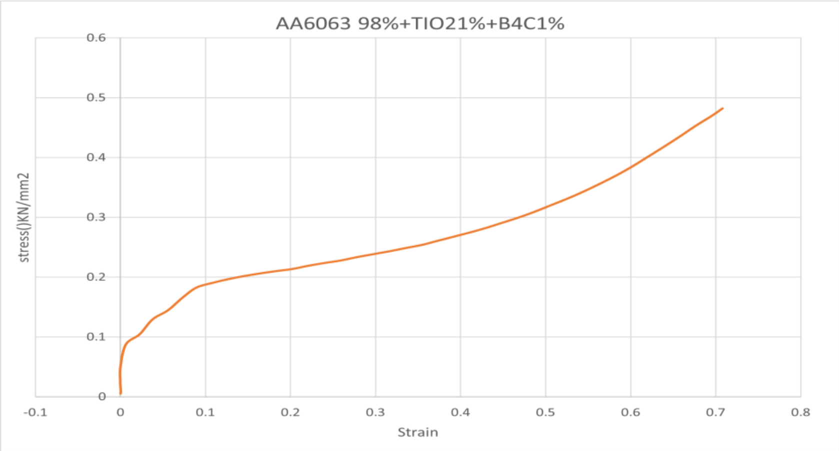
It was observed from above Figure that, the micro-hardness of AMCs has increased with increase in wt% of reinforcement. The micro vicker's hardness of AMCs was found to be maximum (102.03 VHN) for the sample-6. There is increased in hardness compared to the base alloy, and for the wt% hardness was found to be maximum The presence of such hard surface area of particles offers more resistance to plastic deformation which leads to increase in the hardness of composites.

VIII. COMPRESSION TEST:

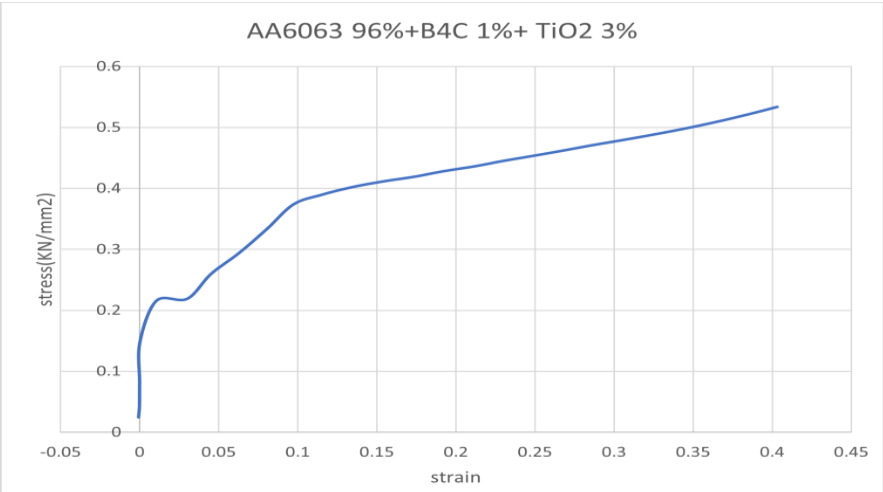
SPECIMEN – 01[AA6063- 100%], LOAD-500(GRAM),TIME-10 (SECONDS)



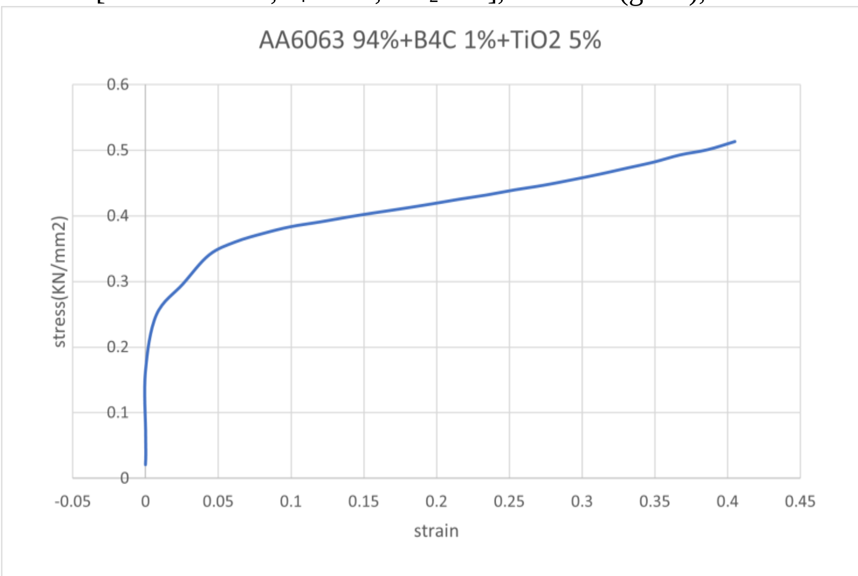
Specimen – 2[AA6063- 98%, B_4C-1%,TiO_2-1%] Load-500 (gram),Time-10 seconds

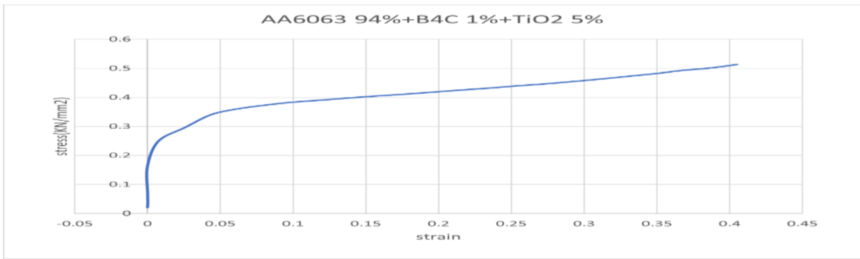


Specimen -3[AA6063-96%,B_4C-1%,TiO_2-3%] ,Load-500(gram),Time-10 seconds

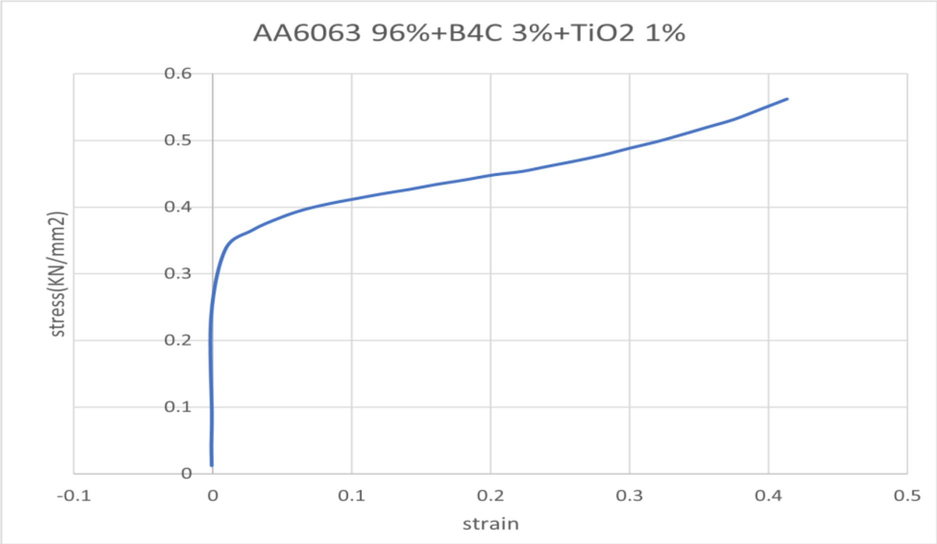


Specimen-4[AA6063-94%,B_4C-1%,TiO_2-5%],Load-500(gram),Time-10 seconds

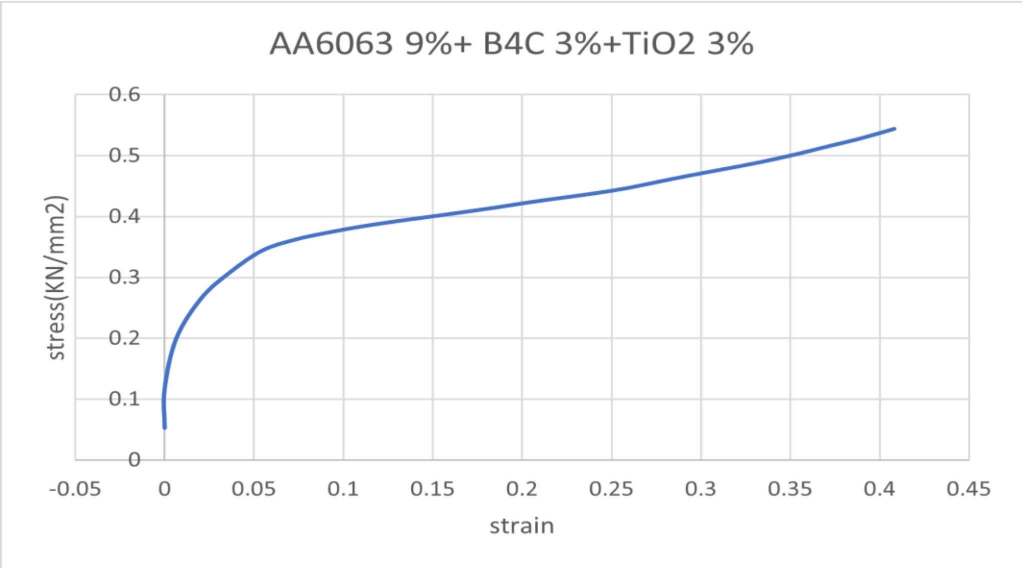




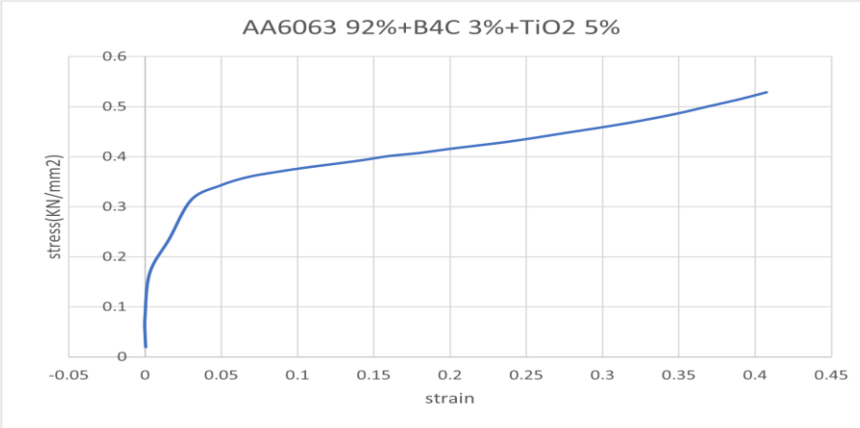
SPECIMEN-5[AA6063-96%,B_4C-3%,TiO_2-1%],LOAD-500(GRAM),TIME-10 SECONDS



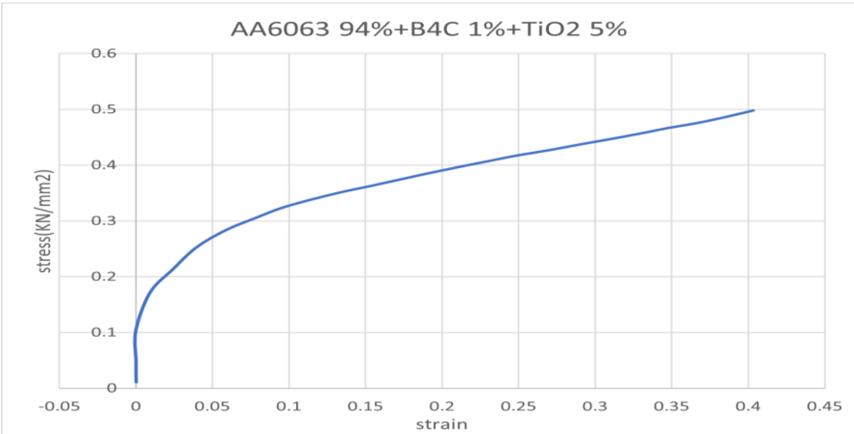
SPECIMEN-6 [AA6063-94%,B_4C-3%,TiO_2-3%],LOAD-500(GRAM),TIME-10 SECONDS



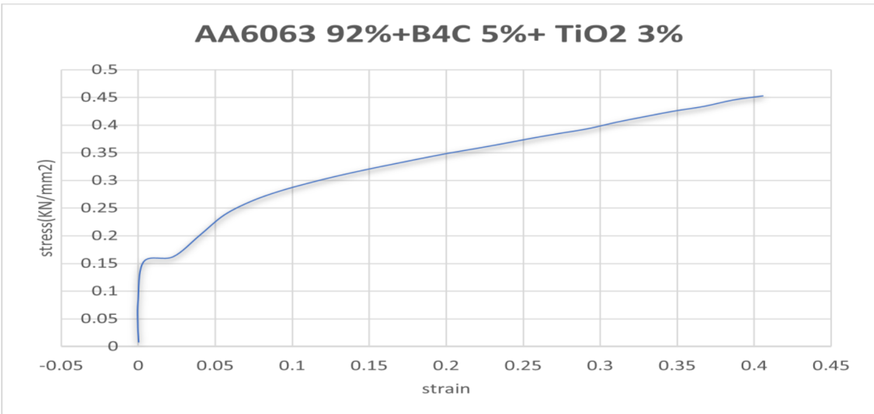
SPECIMEN-7[AA6063-92%,B_4C-3%,TiO_2-5%],LOAD-500(GRAM),TIME-10 SECONDS



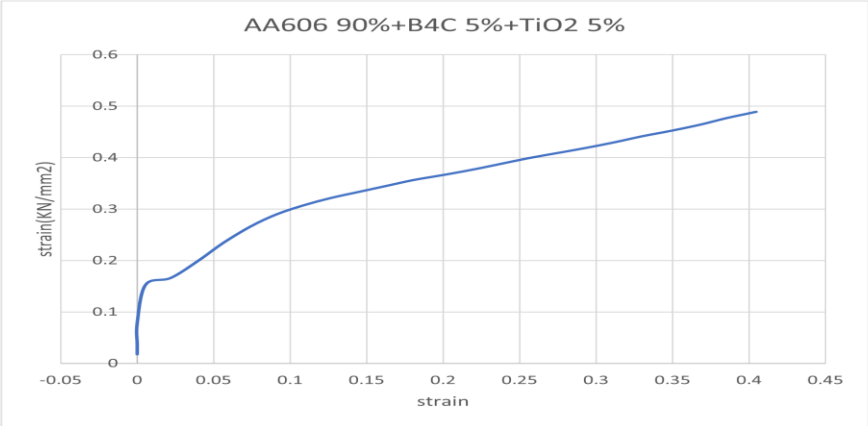
SPECIMEN-8[AA6063-94%,B_4C-1%,TiO_2-5%],LOAD-500(GRAM),TIME-10 SECONDS

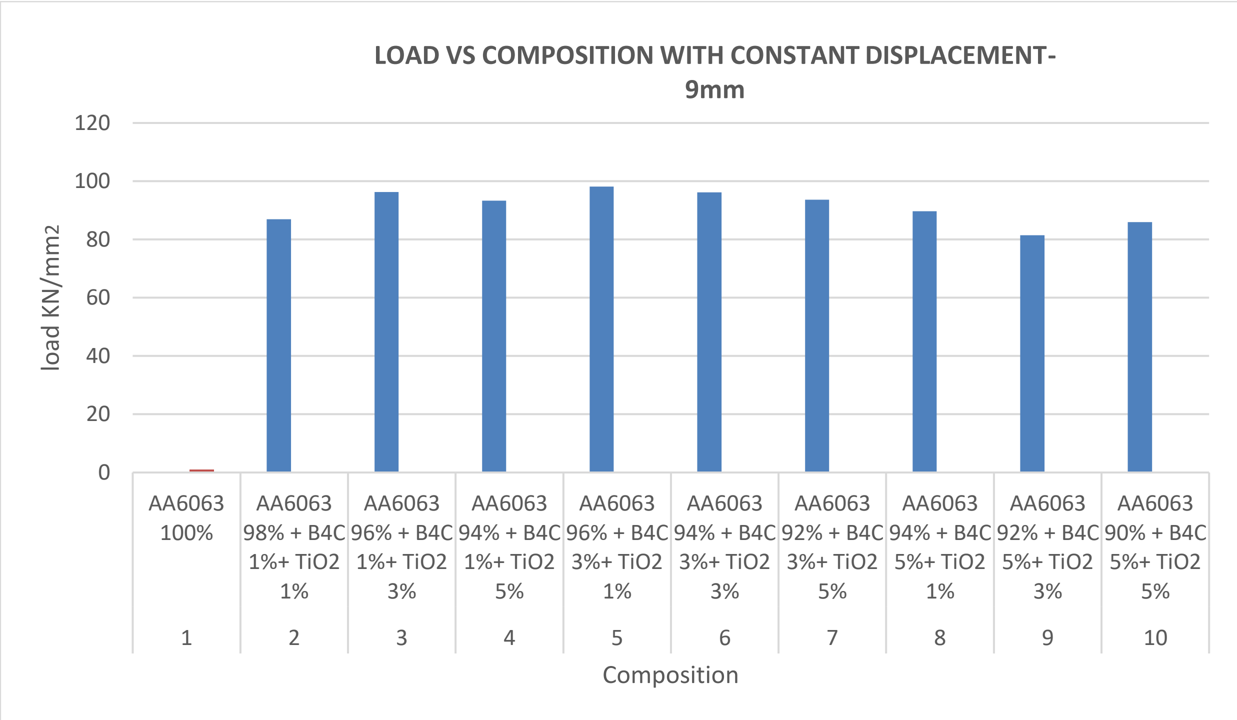


SPECIMEN-9[AA6063-92%,B_4C-5%,TiO_2-3%],LOAD-500(GRAM),TIME-10O SECONDS



SPECIMEN-10[AA6063-90%,B_4C-5%,TIO_2],LOAD-500(GRAM),TIME-10 SECONDS





Above Graph shows the compression strength for Al6063 alloy and combination with 1 3,5 wt. % of B4C & TiO2 particulates composites it is reasoned that as the presence of B4C & TiO2 particles is expanded in base Al6063 alloy, there is an expansion in compression strength of Al6061-B4C & TiO2 composites. Since the carbide or oxide grid is totally masterminded the strength of framework is controlled by the compression strength. Always the particles strength is very high in terms of compression, these high compression strength particles helps in improving the crushing strength of the base Al material

IX. CONCLUSION:

The conclusion of present research work on Mechanical properties of AA-6063 Reinforced with TiO_2 and B_4C Metal Matrix Composites. The material under investigation was prepared using a stir-casting process. The aluminium was used as a matrix; however, boron carbide and titanium dioxide were used as reinforcement.

- ✓ Materials of a composite were selected on the basis of present research trends and their need, for preparation of MMCs.
- ✓ The various processing techniques for processing of a AMMCs werestudied and opted the stir casting method because of its advantages.
- ✓ Using the stir casting technique AA 6063/TiO2&B4C MMCs were preparedsuccessfully
- ✓ The processing standards were strictly followed while composite being processed.
- ✓ After fabrication, mechanical properties analysis is done for the presenceof TiO2 and B4C particles were in AMMCs.
- ✓ Mechanical properties are tested like Hardness and compression using micro- Vickers hardness machine and UTM machine.

The quality of the interface shows its importance in the transfer of physical and mechanical properties of composites. The materials elaborated by stir casting under the conditions of this study showed insufficient cohesion to promote significant improvements of the mechanical properties. Moreover, the incorporation of B_4C & TiO_2 reinforcements leads to an opposite evolution of the mechanical properties.
It is observed that, the Hardness values has been increased with respective to Reinforcement 1,3 and 5% when compare to AA6063 Basematerial.

Future work:
The future work of the present project work is finding some more mechanical properties such as tensile strength, yield strength and wear test.

ACKNOWLEDGMENT

I would like to thank Dr. C. Yuvaraj Professor & Principal, MITS Madanapalle, providing An Excellent Support & Continuous Encouragement. I am Sincerely thankful to My Parents & My Brothers for being a great mentor and providing precious assistance throughout this part of Research work. I would like to thank Mrs. Gayatri Pattar For her valuable support to develop this Paper work.

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