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Investigation of Mechanical Behaviour and Microstructure Analysis of AA5754/TiB2/B4C-Based Aluminium Hybrid Composites

Vanumu Veera Venkata Phanindranadh [1], Palukuri Veerendra [2]
M.Tech Student, Mechanical Engineering, Kakinada Institute Of Engineering &Technology-II, JNTU, Kakinada, India[1]
Asst.Professor & HOD, Mechanical Engineering, Kakinada Institute Of Engineering &Technology-II, JNTU, Kakinada, India[2]
Email - Phanindranadh2757@gmail.com[1], veeru515@gmail.com[2]

Abstract: *The present work deals with the fabrication of the Aluminum matrix composites by ultrasonic dispersion of titanium diboride (TiB2) and boron carbide (B4C) particles in molten Aluminum alloyAA5754. It has been selected as matrix alloy as it is readily castable. The mechanical properties such as hardness, tensile strength will be studied and compared with those of the base alloy. The correlation of the properties with respect to the variation of the processing parameters, viz., weight percentage will be done. The weight percentage of titanium diboride and boron carbide (TiB2+ B4C) will be varied from (5%, 10%, 15% & 20%) . The proposed values are for chosen based on the literature data. In addition, the analysis of the micro-structural properties of metallurgical structure and grain size will be carried out.*

Key Words: *Hybrid composites, Metal Matrix Composite, Aluminum Alloy-5754, Titanium diboride (TiB2), Boron carbide (B4C).*

1. INTRODUCTION :

Hybrid composites are materials that are fabricated by combining two or more different types of reinforcements within a common matrix. Composite material is a material composed of two or more distinct phases (matrix phase and reinforcing phase) and havingbulk properties significantly different from those of any of the constituents. Many of common materials (metals, alloys, doped ceramics and polymers mixed with additives) also have a small amount of dispersed phases in their structures, however they are not considered as composite materials since their properties are similar to those of their base constituents (Titanium diboride and boron carbide property of steel are similar to those of pure iron) . Favorable properties of composites materials are high stiffness and high strength, low density, high temperature stability, high electrical and thermal conductivity, adjustable coefficient of thermal expansion, corrosion resistance, improved wear resistance etc..

A. Matrix Phase

1. The primary phase, having a continuous character.
2. Usually more ductile and less hard phase.
3. Holds the reinforcing phase and shares a load with it.

B. Reinforcing Phase

1. Second phase (or phases) is imbedded in the matrix in a discontinuous form,
2. Usually stronger than the matrix, therefore it is sometimes called reinforcing phase.

1.1. CLASSIFICATION OF THE COMPOSITE

Composite materials are classified (a). On the basis of matrix material.(b). On the basis of filler material.

(A) On the basis of Matrix:

1. Metal Matrix Composites (MMC)

Metal Matrix Composites are composed of a metallic matrix (aluminum, magnesium, iron, cobalt, copper) and a dispersed ceramic(oxides, carbides) or metallic (lead, tungsten, molybdenum) phase.

2. Ceramic Matrix Composites (CMC)

Ceramic Matrix Composites are composed of a ceramic matrix and imbedded fibers of other ceramic material (dispersed phase).

3. Polymer Matrix Composites (PMC)

Polymer Matrix Composites are composed of a matrix from thermo set (Unsaturated polyester (UP), Epoxy) or thermoplastic (PVC,Nylon, Polystyrene) and embedded glass, carbon, steel or Kevlar fibers (dispersed phase).

(B) On The Basis Of Material Structure:

1. Particulate Composites

Particulate Composites consist of a matrix reinforced by a dispersed phase in form of particles.

1. Composites with random orientation of particles.
2. Composites with preferred orientation of particles. Dispersed phase of these materials consists of two-dimensional flat platelets(flakes), laid parallel to each other.

2. Fibrous Composites

1. **Short-fiber reinforced composites**. Short-fiber reinforced composites consist of a matrix reinforced by a dispersed phase inform of discontinuous fibers (length< 100*diameter).
    1. Composites with random orientation of fibers.
    2. Composites with preferred orientation of fibers.
2. **Long-fiber reinforced composites**. Long-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in formof continuous fibers.
    1. Unidirectional orientation of fibers.
    2. Bidirectional orientation of fibers (woven).

3. Laminate Composites

When a fiber reinforced composite consists of several layers with different fiber orientations, it is called multilayer (angle-ply) composite.

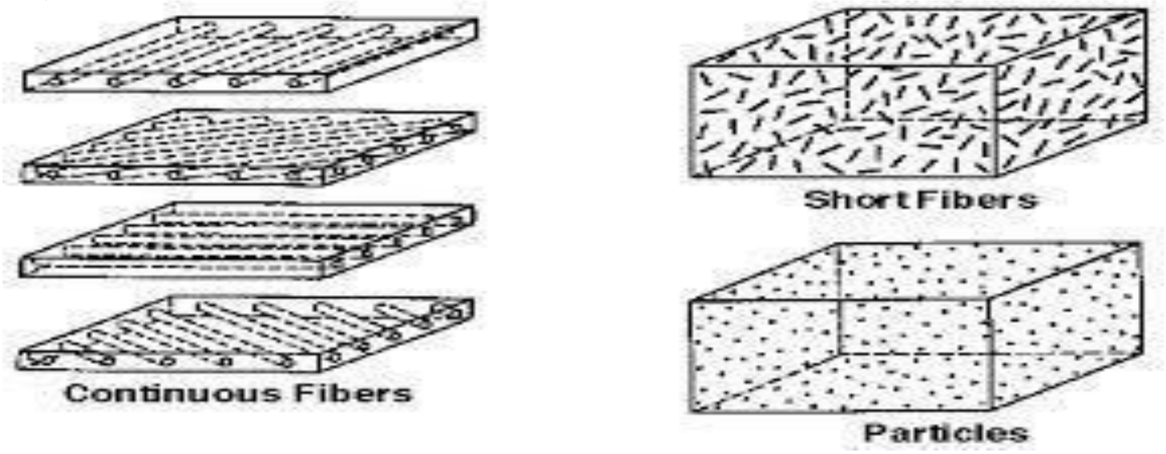


Fig 1.: Composite Classification on Basis of Material Structure

2. LITERATURE REVIEW :

HassabAlla M. A. Mahmoud,1 P. Satishkumar , 2 Yenda Srinivasa Rao , 3 Rohini kumar Chebolu,4 Rey Y. Capangpangan , 5 [1] microstructure and mechanical properties of an MMC based on AA 7075 and strengthened through titanium diboride and boron carbide (SiC) as well as boron carbide (B4C) elements were studied. The (SiC + B4C) combinationwas used in various weight percentages of 4, 8, 12, and 16% to create the hybrid composites utilizing the traditional stir casting procedure. XRD and SEM measurements were used to investigate the dispersion of the reinforced particles. For example, microhardness, impact strength, and ultimate tensile strength were measured on hybrid composites at room temperature. The density and porosity of the materials were also studied. The researchers found that increasing the weight percentage of the (SiC
+ B4C) mixture resulted in a small drop in % elongation. However, hybrid composites comprising 16% (SiC + B4C) weight reduction showed some decrease in hardness and tensile strength. Equated to unreinforced alloys, the hardness and tensile strengthof hybrid composites rise by 8% and 21%, respectively. Reinforcement also resulted in a decrease in impact strength and density,as well as an increase in porosity.

Md. Habibur Rahman, H. M. Mamun Al Rashed[2] This work is to study about the microstructures, mechanical properties andwear characteristics of as cast titanium diboride and boron carbide (SiC) reinforced aluminum matrix composites (AMCs). AMCs of varying (SiC) content (0, 5, 10 and 20 wt. %) were prepared by stir casting process. Microstructures, Vickers hardness, tensile strength and wear performance of the prepared composites were analyzed. The results showed that introducing (SiC) reinforcementsin aluminum (Al) matrix increased hardness and tensile strength and 20 wt. % (SiC) reinforced AMC showed maximum hardness and tensile strength. Micro structural observation revealed clustering and non-homogeneous distribution of (SiC) particles in the Almatrix. Porosities were observed in microstructures and increased with increasing wt. % of (SiC) reinforcements in AMCs. Pin-on-disc wear test indicated that reinforcing Al matrix with (SiC) particles increased wear resistance.

3 . FABRICATION OF THE METAL MATRIX COMPOSITE

Although there are several methods for the preparation of the composite, casting evolved as the one of the most effective methods to produce products with the complex shapes. However it is extremely difficult to obtain uniform dispersion of nano-sized particles in liquid metals due to high viscosity, poor wet ability, and large surface to volume ratio in the metal matrix. So to overcome this problem we use high intensity ultrasonic waves to have uniform dispersion in the liquid phase as they generate the essential non-linear effects required.

3.1. Fabrication Barriers of Nano-Composite

EX-SITU methods which include powder metallurgy, stirring techniques, pressure infiltration and spray deposition are usually more cost efficient. However, the particles are easy to agglomerate and hard to be dispersed. Reinforcements created IN-SITU are usually fine and well distributed. However IN-SITU reinforcement has less opportunity than EX-SITU ones for complex reactions involved in the IN-SITU fabrication routes. Fabrication of MMNCs are much more complex compared to fabrication of MMCs. when the particle size scales down from the micro to the nano level, the major challenges are

The reaction process between the bonding interfaces is still unclear. Reaction effect will lead to the failure of the MMNCs.

- Agglomeration and clustering in bulk materials can still be observed. The dispersion during the processing needs to be optimized.
- Cost effectiveness is another factor that hinders the fabrication of nano composites. With the development of nano technology, theprice of the nano fabrication should be reduced.
- Currently, low volume and rates are observed. A transition to high volume and high rate fabrication is pivotal to apply the technology to real industry fabrication.
- Different processes have been applied, however modeling of these processes are needed.

Aluminium alloy AA5754

Aluminum alloys of the 5xxx series such as **AA5754** are commonly used in the marine industry. AA5754 are often usedin transport applications due to their high specific strength, including marine, automotive and aviation. 5000 series known as 'marine grade' aluminium, is alloyed with magnesium, corrosion resistant but non-heat treatable, hence it is widely used in fabrication such as transportation, tanks, vessels and bridges is widely used in mold tool manufacturing.

3.1.2 Titanium diboride (TiB_2):

Titanium diboride (TiB_2) is an extremely hard ceramic which has excellent heat conductivity, oxidation stability and wear resistance. TiB_2 is also a reasonable electrical conductor, so it can be used as a cathode material in aluminium smelting and can be shapedby electrical discharge machining

3.1.3 Boron carbide(B4C):

Boron carbide (chemical formula approximately B_4C) is an extremely hard boron–carbon ceramic, a covalent material used in tankarmor, bulletproof vests, engine sabotage powders, as well as numerous industrial applications.

Fig 2: Titanium diboride

Fig 3: Boron carbide

FABRICATION OF ALUMINIUM MMC

Aluminium MMC can be produced by different techniques. Some of them are:

- Stir casting or forced vortex technique.
- Powder metallurgy technique.

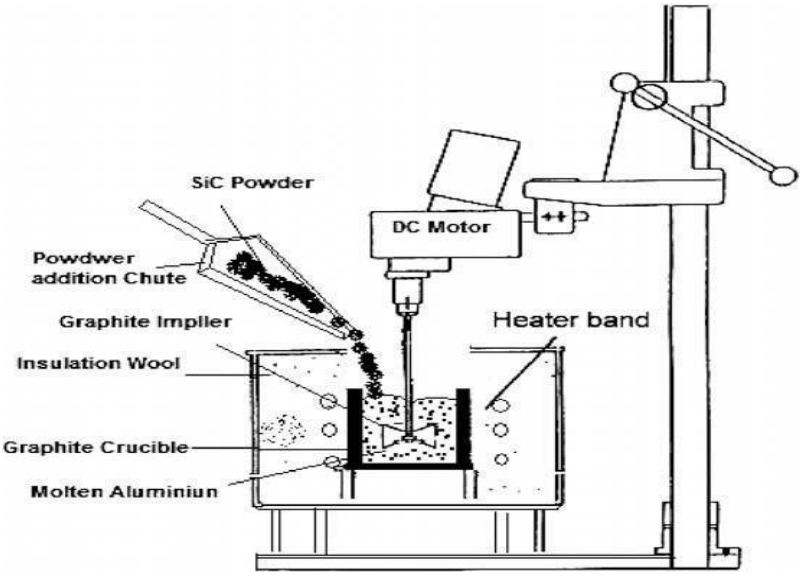


Fig 4.: Layout of the stir casting apparatus

Figure 4. shows layout of the stir casting apparatus. It consist of conical shaped graphite crucible is used for fabrication of Aluminium Metal Matrix Composite, as it withstands high temperature which is much more than required temperature [680°C],along that graphite will not react with aluminium at these temperature. This crucible is placed in muffle which is made upof high ceramic alumina, around which heating element of wound. The coil which acts as heating element is Kanthol-A1. This typeof furnace is known as resistance heating furnace. It can work up to 900°C. Aluminium, at liquid stage is very reactive with atmospheric oxygen. Oxide formation occurs when it comes in contact with the open air. Thus all the process of stirring is carried out in closed chamber with nitrogen gas as inert gas in order to avoid oxidation. Closed chamber is formed with help of ceramic sheet. This reduces heat loss and gas transfer as compare open chamber. A K-type (Chromel/constantan) Temperature thermocouple whose working range is -200°C to 1250°C is used to record the current temperature of the liquid. Due to corrosion resistance to atmosphere EN 24 is selected as stirrer shaft material. One end of shaft is connected to 5 HP DC motor with flange coupling. While at the other end blades arc welded. 4 blades are welded to the shaft at 45°C. A constant feeding rate of reinforcement particles is required to avoid coagulation and segregation of the particles. This can be achieving by using hopper. Aluminium alloy matrix will be formed in the crucible by heating aluminium alloy ingots in furnace. A stirring action is started at slow rate of 30 rpm and increases slowly in between 300 to 600 rpm with speed controller. A mixture of reinforcement (Titanium diboride and boron carbide) is to be incorporated in the metal matrix at semisolid level near 640°C. Dispersion time is to be taken as 5 minutes. After that slurry is reheated to a temperature above melting point to make sure slurry is fully liquid and then it is poured in mould.

4. LAYOUT OF THE STIR CASTING :

4.1 Procedure:

Stir casting process starts with placing empty crucible in the muffle. At first heater temperature is set to 450°C and then itis gradually increased up to 900°C. High temperature of the muffle helps to melt Aluminium alloy quickly, reduces oxidation level, enhance the wettability of the reinforcement particles in the matrix metal. Aluminium alloy AA5754 is used as Matrix material. Required quantity of Aluminium alloy is cut from the raw material which is in the form of round bar. Aluminium alloy is cleaned to remove dust particles, weighed and then poured in the crucible for melting. During melting nitrogen gas is used as inert gas to create the inert atmosphere around the molten matrix. Titanium diboride and boron carbide is used as reinforcement. At a time total 500 gram of molten composite was processed in the crucible. Required quantities of reinforcement powder and magnesium turnings are weighed on the weighing machine.

Reinforcements are heated for half an hour and at temperature of 600°C. When matrix was in the fully molten condition,Stirring is started after 2 minutes. Stirrer rpm is gradually increased from 0 to 300 RPM with the help of speed controller. Temperature of the heater is set to 630°C which is below the melting temperature of the matrix. A uniform semisolid stage of the molten matrix was achieved by stirring it at 630°C. Pouring of preheated reinforcements at the semisolid stage of the matrix enhancethe wettability of the reinforcement, reduces the particle settling at the bottom of the crucible. Reinforcements are poured manuallywith the help of conical hopper. The flow rate of reinforcements measured was 5 gram per second. Dispersion time was taken as 5 minutes. After stirring 5 minutes at semisolid stage slurry was reheated and hold at a temperature 900°C to make sure slurry was fully liquid. Stirrer RPM was then gradually lowered to the zero. The stir casting apparatus is manually kept side and then molten composite slurry is poured in the metallic Mould. Mould is preheated at temperature 500°C before pouring of the molten slurry in the Mould. This makes sure that slurry is in molten condition throughout the pouring. While pouring the slurry in the Mould the flow of the slurry is kept uniform to avoid trapping of gas. Then it is quick quenched with the help of air to reduce the settling time of the particles in the matrix.

4.2 EXPERIMENTAL SETUP

An electric resistance heating unit was used to melt the AA5754 in the graphite crucible. A titanium waveguide which was coupled with a 20 kHz, 2000w ultrasonic converter was dipped into the melt for ultra sonic processing.

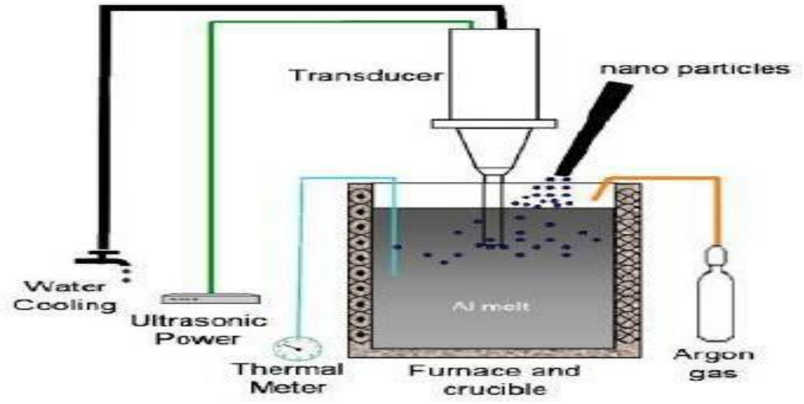


Fig 5: Schematic diagram of Experimental setup

The titanium diboride and boron carbide particles were added into melts during the process from the top of the crucible. The aluminium melt pool was well protected by the argon gas. The ultrasonic processing temperature was controlled to 100*c above thealloy melting point (610*c). An ultrasonic power of 1880 watts from the converter was used to generate adequate processing function inside the crucible. Totally four varieties of nano composites were prepared in which the weight percent of the reinforcement was considered at 5%, 10%, 15% and 20% for the chosen Nano size of 0.5 µm-300 µm titanium diboride and boron carbide particles. As observed during the process the viscosity of the melts significantly increased with the nano-sized titanium diboride and boron carbide particles in the melts. Thus after efficient ultrasonic processing a higher casting temperature of 760^0C was used to ensure the flow ability inside the graphite mould.Thus we obtain 4 nano composites with different titanium diboride and boron carbide percentages in each and one raw AA5754 is also prepared to compare and observe the values.

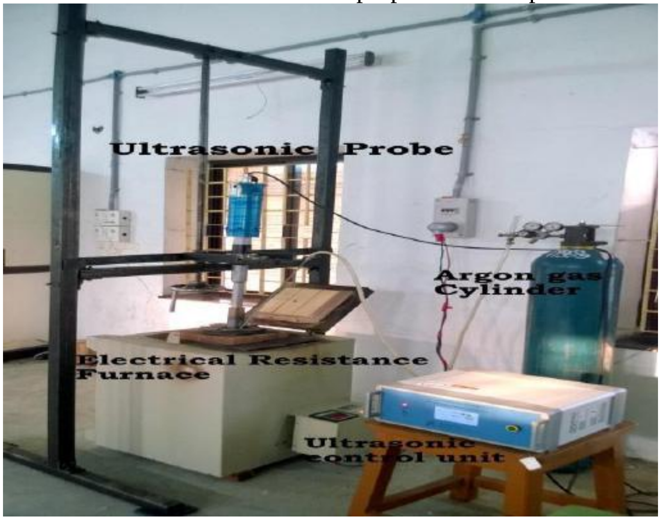


Fig 6: Experimental Setup

After obtaining the 5 pieces we go for the micro structural study to know about the dispersion of the titanium diboride and boron carbide particles in the matrix alloy.

4.3 MICROSTRUCTURES

Microstructure is defined as the structure of a prepared surface or thin foil of material as revealed by a microscope above 25X magnification. The microstructure of a material (which can bebroadly classified into metallic, polymeric, ceramic and composite) can strongly influence titanium diboride and boron carbide properties such as strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behavior, wear resistance, and so on, which in turn govern the application of these materials in industrial practice.

The material sample is prepared by polishing, etching, cutting, vapor deposition etc. The methods are known collectively as metallography as applied to metals and alloys, and can be used in modified form for any other material, such as ceramics, glasses, composites, and polymers. Two kinds of optical microscope are generally used to examine flat, polished and etched specimens: a reflection microscope and an inverted microscope. Recording the image is achieved using a digital camera working through the eyepiece. Here we are using an inverted microscope of magnification 10x to 60x. We obtain the images of the nine specimens as follows:

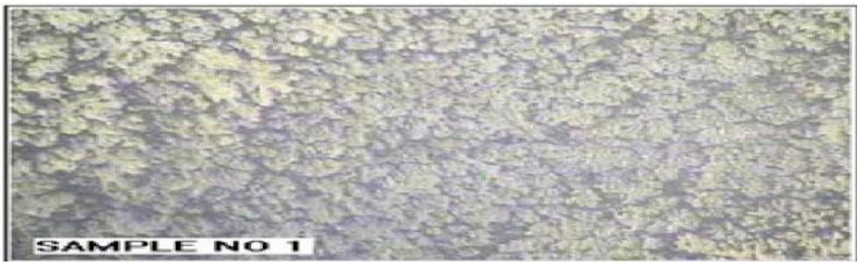


Fig 7: Microstructure of Raw AA5754

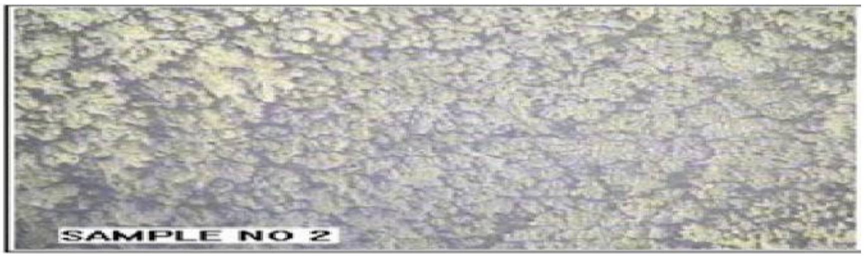


Fig 8: Microstructure of AA5754 with 5% Wt of titanium diboride and boron carbide

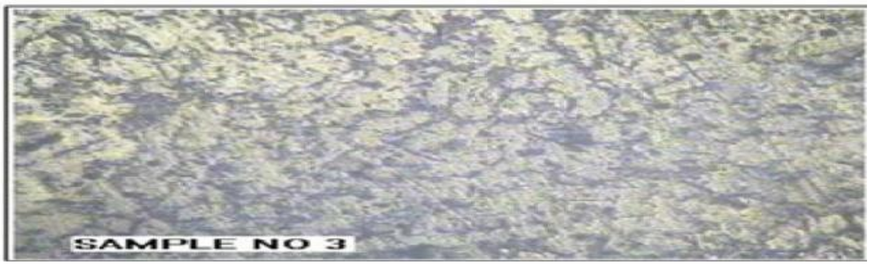


Fig 9: Microstructure of AA5754 with 10%Wt of titanium diboride and boron carbide

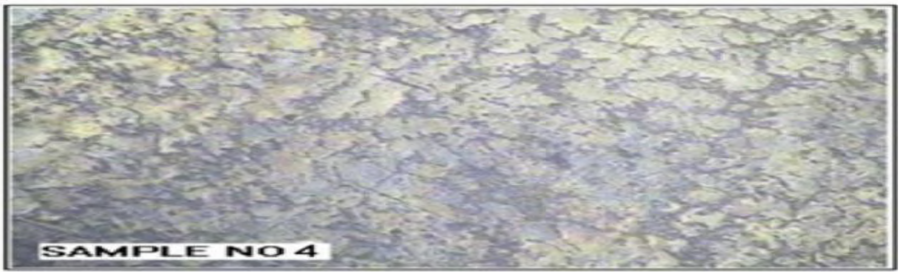


Fig 10: Microstructure of AA5754 with 15%Wt. of titanium diboride and boron carbide

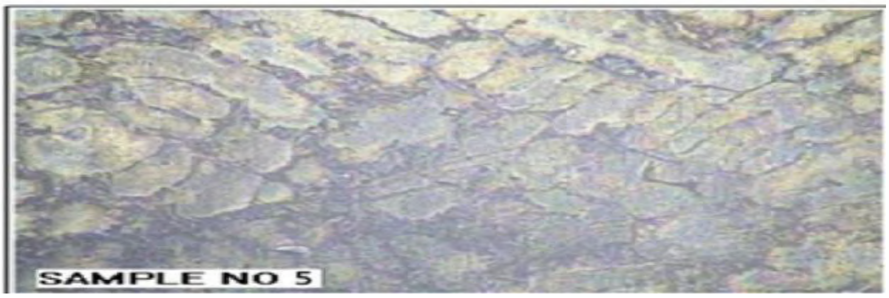


Fig 11: Microstructure of AA5754 with 20% Wt of titanium diboride and boron carbide

From the above micro structural images the distribution of the titanium diboride and boron carbide particles in the matrix alloy is observed and the difference in the distribution of the particles is clearly observed. In the raw cast aluminum alloy, Fig 5.5 the size of the dendritic grains is large and no ultrasonic processing is carried out and no titanium diboride and boron carbide particles are present. Sample No.5 shows the microstructure of the cast aluminium alloy sample with 20 wt.% Titanium diboride and boron carbide particles with ultrasonic processing. The grain sizes from the samples with titanium diboride and boron carbide particles and ultrasonic processing are much smaller.

4.4 SCANNING ELECTRON MICROSCOPE (SEM):

In a SEM, the secondary electrons produced by the specimen are detected to generate an image that contains topological features of the specimen. Figure shows a simplified schematic diagram of a SEM. The electrons produced by the electron gun are guided and focused by the magnetic lenses on the specimen.

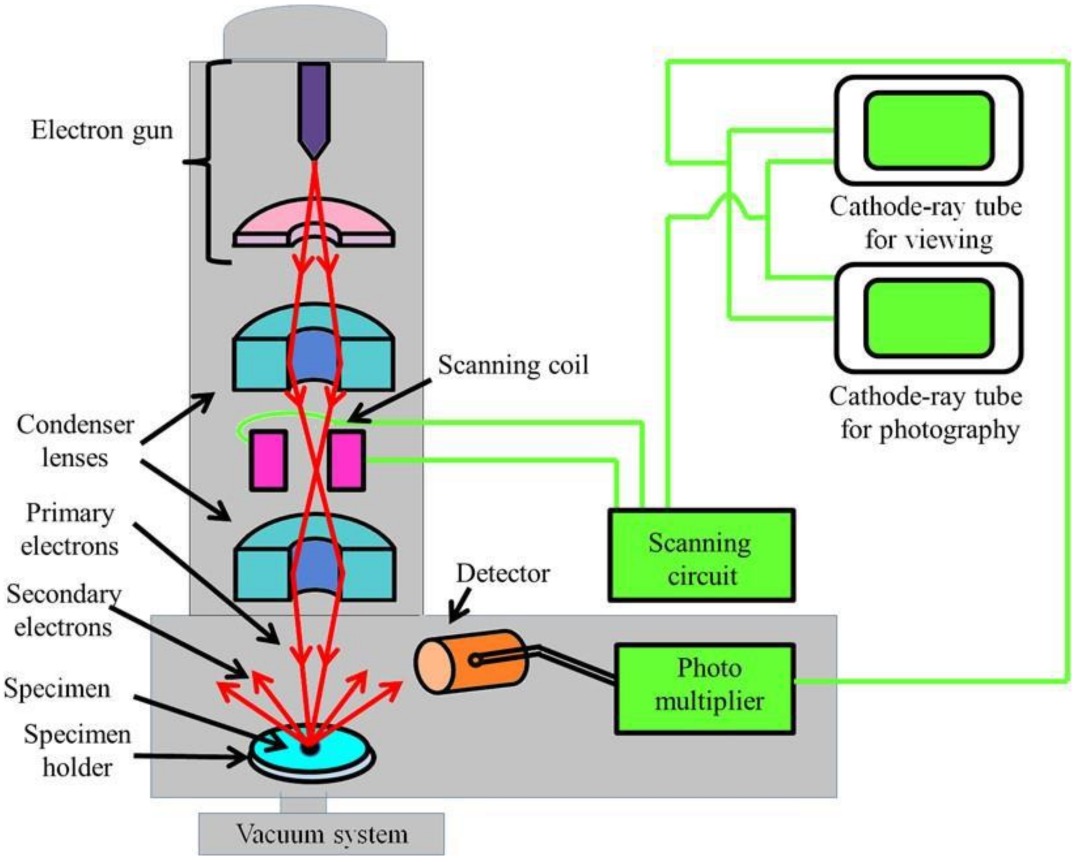


Figure 12: A simplified schematic diagram of a scanning electron microscope

The scanning electron microscope (SEM) uses a focused beam of high-energy electrons to generate a variety of signals at the surfaceof solid specimens. The signals that derive from electron-sample interactions reveal information about the sample including externalmorphology (texture), chemical composition, and crystalline structure and orientation of materials making up the sample. In most applications, data are collected over a selected area of the surface of the sample, and a 2-dimensional image is generated that displaysspatial variations in these properties. Areas ranging from approximately 1 cm to 5 microns in width can be imaged in a scanning mode using conventional SEM techniques (magnification ranging from 20X to approximately 30,000X, spatial resolution of 50 to 100 nm). The SEM is also capable of performing analyses of selected point locations on the sample; this approach is especially useful in qualitatively or semi-quantitatively determining chemical compositions (using EDS), crystalline structure, and crystal orientations (using EBSD). The design and function of the SEM is very similar to the EPMA and considerable overlap in capabilitiesexists between the two instruments.

The focused beam of electrons is then scanned across the surface in a raster fashion. This scanning is achieved by moving the electron beam across the specimen surface by using deflection/scanning coils. The number of secondary electrons produced bythe specimen at each scanned point are plotted to give a two dimensional image. In principle, any of the signals generated at the specimen surface can be detected. Most electron microscopes have the detectors for the secondary electrons and the backscattered electrons. In principle, any of the signals generated at the specimen surface can be detected. Most electron microscopes have the detectors for the secondary electrons and the backscattered electrons. The interaction volume within the specimen showing the regions of secondary electrons (energy < 50 eV) and backscattered electrons.

A secondary electron detector is biased with positive potential to attract the low energy secondary electrons. Detector for backscattered electrons is not biased; the high energy backscattered electrons strike the unbiased detector. As backscattered electrons come from a significant depth within the sample, they do not provide much information about the specimen topology. However, backscattered electrons can provide useful information about the composition of the sample; materials with higher atomic number produce brighter images.

Electron microscope follows the same ideas of optical microscope, but uses electrons instead of light;“Lens” here are not the opticalmaterials (like glass), but electrical field.

4.5 SEM IMAGES

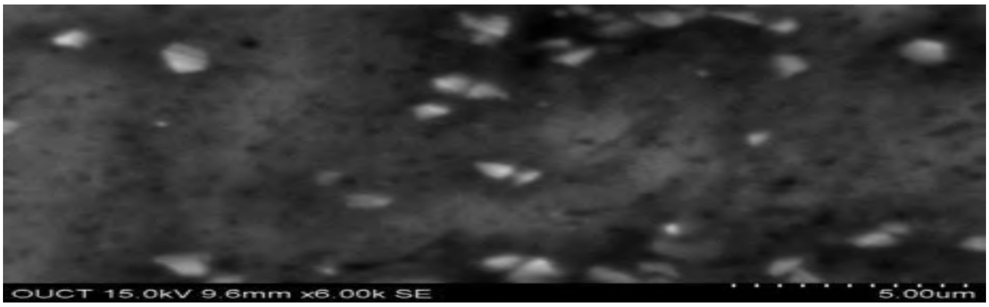


Fig 13: SEM Image OF AA5754 with 5% Wt. of titanium diboride and boron carbide

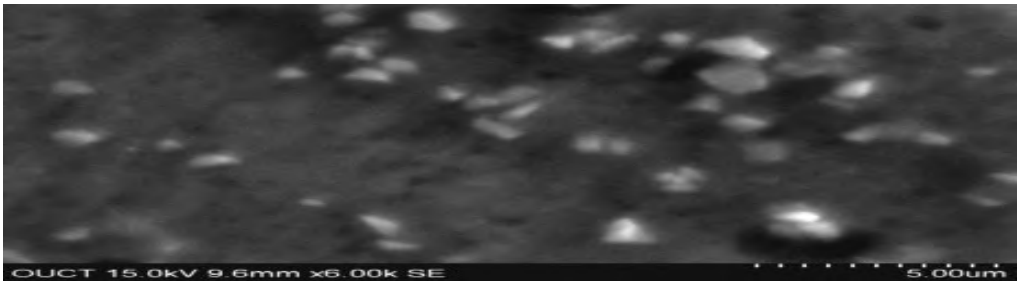


Fig 14: SEM Image of AA5754 with 10% Wt. of titanium diboride and boron carbide

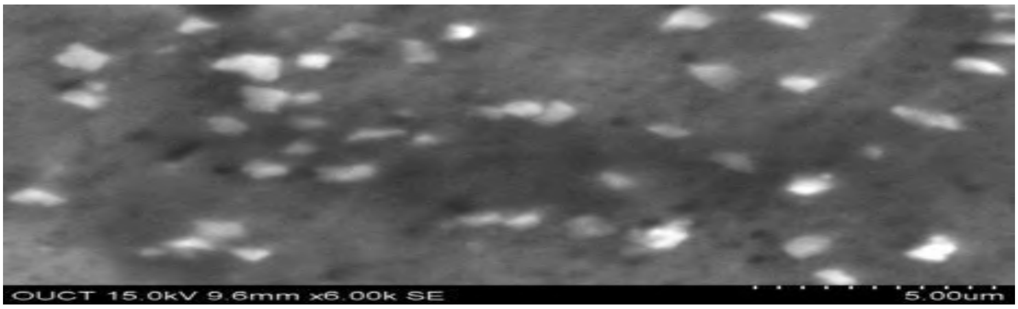


Fig 15:.SEM Image of AA5754 with 15% Wt. of titanium diboride and boron carbide

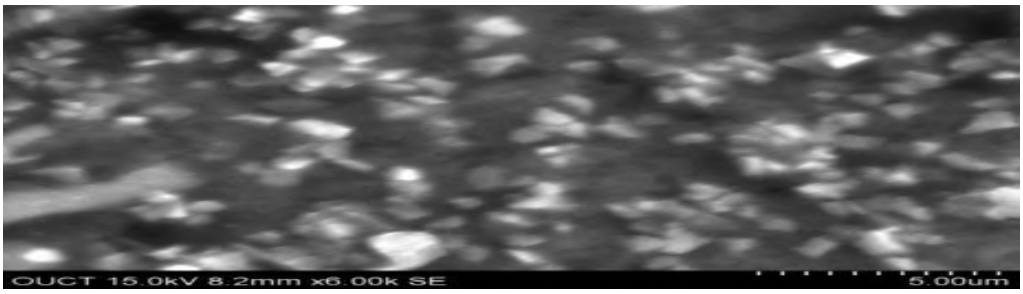


Fig 16: SEM Image of AA5754 with 20% Wt. of titanium diboride and boron carbide

The above images show the dispersion of the Titanium diboride and boron carbide particles in the AA5754 matrix alloy. From the images it is clear that the titanium diboride and boron carbide particles (from 5 to 20 wt. % of size 5µm) were well dispersed in the AA5754 matrix, as shown. Tiny scratches/cracks due to polishing are displayed. High intensity ultrasonic waves have generated strong cavitations and acoustic streaming effects during mixing. Transient cavitations have produced an impulsive impact strong enough to break up the clustered particles and disperse them more uniformly in the liquid.

Qualitative ED analysis

The ED spectrometer is especially useful for qualitative analysis because a complete Spectrum can be obtained very quickly. Aids to identification are provided, such as facilities for superimposing the positions of the lines of a given element for comparison with the recorded spectrum.

In order to verify the composition of the nano-composite, EDS analysis was used. The typical result is shown in Fig below.

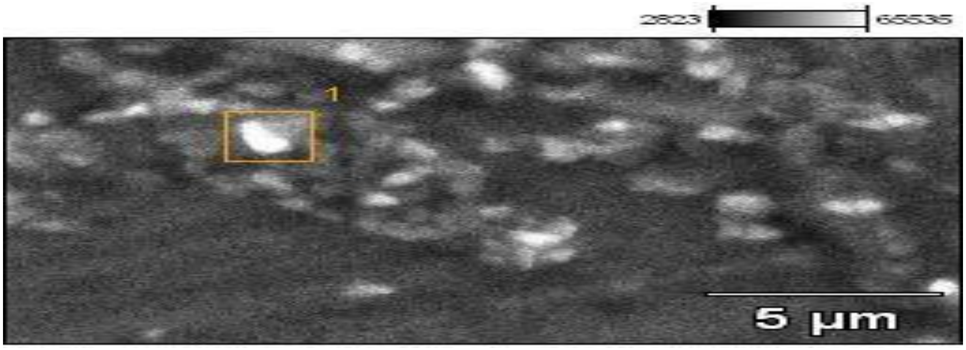


Fig 17: Electron Dispersion Microscope Image

It seems that the composite was protected well during fabrication since the oxidation level is quite low. Since the average size of the Titanium diboride and boron carbide particle is 5µm, it is very difficult to use EDS spot analysis due to the limitation ofthe e-beam resolution in the instrument. Therefore, mapping scanning was employed. Shows the distribution of the elements aluminum (Al), titanium diboride and boron carbide, respectively. The results show that C is distributed uniformly, which indicates a good dispersion of Titanium diboride and boron carbide particles in matrix. From the mapping of Si element, there are some concentrations from the eutectic Si of the alloy.

5. MECHANICAL CHARECTERIZATIONTENSILE STRENGTH :

Fig 18: Piece before breaking in UTM

Fig 19: Piece after breaking in UTM

As observed from the above figures the specimens were subjected to failure almost at the same location. This breaking of the specimens at the same location indicates the uniform distribution of the composite particles in the specimens the stress strain curves were taken as shown below:

1. The ultimate tensile strength value of the raw AL cast alloy was known to be as 263 MPa.
2. On addition of the Titanium diboride and boron carbide for weight per cent 5% the UTS value increased to 282 MPa.
3. On addition of the Titanium diboride and boron carbide for weight per cent 10% the UTS value increased to 304 MPa.
4. On addition of the Titanium diboride and boron carbide for weight per cent 15% the UTS value increased to 288 MPa.
5. On addition of the Titanium diboride and boron carbide for weight percent 20% the UTS value increased to 265 MPa.

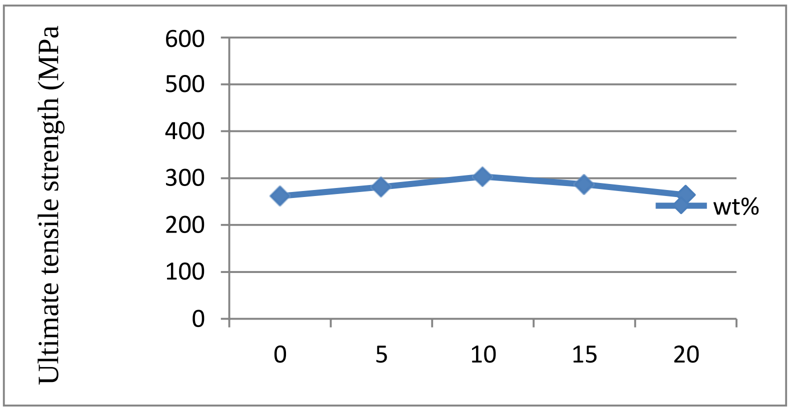


Fig 20: Graph showing **UTS** Vs **Wt (%)**

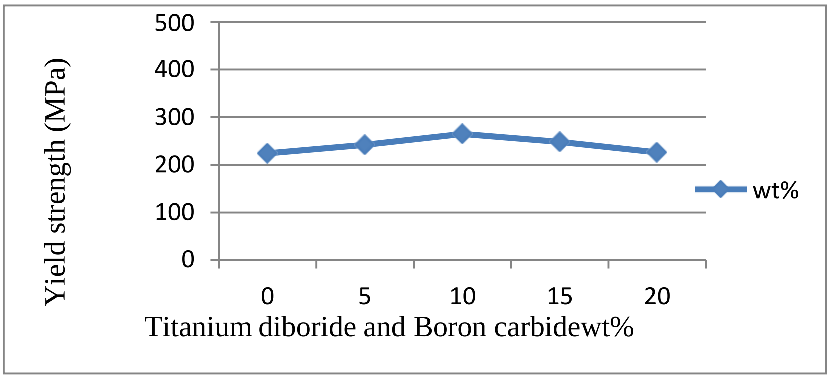
Yield Point:

The Yield point is the point where the elastic deformation stops and the plastic deformation starts. From the stress strain diagrams obtained the following observations are made:

224 MPa is the point where the yielding starts in the case of the plain AA5754.

On addition of the titanium diboride and boron carbide for weight percent 5% the yield strength increased to 242 MPa.

On addition of the titanium diboride and boron carbide for weight per cent 10% the yield strength value increased to 265 MPa.On addition of the titanium diboride and boron carbide for weight percent 15% the yield strength value increased to 248 MPa.On addition of the titanium diboride and boron carbide for weight percent 20% the yield strength value increased to 226 MPa.



From the Fig 21 observations it can be clearly understood that the as the percentage of the nano particles in the composite increase the yield strength value increases which is a positive phenomenon to be observed.

Ductility

Ductility is measured in the terms of the percentage elongation. The elongation percentage for the raw AL cast alloy is said to be 10%. The following observations are observed as the percentage of the Titanium diboride and boron carbide particles increase.

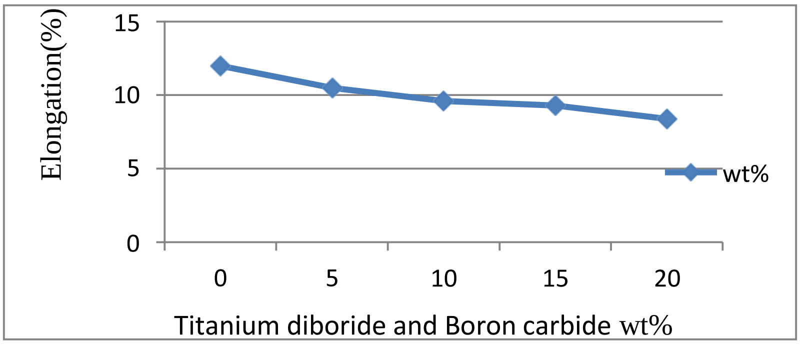


Fig 22: Graph Showing Elongation% Vs Wt%

i. Ductility value on addition of the Titanium diboride and boron carbide for weight per cent 5% is 10.5%.
ii. Ductility value on addition of the Titanium diboride and boron carbide for weight per cent 10% is 9.6%.
iii. Ductility value on addition of the Titanium diboride and boron carbide for weight per cent 15% is 9.3%.

iv. Ductility value on addition of the Titanium diboride and boron carbide for weight per cent 20% is 8.4%

Hardness

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting. Hardness is not an intern Titanium diboride and boron carbide material property dictated by precise definitions in terms of fundamental units of mass, length and time. A hardness property value is the result of a defined measurement procedure. Hardness of materials has probably long been assessed by resistanceto scratching or cutting Micro hardness test.

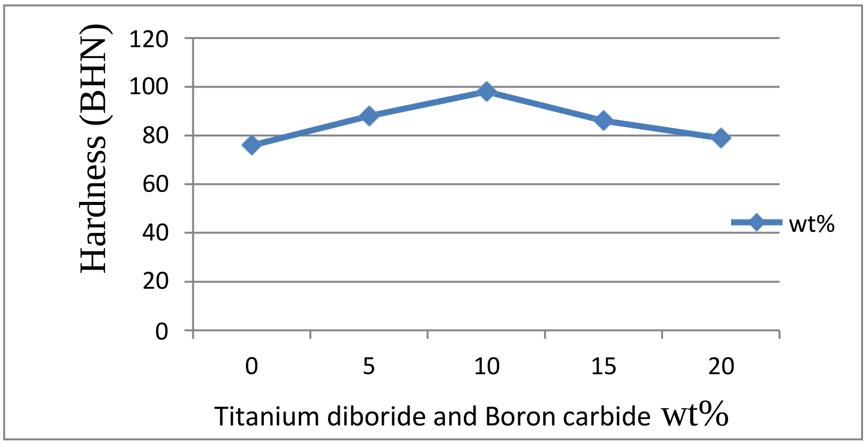


Fig 23: Graph Showing Hardness Vs Wt (%)

The values obtained show that as the composition and the percentage values are increased the hardness values also increased whichis a good sign to be noticed.

5. CONCLUSIONS:

The significant conclusions of the experiment on AA5754- titanium diboride and boron carbide metal matrix composite were as follows. Stir casting method was successfully adopted in the preparation of AA5754- titanium diboride and boron carbide composite containing the reinforcement up to 20%wt. The mechanical properties of the composites are found improved than their base matrix. The micro structural studies revealed the uniform distribution of the particles in the matrix system. Micro-hardness ofthe composites found increases in hardness it will showed that there is a lower %wt of reinforcement. The tensile strength properties of the composite were found higher than that of base matrix that is 263 MPa and AA5754- titanium diboride and boron carbide composites superior tensile strength properties than that the other aluminium5000 series alloy MMCs.

From the studies in overall it can be concluded that AA5754- titanium diboride and boron carbide exhibits superior mechanical and tribological properties. The process parameters affecting the stir casting technique was considered while manufacturing of composites.

- It can be observed from the SEM images and EDS analysis that the particles are well distributed in the base alloy and agglomeration of the particles are greatly reduced, and the melt pool is well protected from the atmospheric conditions.
- In the mechanical characterization the following improvements were observed:
- The ultimate tensile strength of the base alloy is observed to be 263 MPa.
- On addition of the Titanium diboride and boron carbide for weight per cent of 5% the UTS value increased to 282 MPa.
- On addition of the Titanium diboride and boron carbide for weight per cent of 10% the UTS value increased to 304 MPa.
- On addition of the Titanium diboride and boron carbide for weight per cent of 15% the UTS value increased to 288 MPa.
- On addition of the Titanium diboride and boron carbide for weight per cent of 20% the UTS value increased to 265 MPa.
- 224 MPa is the value where the yielding starts for the base alloy.
- On addition of the Titanium diboride and boron carbide for weight percent 5% the yield strength increased to 242 MPa.
- On addition of the Titanium diboride and boron carbide for weight percent 10% the yield strength value increased to 265MPa.
- On addition of the Titanium diboride and boron carbide for weight percent 15% the yield strength value increased to 248MPa.
- On addition of the Titanium diboride and boron carbide for weight percent 20% the yield strength value increased to 226MPa.
- Ductility value on addition of the Titanium diboride and boron carbide for weight per cent 5% is 10.5%.
- Ductility value on addition of the Titanium diboride and boron carbide for to weight per cent 10% is 9.6%.

- Ductility value on addition of the Titanium diboride and boron carbide for weight per cent 15% is 9.3%.
- Ductility value on addition of the Titanium diboride and boron carbide for weight per cent 20% is 8.4%.
- With up to 10% addition of Titanium diboride and boron carbide Mechanical properties are enhanced and with further addition of Titanium diboride and boron carbide the properties starts decreasing.

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Author's Details

P.Veerendra, working as Asst. Professor & HOD, Dept of ME,
Kakinada Institute of Engineering & Technology-II, KIET-II.
Korangi, Yanam Road, Andhra Pradesh-533461.

V. Veera Venkata Phanindranadh, P.G. Student (Machine Design),
Dept of ME, Kakinada Institute ofEngineering & Technology-II, KIET-II.
Korangi, Yanam Road, Andhra Pradesh-533461.