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Fabrication and Micro structural analysis of LM13/B_4C/Gr Hybrid Metal Matix Composite

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Abstract : Due to the inimitable sliding lubricating effect of graphite, aluminum/graphite composites are utilized as self-lubricating materials. The adverse effect of graphite on mechanical properties of composites is the biggest problem for utilizing aluminum graphite composites in industrial elements. Superior tribological behavior compared to aluminum alloys or A1/Gr composites can be attained using hybrid aluminium matrix composites which incorporate ceramic particles and graphite particles. Solid lubricant property of graphite and load bearing ability of ceramic particles are added beneficial of hybrid composites accompanied by declining wear rate. This work deals with the fabrication of the LM13 reinforced with Boron carbide and Graphite particulates by Stir Casting method. Addition of hard reinforcements such as Boron carbide raises strength, hardness, and wear resistance of the composites. AMCs reinforced with Graphite particles have better wear characteristics resulting reduced wear because of formation of a thin layer of Graphite particles, which prevents metal to metal contact of the sliding surfaces. Composite materials were fabricated by reinforcing boron carbide 3%, 5%, 7% and graphite at 2% with the LM13 matrix respectively. Sliding components such as Piston, Bearings, Sheaves, Gears and Pulleys are mainly focused.
Keywords : Boron carbide, Graphite, Hybrid Metal Matrix composite.

Introduction

Aluminium matrix composites when compared with Traditional alloys receives predominant popularity in various technical sectors due to their outrageous feeble life, light weight nature, superior wear and corrosion resistance, excellent elevated temperature oxidation resistance. Due to their superior stiffness to weight properties aluminium matrix composites is used in aeronautical and automobile areas. At the present time, development of aluminium, magnesium, copper, titanium based metal matrix composites is focused in order to investigate their feasible applications in various sectors. The various reinforcements that have been tried out to develop AMCs are graphite, fly ash, alumina, silicon carbide, graphite, boron carbide, titanium carbide, tungsten etc are the commonly used reinforcements. Commonly used materials have some limitations in various properties such as density, stiffness and strength.

Particles, continuous or discontinuous fibres were reinforced in metal matrix composites for achieving required high specific modulus and strength. Required properties such as fatigue strength, better electrical and thermal conductivities, high temperature strength, expansion coefficient, friction coefficient,wear resistance and damping property can be also sustained during composite preparation [1]. Due to the best lubricating effect of graphite during sliding it's used in aluminum/graphite composites as self-lubricating materials. Material factors such as size &percent added and mechanical factors such as sliding speed & applied loads have effect on the tribological properties. Self-lubricating composites are the modern era's requirement to decrease the usage of harmful external petroleum-based lubricants in sliding contacts such as pistons, bearings, sheaves etc .This helps to meet reduced environmental pollution and better sustainability and efficiency in energy management can be achieved.[2]The microstructure of the AA6061-B_4C-Gr hybrid composite fabricated by stir-casting method could be seen that the boron-carbide and graphite particles are distributed uniformly, bonding well with the aluminum matrix. The interface between the Al-matrix, boron-carbide and graphite particles is clean allowing a strong interfacial bonding. No agglomeration of the particles was observed in the composite.[3]Commonly used reinforcements in aluminium matrix composites are alumina, silicon carbide, graphite etc.

Boron carbide is the third hardest material in the world after diamond and boron nitride. Due to higher hardness and toughness boron carbide is employed as a replacement to Silicon carbide and Alumina. Good toughness, low density, enhanced chemical stability, and hardness, better wear resistance and high strengths are the attractive properties of boron carbide composites [4]. Due to the better wettability of the boron carbide particles with the aluminium alloy, homogeneous reinforcement distribution can be achieved. Hardness of the composites gets increased by increasing the wt % of boron carbide particles in the aluminium matrix. This phenomenon is due to the resistance of reinforcement particles to the plastic deformation of matrix material. Up to 8 wt % boron carbide reinforcement, tensile strength increases. Beyond 8%, reduction of tensile strength occurs due to the clustering of reinforcement particles which leads to brittleness. Structural and automotive components of better mechanical properties are developed using this metal matrix composite [5]. Important processing techniques are liquid metallurgy and powder metallurgical techniques .Comparing both techniques liquid techniques are adaptive.

There is unidirectional solidification in liquid metallurgy to produce directional metal matrix composites. Famous liquid metallurgy techniques are stir casting, spray casting and pressure infiltration. Comparing to other methods liquid metallurgy techniques were selected due to their inexpensive nature [6].

Experimental- Materials and methodology

1. LM13

LM 13 aluminium alloy being selected as the base matrix in this research work. It is often used for piston, pulleys, sheaves and bearings and other areas where higher thermal stresses are occurring. Capability to withstand high temperature and loads, good wear resistance and better machinability makes LM13 favourable for such applications.

Table1. Mechanical properties of LM13

Properties	Values
Density (kg/m3)	2700
Tensile strength (Mpa)	170-200
Melting point(°C)	695
Poison's ratio	0.36
Young's modulus (Gpa)	86

2. Boron carbide

After diamond and cubic boron nitride, Boron carbide is the third hardest material. Elevated temperature stability, better hardness and elastic modulus, low density, outstanding thermoelectric properties and greater chemical inertness of boron carbide than alumina and silicon carbide results it a favourable reinforcement for metal matrix composites. Compared to aluminum matrix and silicon carbide, interfacial bonding between the aluminum matrix and the boron carbide reinforcement is more effective.

Table 2. Mechanical properties of Boron carbide

Properties	Values
Density (kg/m3)	2550
Tensile strength (Mpa)	500
Melting point(°C)	3500
Poison’s ratio	0.17
Young’s modulus (Gpa)	460

3. Graphite

Generally graphite is opaque and have greyish-black colour. Both metal and non-metal properties make it unique. Greater electrical and thermal conductivity, flexibility, high refractory nature and chemically inertness are dominant properties of graphite. Low adsorption of neutrons and X-rays make graphite a helpful material in nuclear sectors. It’s engineering applications also extend to vanes, journal bearings, piston rings and thrust bearings. In the fuel pumps and shafts of many aircraft jet engines carbon based seals are used

Table 2. Mechanical properties of Graphite

Properties	Values
Density (kg/m3)	1950
Tensile strength (Mpa)	76
Melting point(°C)	3800
Poison’s ratio	0.21
Young’s modulus (Gpa)	12

4. Stir casting

Stir casting apparatus is shown below. For the fabrication of metal matrix composites it has a graphite crucible which is in cylindrical shape.This crucible is designed in such a way that it is capable of holding higher temperature.As the melting point of graphite is around 3800 degree Celsius. It will not react with aluminum at working temperature.Graphite crucible is positioned on high ceramic alumina muffle.Initially heater temperature is set to 500°C and then it is steadily increased up to 900°C. LM13 is used as matrix material. From the aluminium alloy ingots needed quantity is chopped in rectangular pieces. Properly cleaned Aluminum alloy is weighed and then placed in the graphite crucible for melting. Graphite and boron carbide Powder are used as reinforcements.Melting point of LM13 alloy is 695 degree celsius and due to high muffle temperature it is quickly melted. Elevated temperature also results in lowered oxidation level and intensified wettability of the reinforcement particles in the matrix metal [6].


Fig 1. Stir casting equipment.Fig 2. Casting process

Molten composite mixtures were poured in to the prepared cast specimen moulds. After solidification of the molten mixtures casted specimens were taken out. Proper machining were performed on lathe machine so that test specimens of required dimensionsas per ASTM A370:2015, ASTM E18:2014 and ASTM G99-04 were prepared with high accuracy. Compositions of four prepared samples are given below

Sample 1: LM13/ Gr 2%

Total 500 g

- 490 g of LM13 ,10 g of Gr

Sample 2: LM13/ Gr 2% / B4C 3%

Total 500 g

- 474 g of LM13, 16 g of B_4C,10 g of Gr

Sample 3: LM13/ Gr 2% / B4C 5% ,Total 500 g ie. 464 g of LM13, 26 g of B4Cand 10 g of Gr

Sample 4: LM13/ Gr 2% / B4C 7%. Total 500 g ie.454 g of LM13, 36 g of B4Cand 10 g of Gr

Fig 3. Cast specimens.Fig 4. Test specimens

5. Microstructural analysis

Resolutions upto the light wavelength can be measured using optical microscopes. For understanding the microstructure and relationship between properties the examination of materials by optical microscopy is essential. Study of metals by optical examination is known as metallography. A conventional light microscope is used for this purpose. Coarse structures which are recognizable to the naked eye are macrostructures. Toobserve microstructures, it require magnification. For doing Microstructure analysis, sawing is done as the first operation exactly at the section where microstructure is to be studied. In case of samples having less thickness and size, they are mounted in a resin mould to enable coarse grinding. Then using fine grid emery, hand polishing is done. Nextpolishing is doneon rotating wheel using alumina powder or diamond paste. Finally using dilute acid, etching is performed followed by washing and drying[7]. Microstructural images of samples are given below.

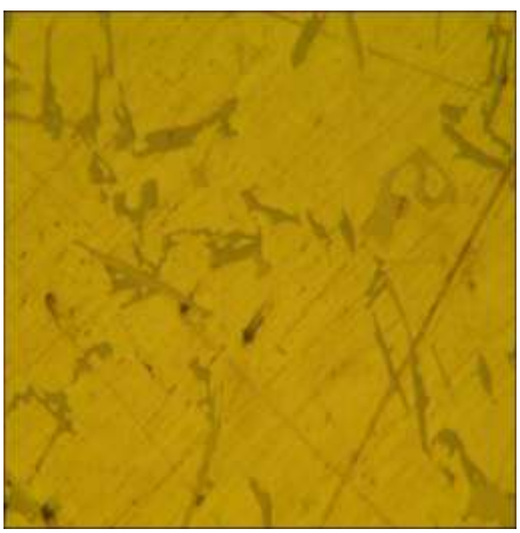

Fig 5. Sample 1 (LM13 /Gr 2%)

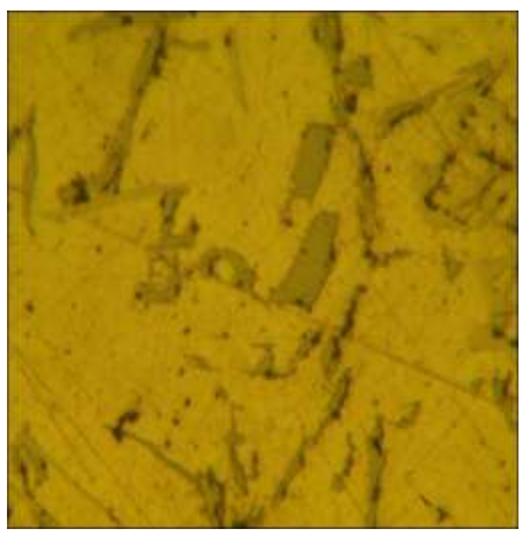

Fig 6. Sample 2 (LM13 /B_4C 3% /Gr 2%)

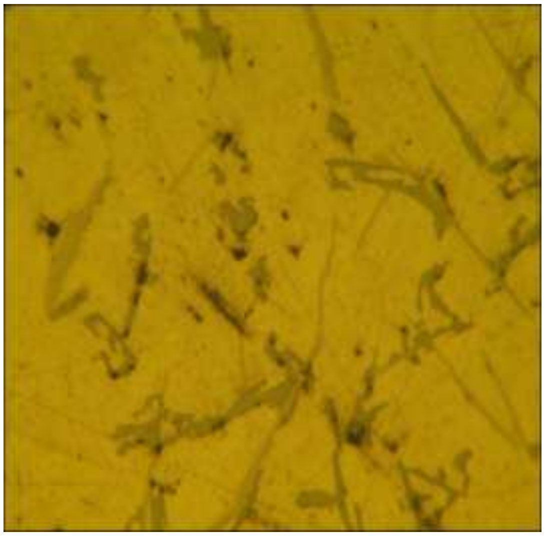

Fig 7. Sample 3 (LM13 /B_4C 5% /Gr 2%)

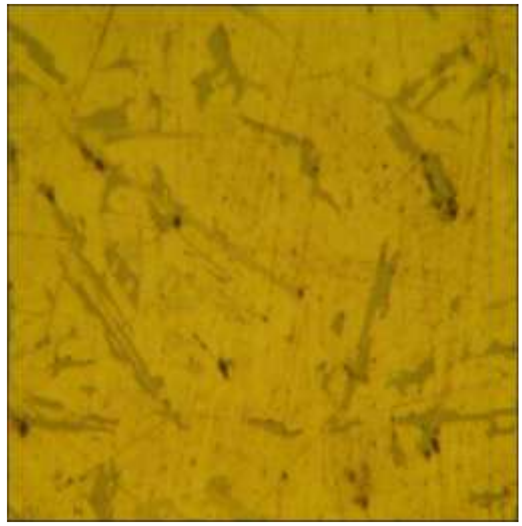

Fig 8. Sample 4 (LM13 /B_4C 7% /Gr 2%)

Results and Discussion

From the microstructure examination of the specimens prepared, homogeneous reinforcement distribution is discovered. Greater wettability of the boron carbide particles with the LM13 alloy is the reason for the homogeneity. Formation of liquid B_2O_3 layer on the boron carbide particles is the reason for wettability. Above certain temperature liquid layer is formed on the surface of boron carbide and the wettability increases due to liquid–liquid reaction [8]. Due to better bonding between the matrix and reinforcement particles less porosity is observed.

Conclusion

Due to enhanced properties obtained by adding various reinforcements, aluminium matrix composites are far better than aluminium alloys. Using stir casting procedure, LM13/B_4C/Gr aluminium matrix composites with varying wt % of 3, 5, and 7 are fabricated along with LM13/Gr 2% composite. Uniform distribution ofreinforcementparticulates on aluminum matrix can be achieved with the stir casting technique. Due to the greater wettability of the boron carbide particles with the matrix alloy homogenous dispersion was observed. Also from literature it has been understood that by increasing the wt % of boron carbide particles in the aluminium matrix, mechanical properties of the self lubricating composites can be improved.

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