Fabrication and mechanical properties evaluation of AL LM 27 alloy reinforced with boron carbide

G R Krishna prasad yadav1[a], J Kishore2[b],Dr R Meenakshi reddy3c
[a]*Department of mechanical engineering GPREC Kurnool-518007 Andhra Pradesh India*
[b]*Department of mechanical engineering GPREC Kurnool-518007 Andhra Pradesh India*
[c]*Department of mechanical engineering GPREC Kurnool-518007 Andhra Pradesh India*

*Corresponding author Email: ___guggulakrishna@gmail.com_____________________________

ABSTRACT

Since a piston is subjected to very high temperature condition along with extreme and sudden compression and tensile forces on combustion as well as on thrust sides, it calls for a material which has very high strength to weight ratio and has very high heat conductivity in order to minimize thermal fatigue. Usually sand-cast or die-cast aluminium is used for engines. pistons made of aluminium alloys are preferred when the alloys are lighter than their cast iron counter parts, provide suitable strength at high temperatures and show good thermal properties.

Aluminium and its alloys have an ever growing demand in many industries such as aerospace, automotive due to their high strength to weight ratio and corrosion resistance. Our current work focuses on synthesis and tribological studies of aluminium LM27, boron carbide composites. In this case AL LM27 and boron carbide is reinforced with metal matrix composite in different percentages. Which results in higher tensile strength, hardness and significantly improved wear resistance as compared to the base alloy.

Keywords: AL-LM27, boron carbide, stir casting.

INTRODUCTION

Composite materials:

A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. However, within the composite you can easily tell the different materials apart as they do not dissolve or blend into each other.

Natural composites:

The bone in your body is also a composite. It is made from a hard but brittle material called hydroxyapatite (which is mainly calcium phosphate) and a soft and flexible material called collagen (which is a protein). Collagen is also found in hair and finger nails. On its own it would not be much use in the skeleton but it can combine with hydroxyapatite to give bone the properties that are needed to support the body.

Early composites:

People have been making composites for many thousands of years. One early example is mud bricks. Mud can be dried out into a brick shape to give a building material. It is strong if you try to squash it (it has good compressive strength) but it breaks quite easily if you try to bend it (it has poor tensile strength). Straw seems very strong if you try to stretch it, but you can crumple it up easily. By mixing mud and straw together it is possible to make bricks that are resistant to both squeezing and tearing and make excellent building blocks.

Modern example:

The first modern composite material was fibreglass. It is still widely used today for boat hulls, sports equipment, building panels and many car bodies. The matrix is a plastic and the reinforcement is glass that has been made into fine threads and often woven into a sort of cloth. On its own the glass is very strong but brittle and it will break if bent sharply. The plastic matrix holds the glass fibres together and also protects them from damage by sharing out the forces acting on them.

Why use composites?

The biggest advantage of modern composite materials is that they are light as well as strong. By choosing an appropriate combination of matrix and reinforcement material, a new material can be made that exactly meets the requirements of a particular application. Composites also provide design flexibility because many of them can be moulded into complex shapes. The downside is often the cost. Although the resulting product is more efficient, the raw materials are often expensive.

Matrix:

The matrix is the monolithic material into which the reinforcement is embedded, and is completely continuous. This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together. In structural applications, the matrix is usually a lighter metal such as aluminum, magnesium, or titanium, and provides a compliant support for the reinforcement. In high-temperature applications, cobalt and cobalt–nickel alloy matrices are common.

Metal matrix composite (MMC):

A metal matrix composite (MMC) is composite material with at least two constituent parts, one being a metal necessarily, the other material may be a different metal or another material, such as a ceramic or organic compound. When at least three materials are present, it is called a hybrid composite.

MMCs are made by dispersing a reinforcing material into a metal matrix. The reinforcement surface can be coated to prevent a chemical reaction with the matrix. For example, carbon fibers are commonly used in aluminium matrix to synthesize composites showing low density and high strength. However, carbon reacts with aluminium to generate a brittle and water-soluble compound Al_4C_3 on the surface of the fibre. To prevent this reaction, the carbon fibres are coated with nickel or titanium boride.

Types of MMCs:

Metal matrix composites (MMCs) comprise a relatively wide range of materials defined by the metal matrix, reinforcement type, and reinforcement geometry. In the area of the matrix, most metallic systems have been explored for use in metal matrix composites, including Al, Be, Mg, Ti, Fe, Ni, Co, and Ag. By far the largest usage is in aluminum matrix composites.

From a reinforcement perspective, the materials used are typically ceramics since they provide a very desirable combination of stiffness, strength, and relatively low density. Candidate reinforcement materials include SiC, Al_2O_3, B_4C, TiC, TiB_2, graphite, and a number of other ceramics. In addition, there has been work on metallic materials as reinforcements, notably W and steel fibers.

Significance of MMCs:

Metal matrix composite materials (MMCs) possess superior combinations of elevated-temperature capabilities, high thermal conductivity, high strength and stiffness, high strength-to-density ratio, and low coefficient of thermal expansion.

MMCs offer various mechanical properties that are not offered by conventional unreinforced monolithic metal counterparts; specifically, high temperature stability, specific strength, and wear resistance. In comparison with conventional polymer matrix composites, MMCs are resistant to fire, can operate in wider range of temperatures, do not absorb moisture, have better electrical and thermal conductivity, are resistant to radiation damage, and do not display outgassing.

Applications:

Over last two decades researchers and manufacturers, i.e., automotive and aerospace, have paid attentions and interests to metal–matrix composites (MMC) owing to their unique physical/mechanical properties and performance.

Some tank armours may be made from metal matrix composites, probably steel reinforced with boron nitride.

- High performance tungsten carbide cutting tools.
- Some automotive disc brakes use MMCs.
- Ford offers a Metal Matrix Composite (MMC) driveshaft upgrade. The MMC driveshaft is made of an aluminum matrix reinforced with boron carbide.
- Honda has used aluminum metal matrix composite cylinder liners in some of their engines.
- Specialized Bicycles has used aluminum MMC compounds for its top of the range bicycle frames for several years.

Reinforcement:

The reinforcement material is embedded into a matrix. The reinforcement does not always serve a purely structural task (reinforcing the compound), but is also used to change physical properties such as wear resistance, friction coefficient, or thermal conductivity. The reinforcement can be either continuous, or discontinuous. Discontinuous MMCs can be isotropic, and can be worked with standard metalworking techniques, such as extrusion, forging, or rolling. In addition, they may be machined using conventional techniques, but commonly would need the use of polycrystalline diamond tooling (PCD).

Continuous reinforcement uses monofilament wires or fibers such as carbon fiber or silicon carbide. Because the fibers are embedded into the matrix in a certain direction, the result is an anisotropic structure in which the alignment of the material affects its strength. One of the first MMCs used boron filament as reinforcement. Discontinuous reinforcement uses "whiskers", short fibers, or particles. The most common reinforcing materials in this category are alumina and silicon carbide.

Classifications of Reinforcements:

Fig.1 Classifications of Reinforcements

Stir casting:

Mix Throwing is a fluid state technique for composite materials manufacture, in which an irregular fortification is blended with a liquid lattice metal by methods for mechanical mixing. The layout of conventional Stir Casting set up is shown in figure.

Aluminum metal matrix composites (AMMCs) have gained significant attention in recent years. Thisis primarily due to their lightweight, low coefficient of thermal expansion (CTE), machinability, and improved mechanical properties, such as increased 0.2% yield stress (YS), ultimate tensile stress (UTS), and hardness. Due to these advantages, they are used in aerospace industries (airframe and aerospace components), automobile industries (engine pistons), and electronic components. Stir casting (vortex technique) is generally accepted commercially as a low-cost method for fabricating AMMCs. Its advantages lie in its simplicity, flexibility, and applicability to large volume production. This process is the most economical of all the available routes for AMMCs production, and it allows very large-sized components to be fabricated.

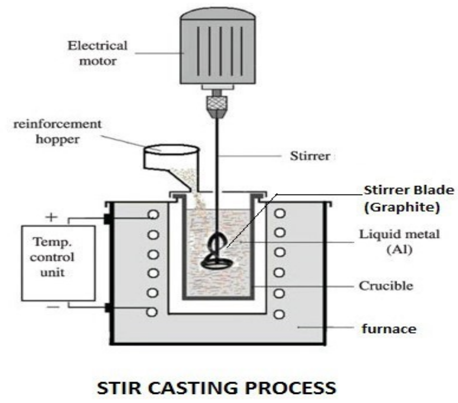

Fig.2 Stir casting process

However, methods of achieving the following in stir casting most be considered:
(i) No adverse chemical reaction between the reinforcement material and matrix alloy,
(ii) No or very low porosity in the cast AMMCs,
(iii) Wettability between the two main phases, and
(iv) Achieving a uniform distribution of the reinforcement material.

Table-1 Chemical composition of AL LM-27

Copper	1.5-2.5
Magnesium	0.35 max
Iron	0.8 max
Silicon	6.0-8.0
Manganese	0.2-0.6
Nickel	0.3 max
Zinc	1.0 max
Lead	0.2 max
Tin	0.1 max
Titanium	0.2 max
Aluminium	Remainder
Others: each	0.05 max
Others: total	0.15 max

Mechanical Properties of LM27 Alloy:

Machinability,Corrosion,Resistance,Heat treatment, Anodising, Strength At Elevated Temperatures.

Selection of reinforcement:

Aluminum has exceptionally poor wear opposition contrasted with ferrous composites. To build the hardness and wear properties of aluminum amalgam, support must have generally high hardness

and wear opposition. Earthenware production are the materials which remained in the best and well in front of ferrous composites. On the off chance that we can make a sound composite with earthenware production as fortification, at that point the composite may have predominant characteristics identical or superior to anything the ferrous combinations.
For the improving the above mechanical properties we selected the Boron carbide (B_4C).

Boron carbide (B_4C):

Fig.3 Boron carbide

Boron carbide (chemical formula approximately B_4C) is an extremely hard boron–carbon ceramic, and covalent material used in tank Armor, bulletproof vests, engine sabotage powders, as well as numerous industrial applications. With a Vickers Hardness of >30 GPa, it is one of the hardest known materials, behind cubic boron nitride and diamond.

uses of B_4C:

- Padlocks
- Personal and vehicle anti-ballistic Armor plating.
- Grit blasting nozzle.
- High-pressure water jet cutter nozzles.
- Scratch and wear resistant coatings.
- Cutting tools and dies.
- Abrasives.
- Neutron absorber in nuclear reactors.
- Metal matrix composites.

Experimental Procedure:

After the die casting of samples, the following operations were performed.

- Specimens were freed from dies and turned to required dimensions on a lathe machine and then polished.
- Brinell Hardness test was conducted on the specimens. Average values were noted

Fig.4 Specimen of BHN

- Tensile test was conducted on turned samples with the help of Tensometer testing machine. And average values of each composition were noted.

Fig.5 Tensile test specimen

- Wear test was conducted on the specimens with the help of Wear testing machine and values are noted

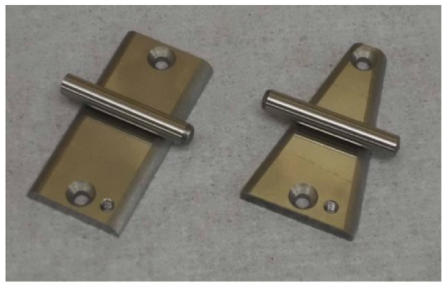

Fig.6 Wear test specimen

Results:

After heat treatment of all samples, each sample was separately tested for the wear, hardness and tensile strength and the average values were analysed by comparing with the zero sample. The results in various tests were discussed below.

Pure LM-27 alloy samples were referred as group-0, LM-27 with 2.5% B_4C samples were referred as group-1, LM-25 with 5% B_4C samples were referred as group-2, LM-27 with 7.5% B_4C as a group-3, LM-27 with 10% B_4C as a group-4, LM-27 with 12.5% B_4C as a group-5.

………………………Eq.s-1

....…………Eq.s-2

Table-2 Resulted values

Group no.	Load for breaking stress(Kg)	Load for BHN, kg	Load for wear resistance (Kg)	Breaking stress	% elongation in length	BHN,	Wear rate
0	320	500	5	150	2	82.5	158
1	400	500	5	166.213	2.606	129.139	48
2	430	500	5	160.336	0.995	157.54	45
3	300	500	5	136.836	1.477	118.73	39.5
4	310	500	5	143.4	1.38	118.73	85.5
5	400	500	5	178.3	3.889	108.9	47.5

Conclusion:

From the experimental and analysis on the LM-27 reinforced with Boron carbide we concluded that the mechanical properties such as Hardness, Wear resistance and Breaking stress were successfully increased and fortunately we decrease the % elongation from 2 to 0.995 for the application of casting of piston.

From the evaluated values better to go with Group-2 values (5% B_4C), its satisfied the above mechanical properties. After Group-2 values the values were predominantly fluctuated

References:

1. **Journal article:**

- Gray, Theodore (2012-04-03). The Elements: A Visual Exploration of Every Known Atom in the Universe. Black Dog & Leventhal Publishers. ISBN 9781579128951. Retrieved 6 May 2014.
- S. Das, 2004. Development of Aluminum Alloy Composite for Engineering Applications, Indian Institute of Materials, 27 (4), pp. 325-334
- B.C., Pai, R.M., Pllia, and G., Satyanaryanak, 1993. Stir Cast Aluminum Alloy Matrix, Key Engineering Materials, 79-80, pp. 117 128.
- Vibunanthan.M, Vidhusan.C, and vignesh.S., Machinability studies of turning aluminium-SiC-B4C hybrid metal matrix composite using ANOVA analysis" International conference on thermal, material and mechanical engineering, July 15-16, 2012, Singapore.
- Rohatgi P K, Cast Aluminum Metal Matrix Composite, JOM (April, 1991), 35.
- Goretta K C, Wu W, Routbort J L, Rohatgi P K in P.K.Rohatgi, P.K.Blau, C.S.Yust, Tribology of Composite Materials (eds.), ASM International, OH, (1990) 147.

- Arivumangai, T. Felixkala, Strength and Durability Properties of Granite Powder Concrete, Journal of Civil Engineering Research, Vol. 4 No. 2A, 2014, pp. 1-6. doi: 10.5923/c.jce.201401.01. ..... 3, Void content (Vv/V): 2.25. 4.

2.Web sites:

- http://www.cast-alloys.com/products/lm_chart.htm
- http://www.aluminiumcastingseurope.co.uk/technical-data/