Evaluation of Mechanical Properties of ZA-27 / Quartz Metal Matrix Composites

Dr.P.V.Krupakara[1] S.G.Abhilash[2]
[1]Professor & Head [2]Assistant Professor
[1]Department of Chemistry [2]Department of Mechanical Engineering
[1,2] Adarsha Institute of Technology, Bangalore-562112

Abstract— This paper deals with the evaluation of mechanical properties of the metal matrix composites when compared with that of matrix alloy. Matrix selected is ZA-27 and reinforcement selected is quartz particulates, which is a ceramic material. The composites are prepared using liquid melt metallurgy technique using vortex method. Metal matrix composites containing 2, 4 and 6 weight percentage of quartz are prepared. Bar castings are machined to get the specimens. Mechanical properties like Ultimate tensile strength, compression strength, hardness and percentage elongation values were found to be higher than matrix alloy. Hence it can be concluded that the composites are more suitable than the alloy matrix for mechanical applications.

Key words: Composites, Vortex, Particulates, Quartz, Compression, Elongation

I. INTRODUCTION

Designers get many advanced benefits in designing the components for automobile and aircraft industry through metal matrix composites (MMCs). These materials maintain good strength at high temperature, good structural rigidity, dimensional stability and light weight.[1-5] The trend is towards safe usage of the MMC parts in the automobile engine which work particularly at high temperature and pressure environments.[6-7] For the last two decades particulates reinforced MMCs has been the most popular.

ZA alloy MMCs have most popular families being represented by ZA-27 alloy reinforced with ceramic particulates. By the addition of second phase into matrix material enhances not only physical and mechanical properties, but also changes the corrosion behaviour significantly. In industries ZA alloys are used extensively with respect to their excellent fluidity, castability and mechanical properties. For the past few years ZA family of alloys has been used widely among zinc based foundry alloys. ZA alloys have got many advantages over the aluminium based ones, especially with respect to high strength with a low casting temperature.[6] These alloys have very good tribological properties.[7] These alloys are also used to various wear resistant application. Lo et.al[9] found that ZA alloys are having better properties than copper, aluminium and cast iron. ZA-27 alloys have been used in bearing and bushing application as a replacement for bronze bearing owing to their low cost and equivalence or superior performance.[10] ZA-27 alloy have a relative high strength compared to a Zinc or aluminium alloy with a low melting temperature.[11] Hence this ZA-27 is the matrix alloy in the present research.

Very little research has taken place so far with respect to the mechanical behaviour of these ZA - 27 alloys. The aim of the present research is to study the Mechanical properties like Ultimate tensile strength, compression strength, hardness and percentage elongation of these ZA-27 alloys reinforced with ceramic particulates like quartz.

II. EXPERIMENTAL PROCEDURE

A. Materials Selection

ZA-27 alloy, which exhibits excellent casting properties and reasonable strength, was used as base alloy. This alloy is best suited for mass production of lightweight metal casting. The chemical composition of ZA-27 alloy is given in Table 1.

Aluminium	Copper	Magnesium	Zinc
26-28%	2-2.5%	0.01-0.02%	Balance

Table 1 Composition Of ZA-27.

Quartz is used as reinforcement in the form of particulates. It has got a layered structure. It has a specific gravity of 2.55, with hardness of 6.0 on the Mohr's scale.

B. Composite Preparation

The liquid metallurgy route using vortex technique[12] is employed to prepare the composites. A mechanical stirrer was used to create the vortex. The reinforcement material used was quartz particulates of size varying 50-80 µm. The weight percentage of quartz used was 2-6 weight percentages in steps 2%. Quartz is added in to the molten ZA-27 alloy melt by creating a vortex in the melt using a mechanical stainless steel stirrer coated with aluminite (to prevent migration of ferrous ions from the stirrer material to the zinc alloy). The stirrer was rotated at a speed of 450 rpm in order to create the necessary vortex. Pre heated but uncoated quartz particulates of 50-80 microns were added in to the vortex slowly. . Castings were produced in permanent moulds in the form of cylindrical rods. [Diameter 30mm and length 150mm] The castings of composites were subjected to machining in CNC lathe to get the specimens for mechanical properties. The matrix alloy was also casted under identical conditions and machined for comparison.

C. Specimen Preparation

The test specimens were prepared by machining from the cylindrical bar castings. The samples for tensile test, each specimen having 10mm dia X 50mm gauge length in size, specimen for compression strength and hardness 20 mm length x 20 mm dia were machined according to BS: 18: 1962 test standards.[13]

III. RESULTS AND DISCUSSION

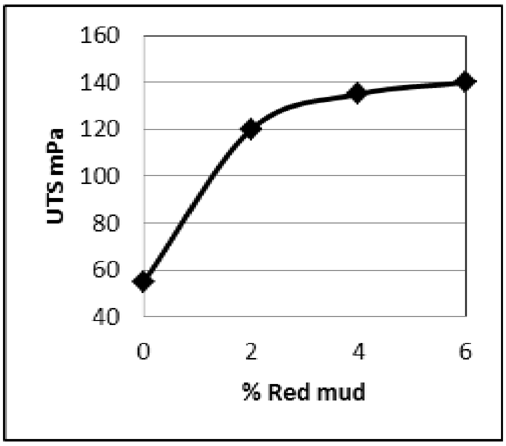

Fig. 1: UTS of Matrix and MMCs

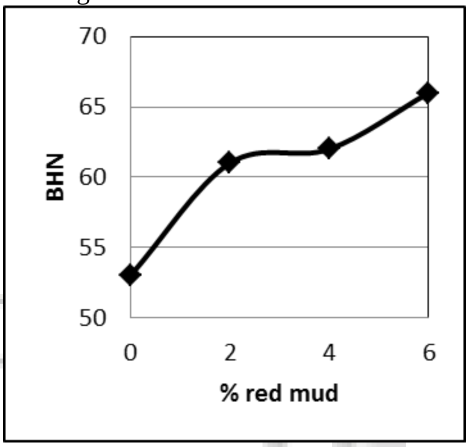

Fig. 2: Hardness of Matrix and MMCs

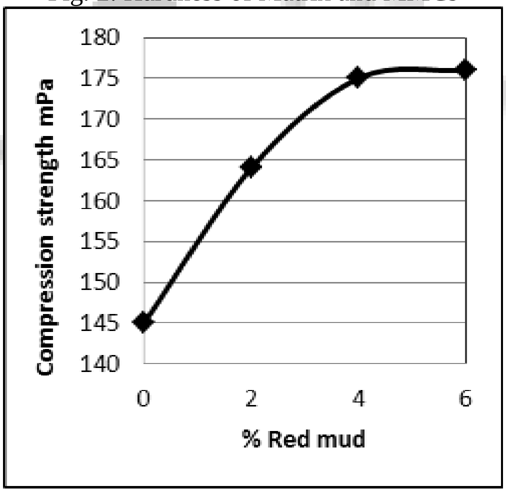

Fig. 3: Compression strength of Matrix and MMCs

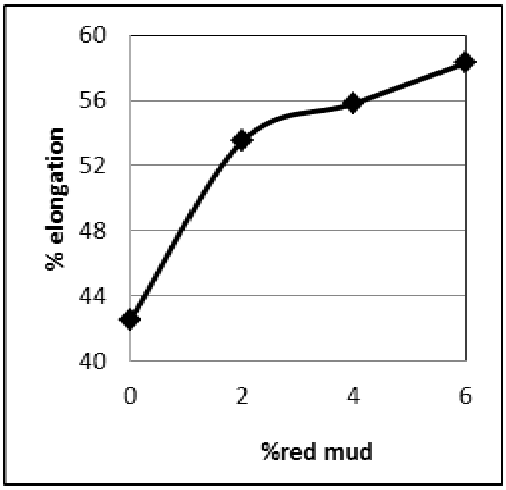

Fig 4: Percentage Elongation of Matrix and MMCs

Figure 1 shows a gradual increase in UTS of the material corresponding to the increase in the percentage of red mud content. The curves in the Figure are very steep and this is understandable by the fact that UTS values have characteristic behaviour somewhat analogous to the plastic region in the stress strain curve in mild steel. However the difference exists in the fact that while for mild steel there is non-proportionality between stress and strain, there is a proportional relation even up to the UTS range. The material has more tendencies to resist the tensile load.

The variation of Brinell hardness (BH) of composites of aluminium is plotted in Figure 2. Totally five specimens for each composite has been tested. For each composite hardness increases with the content of red mud particulates in the aluminium matrix. Resistance to the indentation carried out by means of BH test against an increase of red mud content shows a substantial improvement for a larger percentage of zircon addition. The resistance to indentation is a measure of the ability of the material to bear static loads, abrasion, surface deformation etc. It is to be noted from the Figure that it is not essential that higher tensile strength and corresponding hardness value should be directly proportional to one another. (370-373)

Figure 3 shows the variation of the compression tests with respect increase in the percentage of red mud content in the aluminium matrix. Curves evidently show that for increasing proportion of the reinforcement, compression strength also increases. A close study of the Figure indicates that the compressive strength increases with the red mud particles in the matrix. It leads to the conclusion that the addition of red mud does not promote cohesion between the bonds and that intermolecular spaces do exist. This is directly opposed to the concept of inter atomic bonds where the cohesiveness is greatly improved because the inter atomic forces are much strong. As a result the intermolecular spaces have to be filled up. This is achieved by compressing the material. The intermolecular spaces are thereby decreased by the application of the compression strength. Apart from this fact it is possible that casting defects may also exist where in the voids or any air bubble or blowholes are created. In such cases the application of compressive load will tend to compact the material much closer. As a result of these voids will be filled up with material. This trend gives raise to optimistic evaluation that increasing the percentage of red mud will also increase the compression strength of the material, a property that is characteristic of cast iron and allied materials.

The tensile strength is not much pronounced when compared with the compressive strength. This could be the reason for the existence of intermolecular bonds which are much weaker than the atomic bonds. It may be noted that the elastic strength of the material lies in the very narrow between 50 to 54 kg/mm^2 which is not certainly an appreciable quantity.

Figure 4 shows a gradual increase in the percentage elongation or elastic strength of the material corresponding to the increase in the percentage of zircon content. From this one may infer that there is a possibility of strain hardening results in a higher elastic modulus.

IV. Conclusion

From the experiments conducted to study the effects of adding various volumes fractions of Sic & Fly ash, Sic & Red mud, following conclusions can be drawn.

- ZA-27 MMCs when reinforced with quartz of weight percentage from 0 to 6 percent could be successfully produced by liquid melt metallurgy technique.
- Specimens are machined according to BS: 18: 1962 test standards.
- Ultimate tensile strength values of composites were found to be higher than that of matrix alloy.
- Hardness values of composites increase with increase in quartz content. The values are greater than the compression strength value of matrix alloy.
- The compression strength and percentage elongation of metal matrix composites show higher values than those of matrix alloy.
- Use of composites is more preferable than matrix alloy.

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