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Evaluation of Fracture Toughness of LM13 reinforced with Fused SiO_2 MMC

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Abstract: **-- This paper describes the results obtained from fracture toughness tests performed on chilled LM13-Fused SiO2 composite containing dispersoid (size) content ranging from 3 to 12 wt % varying in steps of 3%. The resulting composites cast in moulds at ambient temperataure containing metallic (copper, Steel, Cast Iron) and non metallic (Silicon Carbide) chills. The effect of strength and fracture toughness for varying chilling rate and dispersoid content was also examined. The strength and fracture toughness tests were carried out in conformance with AFS (American Foundrymen Society) and ASTM (E 399 1990) standards. Results of the investigation reveal that there is good bonding with consistency in the matrix and as the glass content is increased, the strength and fracture toughness increase remarkably and is highly dependent on the location of the casting from where the test specimens are taken. Large particles and the regions of clusters of particles were found to be the locations prone to damage the composite prior to final fracture.**

Keywords**- LM13, Fused SiO2, Strength, Fracture toughness**

I. INTRODUCTION

All Many researchers have shown lot of interest in metal ceramic composites because of their excellent properties [1-5].Fabrication of discontinuously reinforced Al-based MMCs can be achieved by standard metallurgical processing methods, such as power metallurgy, direct casting, rolling, forging and extrusion, and the products can be shaped, machined and drilled using conventional facilities. Thus, they can be made available in quantities suitable for automobile applications. In general, the primary disadvantages of some MMCs for automobile applications are their low ductility and inadequate or poor fracture toughness and fatigue performance com-pared to those of the constituent matrix material [6, 7].

The superior properties like high tensile strength and toughness offered by particulate-reinforced Al-based MMCs make these materials attractive for applications in the automobile, aerospace, defense and leisure industries.

II. LITERATURE SURVEY

It is well known that Al alloy-based composites freeze over a wide temperature range and are difficult to feed into a mould cavity during solidification [8]. The dispersed porosity caused by the pasty type of solidification of long-freezing-range alloy castings can be effectively reduced by the use of chills. Chills extract heat from the melt more rapidly and promote directional solidification. Therefore, they are widely used by Foundrymen in the production of quality castings [9–15]. With the increase in demand for quality composites, it has become essential to produce Al-based composites free from defects. Al-based composite castings are prone to defects in the form of microshrinkage or dispersed porosity, which can be minimized by the judicious location of chills [16]. In spite of the increased application of chills in Al alloy founding, there are currently no data available on the action of chills on the mechanical properties of Al–quartz composites, although there has been some research carried out on the influence of chills on the solidification and soundness of long-freezing-range alloy castings [17–25]. Furthermore, one investigation [26] has demonstrated that chilling has an effect on the structure, properties and soundness of Al alloy castings.

The manufacturing methods available for Al-SiC MMC can be broadly classified into three types. They are solid phase process such as powder metallurgy and diffusion bonding, liquid phase process such as stir casting, infiltration of liquid matrix into the reinforcements and in situ processes, and semisolid method such as spray and rheocasting and compo casting. Of these manufacturing methods, stir casting is found to have moderate properties like low cost, ability to make in different shape and size etc [27, 28].It has been reported that the advantages of MMC over the un-reinforced matrix material includes a potential for high abrasion resistance [29], improved fracture crack propagation resistance[30].

The objective of the present work is to evaluate the Tensile and Fracture toughness of the LM13 reinforced fused SiO2 MMC's.

III. EXPERIMENTAL STUDIES

Composite Preparation

The composite preparation includes thorough mixing of the matrix material LM13 with Fused SiO2 in a graphite crucible with constant stirring.Intially the mold was prepared by keeping chills in proper position Fig 1.After melting the matrix material in crucible Fig 2 at around 7000C , coated fused SiO2 particles preheated to 4000C were introduced evenly into the molten metal alloy by means of special feeding attachments. Meanwhile the dispersoid treated molten nickel was well agitated by means of a mechanical impeller rotating at 450 rpm to create a vortex Fig 3.

The moulds of the plate type of castings (American foundrymen society standard) were prepared using silica sand with 5% bentonite as binder and 5% moisture and finally they were dried in air furnace. The dispersoid treated Al-alloys was be finally poured in to the dried mold which was cooled from one end by varieties of chills set in the mould. After solidification these test blocks will be subjected to heat treatment (aging) and later test specimens were taken out from the chill end to obtain the final casted specimens Fig 4.

Fig1. Mold preparation ingots with Chills

Fig 2. Aluminium being melted

Fig 3. Melted Stir casting

Fig 4. Final Casted Specimens

Strength test procedure

The specimens for the strength test were taken from various locations in the casting namely chill end, 75, 150, 225 mm from chill end, the latter being at the riser end. Tension tests were performed using Instron tension testing machine on AFS standard tensometer specimens. Each test result was obtained from an average of at least three samples of the same location. Soundness of the test castings was assessed by determining its strength.

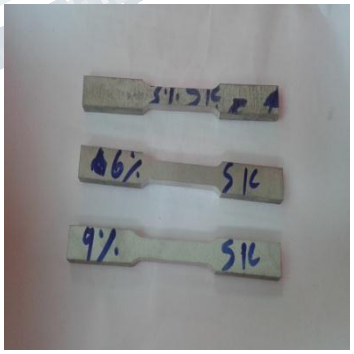

Fig 5. Tensile specimens

Fracture toughness test procedure

Fracture toughness tests were performed using a closed loop INSTRON servo-hydraulic material testing system. The method of testing involves 3-point bend testing (in accordance with ASTM E 399 1990 standards using the specimen containing the chevron notch at the middle) of a machined specimen which have been pre-cracked by fatigue. Fully reversed push –pull, total strain controlled, tension-compression (R = −1) fatigue tests were performed. The tests were performed in a controlled laboratory air environment (temperature 26°C, relative humidity 56%). An axial 12.5 mm notch-mouth clip gauge was attached to the test specimen to control the total strain. From the load, the stress intensity factor K1C (which is a measure of fracture toughness of the material) was calculated using equations which have been established on the basis of elastic strain analysis. The validity of this method depends on the establishment of a steep crack condition at the tip of the crack in a specimen of adequate size. All the ASTM validity conditions were fulfilled in this experiment.

IV. Results and Discussions

Ultimate Tensile Strength (UTS)

The experimental results of the tensile tests done on castings chilled using different chills are tabulated in table 1

Table 1. Ultimate Tensile Strength Test Results (UTS)

Type of Chill	Reinforcement wt %			
	3	6	9	12
Cu	212.011	184.161	132.317	113.12
MS	113.963	77.826	100.612	180.968
SiC	111.76	82.737	107.033	86.631
Graphite	83.539	42.413	85.234	149.08

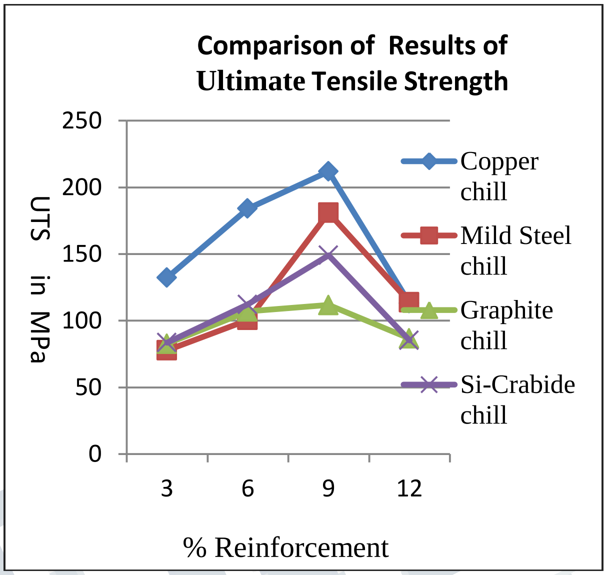

Fig.6 Graph showing the Comparison Results of Ultimate Tensile Strength in Mpa

The experimental results of the ultimate tensile strength tests on castings using various chilled like copper, mild steel, graphite, Si-carbide, If other factors are kept constant, using the copper chills generally causes a marked increase in the UTS. This implies that increasing the rate of chilling results in an increase in the UTS of the material.

However, the chilling effect is more significant on copper chilled casting compared to other chilled castings. It can be clearly seen that if all other factors are kept constant, mild steel, graphite and Si-carbide chills invariably has the lowest UTS. This means that increasing the Copper content results in an increase in the UTS of the material. Also there is almost similar UTS values exhibited at 9 % reinforcement for all chills, which may be due to fine grain structure obtained due to good chilling.

Fracture Toughness

The results of the fracture toughness tests performed on castings chilled using 25 mm thick chill blocks are shown in Table 2. Comparing the results, it can be seen that changing the type of chill seems to have an effect on the fracture toughness of the material. This implies that increasing the rate of chilling by increasing the volumetric heat capacity of the chill block tends to result in an increase in the fracture toughness of the material. Of more significant effect are the fused SiO2 content of the specimen. It can be seen that if all other factors are kept constant, castings chilled using copper block invariably has the highest fracture toughness followed by steel, cast iron , silicon carbide and other chilled composites in that order. Further it is observed from fig 7 that at fused SiO2 contents beyond 9% wt, the values register a decrease in fracture toughness. It is also observed that, farther away from the chill the specimen is taken, the lower is the fracture toughness. This could be because, the farther away form the chill the specimen is, and the lower is the rate of chilling.

Table 2 Fracture Toughness (K1c) Test Results

(in MPa m^0.5) Kmax

Type of Chill	**Reinforcement wt %**			
	3	**6**	**9**	**12**
Cu	**7.84**	**8.492**	**9.632**	**7.227**
MS	**5.97**	**7.546**	**9.706**	**6.148**
SiC	**5.25**	**7.17**	**9.07**	**4.83**
Graphite	**5.487**	**7.752**	**9.0595**	**4.959**

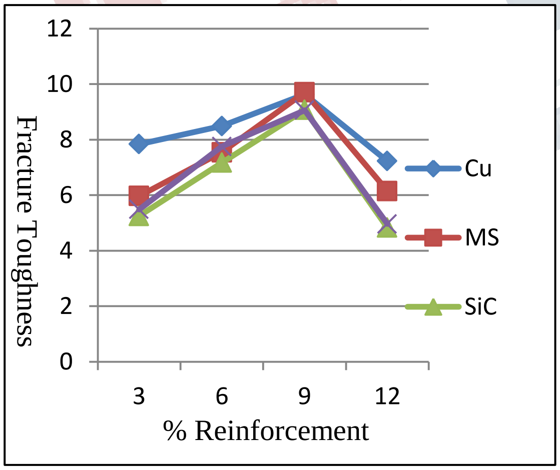

Fig. 7 Effect of Fused SiO2 content on fracture toughness

V. CONCLUSIONS

In the present investigation, of all the chill blocks, copper chill block was found to be the most effective because of its high strength. Dispersoid content up to 9 wt.% was found to increase both strength and fracture toughness and therefore it is considered as the optimum limit. Therefore the introduction of a chilled Al –fused SiO2 composite material has got very good futuristic applications in the field of MMCs technology for the following reasons.

1. The engineering benefits of Al-fused SiO2 based composites can now be realized in the form of chilled castings.

2. UTS of the chilled composites was increased by increasing the addition of dispersoids up to 9 wt.%. Copper end chill was found to be more effective than compared with the other type of chill blocks.

3. It was found that, the mechanical properties are not deteriorated as compared to those of the matrix alloy and small amount of fused SiO2 particles are sufficient to cause a fairly large change in strength and fracture toughness properties.

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