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FINITE ELEMNT ANALYSIS OF TENSILE STRENGTH AND CHARACTERIZATION OF LM13 METAL MATRIX COMPOSITE

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ABSTRACT

This paper describes research on aluminium based metal matrix (LM13) composites reinforced with fused SiO_2 particulates cast using metallic and non metallic chills during solidification to ensure uniform colling. The effect of reinforcement and chilling on Tensile strength, hardness and microstructure are discussed in this paper. It has been observed that chilled MMCs with LM13-9 wt. % reinforcement content proved to be the best in improving the mechanical properties and uniform distribution of particulates has been seen in SEM images. A Finite Element Model has been developed to compare the tensile properties. Finally the results reveal that there is a good agreement that exists between the simulated (FE) values and those of the experimental values, proving the suitability of the boundary conditions.

Keywords: *Chills, Fused SiO_2, Hardness, LM13, SEM, Tensile Strength*

I. INTRODUCTION

Composite materials consist of two or more materials that differ in chemical and physical properties and are not soluble in one another. The primary constituent in a composite material is the matrix phase that provides load transfer and structural integrity, while the reinforcement to enhance mechanical properties. The matrix and reinforcement materials can either be organic (polymers), inorganic (ceramic or glass) or metallic (aluminium, titanium, etc.). The most common forms of reinforcement materials are fibers (long and short), or particulates. Composites provide excellent Tensile strength and hardness compared to the traditional alloys. Matrix materials in Metal Matrix Composites (MMC) are aluminium, magnesium and titanium alloys. Reinforcing materials in MMC are silicon carbide, boron carbide, Silicon carbide, alumina and graphite in the form of particles, short fibers (whiskers) or long fibers. In Aluminium Metal Matrix Composites (AMMC), matrix material is aluminium and reinforcement materials are silicon carbide, aluminium oxide, boron carbide, graphite etc. in the form of fibers, whiskers & particles. This paper discusses the important aspects of strength and hardness and microstructure of MMC especially the Aluminium metal matrix composites.

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II. Literature Survey

Aluminium and its alloys have continued to maintain their mark as the matrix material most in demand for the development of Metal Matrix Composites (MMCs). This is primarily due to the broad spectrum of unique properties it offers at relatively low processing cost [1–3]. Some of the attractive property combinations of Al based matrix composites are: high specific stiffness and strength, better high temperature properties (in comparison with its monolithic alloy), thermal conductivity, and low thermal expansion. The multifunctional nature of Al matrix composites has seen its application in aerospace technology, electronic heat sinks, solar panel substrates and antenna reflectors, automotive drive shaft fins, and explosion engine components, among others [4-6].

Reinforcing an Al alloy with particulates yields a composite that displays the superior physical and mechanical properties of both the metal matrix and the dispersoid. On a weight-adjusted basis, many Al-based metal matrix composites (MMCs) can outperform cast steel, Al, Mg and virtually any other reinforced metal or alloy in a wide variety of applications. Hence, it seems probable that such MMCs will replace conventional materials in many commercial and industrial applications in the near future [7-10].

It is well known that Al alloys that freeze over a wide range of temperature are difficult to feed during solidification. The dispersed porosity caused by the pasty mode of solidification can be effectively reduced by the use of chills. Chills extract heat at a faster rate and promote directional solidification. Therefore chills are widely used by foundry engineers for the production of sound and quality castings. There have been several investigations on the influence of chills on the solidification and soundness of alloys. With the increase in the demand for quality composites, it has become essential to produce Al composites free from unsoundness [11-13].

One of the most powerful functions of finite element modelling is to generate detailed distributions of stress and strain in the matrix and fiber, which are essential for understanding the mechanical behaviour of the composites. For instance, the point where matrix yielding is initiated can be easily located by the finite element analysis. Furthermore, matrix yielding is a gradual process. The yield region expands progressively as the applied load increases. This is also best modelled by the finite element techniques [14].

III. EXPERIMENTAL DETAILS

3.1. 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 700^0C , coated fused SiO_2 particles preheated to 400^0C 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

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treatment (aging) and later test specimens were taken out from the chill end to obtain the final casted specimens Fig 4.

Fig1. Mold preparation with Chill being melted

Fig 2. Aluminium Ingots

Fig 3. Melted Stir casting

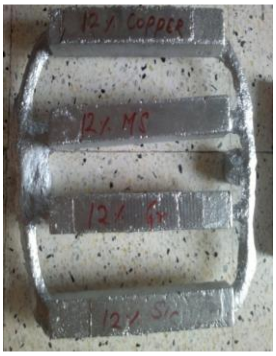

Fig 4. Final Casted Specimens

3.2. Tensile 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.

3.3. Finite Element Analysis

The modeling of the Al based MMC, was carried out by using Abacus software, it was resembled as a structural member (Beam) using suitable assumptions and meshed by Hypermesh. Nastran software was used for analysis. The Stress and deflection properties were studied.

3.4. Microstructure characterization by SEM

SEM images were taken using Scanning Electron Microscope Hitachi SU-1500.The magnification used is 100X to 2000X.

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	132.317	184.161	212.011	113.12
MS	77.82	100.61	180.96	113.96
SiC	82.73	107.03	111.76	86.631
Graphite	83.539	90.04	149.08	85.234

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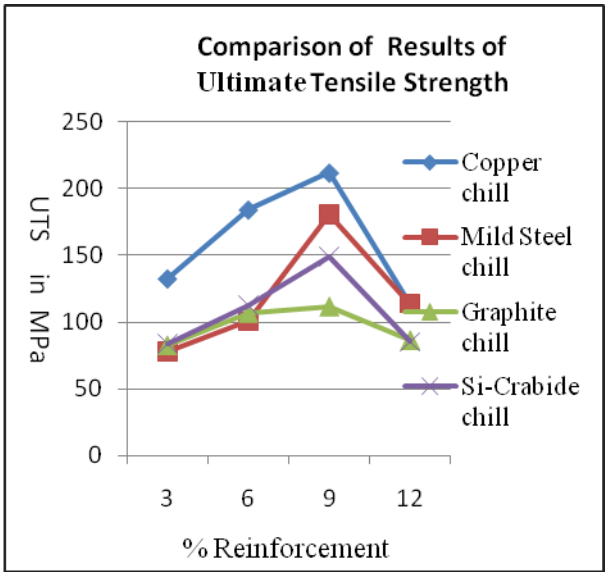

Fig.5 Graph showing the Comparison Results of Ultimate Tensile Strength in Mpa

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.

Finite Element Analysis was carried out by Nastran solver. Meshing was done by Hypermesh as shown in Fig 6. 68643 nodes were used to for analysis.

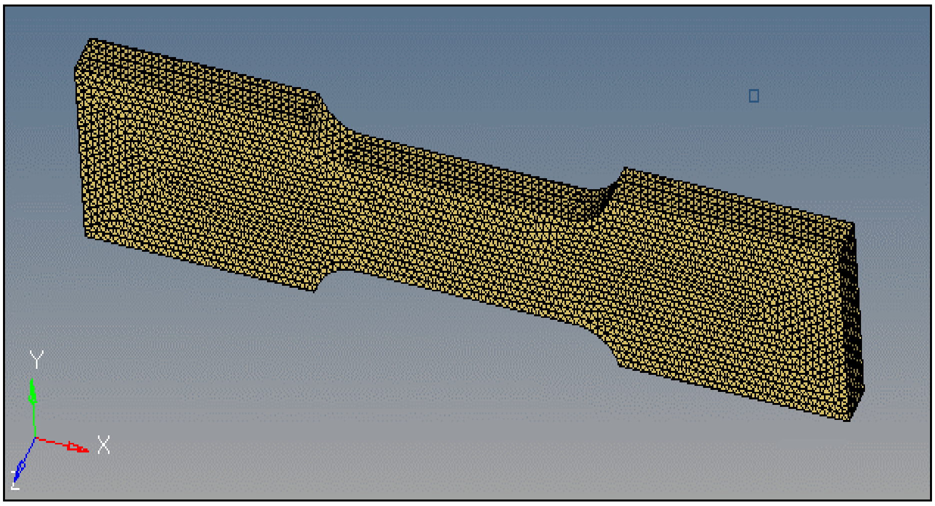

Fig 6.Meshed Model

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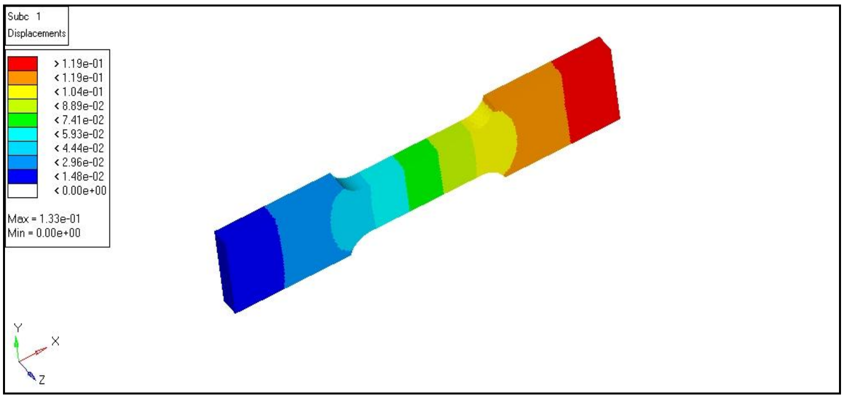
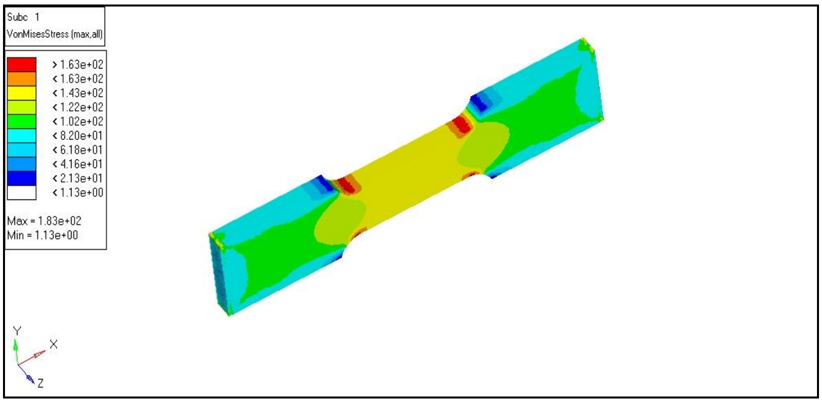
Displacements and Stresses for Copper Chill





The stresses got by the solver are in close agreement with the experimental results.

SEM Images

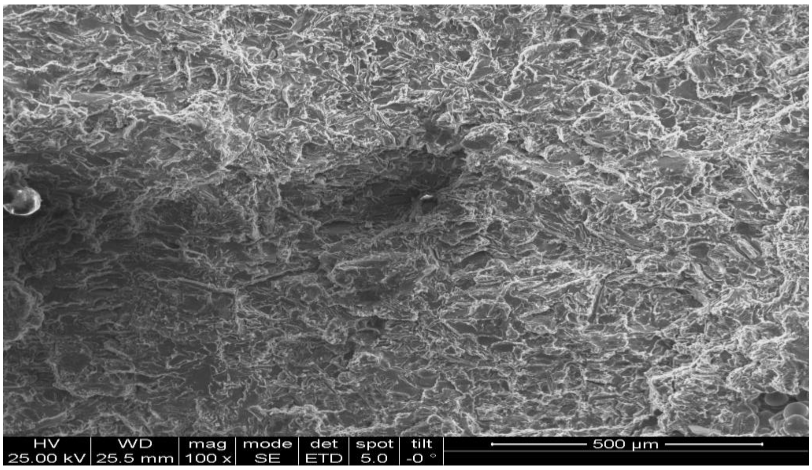


Fig 7. Image for 9 % CU Chill

The Fig 7 shows primary dimples originated from the reinforcement particles whereas micro-voids of smaller size grew from matrix finer precipitates. From systematic analyses of the broken specimens, it was observed the reinforcement particles exposed on the fracture surface were generally broken. Micro-voids were thus considered to form due to reinforcement fracture under load. Particle-matrix interface debonding thus acted as a preferential mechanism of fracture nucleation. Particle cracking towards formation of voids due to preferential decohesion of reinforcement particles from matrix at interface sites. Large craters like structures have been observed, due to presence of higher quantity of hard and ceramic reinforcement particles, leading brittle fracture.

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