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Thermal Conductivity of Metal Matrix Composite A356 with Zirconium Silicate (ZrSiO4)

Vinaya B C
Don Bosco Institute of Technology/Mechanical Department, Bengaluru, India
Email: vinaya2008@gmail.com

***Abstract*—Due to the advancement in the material technology to produce desired materials from various industrial applications and fast changing scenario in the production of lighter and stronger materials, composite materials are gaining wide acceptance due to their unusual characteristics of behavior with their high strength to weight ratios. The most widely used material in these industries is aluminium and their alloys because of their light weight. To make these & alloys of aluminium further versatile and flexible for varieties of application, during which these materials is expected to behave as expected and provide a long life under different environments, the composites have emerged as the single most material, which can provide a better service and better quality. Therefore in the present investigation, a study had been conducted to evaluate the thermal properties, Also to study the microstructure behaviour of A356 with Zirconium Silicate (ZrSiO4) composite castings.**

***Index Terms*— Thermal conductivity, Aluminium 356, Zirconium Silicate (ZrSiO4).**

I. INTRODUCTION

The main advantage of a composite material over conventional material like a monolithic metal is the combination of different properties which are seldom found in the conventional materials. The unusual combination properties include high strength to weight ratio, higher stiffness to weight ratio, improved fatigue resistance, improved corrosion resistance, higher resistance to thermal expansion, excellent optical and magnetic properties, combination wear resistance and fracture toughness etc. There are number of situations in service that demand an unusual combination of properties. Further the present day trend is to go in for light weight constructions for easy handling and reduced space, reduction of as many parts in an assembly, aesthetic appearance and high resistance to weathering attack. These factors have propelled modern designers to develop newer composite materials up to the stage of large-scale production with exacting requirements.

II. METHODOLOGY

A. Selection of Matrix Material

Matrix Material: A356

- Aluminum alloy A356is having the properties over the other Al series material.
- Its strength to weight ratio is excellent and it is ideally used for highly stressed parts such as air craft components.

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Fig1: Shown Ingot Structure of A356

B. Selection of Reinforcement Material

Zirconium Silicate was originally produced by a high temperature electro-chemical reaction of sand and carbon. Zirconium Silicate is an excellent abrasive and has been produced and made into grinding wheels and other abrasive products for over one hundred years. Today the material has been developed into a high quality technical grade ceramic with very good mechanical properties. It is used in abrasives, refractories, ceramics, and numerous high-performance applications. The material can also be made an electrical conductor and has applications in resistance heating, flame igniters and electronic components. Structural and wear applications are constantly developingThe die set is one of the basic tools of the stamping industry. It consists of a lower shoe and an upper shoe, together with guide posts and bushings by means of which the shoes are aligned.The bottom bolster supports the bottom half of the press tool consisting die block, front guide plate, rear guide plate, stripper plate, finger stop etc., They are fastened to the bottom bolster by means of socket head screw and dowels ensures alignment.The top bolster accommodates punches, punch plate, punch back plate etc. They are fastened by socket head screw and aligned by dowels.The top half and bottom half of the press tool are again aligned by guide pillar and guide bush with a fit H7/h6. The guide bush OD is having interference fit with top bolster H7/ P6.

III. FABRICATION OF COMPOSITES

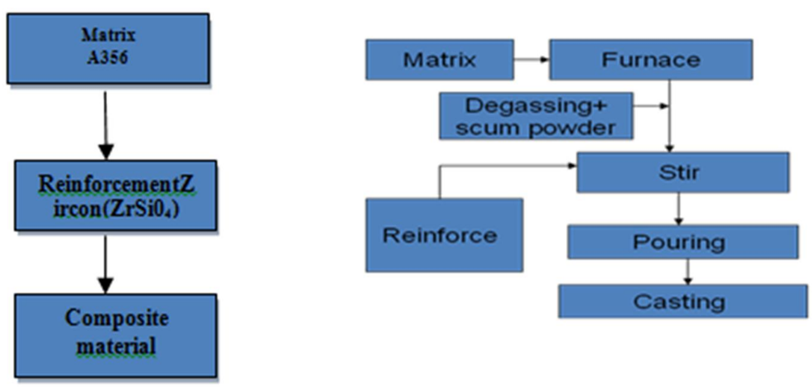

Fig 2: Shows Flow Chart of Composite Fabrication

A.About Stir Casting Method

The Stir-casting techniques currently the simplest and most commercial method of production of MMCs. This approach involves mechanical mixing of the reinforcement particulate into a molten metal bath and transferred the mixture directly to a shaped mold prior to complete solidification. In this process, the crucial thing is to create good wetting between the particulate reinforcement and the molten metal.

Micro structural inhomogeneity can cause notably particle agglomeration and sedimentation in the melt and subsequently during solidification. Inhomogeneity in reinforcement distribution in these cast composites could also be a problem as a result of interaction between suspended ceramic particles and moving solidliquid interface during solidification. This process has major advantage that the production costs of MMCs are very low.

B.Preparation of Composites

This method is used for preparation of A356- ZrSiO4 by vortex method .Base matrix aluminum alloy is heated and melted in a crucible and heated to about 750 degree centigrade in the electric resistance furnace While temperature of melt was about 740 degree centigrade ,next degassing with chlorine or chlorine-based compounds such as hexachloroethane adversely affects the recovery and distribution of particles in the casting, because chlorine presumably impairs the wetting between graphite and aluminum. Fig 5.4 shows Electrical Resistance Furnace. Then the stirrer was immersed gently into the molten metal bath and stirrer was rotated at a speed of 0 to 500 rpm to create a vortex in the liquid metal .The impeller was made of steel and coated to avoid iron contamination.
Preheated ZrSiO4 is added to the melt through the side of the vortex. After completion of addition of ZrSiO4 the stirrer was continued for 10 minutes and stopped was quickly withdrawn. The composite melt was then poured at a preheated temperature into a cast-iron permanent mould.

Fig 3: Shows Electrical Resistance Furnace

C. Aluminum and Reinforcement Calculations

TABLE I: SHOWS AL356& REINFORCEMENT CALCULATIONS

Sl no:	Composite	A356 (Grams)	ZrSiO4 (Grams)
1	A356- 2.5% ZrSiO4	2500	75
2	A356 – 5%ZrSiO4	2500	150
3	A356 – 7.5%ZrSiO4	2500	225

D. Pattern and Mould

A pattern is the replica of the parts to be cast and is used to prepare the mould cavity. Patterns are made of metal. A mould is an assembly of two or more metal blocks. The mould cavity holds the liquid material and essential acts as a negative of the desired product.
Steps Involved:

- Base Alloy: A356
- Reinforcement material $ZrSiO_4$ added by2. 5% weight.

Fig 4 : Hot Molten Metal in Furnace

Fig 5: Adding Scum Powder


Fig 6: Slag Formation   Fig 7: Slag Removal

The Fig No 4 to 7 Shows the Hot Metal in Furnace, Slag Formation Removal


Fig 8: Setting of Stirrer   Fig 9: Adding Reinforcement Material

Fig 8& 9 Shows the Stir Mechanism & Adding Reinforcement

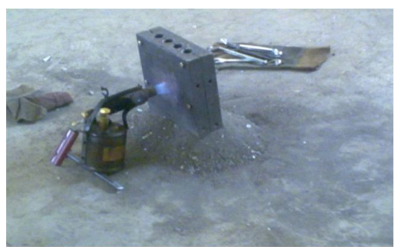

Fig 10 Shows Pouring of Molten Composite Material in to the Pre-Heated Moulds(A356 + {2.5 – 7.5} %$ZrSiO_4$)

Fig 11: The casting removed from mould

After pouring molten composite in to pre heated moulds is left for solidification and the castings removed are shown in figure 11.
The same procedure is followed to prepare castings with 5%, and 7.5% of $ZrSiO_4$ added by weight to the base alloy A356.

E.Specimen Preparation

Specimens are prepared for thermal conductivity and Microstructure as per ASTM standard sizes.

F.Microstructure test specimen

The specimens for the micro structural studies have considered as represented in figure 12

Fig 12: shows the microstructure test specimen

The microstructure samples were ground using abrasive silicon carbide papers of grade 100, 200, 400, 600, 80, 1000 and 1200 grid sizes. The grinding was done in successive steps on each abrasive paper. After every polishing the samples were thoroughly washed, dried and polished on a velvet cloth using alumina as an abrasive on a double disk polishing machine. To obtain a highly polished mirror finished surface a diamond paste of grade 3 microns was used. The samples were etched with picric acid reagent to reveal grain structure.

IV. Micro Structural Test Analysis

These specimens were cut, polished and etched by an etchant commercially available. The micro structural observation was made using a metallurgical microscope and photograph have taken and recorded.

Fig13: show Optical Metallurgical Microscope

V. Results & Discussion

TABLE II: TABULATION OF THERMAL CONDUCTIVITY TEST VALUES AND GRAPH TABULAR COLUMN FOR A356 - ZRSIO4

Time in Sec	T1	T2	T3	Water inlet T4	Water outlet T5
500	140	135	132	30	32
1000	162	158	154	30	34
1500	179	174	170	30	37
2000	185	182	179	30	39
2500	189	183	180	30	40

Observation:

- Current in Ampere I=0.89A.
- Voltage=198V.
- Water inlet temperature $T_4=30^0C$.
- Water flow rate V_{cc}=40cc/Min.

Calculation:

$Mf = (V_{cc} x1000)/(10^6x60)$

$= (40x1000)/ (10^6x60)$

$=6.667x10^{-4}$ kg/sec

$Cp= 4.187x10^3$ J/kg-k

$A=(\pi xd^2)/4$

Thermal conductivity, k= (M_f x C_p x(T5-T4))/(Ax (dT/dX))

$= 6.667\text{x } 10^{-4}\text{x}4.187\text{x}1000\text{x } (32\text{-}30)/3.8\text{x}10^{-4}\text{x}60.801$

=241.640W/m-K

VI. CONCLUSION

1. The A356 reinforced with $ZrSiO_4$ particulates that is A356 -$ZrSiO_4$ metal matrix composition were successfully
fabricated through liquid metallurgy route for 5% ,7. 5%, 10%and 15% reinforcement.
2. The thermal conductivity of the composite found to be higher than the base matrix this is mainly due to the influence of $ZrSiO_{4.}$ The composite with 12% $ZrSiO_{42}$ reinforcement shows the highest improvement in the thermal conductivity
3. The Compression strength of the composite found to be higher than the base matrix this is mainly due to the influence of $ZrSiO_4$,
4. The microstructure of the cast composite shows uniform particle distribution with less priority. This is because of both reinforcement and base material has relatively closed density value.

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