FABRICATION OF STIR CASTING SETUP AND EXPERIMENTAL PLANNING

To cast the aluminium metal matrix composites, it is essential to search and select an economic and efficient technique. Thereafter design and fabrication of an appropriate casting setup is also an important task for casting of different aluminium base metal matrix composites. Liquid stirring technique is one of the important techniques having versatility to cast various metal matrix composites without compromising the quality of casting product. The liquid stirring method is selected for experimental investigation during casting of metal matrix composites. Accordingly a stir casting setup has been designed and fabricated for the purpose. A set of experimental investigation have been carried out in a pre-planned way to investigate the effects of the various parameters of the developed stir casting setup during liquid stirring of Al/\text{SiC}, Al/\text{Al}_2\text{O}_3 and Al/\text{Gr}_p-\text{MMC},s. Three heating furnaces of capacity 1000°C and 1250°C and 550°C capacity are simultaneously design and fabricated for melting the aluminium ingot and agitation of hard reinforced particulates respectively before stir casting.

The objective of the design and fabrication of the stir casting setup is to study the effect of different parameters on the casting of aluminium metal matrix composites properties during casting of Al/\text{SiC}, Al/\text{Al}_2\text{O}_3 and Al/\text{Gr}_p-\text{MMC},s and present the test results for optimal selection of the parameters which may overcome the casting barriers. With the increase in demand due to the industrial acceptance of the Al/\text{SiC}, Al/\text{Al}_2\text{O}_3 and Al/\text{Gr}_p-\text{MMC},s the casting of these composites with very good surface texture, physical, mechanical properties etc. is very much essential to control and maintain the quality of the product minimum cost. In depth research investigation has also been made on the cast composites to investigate the machinability and weldibility of the prepared composites.
2.1 DEVELOPMENT OF STIR CASTING SETUP

More effective and economic casting of Al/SiC, Al/Al₂O₃ and Al/Grp-metal matrix composites requires application of special furnaces and techniques in casting. For utilization of the special technique in casting of Al/SiC, Al/Al₂O₃ and Al/Grp, MMc’s a liquid stirring setup has been designed and fabricated. Three furnaces of capacity 1150°C and 1200°C and 550°C have been designed and fabricated for simultaneous working in such a way that one furnace is used to melt the aluminium metal matrix and other furnace is used to preheat and agitate the hard reinforced particulates. A motor is mounted on a spindle which is keyed to the impeller blades. Motor gives the rotary motion to the graphite impeller. Total arrangement is mounted on a rigid stand. Digital temperature recorder is fitted to each of the furnace to record the furnace temperature during preheating and melting of aluminium matrix. This system of casting is one of the good alternatives to the stationary conventional method in casting of Al/SiC, Al/Al₂O₃ and Al/Grp-metal matrix composites.

The main advantages of the developed liquid stirring system for casting of Al/SiC, Al/Al₂O₃ and Al/Grp-metal matrix composites are described below:

(i) Both the materials e.g. aluminium matrix and hard reinforce particulate are required to preheat and melt simultaneously and this can be easily possible by this developed setup.

(ii) Setup has two temperature regulators cum digital recorder, one for each furnace which indicates the actual temperature of the furnaces and helps to set the proper temperature with time.

(iii) Setup has a speed regulator and tachometer; these are precisely used to control the stirring speed of the graphite impeller and recorded the rpm from the digital recorder. These are most important in regulating and proper homogenizing the mixture during stirring of molten metal matrix and hard reinforced particulates.

(iv) A stop watch is also fitted with the setup to measure the stirring time, time of heating, melting and mixing of metal matrix and hard particulates. It is also an important parameter to note and maintain properly during casting.
Melt stirring technique for production of composite has some important advantages e.g. better bonding of metal matrix and hard particles, easier control of matrix structure, simplicity and low cost of processing. Fig. 2.1 shows the schematic diagram of a stir casting setup and pouring the molten metal after stirring into the mould cavity.[1]

![Fig. 2.1 Schematic diagram of Stir Casting setup with showing pouring the molten metal](image)


### 2.2 FABRICATION OF STIR CASTING SETUP

A fabricated stir casting setup consist of the following main components: (i) three furnaces, (ii) stirring arrangement, (iii) speed regulator for stirrer; (iv) tachometer; (v) digital temperature regulator cum recorder. To melt aluminum alloy matrix above its liquidus temperature (melting temperature 660°C) utilized one of the furnace of capacity 1150°C with accuracy ± 2°C. The design of heating coil is arrange in such a way so that furnace can achieve at least 1050°C temperature while melting of aluminium metal matrix. Simultaneously another furnace to be utilized to pre-heat and agitate the hard reinforced particulates. The capacity of this furnace is selected as 1200°C with accuracy ± 2°C A micro-processor based PID digital temperature controller with dual display is fitted with the furnace. Third furnace of capacity 550°C with accuracy ± 2°C is to be utilized to bake the metal mould simultaneously. The hard reinforced particulate is to be preheated to 1050°C temperature. Accordingly two furnaces are fabricated for the above mentioned purpose.
FABRICATION OF FURNACES

**Furnace 1:** The maximum temperature that could be attained is 1200°C (working temperature 1150°C) and the particulates are to be preheated in this furnace.

**Furnace 2:** The furnace maximum temperature that could be attained is 1150°C (working temperature 1050°C). A stirring arrangement is fitted with this furnace to stir the molten metal during melting and mixing of Al matrix and hard reinforced particulates.

**Furnace 3:** The furnace maximum temperature that could be attained is 550°C (working temperature 430°C). This furnace is simultaneously operated to preheat and baking of fire clay coated metal mould.

**Following materials are used during fabrication of the furnaces are listed below:**

1. **Raw material used for furnace wall:** PCRC sheet (22 S.G) with double coated metallic powder coating is selected for furnace wall material. The sheet has been cut and bent to form a final box of size 150mmX150mm X300mm

2. **Furnace wall insulator:** Zirconia’s cerewool insulation is used and placed between outer cover and heat generator, which insure the uniform distribution of heat. The basic aim of using this insulation is to avoid the heat losses.

3. **Heat Generator:** Kainthal Al Wire (18 S.W.G) in coil form is used as heating element. This design is suitable for working with single phase, 220V, 4 kW, supply.

4. **Temperature Indicator Cum Controller:** Microprocessor based PID digital temperature indicator cum controller is fitted on both the furnaces. Accuracy of indicator is ± 2°C.

FABRICATION OF STIRRING ARRANGEMENT

After melting of aluminium metal matrix it is required to add the hard reinforced particulates and immediately mix these properly for proper homogenizing of reinforced particulate in the molten metal matrix, to serve the purpose a stirring mechanism has been design and fabricated. A speed regulator with tachometer is also fitted to the system to regulate the stirring speed and recording this during mixing of hard reinforced particulate and matrix.
1. Electric Motor: DC motor of capacity 0.092 kW, maximum speed limit 4000 rpm is chosen to rotate the graphite impeller. A variable speed controller is used to vary the speed of the impeller from 100 to 4000 rpm.

2. Stirrer and stirrer spindle: The graphite rod (25 mm diameter) is used as a spindle with an impeller having three blades of sweep capacity 37 mm. The stirrer is mounted on an adjustable heavy stand and connected with a tachometer to measure the rpm of the graphite spindle i.e., graphite impeller.

3. Graphite Crucible: Graphite crucibles of capacity 3 kg and 5 kg are chosen for keeping the metals before put into the furnace.

Fig. 2.2 shows a furnace with fabricated stir casting setup. Another same configuration furnace simultaneously used not shown here. This fabricated stir casting set up is used for experimentation.

![Fabricated stir casting setup](image)
2.3 BRIEF PLANNING FOR CASTING

2.3.1 Mould Making

Metallic mould is prepared and utilized to pour the molten metal matrix and hard reinforced particulate mixture to make the round, and plate shape samples. IS 2002-1962/ high temperature service pipe, medium grade of 40mm nominal diameter x 3.15 mm wall thickness x 250mm long each is used to prepare the cylindrical metal mould(Fig.2.3). The 40 mm inside diameter pipe is longitudinally cut into two halves (Fig.2.4) and a square base of 40 mm x 40 mm cut from IS-1079-1968/5 mm thick plate and welded at the bottom of a half piece 40 mm diameter pipe (Fig.2.5). The prepared two halves moulds are clamped to make exactly cylindrical mould cavity by means of two clamps is shown in Fig. 2.6 and Fig.2.7. Fig.2.7 shows the complete metal mould cavity after proper preparation is used to cast the test samples.

Fig. 2.3 Original Pipe  
Fig. 2.4 Half Circular Section
2.3.2 Preparation of Mould Cavity

Fire clay is prepared properly and coated inside the both halves of the metal mould. Then the clay coated metal mould is allowed to dry in the sunlight for two hours. After that the partially dry clay coated mould is put into the furnace for braking and complete dried before pouring the molten metal matrix and hard reinforced particles.
mixture for casting. Fig. 2.8 shows the fire clay coated metal mould. Fig. 2.9 shows the fire clay coated partially dried clamped mould prepared for baking.

2.3.3 Estimation of Raw Materials for Al/5, 10, 15vol.% SiC-MMC casting

In Al/SiC-MMC casting requires aluminium metal matrix and hard reinforced particulates SiC as a raw materials. Hence, it is essential to estimate the necessary weight of aluminium matrix and proportional volume of exactly requires SiC particles for Al/5 vol%, Al/10 vol% and Al/15 vol% SiC-MMC casing for appropriate sample. First step is to estimate the amount of aluminium metal matrix according to the volume of the prepared metal mould cavity. Second step is to estimate the equivalent volume of the SiC particles with respect to the total volume of the metal mould cavity. Therefore, different volume of the hard reinforced SiC particulates are to be estimated in the pre planned way so that the casting sample should be exactly 5vol%, 10vol%, 15 vol% fraction in Al/SiCp metal matrix composites. The vol % SiC is calculated using the following mathematical relation given below:

\[
\text{Composition (\% by Volume)} = \left( \frac{\frac{m_p}{\rho_p}}{\frac{M_m}{\rho_m} + \frac{m_p}{\rho_p}} \right) \quad \text{Eqn.2.1}
\]
Where $m_p = \text{mass of particulate}$
$\rho_p = \text{density of particulate}$
$M_m = \text{mass of metal}$
$\rho_m = \text{density of metal}$

Utilizing above mathematical relation and considering the density of aluminum is 2.7g/cc and that of SiC is 3.2 g/cc the volume fraction is estimated. The estimated amounts of materials are to be used for casting of different volume fraction metal matrix composites given below in a tabular form.

<table>
<thead>
<tr>
<th>Volume fraction/Mass</th>
<th>Aluminium(gm)</th>
<th>SiC(gm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>847.8</td>
<td>50.5</td>
</tr>
<tr>
<td>10%</td>
<td>847.8</td>
<td>101.5</td>
</tr>
<tr>
<td>15%</td>
<td>847.8</td>
<td>151.5</td>
</tr>
</tbody>
</table>

2.3.4 Estimation of Raw Materials for Al/5, 10, 15 vol.% Al$_2$O$_3$-MMC

Similarly as mentioned in the Art.2.3.3, in casting Al/ Al$_2$O$_3$-MMC requires aluminium metal matrix and hard reinforced Al$_2$O$_3$-particulates as a raw materials. Hence, it is essential to estimate the necessary weight of aluminium matrix and proportional volume of exactly requires Al$_2$O$_3$- particles for Al/5 vol%, Al/10 vol% and Al/15 vol% Al$_2$O$_3$-MMC,s casting of size:40 mm diameter x 250mm long round bar. Above mentioned mathematical relation equation 2.1 is utilized to estimate the actual volume of hard reinforced Al$_2$O$_3$-particulate is required for casting of different volume fraction MMC,s e.g. Al/5 vol%, Al/10 vol% and Al/15 vol% Al$_2$O$_3$-MMC,s. Utilizing above mathematical relation and considering the density of aluminum is 2.7g/cc and that of Al$_2$O$_3$ is 3.97 g/cc the volume fraction was estimated. The estimated amounts of materials are to be used for casting of different volume fraction metal matrix composites given below in a tabular form.
Table 2.2: Material required in grams for casting of different volume fraction Al/Al₂O₃-MMC

<table>
<thead>
<tr>
<th>Volume fraction/Mass</th>
<th>Aluminium</th>
<th>Al₂O₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>847.8</td>
<td>61.544</td>
</tr>
<tr>
<td>10%</td>
<td>847.8</td>
<td>123.09</td>
</tr>
<tr>
<td>15%</td>
<td>847.8</td>
<td>184.63</td>
</tr>
</tbody>
</table>

2.3.5 Estimation of Raw Materials for Al/5, 10, 15vol.% Grp-MMC

Similarly, as mentioned in the Art.2.3.3, in casting of Al/Grp-MMC requires aluminium metal matrix and hard reinforced Grp-particulates as a raw materials. Hence, it is essential to estimate the necessary weight of aluminium matrix and proportional volume of exactly requires Grp-particles for Al/5 vol%, Al/10 vol% and Al/15 vol% Grp-MMC,s casting of size: 38 mm diameter x 250 mm long round bar. Above mentioned mathematical relation equation 2.1 is utilized to estimate the actual volume of hard reinforced Grp-particulate is required for casting of different volume fraction MMC,s e.g. Al/5 vol%, Al/10 vol% and Al/15 vol% Grp-MMC,s. Utilizing above mathematical relation and considering the density of aluminum is 2.7g/cc and that of Grp is 2.2 g/cc the volume fraction was estimated. The estimated amounts of materials are to be used for casting of different volume fraction metal matrix composites given below in a tabular form.

Table2.3 Material required in grams for casting of different volume fraction Al/Grp-MMC

<table>
<thead>
<tr>
<th>Volume fraction/Mass</th>
<th>Aluminium</th>
<th>Grp</th>
</tr>
</thead>
<tbody>
<tr>
<td>5%</td>
<td>847.8</td>
<td>34.54</td>
</tr>
<tr>
<td>10%</td>
<td>847.8</td>
<td>69.08</td>
</tr>
<tr>
<td>15%</td>
<td>847.8</td>
<td>103.62</td>
</tr>
</tbody>
</table>

2.3.6 Measuring and Testing Equipments used for Experimental Investigation

Various cast MMC samples were measured for density using Archimedes principle. Volume fractions of composites were examined using image analyzer. Microstructural investigation was carried out through optical micrographs and SEM graphs. Microhardness tester and tensile tests were done on microhardness tester and ultimate tensile strength testing machine. Digital micrometer Mitutoyo, Japan, of resolution
0.001 mm was used to measure the cast sample diameter. Surfcom 130A surface roughness measuring instrument was used to measure the surface roughness values of the machined surfaces. Tool makers microscope of resolution 0.001 mm was used to measure the flank wear width of the cutting tools after each turning operations.

2.4 FLOW CHART OF EXPERIMENTAL INVESTIGATION

A flow chart Fig. 2.10 given below represents the detail steps with brief procedures are to be considered for experimental investigation during preparation of MMC,s during stir casting.

1. **Cut small pieces from A6061-Comertially available Al- ingot.**

2. **Weighed the small pieces cut from Al-ingot and put into the crucible; Metal matrix and crucible keep inside the furnace (capacity150°C) for meting.**

3. **Estimated amount of hard reinforced particulates e.g. SiC, Al2O3, Grp of average particle size 34 μm put into the separate crucible and placed inside another furnace(capacity1200°C) for pre heating and agitating the particles.**

4. **Allow the Al-ingot to the above melting temperature, furnace temperature reach to 900°C and keep for 2 to 3 hours**

5. **Allowing the molten metal matrix to semi-liquid state**

6. **Add preheated reinforcement particulate**

7. **Stirring the molten metal matrix and hard reinforced particulates for proper mixing and homogenizing with variation of the range of impeller rotational speed from 150 rpm to 300 rpm**

8. **Again, reheat the mixture of metal matrix and hard reinforced particulate to above liquidus temperature for further agitation with continuous stirring for a stipulated period of time min.**

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According to the above mentioned brief planning different sets of casting experiments have been performed and explained the test results with photographic views of the casting samples etc. in the next chapter 3.