CHAPTER 3

WORK MATERIAL PREPARATION

3.1 INTRODUCTION

The previous chapters have clearly demonstrated the importance of aluminium matrix in the present scenario, the issues in their production and machining. This chapter presents the methods of preparing work material and reasons for selecting stir cast method. Research findings are quoted for justifying the selection of work material and method of preparation adopted in this study.

3.2 PRODUCTION OF MMC

MMCs can be produced by different methods which are majorly classified as solid state route, liquid state route and spray method. The selection of suitable process depends on quantity and distribution of the reinforcement components, the matrix alloy and the application.

In general, the following product engineering types are possible:

- Melting metallurgical processes
  - Infiltration of reinforcement preforms by squeeze casting
- Stirring the particles in metallic melts, followed by sand casting, permanent mold casting or high pressure die casting.

- Powder metallurgical processes
  - Pressing and sintering of composite powders
  - Extrusion or forging of metal-powder particle mixtures

- Hot isostatic pressing of powder and fiber mixtures

- Joining and welding techniques

- Machining techniques

At present, melting metallurgy is more economical and well proven method for the production of MMCs. Stir Casting is the simplest and the most cost effective method of liquid state fabrication (Clyne, 2001).

Surappa (2003) in his research article has mentioned that the PAMCs are less expensive than Continuous Fibre Reinforced Aluminium Matrix Composites (CFAMCs) and simplest and most commercially used technique is ‘stir casting’. Hashim et al (2001) have tried the ways to reduce porosity and increase homogeneity of reinforcement by controlling various process conditions in production of MMC by stir cast method. They also presented the difficulties encountered in achieving this and still conclude the method as a cost effective one.

3.2.1 Stir Cast Method

In the stir casting method the muffle furnaces are used to heat up the aluminium alloy and the silicon carbide material after placed in a crucible. The SiC particles are added to the aluminium melt at hot condition and the stirring is carried out in a mechanized manner. The arrangement has
provisions to control the speed and position of the stirrer. Display unit helps to monitor the furnace temperatures and a control unit to regulate the temperature.

Stir casting is a liquid state method of composite materials fabrication, in which a dispersed phase (ceramic particles, short fibers) is mixed with a molten matrix metal by means of mechanical stirring.

3.2.2 Selection of Work Material

Of all MMCs, particulate reinforced aluminium matrix composites (PRAMCs) constitute largest quantity of composites produced and utilized on volume and weight basis. To select a suitable reinforcement material for aluminum, important facts such as density, wettability and thermal stability were considered (Brahim et al 1991). Silicon carbide (SiC) is a widely used reinforcement material because of its good wettability with the aluminum matrix (Brahim et al 1991, Hashim et al 2001). SiC is considered to be an optimal reinforcement phase for aluminium and its alloys (Monaghan 1994) because of

- low density, only one slightly higher than aluminium
- high modulus and strength
- readily available at low cost

It is possible to incorporate up to 30% ceramic particles in the size range 5 to 100 microns in a variety of molten aluminium alloys (Surappa, 2003). In another study made by Al-Haidary and Jabur Al-Kaaby (2007) it was shown that friction coefficient decreased with increasing SiC particle content and particle size of 25 microns was optimal for improving wear resistance. However, SiC reacts with molten aluminum at temperatures above 1000 K to form Al₄C₃, releasing silicon into the matrix. Nevertheless, this
reaction can be suppressed by high silicon content. Li et al (2008) have reported that an addition of 7 wt % of silicon can significantly suppress this reaction at temperatures below 800 ºC. In addition to this, A356/SiC/20P composite had showed bad machinability when compared with A6061/SiC/20P and A383/Al₂O₃/20f (Paulo Davim 2002). This A356 aluminium alloy contains Si > 7%. Hence in this research, the preparation of work material is done by choosing A356 as matrix material and SiC particles as reinforcing material.

3.2.3 Work Material Preparation

AMC work materials are prepared using stir cast method with A356 aluminium alloy whose chemical composition is presented in Table 3.1. The composite material is reinforced with 5%, 10%, and 15% silicon carbide by weight.

<table>
<thead>
<tr>
<th>Constituents</th>
<th>Cu</th>
<th>Si</th>
<th>Mg</th>
<th>Mn</th>
<th>Fe</th>
<th>Ni</th>
<th>Ti</th>
<th>Zn</th>
<th>Pb</th>
<th>Sn</th>
<th>Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage</td>
<td>0.08</td>
<td>7.08</td>
<td>0.52</td>
<td>0.12</td>
<td>0.36</td>
<td>0.005</td>
<td>0.054</td>
<td>0.014</td>
<td>&lt;0.002</td>
<td>0.015</td>
<td>balance</td>
</tr>
</tbody>
</table>

Hashim (2001) had experimented and found that wettability of SiC in casting A356 greatly improved when dealing with temperatures above 900 ºC. Furthermore improvement in wettability was obtained by adding coverall GR 2815, a grain refining flux. While adding particles to the melt agglomeration of particles will occur and care should be taken to disperse them with proper stirring. Coordination of melt temperature stirring speed and time is important to avoid any reactivity of the components as they can result in dissolution of the reinforcement components.
Ahmed et al (2005) studied the effects of porosity on mechanical properties of AMC. They used conventional (no preheating of SiC) and modified (pre heating SiC at 750ºC) and presented several findings as;

- modified conventional stir casting method had decreased the porosity occurrence for a total of 67.94%
- % SiC content increases porosity %
- Increasing in stirring speed helps for uniform distribution of SiC but increases porosity content
- SiC of 12% at 200 rpm is the best combination to get minimum porosity
- Better tensile strength and % elongation are obtained by modified method

The processing steps followed for preparing AMC (Sahin 2003, Ahmed et.al 2005), used in the present study are shown in Figure 3.1.

Figure 3.1 Process flow chart of MMC production
The metal moulds and stir casting set up used to cast the composite material are respectively shown in Figure 3.2 and Figure 3.3. The work specimens removed from the metal mould are presented as photograph in the Figure 3.4. The dimensions of the specimen are measured using vernier caliper and found to have 25 mm diameter and 175 mm in length.

Figure 3.2 Sketches of metal mould
3.2.4 Properties of Work Material

The specimens are further cut into pieces measuring Ø25 mm x 25 mm using power hacksaw and the cut surfaces are smoothened with fine grit emery paper. Figure 3.5 shows the Rockwell Hardness Tester which is used to measure the hardness of the work specimen with following test conditions.

- Indenter: Ball type
- Diameter of the indenter: 2.5 mm
- Load applied: 187.5 kgf
The indentation is carried out at three places on both sides of the specimen and the average diameter of the impression is determined as 1.8 mm. The Brinell Hardness Number (BHN) is calculated using the Equation (3.1) and arrived as 63 BHN.

\[
\frac{2P}{\pi D(D - \sqrt{D^2 - d^2})} \tag{3.1}
\]

By weighing the specimen the mass is found to be 88 grams and from the dimensions, the mass density of the composite is calculated as 2.56 g/cc.

The work material micrographs, obtained through Scanning Electron Microscope (SEM), are presented in Figures 3.6 to 3.8; show the
presence of silicon carbide particles in the matrix alloy for different proportions.

Figure 3.6 SEM micrograph of work material with 5% SiC

Figure 3.7 SEM micrograph of work material with 10% SiC
Now the prepared specimens are ready for machining under ECM. Before conducting the trials the experimental design has to be finalized.

3.3 SUMMARY

The chapter is initiated with selection of matrix metal and reinforcement material based on past literatures. The composite work specimen preparation procedure is designed and demonstrated. Determination of properties like hardness and density of the prepared materials are included. The succeeding chapter illustrates the steps involved in experimental design and how to identify the influencing parameters.

Figure 3.8 SEM micrograph of work material with 15% SiC