CHAPTER 4

FABRICATION OF MANUFACTURING SET-UP AND MANUFACTURING OF MMC BRAKE DRUM

4.1 INTRODUCTION

The fabrication of manufacturing set-up and the manufacturing of MMC brake drum are explained in this chapter. The manufacturing of MMC brake drum involves the casting, heat treatment and the machining of brake drum to required size.

4.2 SELECTION OF MANUFACTURING PROCESS

Even though the MMCs have highly promising mechanical and thermal properties, they have been afforded only limited use in very specific applications. Shortcomings such as complex processing requirements and the high cost of the final product have been the greatest barriers for their proliferation. There are different methods available for fabricating the MMCs and are classified into any one of the following categories.

4.2.1 Solid State process
4.2.2 Liquid State process
4.2.3 Deposition Process
4.2.1 Solid State Process

The solid state processes are generally used to obtain the highest mechanical properties particularly in discontinuous MMCs. In these processes, segregation effects and the formation of brittle reaction product are minimum when compared to liquid state processes.

4.2.1.1 Powder consolidation

Powder metallurgy is one of the most common methods for fabricating ceramic particles reinforced MMCs. Blending of metallic powder with ceramic fibers or particulate is a versatile technique for MMC production. After blending the metallic powder with ceramic reinforcement particulate, cold isostatic pressing is utilized to obtain a green compact that is then thoroughly outgassed and forged or extruded.

4.2.1.2 Diffusion bonding

Diffusion bonding is used for consolidating alternate layers of foils and fibers to create single ply or multiply composites. This is a solid state creep deformation process. The creep flow of the matrix between the fibers make complete metal to metal contact, diffusion across the foil interfaces completes the process. The pressure and the time requirements for consolidation can be determined from matrix flow stress, taking into consideration of the above matrix flow processes. To avoid fiber degradation, care must be exercised to maintain low pressure during consolidation.
4.2.2 Liquid State Process

A majority of commercially viable applications are now produced by liquid state processing because of certain inherent advantages of this processing technique. The liquid metal is generally less expensive and easier to handle than powders. Also the composites can be produced in a wide variety of shapes, making use of different methods already developed in the casting industry for non-reinforced metals. Liquid state processing technologies are currently being investigated and developed utilize a variety of methods to physically combine the matrix and the reinforcement. The important manufacturing processes are infiltration, dispersion, spraying and in-situ.

4.2.2.1 Infiltration

Infiltration processes involve holding a porous body of the reinforcing phase within a mould and infiltrating it with molten metal that flows through interstices to fill the pores and produce a composite. The infiltration process and the pressure driven infiltration process are shown in Figure 4.1 and Figure 4.2 respectively. The main parameters in infiltration processes are the initial composition, morphology, volume fraction and temperature of reinforcement, the initial composition, and temperature of infiltrating metal, and the nature and magnitude and external force applied to the metal. In some cases, the metals spontaneously infiltrate the reinforcement without any external force applied on it. To overcome poor wetting, mechanical work is applied on the molten metal to force the molten metal into the preform. The pressure required for infiltration can readily be calculated on the basis of the necessary meniscus curvature and corrections can be made for melt/fiber wetting. In practice, substantial pressures in the MPa range are likely to be needed. In most cases, fibers do not act as preferential crystal nucleation sites during melt solidification.
One consequence of this is that the last liquid to freeze, which is normally solute-enriched, tends to be located around the fibers. Such prolonged fiber/melt contact, often under high hydrostatic pressure and with solute enrichment, tends to favour formation of a strong interfacial bond.
4.2.2.2 Dispersion process

In dispersion process, the reinforcement is incorporated in loose form into the metal matrix. Since most reinforcement system exhibit poor wetting, mechanical force is required to combine the phases, generally through stirring. This method is currently the most inexpensive method to produce MMCs. MMCs can be produced in large quantities which can be further processed through conventional manufacturing processes. Figure 4.3 shows the dispersion process. The simplest method is the Vortex method, which consists of vigorous stirring of liquid metal and the addition of particles in the vortex. This method usually involves prolonged liquid-ceramic contact, which can cause substantial interfacial reaction. This has been studied in detail for Al-SiC, in which the formation of Al$_4$C$_3$ and Si can be extensive. This both degrades the final properties of the composite and raises the viscosity of the slurry, making subsequent casting difficult. The rate of reaction is reduced, and can become zero, if the melt is Si-rich, either by prior alloying or as a result of the reaction.

![Figure 4.3 Dispersion process](image)
The reaction kinetics and Si levels needed to eliminate it are such that it has been concluded that the casting of Al-SiC\textsubscript{p} involving prolonged melt holding operations is suited to conventional (high Silicon) casting alloys, but not to most wrought alloys. Porosity resulting from gas entrapment during mixing, oxide inclusions, reaction between metal and reinforcement, particle migration and clustering are the critical factors for the success of this dispersion process.

4.2.2.3 Spray process

In this process, droplets of molten metal are sprayed together with the reinforcing phase and collected on a substrate where metal solidification is completed. The critical parameters in spray processing are the initial temperature, size distribution and velocity of the metal drops, the velocity, temperature and feeding rate of the reinforcement and the nature and temperature of the substrate collecting the material. Most spray processes use gasses to atomize the molten metal into fine droplet stream. One advantage of the spray process is the fine grain size and low segregation of the resulting matrix microstructures. Figure 4.3 shows the spray process.

![Figure 4.4 Spray process](image-url)
4.2.2.4 In-situ Process

The in-situ composites are first used for the materials produced through solidification of polyphase alloys. When the polyphase alloys solidify, they may exhibit a fine lamellar or rod-like structure of β phase in an α phase matrix. The reinforced inter-metallic alloys may be produced by controlled solidification or by chemical reaction between a melt and solid or gaseous phases. The schematic diagram of manufacturing in-situ composites through the reaction of molten metal with a gas is shown in Figure 4.5.

![Figure 4.5 In-situ Process](image)

4.2.3 Deposition Process

In a typical low pressure plasma deposition process, the aluminium (alloy) powder plus reinforcement are fed into low pressure plasma. In the plasma, the matrix is heated above its melting point and accelerated by fast moving plasma gasses. These droplets are then projected on a substrate, together with the reinforcement particles. The latter particles remain solid during the whole process if one use lower power settings or may be partially
or fully melted when higher power settings are used. By a gradual change of the feeding powder composition, gradient materials can easily be produced.

### 4.3 FABRICATION OF DISPERSION PROCESS CASTING SET-UP

A dispersion process casting setup has been fabricated for manufacturing the Al MMC. It consists of three basic arrangements as shown in Figure 4.6. The melting arrangement has been used for melting and holding the liquid metal at a desired temperature (750°C) while stirring.

![Schematic diagram of the dispersion casting set-up](image)

**Figure 4.6 Schematic diagram of the dispersion casting set-up**

The Stirring arrangement has been designed to create a vortex on the molten metal. The schematic representation of the dispersion casting set-up is shown in Figure 4.6.
Figure 4.7 Manufacturing set-up

Figure 4.8 Aluminum alloy  Figure 4.9 SiC Particles

Figure 4.10 MMC brake drum
4.3.1 Melting Arrangement

An electric resistance type furnace with a temperature controller has been used to melt the aluminium alloy. The furnace has a capacity of 3.5kw power rating with a maximum operating temperature of 1200ºC and capable of melting 5 kg of aluminium in a batch. The furnace has the provision to maintain the required temperature. A graphite crucible has been used to hold the aluminium alloy inside the furnace. It has a provision to take it and pour the molten metal into the mold.

4.3.2 Feeding Arrangement

The feeding arrangement facilitates the uniform feeding of the preheated reinforcement particles into the vortex of the liquid metal. A funnel fitted with a metal tube has been fixed along the stirring arrangement. The free end of the metal tube is kept just above the vortex of the molten metal when the stirring setup is at the lowest position.

4.3.3 Fabrication of Stirrer Arrangement

A stirrer, which has four blades welded perpendicular to each other on one end of the long steel rod, has been fixed to the shaft of the motor. A sliding arrangement has been made for lowering and rising of the motor and stirring assembly. The electric motor has been connected to a speed controller (autotransformer) to vary the speed of the stirrer.

4.4 MANUFACTURING OF Al MMC BRAKE DRUM

The MMC brake drum has been manufactured through dispersion process. The sequence of manufacturing consists of melting the aluminium
alloy, preheating the reinforcement particles, creating vortex on the molten metal through stirring, uniform feeding of the reinforcements and the pouring of the composite slurry into the mould.

### 4.4.1 Melting of Aluminum Alloy

The required quantity (3kg) of A356 aluminium alloy has been placed in the graphite crucible and kept inside the furnace. The alloy is heated in the electrical resistance furnace and the temperature is set at 750ºC using the temperature controller. The temperature of the aluminium alloy has been increased and the melting takes place at 660ºC. Then, the temperature of the molten increases and it is maintained at 750ºC. The melting of the aluminium alloy is shown in Figure 4.7.

### 4.4.2 Preheating of Reinforcement Particle

The preheating of the reinforcement particles is carried out in an electrical muffle furnace. The reinforcement is heated up to a temperature of 750ºC and maintained at this temperature for 30 minutes.

### 4.4.3 Stirring

The motor-stirrer assembly is lowered so that the stirrer is submerged in the molten metal. Then, the stirrer is rotated at a speed of 500rpm using the speed controller. This creates a vortex on the molten metal surface. The preheated silicon carbide particle (43µm) is uniformly fed through the feeding arrangement. The feeding and the stirring are simultaneously carried out until the calculated preheated reinforcement is fed into the molten metal. After the addition of the reinforcement, stirring is
continued for 10 minutes at a reduced speed of 100rpm to make the homogenous composite slurry.

4.4.4 Casting

The composite slurry is then quickly poured into a mould and allowed to solidify. The solidified casting has been removed from the mould and cleaned. The gates and risers are removed and it is subjected to T6 heat treatment. The aluminum alloy and the reinforcement (SiC) used for making the MMC brake drum are shown in Figure 4.8 and Figure 4.9 respectively.

4.4.5 Machining of Casting

The cast MMC drum is then machined in a lathe machine using the carbide tool. The machining has been found to be very tough because of the presence of the hard ceramic reinforcements. The turning and the facing operations have been completed to get the required dimensions for the brake drum. The machined MMC brake drum is shown in Figure 4.10.

4.5 CONCLUSIONS

A dispersion casting set-up has been fabricated to manufacture the MMC brake drum. The MMC brake drum has been manufactured by using this casting set-up. The cast MMC brake drum is then machined to the required size using a conventional lathe machine using a diamond tipped tool. A specimen from the same lot is subjected to optical microscopy to ensure the uniform distribution of the reinforcement in the matrix. It can be concluded that the dispersion process is the economical and viable method for mass production of MMCs.