CHAPTER 3

MATERIALS AND EQUIPMENT

3.1 INTRODUCTION

A detailed discussion on materials for composites, production process as well as equipment used for evaluating the properties of the aluminium alloy metal matrix and hybrid composites is given in this following section.

3.2 MATERIALS

The materials selected for producing aluminium alloy metal matrix and hybrid composites are described in the following section.

3.2.1 Matrix Material

In this study, Al-Si10Mg aluminium alloy (Table 3.1) with the density of 2800 kg/m^3 was used as the matrix material. Al-Si10Mg alloy exhibits excellent resistance to corrosion under both ordinary atmospheric and marine conditions along with high strength and hardness.

Table 3.1 Chemical composition of aluminium alloy used (wt.%)

Al	Cu	Mg	Si	others
85.629	0.145	0.481	12.651	1.094

3.2.2 Reinforcements

Generally, the following requirements are applicable for selection of reinforcement materials: low density, compatibility with matrix alloy, chemical compatibility, thermal stability, high compression and tensile strength and economic efficiency. In metal matrix composites, reinforcement like alumina, silicon carbide strengthens the metal matrix both extrinsically, through load transfer to the ceramic reinforcement, and intrinsically by increasing the dislocation density. The interaction between the particulate reinforcement and the metallic matrix is the basis for the enhanced physical and mechanical properties associated with metal matrix composites. In hybrid metal matrix composites, a soft reinforcement like graphite and molybdenum disulphide contribute to low wear rate, friction, and anti-seizing properties.

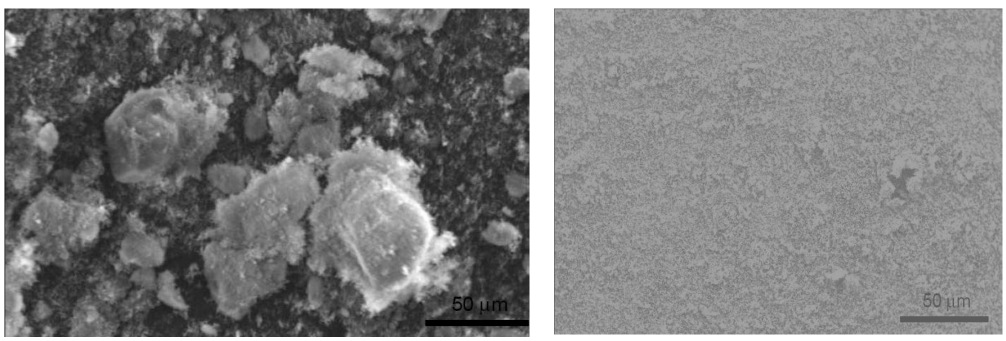
3.2.2.1 Hard reinforcement

In this study, aluminium oxide (Al_2O_3) particles (Figure 3.1 (a)) were used as reinforcement with an average particle size is 10-20 µm. Aluminium oxide possesses very low reactivity in molten metal and is relatively cheap. The resultant improvement in composite properties, such as stiffness, strength, and fracture toughness, though not as high as those of either the silicon carbide or boron carbide reinforcement as well as low reactivity and the low cost make this reinforcement very attractive for the production of cast metal matrix composites that require moderate strengths and stiffness improvement with very good wear resistance.

3.2.2.2 Soft Reinforcement

Molybdenum disulphide (MoS_2) solid lubricant is used as a soft reinforcement in this research work. The average particle size of MoS_2 is

1.5μm with density of 4.8 g/cm^3 (Figure 3.1 (b)). The low friction and easy cleavage of molybdenum disulfide is intrinsic to the material and a result of its crystal structure. The presence of condensable vapours is not required for molybdenum disulfide to exhibit low friction, as it is in the case of graphite, it has been established that condensable vapours play an important role in determining the friction and wear characteristics of a lubricant film of molybdenum disulfide. Special attentions have been given to relative amounts of solid lubricants in the metal matrix composites, since they affect the mechanical properties and tribological properties significantly.



(a) Alumina **(b) Molybdenum disulphide**

Figure 3.1 SEM micrograph of the reinforcements

3.3 PRODUCTION OF AMMC BY STIR CASTING

Al-Si10Mg alloy was charged into an electrical resistance-heated furnace modified for this investigation. The melting process was carried out under argon atmosphere in a graphite crucible, and heated to 1073 K. Mixing of reinforcement was conducted with a graphite impeller by stir casting method with separate graphite crucible. The pre-heated alumina incorporated into molten metal and stirring was continued for a further ten minutes. The molten mixture was solidified in a cast iron die in the form of cylindrical pin of diameter of 14 mm and length 73 mm. In the present work, Al-Si10Mg MMCs reinforced with 5 wt. % and 10 wt. % alumina were produced. The same procedure was repeated for hybrid metal matrix composite with 2 wt. %

and 4 wt. % of molybdenum disulphide and unreinforced alloy. The photograph of cast composites and machined wear pin is shown in Figure 3.2.

Figure 3.2 Composite castings and wear test pins

3.4 EQUIPMENT USED FOR CHARACTERISATION

Density of composites is determined using top loading electronic balance (Mettler Toledo make). According to the Archimedean principle, a solid body immersed in a liquid apparently loses as much of its own weight of the liquid it has displaced. This makes it possible to determine the unknown value. The density of the solid body is determined by using a liquid of known density.

Microstructure of the composite specimens was carried out using Carl Zeiss Goettingen Optical microscope. The specimens were metallographically polished to obtain average roughness value of 0.8 μm.

The micrographs of the polished specimens were recorded with different magnifications. Microhardness values were measured at various locations in composite specimen employing Mitutoyo microhardness tester with diamond indenter at a load of 100 g. The average of five readings was taken as the hardness of composites.

Tensile testing was carried out using Hounsefield tensometer. The ultimate tensile strength of the specimens was calculated from the load at which fracture occurred.

Morphology of worn surface of the composite specimen are carried out using JEOL JSM 6360, T100 Scanning Electron Microscope (SEM).

3.5 DRY SLIDING WEAR TEST

The technique used for studying dry sliding wear of composites is described in the following section.

3.5.1 Pin-on-disc Apparatus

Dry sliding wear behaviour of composites were studied using a pin-on-disc apparatus (DUCOM make), Figure 3.3 shows the arrangement of pin-on-disc apparatus. The disc material was made of EN-32 steel with a hardness of 65 HRC.

The pin specimen is pressed against disc at a specified load usually by means of an arm and attached weights. The apparatus have a friction force measuring system, for example, a load cell, that allows the coefficient of friction to be determined.

Figure 3.3 Pin-on-disc apparatus

3.5.2 Dry Sliding Wear Test Procedure

The dry sliding wear tests were carried out at room temperature ($30^oC \pm 3^oC$, RH 55 % ± 5%) under dry sliding condition in accordance with the ASTM G 99-95 standard. Cylindrical pins of 10 mm diameter and 40mm long were machined from composite casting and metallographically polished (Figure 3.2). Immediately prior to testing, were cleaned and dried using acetone to remove all dirt and foreign matter from the specimens. The following Equations (3.1- 3.4) are used for calculating volume loss, wear rate, specific wear rate and coefficient of friction.

$$\text{Volume loss} = \frac{m_1 - m_2}{\rho} \times 1000 \ \ mm^3 \tag{3.1}$$

$$\text{Wear rate} = \frac{V}{D} \ mm^3/m \tag{3.2}$$

$$\text{Specific wear rate} = \frac{V}{L \times D} \ \ mm^3 / N\text{-}m \tag{3.3}$$

$$\text{Coefficient of Friction, } \mu = \frac{F_T}{F_N} \tag{3.4}$$

where m_1 is the mass of the specimen before the wear test, m_2 is the mass of the specimen after the wear test, ρ is the density of the composite in g/cm^3, V is the volume loss in mm^3, L is the applied load in Newton, and D is the sliding distance in metre. The coefficient of friction is calculated by the ratio between tangential forces (F_T) and the normal force (F_N). The tangential force is obtained from the load cell fitted in the pin-on-disk apparatus. The measured tangential force measured only during the steady state condition.

3.6 HIGH STRESS ABRASIVE WEAR TEST

The same pin-on-disc type apparatus was employed to evaluate the high stress abrasive wear characteristics of composites. The disc was covered with commercial SiC emery sheet was fastened to a rotating disc. In order to encounter fresh abrasive material, the specimen was also moved against the parallel surface of the rotational steel disc. Mass loss of the specimens were measured before and after the wear test using electronic weighing balance (accuracy 0.0001 g) were repeated with additional specimens to obtain sufficient data for significant results.

3.7 SUMMARY

Continuous improvements in testing and manufacturing processes to obtain improvement of properties at lower cost remains at the forefront of efforts to expand the importance of metal matrix composites. During materials development and testing, every effort was made to ensure quality of the composites as well as reliability and repeatability of test methods adopted. The test methods, in particular wear test methods were carried out with reference to common occurrences of friction and wear in machinery to understand and solve existing or expected wear problems leading to significant cost reduction.