CHAPTER 5

CHARACTERISATION OF MECHANICAL AND TRIBOLOGICAL PROPERTIES OF SELF- LUBRICATING ALUMINIUM /MOLYBDENUM DISULPHIDE COMPOSITES

5.1 INTRODUCTION

Molybdenum disulphide (MoS_{2p}) is an important solid lubricant with low coefficient of friction under both normal atmospheres as well as in vacuum additionally does not rely on adsorbed vapours or moisture. It also has a relatively higher load-carrying capacity than other commonly used lubricants, such as graphite and PTFE. The friction coefficient of MoS_2 is in the range of 0.002-0.3 compared with that of graphite with 0.05-0.15 and PTFE with 0.03-0.1 .It also exhibits a better adhesion property than graphite (Lansdown 1999). Numerous composites developed based on aluminium graphite have been reported in literature. However, limited research on composites based on Aluminium- MoS_{2p} has been reported. An attempt has been made in this work to develop Al-Si10Mg/MoS_{2p} composites and investigate its microstructure, mechanical and tribological properties. Influence of the addition of MoS_{2p} in Al-Si10Mg (self lubricating composites - Al-Si10Mg/2MoS_{2p} and Al-Si10Mg/4MoS_{2p}) are compared with that of unreinforced alloy.

5.2 MICROSTRUCTURES

Optical micrographs of unreinforced Aluminium alloy as well as those of composites (Figure 4.1a-c) show as cast (dendriditic) structure consisting of silicon particles in a eutectic matrix. Microstructure of the composites (Al-Si10Mg/2MoS_{2p} and Al-Si10Mg/4MoS_{2p}) show increasingly refined microstructural features. This structural refinement can be attributed to the heterogeneous nucleation caused by the MoS_{2p}. Al-Si10Mg/4MoS_{2p} composite displays the finest microstructure because of higher fraction of MoS_{2p} addition. Figure 5.1 1b and 1c also confirm the uniform distribution of MoS_{2p} within the alloy.

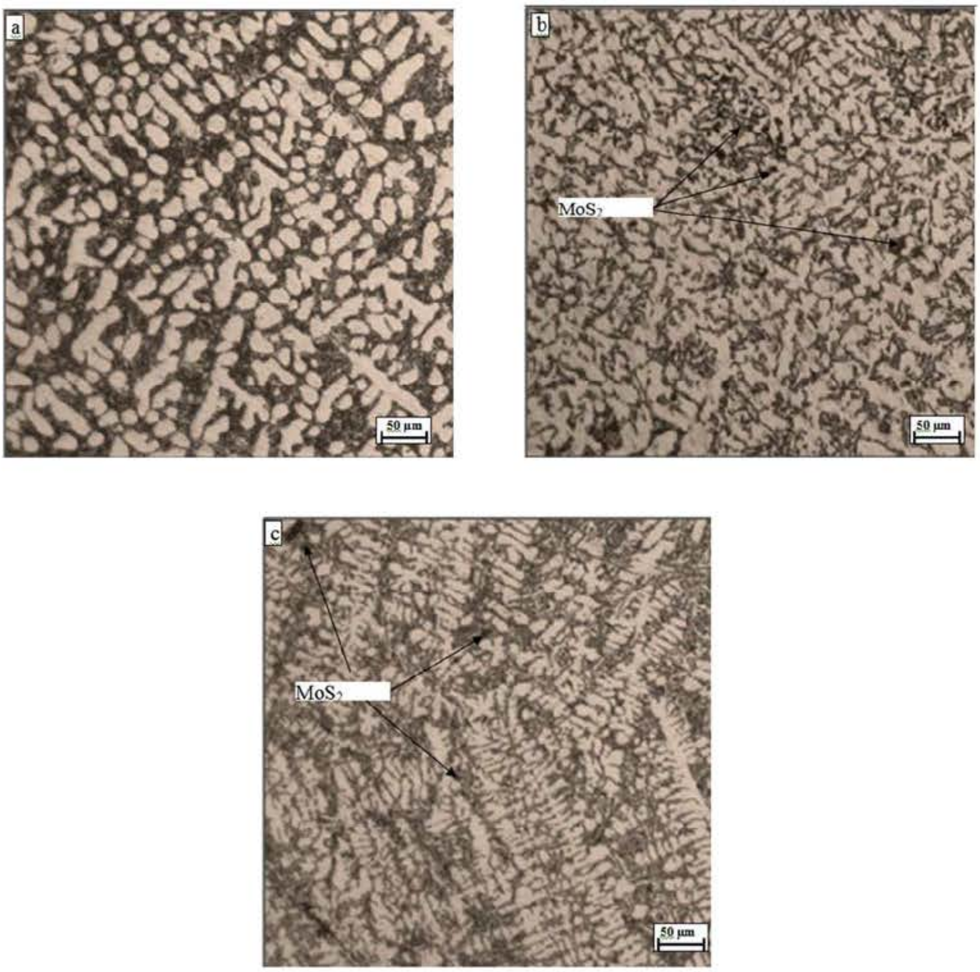

Figure 5.1 Microstructures of material a) Al-Si10Mg b) Al-Si10Mg/2MoS_{2p} c) Al-Si10Mg/4MoS_{2p}

5.3 PROPERTY EVALUATION OF ALUMINIUM/ MOLYBDENUM DISULPHIDE COMPOSITES

Results of the experiments done to evaluate the mechanical properties of the composites (density, hardness and tensile strength), are given in Table 5.1 and show the average values of different compositions measured at five different sections /positions.

5.3.1 Density

Density of MoS_{2p} was found to be higher than the aluminium alloy and can be attributed to the higher density of MoS_{2p} . Density of Al-Si10Mg/2MoS_{2p} and Al-Si10Mg/4MoS_{2p} was marginally higher than the aluminium alloy by 1% and 2% respectively.

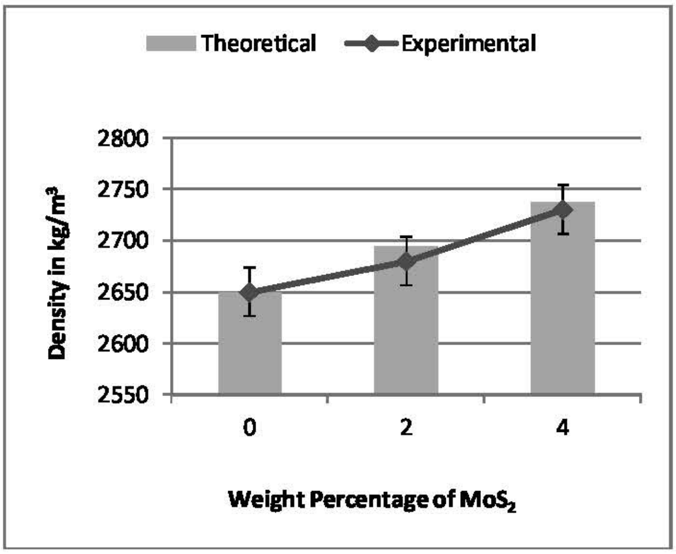

Figure 5.2 Variation in density of composite with increase in Weight Percentage of MoS_{2p}

This is in agreement with the theoretical density found by rule of mixtures using the Equation (5.1)

$$\rho_c = \frac{\rho_{MoS2}\rho_{Al}}{\rho_{Al}M_f^{MoS2} + \rho_{MoS2}\, M_f^{Al}}\ kg/m^3 \tag{5.1}$$

where M_f^{MoS2} &ρ_{MoS2} are the mass fraction and density of MoS respectively.

M_f^{Al}andρ_{Al} are the mass fraction and density of Aluminium alloy respectively.

5.3.2 Hardness

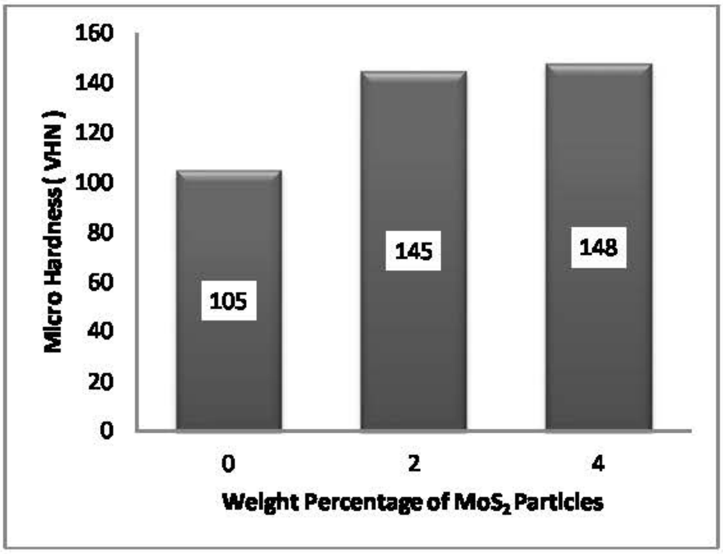

Figure 5.3 Variation in hardness of composite with increase in Weight PercentageMoS$_{2p}$

From the Figure 5.3 it is clear that as the reinforcement percentage increases the micro hardness also increases. There may be two mechanisms which can cause the observed increase in hardness. Primarily, the Coefficient of thermal expansion (CTE) of particles (MoS_2: 8.43μm/m°C) is less than that of aluminium alloy (22.3μm/m°C), an enormous amount of dislocations are generated at the particle–matrix interface during solidification process, which further increases the matrix hardness. Higher the amount of particle–matrix interface, the more is the hardening due to dislocations. Secondarily though the hardness of the basal planes of MoS_2 are soft, having a hardness of 1.0 to 1.5 on Moh's scale (approximately 27-36 Hv) the edges of the MoS_2 crystal are very hard with a hardness of 7.0 to 8.0 on Moh's scale (approximately (approximately 1160 -1560 Hv). These hard edges which are exposed to the surface also increase the hardness of the composites.

Therefore, the hardness of the composites increases with increase in volume fraction of the reinforcement. Hardness increases by 38% in the case of Al-Si10Mg/ $2MoS_{2p}$ while in the case of Al-Si10Mg/$4MoS_{2p}$ it is 41%

5.3.3 Ultimate tensile strength

Ultimate Tensile Strength (UTS) of Al-Si10Mg alloy was found to be 218.45MPa. It has been reported in previous researches that the addition of Al_2O_3 to AA6061 and AA7005 causes an increase in tensile strength (Ceschini et al. 2006). Contrary to this, studies on addition of Al_2O_3 to 2024 Al –alloy have shown a decrease in UTS(Abdel-Azim et al. 1995). In the present study, ultimate tensile strength considerably decreases due to the addition of 2 and 4% by weight MoS_2 by 15% and 22% respectively. This decrease in UTS is may be due to two reasons:the primary cause may be due to the various mechanisms like particle pull out and crack propagation caused by the presence of MoS_{2p}. Similar results were reported in SiC_p/aluminium-alloy composites (Cöcen and Önel 2002) and aluminium-Al_2O_3, aluminium-illite, aluminium-SiC particle (Surappa and Rohatgi 1981) and aluminium graphite composites. Secondary cause is the low ultimate tensile strength of MoS_2 (approximately 70MPa) compared to the base matrix(218 MPa), which results in decreased UTS.

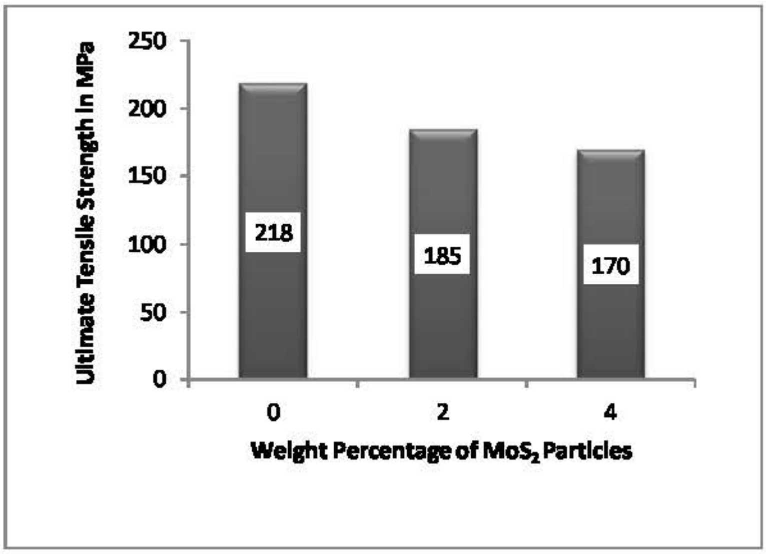

Figure 5.4 Variation in Ultimate Tensile Strength of composite with increase in Weight Percentage of MoS_{2p}

5.3.4 Percentage Elongation

The elongation of the composites showed a marginal decrease than unreinforced alloy indicating that the addition of MoS_{2p} lowered the ductility of the composite. Addition of 4 and 4 wt% MoS_{2p} resulted in a decrease in %elongation by 27% and 34% respectively. This is in agreement with the results observed in SiC reinforced of 2124,7075 alloys and monolithic aluminium(Doel and Bowen 1996 and Hall et al. 1994).

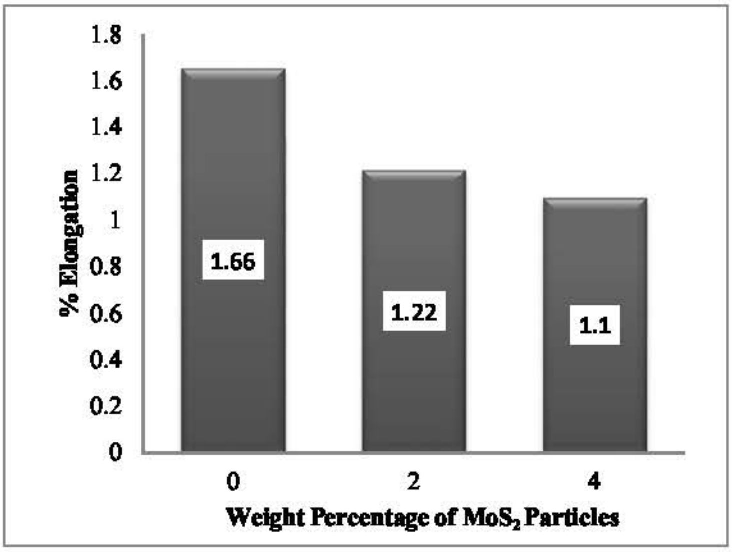

Figure 5.5 Variation in %Elongation of composite with increase in Weight Percentage of MoS_{2p}

5.3.5 Investigation on fracture behaviour of composites

Scanning Electron Microscopic studies of fractured surface was carried out to investigate the fracture modes in the composites.Figure 5.6 a-c shows the SEM fractographs of Al-Si10Mg, Al-Si10Mg/2MoS_{2p} and Al-Si10Mg/ 4MoS_{2p} respectively. From fractographs of the tensile test specimens (Figure 5.6 a), it can be seen that in the aluminium matrix alloy fracture was primarily fibrous showing microscopic void formation, their progressive growth and final coalescence around the reinforcement particles. It can be further observed that while the unreinforced alloys shows predominantly ductile fracture (fibrous regions), the composite specimens show increasing mixed mode (ductile and brittle regions). Fractographic studies also reveal features such as particle pullout, crack growth and propagation, which promote fracture.

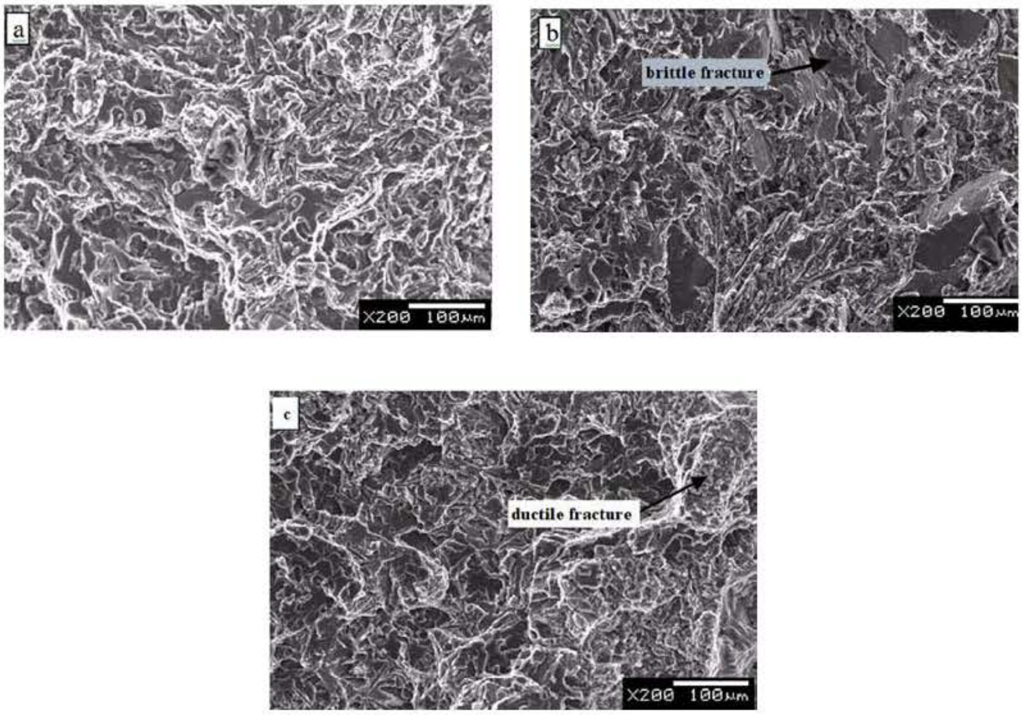

Figure 5.6 Fractomicrograph of material a) Al-Si10Mg b) Al-Si10Mg/2MoS$_2$ c) Al-Si10Mg/4MoS$_2$

5.4 TRIBOLOGICAL CHARACTERISATION OF SELF-LUBRICATING ALUMINIUM/ MOLYBDENUM DISULPHIDE COMPOSITES

Investigations on dry wear behaviour of Al-Si10Mg/MoS$_{2p}$ Composites were conducted using a Pin on Disk apparatus (discussed in section 3.3). A RSM-GA approach was employed for modelling, analysis and optimisation of wear behaviour of Al-Si10Mg/SiC$_p$ composites.Modelling of wear rate using RSM requires the experiments to be conducted as per DoE, as discussed in the following section.