ABSTRACT

In general, aluminium alloy components are light in weight and widely used in general engineering applications. But, they lack in good resistance to wear, particularly under poor, partial or boundary lubricated conditions. With solid lubricant particles dispersed in the matrix of aluminium alloy, this material exhibits good potential for resistance to wear and consequently, becomes more suitable for tribological applications. Aluminum based Metal Matrix composites (MMCs) have become a very valuable addition to the field of newer materials for high performance tribological applications. Aluminium based composites are being increasingly used in automobiles, aerospace, marine and mineral processing industries. Aluminium matrix composites are normally processed by the liquid casting technique or powder metallurgy route. In this work, the casting was done by the liquid casting technique. The particulates were mechanically stirred and well distributed over the liquid metal, before casting and solidification. Thus, this research work aims to identify the ability of AA 6061 and AA 7075 to acquire resistance to wear, when they were cast as composites with graphite, Al$_2$O$_3$ and B$_4$C as reinforcements. In all the investigations, the wear tests were conducted on pin-on-disc apparatus at room temperature.

Generally, a lubricant is externally added to reduce the wear. This poses a problem when the materials need periodic applications of the lubricant, particularly to wear parts which are difficult to access. For such applications, self-lubricating materials are preferred because the solid lubricant contained in them can be automatically released during the wear
process, to reduce the wear. Graphite is one of the most widely used solid lubricant materials.

In this work, AA 6061 and AA 7075 are reinforced with 5, 10, 15 and 20 wt. % of graphite. The dry sliding wear of the aluminum/graphite particulate was found to decrease with graphite content and touched a minimum wear rate with 5 wt. % graphite content. It is evident that the tribological behaviour of the aluminum alloy improves due to the addition of graphite particulates, which act as a solid lubricant. During dry sliding, the aluminium alloy graphite forms a layer of graphite with a solid lubricant between the contacting surfaces. It helps in reducing the friction coefficient and improving the tribological behaviour of the base alloys AA 6061 and AA 7075. The mechanical property of the composite material decreased with increasing graphite content.

The coefficient of friction of AA 6061/graphite and AA 7075/graphite composites were also found to decrease with the addition of graphite particles and recorded a 2.5 times lower value than that of the base alloy AA 6061 and a 2 times lower value than that of the base alloy AA 7075. Aluminium based MMCs reinforced with ceramic particles, developed better mechanical properties than unreinforced aluminium alloys and are widely used for tribological parts, due to their high ratio of strength/density and improved wear resistance. B₄C is the one of the most promising ceramic materials due to its high strength, low density and high hardness. Aluminium requires a temperature as high as 1100°C for wetting the B₄C surface. At such high temperature, the processing leads to the formation of undesirable compounds such as Al₃BC, AlB₂ and Al₄C₃ due to the chemical reaction between Al and B₄C. These reaction products degrade
the mechanical properties of the composites. The wetting between Al and B₄C is poor below 1100°C and this poses a difficulty in the production of Al- B₄C composites by mixing particles into the liquid phase. Aluminium/B₄C composites are fabricated through the casting route with the addition of K₂TiF₆ flux, forming TiC and TiB₂ reaction layer at the interface, overcoming the wettability problem.

The AA 6061 and AA 7075 produced with 5, 10, 15 and 20 vol. % of B₄C particulates exhibited an increase in the hardness, with increasing volume fraction of particulates, because of the increase in the ceramic phase of the matrix alloy. The higher hardness of the composites is because of B₄C particles acting as obstacles to the motion of dislocation. The ultimate tensile strength of aluminum 6061 and 7075 alloys increases with the addition of B₄C particulates due to the induction of higher strength B₄C particles into the matrix alloy, offering more resistance to the tensile stresses. The flexural strength was found to increase with increasing content of B₄C, which prevents the quick expansion of cracks through the composite and limits the deformation of the composites.

The ultimate compressive strength of the aluminium alloys increases with increasing content of B₄C particles more than that of the aluminium metal matrix. The increase in the amount of B₄C particles leads to a decrease in the distance between the particles, causing an increase in the stress required for the dislocation movement between the B₄C particles, resulting in higher material strength. The wear resistance of the composites increased with the addition of B₄C particles content. The wear rate is significantly less for composites compared to aluminum matrix material. The wear rate at 10 vol. % of B₄C is 45 times lower than the wear rate for the base
alloy AA 6061 material and 52 times lower than the wear rate for the AA 7075 matrix material. The friction coefficient of aluminium/B₄C composites decreases with the addition of the B₄C particles content. The coefficient of friction reaches a minimum of 0.32 at 10 vol. % of B₄C with AA 7075 and remains steady between 0.3 and 0.4 thereafter. With AA 6061, the coefficient of friction is 0.3 at 10 vol. % B₄C content. The MML formed on the surface which acts as a layer of solid lubricant, appears to be responsible for this behaviour.

With AA 7075/Al₂O₃/5 wt. % graphite hybrid composite, the presence of graphite exhibits a trend of lessening the wear, due to the formation of a thin layer of graphite on the tribo surface. The governing wear mechanism is abrasion and delamination. The presence of graphite in the hybrid composite has also been able to decrease the friction coefficient of the composite and this is attributed to the release of graphite, which acted as the solid lubricant during the wear process. In the AA 7075/graphite composite, the Al₂O₃ particulates in the hybrid configuration, improve the mechanical properties and wear behaviour. The wear rate of AA 7075/Al₂O₃/5 wt. % graphite hybrid composite at 2 wt. % of Al₂O₃ content was lower compared to that of the AA 7075/graphite composite. The AA 7075/B₄C composite exhibited relatively a good potential for occurring tribological properties and to developing resistance to wear at 10 vol. % of B₄C content.