**Investigations on Mechanical, Tribological and Electric discharge machining characteristics of hybrid aluminum matrix composites.**

**ABSTRACT**

The necessity to develop new materials with better mechanical and tribological properties led to the development of Aluminium Matrix Composites (AMCs). While AMCs have already proven their worth as lightweight materials, the current challenge is to make them cost effective.   
A significant reduction in reinforcement cost will make the AMCs cheaper. Since the cost of fly ash is much lower than most other reinforcing materials (SiC, Al2O3 and TiB2), it was chosen as one of the reinforcements.  
The literature review reveals thatextensive studies have been done on fly ash reinforced and graphite reinforced AMCs individually, but very limited research has been conducted on hybrid composites containing both fly ash and graphite particulate reinforcements. Therefore, an attempt was made to fabricate aluminium/fly ash/graphite (Al/FA/Gr) hybrid composites to analyze their mechanical properties, tribologicalbehaviour as well as the Electric Discharge Machining (EDM) characteristics.

Matrix material selected for the present study was AlSi10Mg alloy and the reinforcements were fly ash and graphite particles (average particle size 53 to 75 μm). AlSi10Mg alloy was reinforced with fly ash in varying amounts (3 wt.%, 6 wt.% and 9 wt.%) with a constant 3 wt.% graphite to synthesize the hybrid composites through stircasting technique. Unreinforced aluminium alloys as well as aluminium alloy reinforced with 3 wt.% graphite (Al/3Gr) were also cast for comparison studies with the hybrid composites.

Microstructural investigations confirmed the uniform distribution of reinforcements in the matrix.Density of the hybrid composites decreased with an increase in the weight fraction of fly ash particles. Density of AlSi10Mg/9wt.% fly ash/3wt.% graphite (Al/9FA/3Gr) hybrid composite was the lowest among all the composites. Mechanical properties of Al/FA/Gr hybrid composites were better compared to those of the Al/3Gr composite and unreinforced aluminium alloy.Strengthening of hybrid composites may be attributed to the higher load carrying capacity of hard fly ash particles. However, there was a decrease in the strength and Young’s modulus of the Al/3Gr composite in comparison to aluminium alloy. Percentage elongation of the hybrid composite decreasedas the fly ash content increased. Therefore, increase in the strength of hybrid composites occurred at the expense of ductility of the base alloy.

Dry sliding wear and friction behaviour of unreinforced alloy and composites were studied by varying the applied normal load from 9.81 N to 49.05 N for a constant sliding speed of 2 m/s and a sliding distance of 2400 m. Dry sliding wear behaviour of unreinforced alloy and composites was also investigated by varying the sliding distance from 600 m to 2400 m for a constant applied load of 19.62 N and a sliding speed of 3 m/s. Wear test results indicated that the wear rate of hybrid composites, Al/3Gr composite and unreinforced alloy increased with an increase in applied normal loads but showed a decrease with an increase in sliding distances. Al/9FA/3Gr hybrid composite exhibitedthe highest wear resistance compared to both unreinforced alloy and Al/3Gr composite at all applied loads and sliding distances. This improvement in tribological characteristics of hybrid composites can be attributed to the higher load carrying capacity of hard fly ash particles and the formation of a lubricating film of graphite between the sliding interfaces. Decrease in coefficient of friction (COF) of hybrid composites occurred due to the presence of hollow cenospheres in fly ash and also due to graphite.Abrasive wear and delamination were dominant in the mild wear regime (low normal loads) of aluminium alloy and composites and the both wear rates and COF were low. In the severe wear regime (high normal load), the dominant wear mechanism was adhesive wear characterised by higher wear rates and formation of transfer layers. Adhesive wear was not observed in Al/6FA/3Gr and Al/9FA/3Gr hybrid composites even at a high load of 49.05 N due to the increased wear resistance.Abrasive wear was dominant at the beginning of sliding for unreinforced alloy and composites and the resulting wear rates were high. As the sliding distance increased, the wear mechanism changed from severe abrasive wear to mild oxidative wear with wear occurring due to the removal of oxide fragments resulting in a reduction in the wear rate. At higher sliding distances, both the aluminium alloy (1800 m) and Al/3Gr composite (2400 m) exhibited delamination wear with formation of large craters. Severe delamination wear was not observed in Al/9FA/3Gr hybrid composite even up to a sliding distance of 2400 m due to the enhanced wear resistance.

Taguchi Design of Experiments(DOE) reveal that load was the most dominant parameter having the highest statistical influence on the wear rate of composites, followed by sliding speed and fly ash content.Results obtained from Signal-to-Noise ratio analysis and Analysis of Variance indicated that sliding distance has the highest influence on the volumetric wear loss and COF of hybrid composites. A significant increase in the volumetric wear loss of hybrid composites was observed with increasing sliding distance and load. However, a decrease in volumetric wear loss and wear rate was observed with an increase in both sliding speed and fly ash content. Wear mechanism was observed to change from severe abrasive wear to mild oxidative wear at high sliding speeds. Mild oxidative wear was predominant at high sliding speeds (3 m/s) and lower loads.An increase in COF of composites with increasing load was observed, but COF decreased with increase of sliding distance, sliding speed and fly ash content. Multiple linear regression models were developed which were effectively used to predict the wear rate, volumetric wear loss and COF of the hybrid composites.

Optimization of EDM parameters for Al/9FA/3Gr hybrid composite using Taguchi DOE showed that peak current, pulse-on-time (Ton) and flushing pressure were the main factors contributing to Surface Roughness (SR), Material Removal Rate (MRR) as well as Tool Wear Rate (TWR) in the order of importance listed. Multiple linear regression models were developed, which could be effectively employed to predict the SR, MRR and TWR.Optimal parameter combination was determined by Grey relational analysis for obtaining the maximum MRR as well as minimum SR and TWR.