ABSTRACT

Aluminum alloys are increasingly used industrially for production of automobile components due to their good strength, stiffness, wear résistance, thermal stability, corrosion resistance and their light weight quality compared to other materials. Composite materials are replacing monolithic materials because of their ability to provide suitable combination of properties through proper selection of reinforcement. Al alloys are popularly used as matrix material for metal matrix composites. AMCs provide better machinability as well as good wear and thermal characteristics. AMCs reinforced with hard particles such as Al_2O_3, B_4C, SiCp, WC and soft particles such as graphite and molybdenum disulphide enhance high strength, hardness and improve wear and frictional characteristics. Several researchers have conducted investigations on AMCs and reported that the size and weight percentage of the reinforcement primarily influences the hardness of the composites followed by other factors. In the present study, AlSi7Mg alloy was chosen as the matrix and reinforced with varying proportions of WC and constant graphite (Both < 1 microns) composites were fabricated through stir casting method. Graphite was used to provide the lubrication effect through the formation of lubricant film. WC is one of the reinforcements having the hardest high melting point. Three different composites (in wt %) Al/3WC/3Gr, Al/6WC/3Gr, Al/9WC/3Gr with a constant 3% graphite were prepared along with unreinforced alloy samples for comparison purposes. Design of Experiments (DOE) based on Taguchi method was employed to study the effect of process parameters on machinability, wear rate and Coefficient of Friction (COF) both at room and high temperatures. Multiple linear regression analysis were carried out, models were developed for machinability and wear parameters. Confirmation experiment using Scanning

Electron Microscopy (SEM) investigation was done to confirm the validity of the regression model developed.

Density of Al/9WC/3Gr was found to be higher than other composites due to the higher density of WC. Hardness of the composites increased with increasing weight percentage of reinforcement content due to the very high hardness of WC. A maximum increase in hardness of 31% was obtained in Al/9WC/3Gr hybrid composites. Tensile strength of the composites increased due to the addition of WC and Al/9WC/3Gr exhibited the highest tensile strength. Microstructural investigation showed a uniform distribution of WC and Gr particles in the matrix and with good interfacial bonding.

Machining of composite material in conventional machining process is very difficult and the tool wear rate is also very high compared to non-conventional machining process. Investigation of machining process was carried out in Wire cut Electrical Discharge Machine (WEDM) for studying the machining behavior as well as to obtain conditions that will give maximum MRR, minimum KW and the best surface finish. Process parameters chosen were pulse-off time, input power, voltage, wire speed, wire tension and weight percentage of reinforcement content. Voltage gap and water pressure were taken as constants. Three levels were selected for each process parameters. MRR value increased with increase in input power and voltage and increase in pulse-off time, while wire speed and wire tension decreased the SR. KW decreased with increasing pulse-off time and voltage. ANOVA results showed that input power had a major influence on MRR and voltage was the most influential parameter in SR. Input power exhibited a significant influence on KW.

Tribological characteristics (wear and Coefficient of friction) of unreinforced alloy and hybrid composites were investigated during dry sliding wear test. Process parameters were applied load (10 N,15 N and 20 N) sliding speeds of 1 m/s,1.5 m/s and 2 m/s for different WC contents (3 wt %, 6 wt % and 9 wt %). Sliding distance was kept constant at 3000 m. SEM analysis was carried out on worn surfaces of Al alloy and Al/WC/3Gr hybrid composites to investigate wear features, operating wear mechanism as well as transition from one mechanism to the other.

Sliding speed is one of the major factors influencing the wear rate of the composites. Increase in sliding speed decreases the wear rate and COF. As the applied load increases, the wear rate and COF also increased. Severe delamination was observed at higher load conditions. With an increase in the weight percentage of reinforcement content, the wear rate and COF decreased due to higher amount of WC, which results in wear of the matrix. Optimum conditions for minimum wear rate and COF were obtained using ANOVA where load = 10 N, SS = 2 m/s and reinforcement content = 9%. ANOVA studies also indicated that sliding speed had the highest contribution for wear rate followed by % reinforcement and applied load. For COF, applied load had the highest influence followed by reinforcement and sliding speed. Compared to unreinforced alloy, hybrid composites showed better wear resistance and lowest wear rate as observed in Al/9WC/3Gr hybrid composites. Regression equations were generated for wear rate and COF to develop the correlation between the significant factors influencing these responses and were found to have a very good fit. Interaction effect had a very small effect on wear rate and COF.

High temperature wear behavior was studied at temperatures of 50°C, 75°C and 100°C. In this study, loads of 10 N, 15 N and 20 N along with a sliding speed of 1 m/s, 1.5 m/s and 2 m/s and weight percentage of reinforcement (3 wt %, 6 wt % and 9 wt %) were used for investigation. A constant sliding distance of 1000m was used in the study. As both load and temperature increased, the wear rate and COF showed an increase. An increase in sliding speed and reinforcement content decreased the wear rate and COF. At 50°C, only limited wear was observed in all the composites tested at different sliding speeds and loads. Comparatively higher wear was observed in unreinforced aluminum alloy. Smooth and finer wear tracks were formed in Al/9WC/3Gr composite which indicated that this composite had the highest wear resistance. Higher wear rate with severe delamination in the Al alloy was observed at 75°C. Increase in reinforcement content up to 9% showed increased wear resistance. Severe wear was observed at 100°C for both parent metal and hybrid composites. Deeper and wider grooves, as well as delamination were observed. Increase in test temperature results in increase in the wear rate and COF for both unreinforced aluminum alloys and hybrid composites. Optimum values of test parameters for wear rate and COF obtained from ANOVA where load = 10 N, SS = 2 m/s reinforcement content = 9 % and a temperature of 50°C. Percentage of reinforcement content was the most influential factor on high temperature wear rate and COF followed by applied load and temperature.

Confirmation experiment using different set of test parameters than those used in DOE were conducted to validate the parameters used in both machinability and tribological characteristics on the response variables (MRR, SR and KW in machinability, wear rate and COF in tribological studies).

In summary, it can be concluded that the incorporation of hard WC particles improves the mechanical properties and wear characteristics while the graphite addition serves as lubricant improving both machining and wear characteristics.