ABSTRACT

The Metal Matrix Composites (MMCs) are used extensively now a days in many fields including aerospace, automotive, electronics, defence, and consumer appliances. This increased applicability of MMCs may be attributed to its desirable properties like good strength to density ratio, lower coefficient of thermal expansion, better wear resistance, good stiffness to density ratio, and fatigue resistance. These specific properties can very well be used in automobile field for reduction of vehicle weight, with less fuel consumption and reduced emission. The reinforcements like Aluminium Oxide (Al_2O_3), Silicon Carbide (SiC), Hexagonal Boron Nitride (HBN), Tungsten Disulphide (WS_2) are commonly added to the metal matrices to improve the mechanical and physical properties of the base material through different processes, which produces MMCs. Magnesium is one of the abundant materials available in the world and its strength to weight ratio is also suitable for its application in automobile component manufacturing. Magnesium composites have the advantages of good stiffness, high specific strength, good electrical conductivity, excellent heat dissipation, good castability, formability and machinability.

Usage of solid lubricants instead of the liquid lubricants is more preferred at present considering the environmental aspects. Graphite is one of the important solid lubricants used in industry. Graphite's lamellar structure provided larger load bearing capacity perpendicular to the layers and hence able to slide along the layers which makes it an effective solid lubricant.

In this present doctoral work, fabrication of magnesium metal matrix composite with graphite reinforcement followed by the analysis and optimization of tribological, machining properties have been mainly focused. The magnesium metal matrix composite samples have been prepared with 1%, 3% and 5% weight of Graphite reinforcements. The MMC samples have been manufactured through stir casting route, which ensures the uniform mixing of reinforcement in the metal matrix. Inert atmosphere has been used to avoid oxidation and self-immolation behavior of magnesium at higher temperature. The uniform distribution of graphite reinforcement in the magnesium alloy matrix is ensured with the help of optical microscope and Scanning Electron Microscope (SEM) studies. The hardness of the resulted MMCs is examined using Brinell hardness test.

Hardness test reveals that the hardness of Magnesium metal matrix composite increases with increase in the weight percentage of graphite reinforcement. Presence of graphite or carbon in any material usually increases the hardness of the material which has been evident from the present data also.

Magnesium metal matrix composite's tribological characteristics have been evaluated using pin on disc test method. Percentage of reinforcement, sliding velocity and applied load have been taken as the factors/variables for evaluating wear rate and friction coefficient. For each factor, three levels have been considered and for the Design of Experiment (DoE), Taguchi technique has been used. L27 orthogonal array has been arrived at and optimisation carried out using MINITAB 16 software. Analysis of Variance (ANOVA) and Signal to Noise ratio (S-N) models have been considered in order to understand the interaction between the three factors viz., percentage of reinforcement, sliding velocity and applied load.

Magnesium composite components have been fabricated mostly by turning operation using single point cutting tools in industries. The surface finish and productivity are the major challenges in the machining of MMCs. To achieve this, in the developed magnesium MMCs, factors like cutting forces, temperature and depth of cut need to be optimised. Hence, to optimize the machining parameters to achieve less cutting force, less cutting temperature with good surface finish, Response Surface Methodology (RSM) has been used. The experiment trails have been planned using face centered central composite design of RSM. Turning process has been carried out using magnesium MMC specimen with 5% graphite reinforcement at various levels of cutting speed, feed and depth of cut. The surface finish and cutting forces have been evaluated as a function of cutting speed, feed and depth of cut. The cutting forces and temperature have been measured using lathe tool dynamometer and thermocouples respectively.

Wear tests have shown that the presence of solid lubricant reinforcement i.e., graphite reduced the wear rate. Increase in graphite reinforcement percentage in the magnesium matrix reduces the wear rate to a considerable quantity. Graphite reinforcements expose during machining process, which acts as lubricant and hence reduces wear rate.

Increasing load removes the lubricating layers and results in more wear till the next layers formed between the sliding faces. It also increases the friction coefficient. While increasing the sliding distance the wear and friction got reduced due to the graphite layer formation during the sliding, making it to act as a lubrication layer.

The machining studies reveal that the surface roughness has been affected significantly by cutting speed and feed rate. For obtaining better surface finish, we need to process with higher cutting speed and lower feed rate whereas, the variation in depth of cut has minimal effect on the surface finish. The presence of graphite reinforcements during machining reduces the interface between the cutting edge and the specimen, which results in the reduction of cutting forces as well as improvement in surface finish.

During turning, the cutting forces decreases with increase in cutting speed. When there has been an increase in feed or depth of cut it results in increase of cutting force.

Cutting temperature has influenced by the interaction between feed versus depth of cut and the cutting speed versus feed. When there has been a rise in cutting speed, feed and depth of cut, there has been also an increase in the temperature developed. It has been because of short machining duration and more friction due to which built up edge resulted in cutting tool. Brittleness of the heat affected zone during turning also results in fragmented chip, which have been short in length.

By RSM technique, regression equations for surface finish, temperature and cutting forces have been arrived as surface, contour plots of surface finish, temperature and cutting forces have been also evaluated with two independent variables.

Thus the solid lubricant graphite reinforced magnesium metal matrix composites can be used where ever the wear resistance, good hardness, surface finish and machinability are essential.

Since MMCs find applications in aerospace, in future fatigue properties of graphite reinforced magnesium metal composite may also be studied.