ABSTRACT

Aluminum Metal Matrix composites are used in functional applications, unequivocally, in thermal management, defense, automobile and aerospace. These composites are used to manufacture light weight products owing to their high specific mechanical properties and low density. Ceramic materials, being generally hard and brittle components, are dispersed into the matrix to obtain properties that are superior to conventional alloys. Aluminum alloys are preferred due to their high strength to weight ratio, corrosion resistant properties and perfusion in nature, since their advantages being low, owing to low wear resistance property, hybrid composites are being widely used as substitutes of these metal matrix composites for improving their physical properties. Metal matrix composites consist of two materials with one being metal; the other can be of different material that acts as reinforcement. Metal matrix composites comprising of three constituents are called hybrid composites while reinforcements are used to improve their properties.

Hybrid composites of Aluminum with silicate and fly ash characterised with high specific strength and excellent corrosion resistance are used in various engineering applications. Since ceramic materials such as silicon carbide, aluminium oxide, and titanium boron are expensive, Silicate particulate, obtained from naturally available rock makes it an amazing dispersoid, to provide low cost metal matrix composites. Silicate, which is available in large quantities having hardness values of 981–1161 H, and composed of alumina silicates of calcium, is chemically inert even at higher temperatures and softening at temperatures of 1413K–1553K is being extensively used. On the other hand, Fly ash being one of the most inexpensive and low density reinforcement, available in large quantities as
solid waste by-product, during combustion of coal in thermal power plants, is being preferred as reinforcement material in the matrix. Hence, composites with fly ash as reinforcement are likely to overcome the cost barrier for the making of metal based matrices. It is expected that the incorporation of fly ash and silicate particles reinforced aluminum composites will be gaining importance because of their low costs with advantages like isotropic properties.

The hard particles present in a metal matrix composite, are a cause of concern as they present severe problems in machining. Efforts have been made to develop machinable materials of these products, since, whatever the case might be, a little amount of finishing needs to be done in order to complete the assembly process. However, for joining and assembling, secondary machining processes such as drilling and turning are necessitated. Drilling is often the last of the manufacturing processes to be conducted on a part before assembly. In drilling, the surface of interest is the side wall of the hole, which is burnished by the rubbing action of the twisted flutes of the drill and the material that escapes outwards. Turning is the most widely used process among all the machining processes. The increasing importance of turning operations is gaining new dimensions, in the present industrial age, in which the growing competition calls for all the efforts to be directed towards the manufacture of machined parts economically. Surface finish is one of the most critical quality measures in mechanical products. Now a days, owing to the criticality in competition, a customer seeks and demands a high quality finished product, hence surface finish and material removal, which are the most competitive parameters in today’s manufacturing industry, call for easily machinable materials.

In the past, Researches have been carried out on the mechanical and wear properties of Aluminum metal matrix composites with different
reinforcement materials. It can be stated, that a good volume of research has been carried out on the mechanical, wear and machining characteristics of aluminum metal matrix composites, with different reinforcement materials. As far as the case of hybrid LM24 alloy composites, is concerned, very limited literature is available covering the various aspects such as mechanical properties, wear behaviour and machining studies of aluminum alloy metal matrix composites, based on the various experiments conducted on these composites. But tribological studies and optimization of machining parameters for drilling and turning on LM24/Silicate/ Fly Ash Hybrid Composite under different conditions has not been reported so far. Hence, in this research work, an attempt has been made to study the wear behaviour, mechanical properties and machining characteristics, under different conditions, on LM24/Silicate/ Fly Ash Hybrid Composite.

The first stage of this research work has been to fabricate the aluminum alloy with a Silicate/ Fly Ash Hybrid using stir casting method. The dissolving was done in an electrical resistance heater and the stir casting technique was adopted to obtain the composite samples. The melt was maintained at a temperature between 1025K and 1075K for an hour, Two thermocouples and one proportional integral derivative controller were used while the temperature of the furnace was precisely measured and controlled in order to obtain a sound quality of the composite. To start with, the composite was prepared using LM24 aluminum alloy with silicate and fly ash. The chemical composition of LM24 is given in Table 1. Silicate particles of 100 mesh sizes, varying from 4 to 24 wt. %, in steps of 4 wt. %, were used to prepare the composites. Fly ash consists of refractory oxides like silica, alumina, and iron oxides in the proportion of 4 wt. % reinforcing phase. An Aluminite coated mechanical stirrer was necessitated, in order that the migration of ferrous ions, from the stirrer into the matrix alloy melt, could be
prevented. The silicate was preheated to a temperature of 713K and then introduced into the slurry. The stirring was continued until particle and matrix wetting occurred. Finally, the melt was degassed, deslagged and the refined metal was poured into a cylindrical mould. After the mould was cooled down to room temperature, the specimen were taken out and cut to required dimensions.

Second stage of this research work was to study the tribological characteristics of LM24/Silicate/ Fly Ash Hybrid Composite. The wear test was carried out using pin on disc apparatus and pins were tested against the steel disc possessing a hardness of 62 Rockwell hardness C scale. Prior to the tests, the pins were polished with a silicon carbide-1200 grit polishing paper and cleaned with acetone. The wear tests were conducted using an applied load range of 15-75 N in varying step of 15 N at sliding velocities of 0.75 to 3 m/s in step of 0.75 m/s and with a constant sliding distance of 3000m. The volume loss of the pin was calculated, before and after each wear test, using an electronic digital weight balance having an accuracy of 0.1 mg. All these tests were conducted at room temperature of 300K and a relative humidity of 48%. A Metallurgical microscope was used to capture the microstructure of the composite while a scanning electron microscope was used to study the morphology of the composite. Hence, in this work, load (15, 45, 60 N) sliding velocity (0.75, 1.5, 3 m/s) and % of silicate particles (8, 16, 24 wt. %) were identified as the main parameters for the objective of minimization of wear rate and an experimental plan based on Taguchi’s L9 orthogonal array had been selected.

The third stage of this research work was the optimization of machining parameters for drilling LM24/24 wt. % silicate/ 4 wt. % fly ash hybrid composite using the Taguchi technique and the grey relational analysis. The drilling tests were conducted on a radial drilling machine and
experiments carried out on LM24/24 wt. % silicate/ 4 wt. % fly ash hybrid composite, which was cut into plates of about 200x100x20mm. Equal spacing was maintained between successive drilled holes in the plate. Titanium aluminium nitride coated drill bit was used throughout the experimental work. The responses, such as average surface roughness and cutting force, which are mostly used in industries, were considered for this study. The cutting force and torque was measured using strain gauge dynamometer and the surface roughness was measured using SURFTEST 211. Hence, in this work, cutting speed, feed and point angle of drill were identified as a factors, for the purpose of minimization of surface roughness and cutting force. In this work, three factors and its levels selected for drilling operation were, cutting speed (30, 60, 90 m/min), feed (0.5, 1, 1.5 mm/rev) and point of angle (100, 120, 140 degree) and an experimental plan, based on Taguchi’s L₉ orthogonal array was selected.

Fourth stage of this research work required the optimization of machining parameters for computer numerical control turning LM24/24 wt. % silicate/ 4 wt. % fly ash hybrid composite using Taguchi technique and grey relational analysis. The experiments were conducted on Fanuc computer numerical control lathe. Work piece positioning accuracy the machine was ± 0.010 and a run out was tested by dial gauge with a heavy duty magnetic base. LM24/24 wt. % silicate/ 4 wt. % fly ash hybrid composite, of diameter 25 mm and machined length of 30 mm, was taken as the work piece material, for all trials, and a Titanium aluminium nitride coated insert was selected. Tool geometry of CNMG120408 and tool holder of PCLNR25 × 25 M12.1 were selected. Three factors, at three levels, considered as parameters, for this research work were, Cutting speeds (50, 100, 150 m/min), feed (0.2, 0.4, 0.6 mm/rev) and depth of cut (0.5, 1.5, 2.5 mm). The surface roughness and material removal rate were the important characteristics in the turning
operation and hence minimization of surface roughness and maximization of material removal rate were taken as the objectives of this research work. Surface roughness was measured for all the cases by the SURF TEST 211 tool and results denoted by Ra. Hence, an experimental plan based on Taguchi’s L_9 orthogonal array was selected under dry conditions with different combinations of the parameter levels. Taguchi method was applied to a single response optimization and grey relational analysis was employed to multiple response optimizations. LM24/silicate/fly ash hybrids composite is increasing the mechanical properties. The hardness of the LM24/silicate/fly ash hybrid composite increases with the addition of silicate and it is higher than that of base alloy. The fly ash addition normally decreases the strength but with the addition of silicate particles, improves the mechanical properties. The density was decreased with increasing silicate content.