ABSTRACT

Aluminium Matrix Composites (AMCs) are exploited continuously in numerous applications owing to their superior properties such as high strength, hardness, low density, low heat expansion coefficient, and stable properties at elevated temperatures. The mechanical properties of the AMCs are governed by the selection of suitable reinforcement particles and fabrication processes. The vital aspect which limits the utilization of AMCs is the high cost of the ceramic reinforcements and cost of fabrication. This concern could be abridged by employing cost-effective reinforcements such as fly ash, agro-wastes, and natural minerals.

The reinforcement materials chosen for this research work are metakaolin particles with an average particle size of 200 nm and Si_3N_4 particles with an aggregate particle size of 50 nm. AA6082 is employed as the matrix material. Metakaolin is an ultrafine and hard pozzolanic material manufactured by calcination of the natural ceramic kaolinite at a temperature ranging from 650 to 900°C. At present, metakaolin is used as a partial replacement for cement in concrete. Silicon Nitride (Si_3N_4) is a ceramic material with exceptional fracture toughness.

The stir casting technique is the most straightforward and economical processing method of fabricating particle reinforced aluminium matrix composites. However, while using nano-sized reinforcement particles, this trend is not being perceived because of the development of agglomeration and particle cluster porosity. Ultrasonic cavitation assisted stir casting technique could be employed to avoid agglomeration and wettability concerns.

This research work highlighted the preparation and characterization of AMCs with AA6082 as the matrix and metakaolin and nano-Si_3N_4 particles as the reinforcements. The hard metakaolin particles improved the strength, hardness, and wear behaviour of the AA6082 matrix while considerably degrading the ductility of the material. Hybridization of the AA6082-metakaolin AMC by incorporating nano-Si_3N_4 as the secondary reinforcement material could rectify the ductility issues. Moreover, the mechanical and wear behaviour of the AMCs were also found to be improved. Initially, the composites were prepared with metakaolin as single reinforcement, and the optimum amount of reinforcement for attaining the improvement in properties of the composites was determined as 7.5 weight (wt.) %. The effect of the nano Si_3N_4 particles as reinforcement in the AA6082 matrix along with metakaolin particles was determined further.

An attempt has been made to construct a mathematical model for the wear parameters of the prepared AMCs. Response Surface Methodology (RSM) with the Central Composite Design (CCD) has been utilized for developing the mathematical model. The optimized wear parameters for desired wear behaviour has also been evaluated. An attempt has also been made to study the effect of ceramic reinforcements on the workability of the AMCs. The workability study was done by means of cold upsetting tests in which the cylindrical samples were subjected to quasi-static compression.