Notification: F.No.COE/Ph.D/(Notification)/568/2024
Dated: 04-10-2024

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Title of the Thesis:	Characterization & Tribo-Mechanical Behavior of Al-MHA-Si_3N_4 Hybrid Composites Developed by Powder Metallurgy Method.
Keywords:	Powder Metallurgy (PM), Mustard Husk Ash (MHA), Pallet, Hybrid Composites, Tribo-Mechanical Testing, Machine Learning.

FINDINGS

Aluminium metal matrix composites are the new generation materials having improved tribo-mechanical properties as compare to monolithic materials. The Aluminium based composites have high strength to density ratio which full fill the requirement of light weight and high strength component required in automobile and aviation industries. The Aluminium alloys exhibit good properties like low density, high strength, good machinability, and durability, easily available and optimum cost. The tribo-mechanical properties of the Aluminium metal matrix composites are improved with conventional reinforcements (SiC, Al_2O_3, TiB_2, Si_3N_4). Moreover, addition of agriculture paddy as reinforcement improves the mechanical, physical and thermal properties of developed composites which make them suitable for various sectors of engineering.

The research work has been carried out with the aim, development of Aluminium based hybrid composites has light weight, stand against dynamic environmental conditions, optimum cost, excellent tribo-mechanical properties and useful for automobile sector.

Hence the pure Aluminium (Al) reinforced with mustard husk ash (MHA) and silicon nitride (Si_3N_4) hybrid composites were developed by powder metallurgy method. The experimental analysis was conducted under required environmental conditions to assess the physical and tribo-mechanical properties of the developed (Al-MHA-Si_3N_4) hybrid composites.

1. The fine Aluminium powder of 99.7% purity used as matrix material. The α-silicon nitride (Si_3N_4) has average particle size ≤10 μm taken as reinforcement. The mustard husk ash was prepared by the burning of mustard husk at 600 ^{0}C for one hour in a muffle furnace. The average size of the mustard husk ash particle was ≤75 μm. Firstly, the weight of Aluminium powder, silicon nitride powder (Si_3N_4) and mustard husk powder was done according to the composition decided in research. In the next stage the matrix material Aluminium was mixed with reinforcement materials (Si_3N_4 & MHA) with 5wt % of Si_3N_4 and (0, 2.5wt%, 5wt%, 7.5wt% and 10wt%) of MHA with different five compositions. The mixing of these compositions was carried out at 100 RPM with simple ball miller of BAXCO-2021 series keep ball to powder ratio (BPR) 10:1 for 180 minutes. In the next stage green cylindrical pallets were developed according to ASTM standards, with five different compositions at 300MPa, 400MPa, 400MPa, 500MPa, 600MPa, and 700MPa compaction pressure. Then the green pallets were sintered in tube furnace at 500^{0}C in meticulous ether of

Nitrogen for 45 minutes with supply of 50mL/min and heating and cooling was maintained 5 ^{0}C/min.The flow of nitrogen gas was continue till the room temperature was achieved.

2. The tribo-mechanical testing of developed Al-Si_3N_4-MHA hybrid composites was performed. The hardness test of the pallets was performed on Mitutoyo vikers hardness and Rockwell hardness tester. The compressive strength of the pallets was performed on Ganasen hydraulic compression machine of 100 kN. The wear behavior test was performed on pin on disc machine (DUCOM, Model No.TR-20L-PHM800-SHM850) at sliding distance (SD) 300m, sliding speed 1.5 m/s and 35 N load was applied during wear testing of the pallets. The SEM analysis after wear test was carried out for analysis of wear mechanism of worn surfaces of hybrid composites from pallet A to pallet E. The uniform distribution of reinforcement material into matrix material was observed. The presence of hard ceramic particles in reinforcement and compaction pressure enhances the wear resistance behavior. The tensile strength and low cycle fatigue strength of the pallets was calculated on the computerized tensometer (KIPL, Hadapsar, Pune, India of model PC2000) and computerized UTM and fatigue testing machine 100 kN respectively. The pulling speed of tensometer was fixed at 3mm/min and having the maximum load capacity limit between 1 N to 20050 N and proof stress of the tensometer was kept at 0.2%. The low cycle fatigue test was performed at load ratio R 0.4 and frequency of 3 Hz.

   The findings were that the hybrid composites reinforced with mustard husk ash (MHA) and Si_3N_4 reveal superior tribo-mechanical properties of composites with compaction pressure. The micro hardness of the pallet A at 300 MPa is 35.18 VHN average value of 10 readings and value of hardness for pallet E (Al+10wt%MHA+5wt%Si_3N_4) compacted at 700 MPa gives the value 63.8 VHN. The compressive strength of the hybrid composites pallet A is 166 MPa enhance to Pallet E is 319 MPa due to increase the wt% (0 - 10wt %) of the reinforcement and compaction pressure. The tensile strength of the pallet A is 48.81 MPa and Pallet E is 118.92 MPa composites also enhanced with reinforcement and compaction pressure. The reduction in the weight of Al-MHA-Si_3N_4 hybrid composites was found from 0.1459 mg to 0.0167 mg which is nearly 87% as compare to pure metal and coefficient of friction increase by 9.7% with addition of reinforcement and compaction pressure. The no. of low fatigue cycles decreases with increase the applied stress. The number of fatigue cycles increase 23038 to 56696 of Al-MHA-Si3N4 hybrid composites which is 40% enhancement in the fatigue life. The endurance limit was at a tensile stress of 24.4 MPa and 12494 cycles for infinity fatigue life cycles. Further, increase of the reinforcement wt% above 10wt% the tribo-mechanical properties of the hybrid composites start decline.

3. The machine learning (ML) tool is used to logical analysis of gathered data of tribo-mechanical testing. The influence of the input parameters on the output was analyzed. In this research two input parameter are set, one is reinforcement weight% (0 - 10wt %) and another is compaction pressure between (300MPa-700MPa). The three techniques SVM, Decision Tree and ANN are applied. After correlation of these techniques ANN model was found best correlation in the form of output data. It was observed that parameters which influence the physical properties and tribo-mechanical properties were mustard husk ash wt%, and compaction pressure, respectively.