ABSTRACT

The term ‘co-continuous’ refers to a class of composites in which the two phases namely, metal and ceramic are topologically interconnected. This results in a three-dimensionally interpenetrating structure with near to isotropic properties. Co-continuous ceramic composites (referred to as C4) possess the advantages of higher wear resistance, enhanced thermal and electrical conductivity, high stiffness and hardness over discontinuous phase composites.

In the present work, three aluminium alloys namely AA2024, AA6063 and AA7068 were gravity infiltrated into porous SiC performs to manufacture co-continuous composites. The effect of varying machining parameters namely, speed, feed and depth of cut during end milling of C4, on the multi-responses of surface roughness, tool wear and depth of cut was investigated using Response Surface Methodology (RSM). Non-linear regression models were generated and optimal machining parameters were determined using desirability analysis. Confirmation experiments performed, validated the models with a ± 10 % error in prediction. Tests have shown that, by applying this technique, an improvement in the response characteristics of surface roughness and tool wear has been achieved.

These co-continuous composites also have potential in friction and braking applications due to their unique tribological characteristics. Hence, the present work also conducted a Taguchi Grey Relational Analysis (GRA) based optimization of wear parameters such as applied load, sliding speed and sliding distance. The effect of the parameters on dry sliding wear performance of the fabricated co-continuous composites was investigated. A Taguchi L9 orthogonal array was designed and nine experimental runs

were performed based on designed experiments. The coefficient of wear and specific wear rate were recorded for each experiment.

Initially, infiltration temperature and time of soaking were selected and optimized for effective gravity infiltration to produce an interpenetrated Al/SiC C4. The optimization study identified that, in order to obtain an infiltration depth of 22 mm, 3 hours of soaking at 800 ºC was the optimum value. The structural, metallographic and non-destructive characterizations namely, radiographic tests, XRD and SEM ensured the absence of blow holes or any other internal flaws and deleterious products in the C4 samples fabricated using the optimized parameters. Furthermore, the hardness assessment of pressureless gravity infiltrated Al/SiC C4 samples revealed that, the hardness of C4 are 30-50 % superior than their respective monolithic infiltrant alloy. The Brinell hardness of AA2024 alloy and AA2024/SiC C4 is estimated to be 48 and 103 BHN respectively whereas the hardness of AA6063 alloy and AA6063/SiC C4 is found to be 26 and 74 BHN respectively. AA7068 based alloy and C4 exhibits an average hardness of 71 and 122 BHN respectively. This substantiates that, the SiC ceramic preform contributes to the enhanced hardness of the C4 compared with that of the monolithic alloy.

The multi-response optimization (MRO) analysis using RSM, on the machinability of C4 by varying speed, feed and depth of cut concluded that, the optimal machining parameters for AA2024/SiC C4 are, speed of 3000 rpm, feed of 749.91 mm/min and depth of cut of 0.6 mm. The corresponding values for AA6063/SiC C4 were 4804.02 rpm, 750 mm/min, 0.6 mm and AA7068/SiC C4 were 3000 rpm, 450 mm/min and 0.6 mm respectively. In addition, the individual desirabilities for SR, TW and MRR for AA2024/SiC were 0.9989, 0.9034 and 0.9903. The corresponding values for AA6063/SiC C4 were 0.8939, 1.000, 0.8813 and AA7068/SiC C4 were 0.9813, 0.86335 and 0.92284 respectively. The composite desirability for the combination of all the goals for the three C4 samples was 0.9633, 0.9236 and 0.9212, close to the highest attainable desirability of 1. The surfaces, contours and equations reveal that, feed rate and depth of cut have a major influence on surface roughness followed by cutting speed. The interaction between feed rate and depth of cut also influences the smoothness of the surface. The detailed analysis of trend plots of the machinability studies reveal that, the AA6063/SiC C4 which possesses the lowest hardness among the three composites, exhibits highest surface roughness values. In comparison, the C4 composed of AA7068/SiC exhibits better surface finish and the highest tool wear due to its high hardness among the three composites.

The multi-response optimization on the wear behavior of fabricated C4 was performed using GRA by varying applied load, sliding speed and sliding distance. This analysis nominates the optimum wear parameters of AA2024/SiC C4 as 20 N, 1 m/s and 3000 m. In the case of AA6063/SiC and AA7068/SiC C4 the optimum design parameters were obtained as 60 N, 1 m/s, 1000 m and 20 N, 1 m/s, 1000 m respectively. Additionally, the sliding speed had the highest influence of 60.31 % for AA2024/SiC C4 followed by sliding distance with 13.89 % and applied load with 2.13 %. An improvement of 35.17 % in Grey Relational Grade (GRG) of the wear test at optimal conditions was observed over the initial design parameters for AA2024/SiC C4. Similarly, sliding speed had the highest influence of 61.04 % for AA6063/SiC C4 followed by sliding distance with 24 % and applied load with 14.8 %. The improvement in GRG in this case, was 34.67 %. The MRO for AA7068/SiC C4 showed that sliding speed had the highest influence of 82.8 % for AA7068/SiC C4 followed by sliding distance with 15.04 % and applied load with 2.13 %. The improvement in GRG of optimal conditions over the initial design parameters for AA7068/SiC C4 was 27.25 %. SEM analysis of the worn surfaces of the three Al/SiC C4 showed severe adhesive wear at initial design parameters and shallow wear tracks signifying predominantly abrasive wear at the optimal parameters. Similar to machinability studies, the analysis of trend plots revealed that, the friction coefficient decreased with an increase in the applied load for all three C4 samples considered. The trend plot of specific wear rate revealed that wear rate increased with the load applied on the wear specimen for all the composites. Further, for all loading conditions, the COF and the wear rate varied inversely with the hardness of the composites. The C4 sample of AA7068/SiC exhibited the lowest COF values due to its high hardness while a higher wear rate was displayed by the relatively soft AA6063/SiC C4. Overall, the MRO studies on machinability of Al/SiC C4 proposes that, RSM based MRO is beneficial to identify the optimum machining parameters. The MRO studies on wear behavior of Al/SiC C4 proposes that, GRA based MRO is beneficial to identify the optimum wear parameters for materials such as Al/SiC co-continuous composites.