CHAPTER 06

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The study focuses extensively on the aspects related to microstructural, physical and mechanical properties of as-cast as well as heat treated Al 7075/SiC\textsubscript{p} MMCs, parametric optimization for mechanical properties and machinability of the optimized MMC sample in terms of cutting temperature, surface roughness, tool wear and chip morphology during turning in dry and SIC environments using multilayer coated carbide inserts. Based on results of the research, following conclusions may be drawn.

1. Optical micrographs of SiC\textsubscript{p} reinforced Al 7075 matrix composites, produced by liquid metallurgy stir casting method reveal homogeneous dispersion of reinforcements in the matrix alloy with some local agglomerations. T6 condition of heat treatment reduced the particle agglomeration up to a considerable extent. The particle agglomeration increased with increase in reinforcement weight percentage and reduction of particle size. EDX spectra show presence of highest percentage of Al, along with other elements like Si, Zn, Mg, C and O in the MMC samples. XRD patterns show three phases i.e. solid solution of Al (Al\textsubscript{SS}), SiC and Al\textsubscript{2}CuMg. In these patterns intensities of SiC peaks increase with increasing the reinforcement contents in the MMCs.

2. Density of most of the MMC samples was lower than that of the unreinforced alloy, even though SiC is of higher density than the Al 7075 alloy. Density and percentage of porosity in the MMCs increased with increase in weight percentage of SiC\textsubscript{p} content. A rapid increase of porosity was observed due to combined influence of increase in weight percentage of SiC particulates and reduction of their mean size in the MMCs; however no specific trend for porosity was found due to variation of particle size only.

3. T6 condition of heat treatment increased the microhardness, yield strength, ultimate tensile strength, compressive strength, impact strength and flexural strength of all the test samples, but reduced their ductility and maximum deflection.
4. Increase of reinforcement content and reduction of their mean particle size improved the microhardness (HV), compressive strength and impact strength of the MMCs, but reduced their ductility, flexural strength and maximum deflection. Yield strength of the MMCs reduced with increase in reinforcement content, but increased with reduction of their particle size, both in as-cast and heat treated conditions. For the as-cast composite samples, the ultimate tensile strength increased for SiC\(_p\) content up to 15 weight percentage and then reduced for 25 weight percentage of SiC\(_p\) content. However, for heat treated MMCs, a gradual reduction of ultimate tensile strength was observed with increase in the SiC\(_p\) content. On reduction of particle size, the ultimate tensile strength increased for all the MMC samples.

5. Linear regression models were developed for the mechanical properties of the heat treated MMCs. High coefficients of determination (R\(^2\)) for the models indicated very good prediction of the responses. Normal probability plots of residuals depicted normal distribution of errors and significance of the models.

6. During multiple performance optimization of fabrication process parameters for mechanical properties of the heat treated Al 7075/SiC\(_p\) MMCs, the highest value of the mean grey relational grade was achieved for the MMC with mean SiC\(_p\) size 6.18 \(\mu\)m and 25 weight percentage of SiC\(_p\) content. It is the recommended combination of the levels of process parameters for fabricating the Al 7075/SiC\(_p\) MMC to achieve the optimal values of hardness, ultimate tensile strength, compressive strength, impact strength and flexural strength simultaneously. 41.9% of improvement in grey relational grade was achieved during confirmation experiments. ANOVA results for grey relational grade revealed the mean size of SiC\(_p\) was the more influencing process parameter than its weight percentage in the MMCs.

7. SiC environment reduced the cutting temperature, average surface roughness and tool flank wear during turning the heat treated (T6 conditioned) Al 7075/25 wt.% SiC\(_p\) (6.18 \(\mu\)m) MMC.

8. Dissipation of heat from machining zone to the air-water spray may be the cause of temperature reduction during turning in SiC environment. Formation of grooves,
particle pull-out and particle fracture were the causes of surface imperfections during turning the MMC. Abrasion and adhesion were the principal flank wear mechanisms for the multilayer TiN coated carbide inserts during turning.

9. In dry machining condition the chips were saw-toothed, semi continuous, tubular and spiral shaped with large curling circle radius, which deteriorated the quality of machined surfaces; however, in SIC environment, the chips were short, thin flaked, segmented and C-shaped with small curling circle radius, which are desirable to reduce the roughness on the machined surface.

10. Main effects plots for $T$, $Ra$ and $VBc$ revealed that the cutting temperature and flank wear increased with increase in any of the machining parameters (i.e. spindle speed, feed or depth of cut); however, the surface roughness reduced with increase of spindle speed and increased with increase of either feed or depth of cut, while turning the heat treated Al 7075/25 wt.% SiC$_p$ (6.18 µm) MMC sample in SIC environment. The mean flank wear increased from 0.1315 mm to 0.2253 mm (around 71%), as the spindle speed increased from 250 rpm to 1575 rpm.

11. Quadratic response surface models were developed for $T$, $Ra$ and $VBc$ during turning the heat treated Al 7075/25 wt.% SiC$_p$ (6.18 µm) MMC in SIC environment. The adequacy and fitness of the models were confirmed from the high values of determination coefficient, $R^2$ (close to 100%). High significance of the regression equations were confirmed through ANOVA. Normal probability plots show that the residuals lie reasonably close to the normal probability lines, implying that residuals are distributed normally and the terms mentioned in the quadratic regression models are significant and adequate. The adequacy of the models was also verified through the plots for residuals versus the fitted values and the plots for residuals versus observation orders. Surface plots and contour plots for cutting temperature, average surface roughness and tool flank wear in spindle speed-feed plane (at a hold value of depth of cut = 0.35 mm) reveal that the cutting temperature increases on increasing spindle speed or feed, average surface roughness reduces on increasing spindle speed but increases on increasing feed and flank wear increases on increasing either spindle speed or feed.
12. Grey relational analysis revealed that during turning the heat treated Al 7075/25 wt.% SiC$_p$ (6.18 µm) MMC in SIC environment, a combination of spindle speed, feed and depth of cut of 250 rpm, 0.05 mm/rev and 0.2 mm respectively, was the optimal combination of machining process parameters for the multiple performance characteristics, i.e. cutting temperature, arithmetic average of surface roughness and tool flank wear. From the confirmation test the improvement in grey relational grade was 50.61%. ANOVA results for grey relational grade revealed feed was the most significant machining process parameter followed by spindle speed and depth of cut.
SCOPE FOR FUTURE WORK

Several investigations for further work can be recommended as an extension to the present research. Further research may be concentrated on the following issues:

1. Size of SiC particulates may be reduced to Nano level to fabricate SiC Nano-particulate reinforced Al 7075 MMCs. The fabrication process may be modified by using ultrasonic vibration instead of the simple motorized stirring to achieve more uniformity in dispersion of reinforcements. Further, the fabrication process may be conducted in inert gas atmosphere to prevent oxygen contaminations in the MMCs.

2. Different thermal properties such as specific heat capacity, coefficients of thermal expansion, thermal conductivity and thermal stress; and mechanical properties such as shear strength, creep and fatigue strength may be investigated to recommend the MMCs for suitable and advanced applications.

3. Future work may also involve analysis of extended cutting parameters, different tool geometries and tool materials. Some additional variables, such as cutting tool nose radius and cutting time may be taken into consideration for further research in turning the MMCs to investigate the progression of flank wear, surface roughness and cutting forces in Spray Impingement Cooling (SIC) and Minimum Quantity Lubrication (MQL) environments.

4. The machining process parameters may be optimized for the desired responses using advanced soft computing techniques like Fuzzy Logic (FL), Artificial Neural Network (ANN), Genetic Algorithm (GA), Simulated Annealing (SA), Ant Colony Optimization (ACO) and Particle Swarm Optimization (PSO).

5. Finite Element Model (FEM) for the MMC turning can be developed using various high-end softwares to understand the fundamentals of MMC turning process and predict various responses like cutting temperature, surface roughness, tool wear, chip morphology, cutting forces, stress on the cutting tool and residual stresses.