NAME OF THE SCHOLAR: VINOD KUMAR SAINI
NAME OF SUPERVISOR: Prof. (Dr.) ZAHID A. KHAN
DEPARTMENT: MECHANICAL ENGINEERING
TITLE OF THESIS: SOME STUDIES ON MACHINING OF METAL MATRIX COMPOSITE USING WIRE ELECTRIC DISCHARGE MACHINING

ABSTRACT

In the recent past, there was a need for producing less expensive materials which can simultaneously provide optimum level of performance. MMCs are newly developed class of materials which are widely used in aerospace, automotive, sports, dies and mould industries because of their ability to maintain high strength to weight ratio at elevated temperature, excellent wear resistance and low thermal expansion. Aluminium alloys are lightweight, environmental resistance, high thermal and electrical conductor. Two alloys Al 6061 and Al 7010 were chosen for this study. These alloys possess better mechanical properties which make them attractive for use in aerospace and automotive industries. Most of the present work on MMCs has focused on aluminium alloys as the matrix metal with particulate reinforcement such as SiC and Al_2O_3 because of their greater ease of manufacture, lower production costs etc.

In the present study, an attempt has been made to develop an aluminium alloy based silicon carbide particulate MMCs using stir casting with an objective to develop a conventional low cost method of producing MMCs and to obtain homogenous distribution of ceramic material. Stir casting set-up was developed for fabricating the MMCs. Stir casting set-up comprised of a furnace, crucible, DC Motor, stirring system, argon gas cylinder and it has been used for successful fabrication of two composite materials (Al 6061/ SiCp 10% and Al 7010/ SiCp 10%) with 37 µm SiC particulate size. Microstructural and mechanical characterization of the two cast Al 6061/ SiCp 10% and Al 7010/ SiCp 10% MMCs were carried out. It is revealed from the microstructure examination that the SiC particles are distributed fairly homogeneous in the matrix. Examination of mechanical properties of both the MMCs shows improvement in the tensile strength and hardness. However, percentage elongation and impact strength of both the MMCs are found to be reduced due to the presence of SiC as reinforcement which is very hard and brittle in nature.

WEDM is an important thermal advanced machining process, capable of accurate machining of a variety of difficult to machine materials. WEDM is a spark erosion process in which sparks are generated between the electrically conductive workpiece and a wire electrode flushed with a dielectric fluid. In the present research an attempt has been made to investigate the effect of WEDM parameters on the performance of this process during machining of two fabricated MMCs. Preliminary experiments (one factor at time) were carried out in order to identify the critical WEDM parameters and to decide the range and levels of various input parameters. After the preliminary experimentation three machining parameters, i.e. pulse on time (Ton), pulse off time (Toff), peak current (Ip) each at three levels were selected as input variables and Gap Current (GC), Average Cutting Rate (ACR), surface roughness (SR), Material Removal Rate (MRR) and microstructure were chosen as response variables.

Box Behnken Design (BBD) of Response Surface Methodology (RSM) has been used to design the experiment. Main experiments were conducted to investigate the effect of input variables on the process performance/response variables i.e. gap current, average cutting rate, surface roughness and material removal rate. Normal probability plots were drawn for residuals to check the normal distribution of data. The regression model equation for all the responses as a function of input process variables were developed using experimental data. Analysis of Variance (ANOVA) was employed to analyze the significant effects of the WEDM parameters. Effect of individual parameters and their interaction were analyzed by both statistical and graphical

representations. Multi-response optimization based on desirability function was used to obtain optimum level of WEDM parameters. Confirmation experiments were carried out to validate the findings of the studies. Results of the present study reveals that during WEDM of Al6061/SiCp10% and Al7010/SiCp10% gap current increases with increase in pulse on time, peak current and decreases with increase in pulse off time. Average cutting rate increases with increase in both peak current and pulse on time but decreases with increase in pulse off time. Surface roughness increases with increase in both peak current and pulse on time but decreases with increase in pulse off time. MRR increases with increase in both peak current and pulse on time but decreases with increase in pulse off time.

The influence of each parameter on the responses is established using ANOVA at the 5% level of significance. ANOVA results for GC (6061/SiCp 10%) shows that the factors A (pulse on time), B (pulse off time), C (peak current) the quadratic term B^2, C^2, the interaction AC and BC all have a significant effect on GC however A^2 and the interaction AB has no significant effect on the GC. ANOVA results for ACR (6061/SiCp 10%) shows that the factors A, B, C, the quadratic term B^2 have a significant effect on ACR however the quadratic terms A^2, C^2, the interaction terms AB, BC and AC has no significant effect on the ACR. ANOVA Results of SR (6061/SiCp 10%) shows that the factors A, B, C, the interaction terms AB, the quadratic term and B^2, C^2 have a significant effect on SR. However, the quadratic terms A^2, the interaction terms BC and AC do not have a significant effect on the SR. ANOVA results of MRR (6061/SiCp 10%) shows that the factors A, B, C, the quadratic terms A^2, B^2, C^2, interaction terms AB, BC and AC all have a significant effect on MRR. ANOVA results for GC (7010/SiCp 10%) shows that the factors A, B, C, the quadratic terms A^2, B^2, C^2, interaction terms AB, BC and AC all have a significant effect on GC. ANOVA results of ACR (7010/SiCp 10%) shows that the factors A, B, C, the quadratic terms A^2, B^2, the interaction terms AB, BC and AC all have a significant effect on ACR. However the quadratic term C^2 has no significant effect on the ACR. ANOVA results for SR (7010/SiCp 10%) shows that the factors A, B, C, the quadratic term B^2, C^2, interaction term AB and AC all have a significant effect on SR. However the quadratic term A^2, the interaction term BC has no significant effect on the SR. ANOVA result of MRR (7010/SiCp 10%) shows that the factors A, B, C, the quadratic terms B^2, C^2, interaction terms AB and AC all have a significant effect on MRR. However, the quadratic terms A^2, the interaction term BC has no significant effect on the MRR.

From the results of ANOVA, the values of the correlation coefficient (R^2) of gap current, average cutting rate, surface roughness, and MRR is 0.9988, 0.9960, 0.9875, 0.9972 respectively, for Al 6061/SiCp and in case of Al 7010/SiCp MMC, this value is 0.9985, 0.9975, 0.9855, 0.9943 respectively. These results show that the developed models are precisely adequate for predicting the responses because the value of correlation coefficients is near to unity.

It was found that the maximum absolute percentage errors between experimental results and RSM predicted values of gap current, average cutting rate, surface roughness, and MRR are 3.13, 5.44, 5.61, 4.33 respectively, for Al6061/SiCp and in case of Al 7010/SiCp MMCs maximum absolute percentage error values are 2.44, 5.74, 6.80, 5.82 respectively.

Maximum absolute percentage error values for confirmation experiments of gap current, average cutting speed, surface roughness, and MRR 3.38, 2.45, 2.16, 2.22 respectively, for Al6061/SiCp and in case of Al 7010/SiCp MMCs maximum absolute percentage error values are 6.0, 9.6, 3.81, 3.37 respectively. It can be revealed that the maximum absolute percentage error was very less. This result shows that the developed models were precisely adequate for predicting the responses for the given input parameters.

After the main experiments, recast layer and other thermal damage on the machined surface was investigated. Scanned electron microscope (SEM) micrographs of machined surface were taken at various input parameters, to study the recast layer and surface damage. The more surface damage was observed due to the high heat in micrograph of Al6061/SiCp 10% and Al 7010/SiCp 10% at higher pulse on time. Finally, a comparison of the WEDM process performance in machining of Al 6061/SiCp vs. Al 7010/ SiCp has been made.