Finite element simulation of machining Al/SiC metal matrix composite

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ABSTRACT – Metal Matrix Composites (MMC) are a new kind of material to the world community especially in the field of engineering. MMC are placed in a composite group where they have received very high demand due to their properties. However, despite the public's interest in this material, MMC are classified as one of the hard-to-machine materials due to the presence of the hard-abrasive reinforcement particles that is harder than the existing cutting tools. Furthermore, the lack of commercialization of a specific cutter for the machining of MMC materials indirectly affects cutting performance such as surface roughness, high cutting force, high cutting temperature and reduce tool life. The aim of this paper is to perform finite element modeling simulation for machining Aluminium Silicon Carbide (Al/SiC) MMC material. The FE modeling start with the extraction of end mill geometrical feature model prior to the Al/SiC material definition. ANSYS Explicit Dynamics was used for the modeling and machining simulation. Good agreement between simulation and experimental results show the validity of the model in handling real-field problems. The proposed FE modeling technique can be used as an input in the process planning and decision-making levels.

1. INTRODUCTION

Metal matrix composite (MMC) is a newly introduced type of material that have multiple desirable mechanical characteristics such as high strength, hardness, wear resistance and weight-to-weight ratio. Aluminium, titanium and magnesium alloy are utilized as the matrix material, while silicon carbide (SiC) and alumina (Al_2O_3) are the most common reinforcements. SiC particle-reinforced MMC materials have become useful engineering materials because of their properties which are low weight, heat-resistant, wear□resistant and low cost. Previous studies show that both extrinsic parameters (cutting speed, feed rate, cutting depth and cutting tool type) and intrinsic parameters (particulate size, volume fraction and reinforcement type) affect the machinability of particle reinforced MMCs [1].

Due to the extreme expense and time-consuming of performing an experiment according to the experiment design, prediction models are the best option as they provide several advantages that allow a prevalent method to evaluate arbitrary geometries and loading conditions. FEA has been applied comprehensively with consistency in the use of numerical methods. Nevertheless, to achieve credible and reliable findings this study requires a broad collection of generation data. The advantages of the prediction model in the machining process would result in maximising the cutting tool output, in addition to increasing the efficiency of the workpieces. Through designing the prediction model, the conditions that happened by cutting method that could uncover the phenomena and analyse it. Therefore, it is difficult to monitor all of the variables that led to the efficiency and quality problems. Very few attempts were made during the machining process to produce predictive models for the behaviour of MMCs. To fully understand the behaviour of the material, further research on the prediction of the machining forces and machining parameters is needed [2].

2. METHODOLOGY

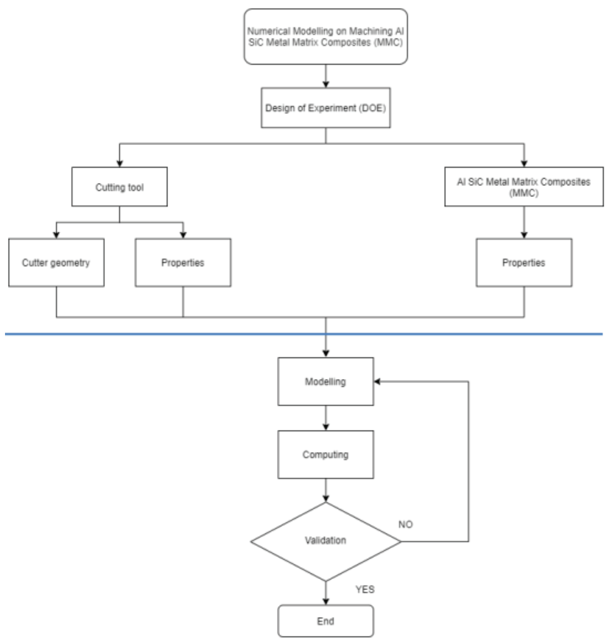

Figure 1 Research flow chart

Figure 1 shows the methodology for the FE modeling step. Table 1 depicted the orthogonal array design matrix for four variables and three levels, which involves nine experiments. Meanwhile, the 'smaller the better' S/N ratio is used to determine the results obtained by minimal temperature and stress.

Table 1 Factors and levels

	-1	0	+1
Rake angle	5	10	15
Clearance angle	6	10	17
Helix angle	30	40	60
Flute number	2	3	4

3. RESULTS

Figure 2 shows the simulation result for the FE model. From the result, it shows the temperature ranges of the workpiece, the device and the chip can be measured in simulation for the entire time span. The content and distribution of heat inside the device, the workpiece and the chip were determined by means of measured temperature fields through an autonomous device independent of the Finite Element system. The heat flows are derived from heat content changes. Figure 3 shows the temperature and S/N ratio value for the machining simulation.

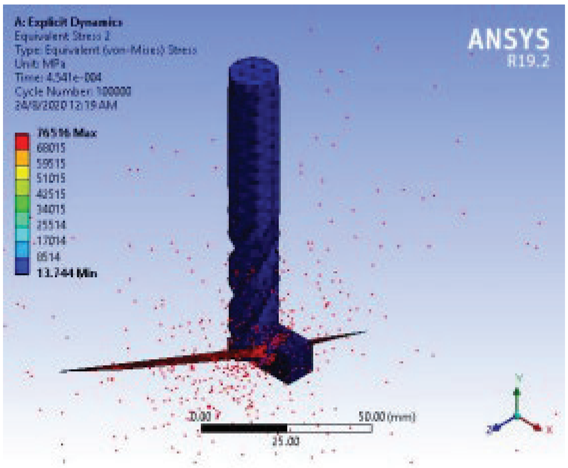

Figure 2 Simulation result

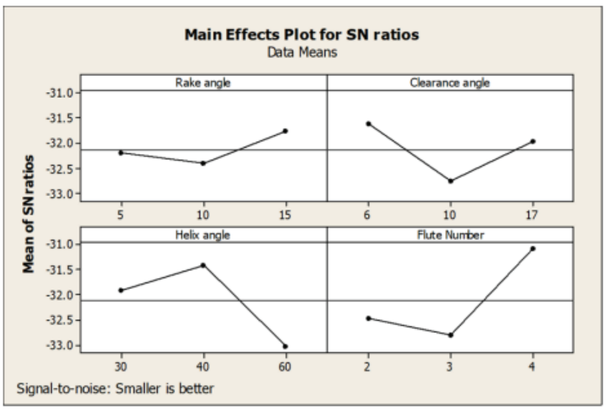

Figure 3 Temperature and S/N ratio value

The simulated results show that the optimum combination of cutter geometrical features can improved the machining process for this case it can generate better shearing action which will reduce the cutting force and reduce the heat generated.

The temperature distribution has a major influence on the production of tool wear, which contributes to a major wear rate in high-temperature areas, the cutting edge can easily be worn and blunted, particularly at tip points. High wear in a two-flute end mill therefore focuses primarily on two cutting tip points. To this degree, the high helix angle and positive rake angle may not be ideal for heavy-duty operations with the purpose of reducing tool temperature in order to minimize tool wear and prolong tool life [3].

4. CONCLUSIONS

This study focuses on the optimization of cutter geometries for machining Al/SiC Metal Matrix Composites (MMC) material. All the of cutter geometrical features namely rake angle, helix angle, clearance angle and number of flutes have significant effect on the temperature and stress value. Flutes number is the dominant factor affecting the temperature value followed by helix angle, clearance angle and rake angle. Finite Element simulation can be use as a tool for the development of new tool design with reasonable result which can substantially save the fabrication time and costs.

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