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Investigation of Vibration, Stress and Temperature during Drilling of Aluminium 6061 Alloy with Silicon Nitride Reinforcement

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Abstract: ***The reinforcement of metal matrix composite (MMC) has direct bearing on the quality of drilled hole. Based on the composition, the vibration amplitude varies as the hole is drilled. This in turn affects the quality of the drilled hole. The quality of drilled hole is also related to the stiffness of the component and behavior of material at high temperature. In order to suppress vibration amplitude, the damping coefficient can be increased to the extent possible. This often leads to achieving good quality of drilled hole. The MMC considered in this study is the aluminium silicon nitride. The base is aluminium 6061 with reinforcement being silicon nitride. In the experimentation, thrust force data, vibration data, temperature data of the composite component with increasing the percentage of silicon nitride are collected. The test component is analyzed in ANSYS WORKBENCH. Natural frequencies for different modes are recorded and specimen response is simulated for different percentage of silicon nitride.***

Keywords: ***Aluminium 6061, silicon nitride (Si3N4), drilling, thrust force, vibration, finite element analysis, modal analysis.***

I. INTRODUCTION

The factors are considered for indicating the quality of drilled hole are its inside diameter and surface roundness. These are influenced by the cutting conditions such as cutting speed, feed rate, tool material, geometry and the diameter of the tool. The quality of the drilled hole also depends on the dynamic properties like natural frequency of the component and stresses induced during drilling operation. The behavior of MMC plates resting on drilling machine during the drilling operation has wider interests. Dhavamani and Alwarsamy [1] investigates the drilling of aluminium silicon carbide (AlSiC) process by taking into account the effect of machining time on metal removal rate, surface roughness, volume fraction, surface energy, cutting speed, feed, diameter of cut and flank wear. In their work they attempt to establish a comprehensive mathematical model for correlating the interactive and higher-order influences of various machining parameters. Alakesh Manna and Kanwaljeet Singh [2] state that the machining of AlSiC materials with 10% of silicon nitride component is difficult due to the presence of reinforced SiC particulates in the aluminium matrix composite. Tsao and Hocheng [3] worked on the prediction and evaluation of thrust force and surface roughness in drilling of composite material using candle stick 10% of silicon nitride component tool. They establish a relation between the spindle speeds, feed rate, and drill diameter with the generated thrust force and surface roughness in operation of drilling. Jagadish and Ravindra [4] have considered vibration monitoring as the most widely used technique because most of the failures in the machine tool could be due to increased vibration level. Experiments were carried out using the condition monitoring instrument to measure vibration extremity for different spindle speed. From the numerical analysis and experimentation, it was found that the vibration velocity increases as the spindle speed and depth of the defect increases. [4] Umesh Gowda and Ravindra [5] carried out an experiment for optimization of process parameters in drilling AlSi3N4 metal matrix composite materials.

II. COMPONENTS USED FOR TEST

For the present study, three compositions are used for testing. With aluminium 6061 as the base, percentage of silicon nitride is varied to result in three compositions of MMC. Silicon nitride is selected as a reinforcing material because of its mechanical behavior at high temperature. The aluminium metal matrix components were fabricated using stir casting method [5].

III. FINITE ELEMENT ANALYSIS OF COMPONENT

The component is modeled using solid edge software. Manufacture of the component and geometric dimensions there on are used to model the component. Using the cross sectional area, the part is extruded. Displacement boundary conditions on the model include fixing both ends, with all degree of freedom constrained on the surfaces. Also the evaluated engineering properties of the three composite compositions by rule of mixture calculation are given in Table 2.

TABLE 2 ENGINEERING PROPERTIES OF THEAL6061 SI3N4 COMPOSITE MATERIAL

Property	Unit	0% of Si_3N_4	6% of Si_3N_4	10% of Si_3N_4
Density	Kg/m^3	2700	2860	2964.8
Modulus of Elasticity	GPa	70.8	85.699	95.209
Poisson's ratio		0.33	0.3408	0.34771

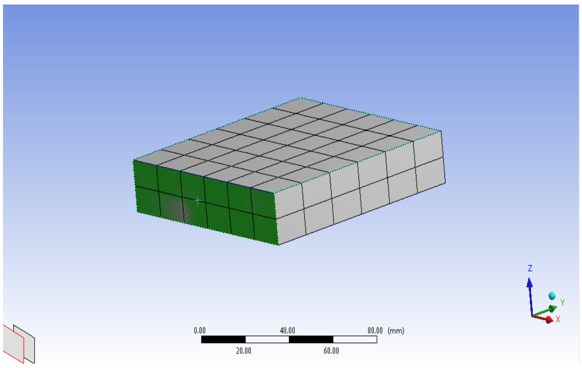

Fig.1 Meshed model of Al6061 silicon nitride MMC component.

IV. RESULTS AND DISCUSSIONS

The prepared CAD models were imported to ANSYS workbench and were meshed. Engineering properties of material like Young's modulus, Poisson's ratio and density were inputted as given in Table 2. Modal analysis performed to determine the natural frequencies of the specimen. Natural frequencies were extracted for the first six modes. The deformations for each of the mode are recorded. The procedure is repeated for other two cases of component. Fig. 1 shows the meshed model of the component. The displacement boundary conditions are that the opposite faces are fixed similar to that when it is being held during, the drilling operation. Similar analyses are carried out for other percentages of weight composition of Si3N4. Natural frequencies for different modes are shown in Fig 3. For varied speed and feed and diameter of the drill bit the stresses are shown recorded as shown in table 4.

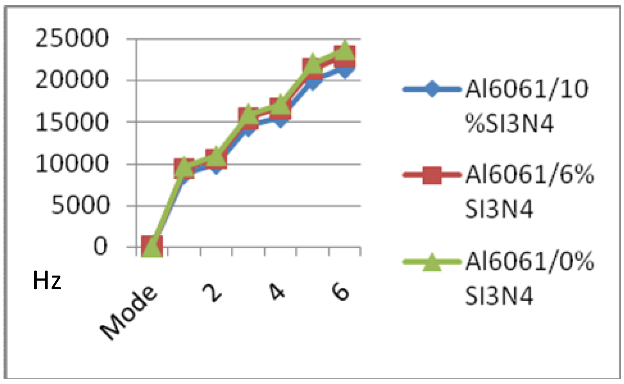

Fig. 3 Plot of natural frequencies.

Stresses are calculated from the force values obtained from dynamometer readings. Though the stress values are low, they show an increase in value as the percentage of Si3N4 is increased in the aluminum base. They also show an increase with increased speed and feed rate. Graphical representation of the same is shown in Fig. 4. Vibration velocity is taken on Y-axis and Speed/Feed combinations of Table-4 are taken on X-axis. Also obtained from the experimentation is the vibration data in the form of vibration velocity in mm/second. Vibration velocity is obtained by the pulse meter. Table 5 shows the data of vibration velocity with increasing feed and speed. The graphical representation of the same data is shown in Fig. 5. Though there is a general increase in vibration velocity for increasing percentage of Si3N4, there is also some decrease at certain percentages.

TABLE 4 VARIATION OF STRESSES DURING DRILLING OPERATION

Sl. No.	Speed in RPM	FEED in mm/rev	Dia of Drill Bit in mm	Stress (MPa)		
				0% of Si_3N_4	6% of Si_3N_4	10% of Si_3N_4
1	360	0.095	6	0.002943	0.00293	0.005886
2	360	0.095	6	0.004905	0.00586	0.005886
3	360	0.095	6	0.005886	0.00687	0.006867
4	490	0.19	8	0.015696	0.01462	0.016958
5	490	0.19	8	0.018639	0.02061	0.023087
6	490	0.19	8	0.023544	0.02748	0.028006
7	680	0.285	10	0.026107	0.02835	0.028597
8	680	0.285	10	0.027043	0.02876	0.028777
9	680	0.285	10	0.02889	0.02898	0.028967

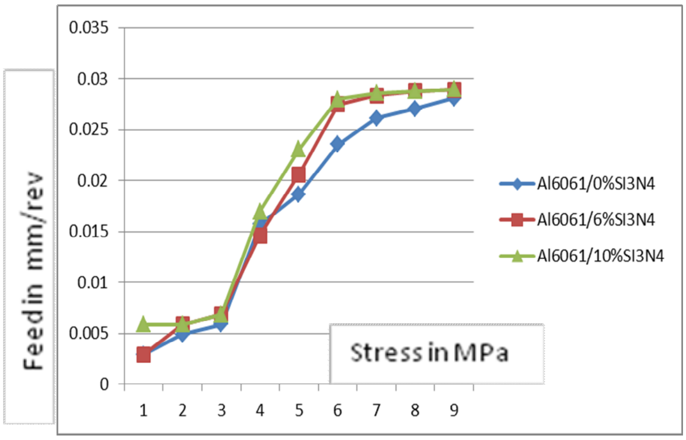

Fig. 4 Stresses developed during drilling process

Also obtained from the experimentation is the vibration data in the form of vibration velocity in mm/second. Table 5 shows the data of vibration velocity with increasing feed and speed. The graphical representation of the same data is shown in Fig. 5. Though there is a general increase in vibration velocity for increasing percentage of Si3N4, there is also some decrease at certain percentages.

TABLE 5 VARIATION OF VIBRATION VELOCITY OBTAINED FROM EXPERIMENTATION

Sl. No	Speed in RPM	Feed in mm/ rev	Dia. of Drill Bit in mm	Vibration Velocity in mm/sec		
				0%	6%	10%
1	360	0.095	6	0.6	1	1
2	360	0.095	6	0.6	1.1	1.1
3	360	0.095	6	0.8	0.8	1
4	490	0.19	8	1	1.8	1.2
5	490	0.19	8	0.9	1.9	1.2
6	490	0.19	8	1.3	1.9	1.3
7	680	0.285	10	1.8	1.3	1.7
8	680	0.285	10	2.5	1.5	1.5
9	680	0.285	10	2.8	2.4	1.8

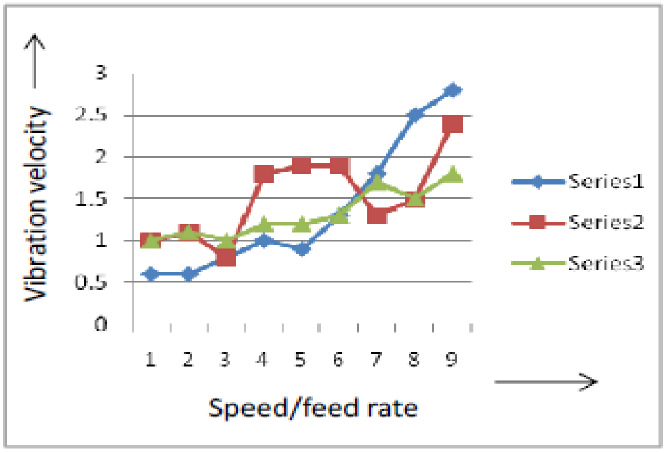

Fig. 5 Vibration velocity during drilling process

V. CONCLUSIONS

The MMC component obtained from stir casting subjected to free vibration test to evaluate the damping behaviour and natural frequency of the composites. It is shown that Silicon nitride has an effect on vibrational property and stresses generated in aluminium metal matrix composites. For 6% by weight addition of silicon nitride, there is reduction in vibration velocity for certain speed and feed rates. This infers that increasing the silicon nitride content reduces the vibration in the material. At high temperatures silicon nitride changes to liquid phase which acts as lubricant during drilling operation. This leads to better quality of the hole and also minimizes the energy loss and noise.

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