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Machinability Study on Aluminium Metal Matrix Composite Using Finite Element Analysis

Sunil Kr. Rajbanshi [1], Raghuna Nandan kumar giri[2], Suraj Gurung[3] & S.S.Raju[4]
[1,2,3]Student, Gandhi institute of engineering & Technology, Gunupur, Odisha, India
[4]Assistant Professor, GIET, Gunupur, Odisha ,India

Abstract: *The process of simulation is an important part of any production/manufacturing process. It helps in reducing the total cost of production and also helps in avoiding the tool failure rate. In upcoming future, the use of aluminum and its composite is going to play a big role in any type of manufacturing and production field. This makes important to study the parameters related to machining of Al-composites. It can be observed that the machining operation is mainly influenced by cutting speed, depth of cut, feed. Parameters which are to be found by the help of simulation are feed rate, tool wear, machining time, power consumption and different forces which are generated during the machining process. A simulation model based on finite element method is carried out using DEFORM-2D Software. The simulation result is compared with experimental results.*

Key words: Al-MMC, Machinability, Deform 2D,

1. Introduction

The future of automotive and also the shipyard and many more fields are going to be largely dependent upon the aluminum and its alloys. The property such as light weight high toughness, high ductility, corrosion resistance and its load carrying capacity makes its study more important as compared to other metals. This study is carried out by the help of FEM analysis [1-2]. FEM is used because it makes easy do determine the parameters in the metal cutting process and also in modeling and simulation. It has many important advantages that may not be obtained by using any other methods. Some of the benefits are: determination of cutting forces and shape of chips solves the problem regarding contact between the bodies, shows the result of different materials [3-4]. There is mainly two type of cutting method: orthogonal cutting and oblique cutting methods. This test is carried on by the orthogonal cutting method. It means the cutting of plane surface that fulfills the following requirements: - the cutting edge is normal to the direction of cutting speed, the length of cutting edge is greater than that of cutting width and during cutting the cutting speed should remain constant[5].

2. Literature review

A deep knowledge about the orthogonal cutting method and its updated method in the main stage of modeling can be studied in publications of Tamizharasan [6], Bhoyar [7] and Ezilarasan [8].The finite element modeling and simulation is one of advanced topic for the research. Previously it was very difficult to do simulation and study the machining process at a microscopic level. Now the simulation and analysis are done by the help of DEFORM-2D and DEFORM-3D software which are based on finite element analysis. DEFORM is a software used by engineers that ease a designer to analyze the metal forming, different heat treatment processes, machining and mechanical joining process with the help of a computer system without going off huge trial and error methods to a shop. The result of simulation using FEM is largely depending upon the correctness of the material model. The data required for modeling is obtained by various machining and mechanical test. This method is applicable for a wide range of materials. The materials used in this simulation process are die material (carbide 19% cobalt) as tool material and Al- 1100, cold [70f (20c)] as working material.

Arrazola et al [9] determine the effect of different cutting parameters during machining of superalloy Inconel 718 by the help of cemented tungsten carbide tool (k20) insert tool. He also gave the relation between the different parameters of cutting like cutting speed, depth of cut, feed, cutting forces, cutting temperatures and tool life in high-speed turning of Inconel 718 to determine the optimum value of the cutting parameters. In 2010, he again worked on the same Inconel 718 to enhance the machining characteristics. He used some quantity of lubricants by the help of nozzle at some velocity and pulse. It was concluded that the use of lubricants at some pressure with pulse lead to lower the cutting force, cutting temperature and tool wear.

[5& 6] the author did an experiment to study the wear mechanism on uncoated carbide tool and also the PVD and CVD tools in an oblique cutting operation on income 718.

Senthilkumar [10] and Ezugwu [11] did some experimentation to determine the effect of cutting speed on the surface roughness and the type of chip formation during the machining of nickel based alloy. The study also showed the different type of wear caused due to cutting speed on coated and uncoated carbide inserts.

Nouari, Tanase [12] and [13] developed the optimal machining parameters like feed, depth of cut, machining speed and also the different cutting forces for the improvement of surface integrity in terms of surface roughness and residual stress in the finish turning of Inconel 718. He modeled the experimentation by using ANN and GA then genetically optimized neural network system was used to determine the optimal condition for minimization of the tensile residual stress.

3. Simulation modeling

The simulation process with finite element method is an efficient process for analyzing the chip formation process and through the help of this, can predict the machining performance parameters such as speed, depth of cut (DOC) and feed with temperature, feed force, strain, stresses and damage are responses.

The finite element simulation can be performing through listed experimental data in Table 1. Here different experimental simulations are followed with Deform 2D to measure machineability response.

3.1 Load prediction analysis.

With the following input parameter, the experiment was carried out on deform 2D to find out the load prediction response are listed in Table 2. Here, three variables are mainly considered, these are speed, feed, depth of cut. Through the entire process of machining, the value of these parameters is varied as given in below Table.

Table 1: Experimental design

Experiment	*Speed*	*DOC*	*Feed*
1	200	0.32	0.08
2	200	0.56	0.12
3	200	0.8	0.16
4	410	0.32	0.08
5	410	0.56	0.16

DOC:-depth of cut

Thus, before simulation, we prepared the insert time chart or load prediction chart which was found to be linear. Fig.1 and fig.2 show the input parameters at Constant speeds 200 and 410 rpm respectively. The inputs parameters are used in an ascending order i.e. initially feed and doc are kept small and they increased in each step of experimentation.

Table 2: experimental Responses

E	*SE*	*SER*	*D*	*Se*	*V*	*Dt*	*T*
1	3.70	73600	0.93	132.0	3670	1.40	104
2	1.86	27450	0.53	65.9	1665	0.71	61.75
3	2.95	27400	0.54	66.3	1665	0.74	63.45
4	1.83	96700	0.56	66.1	3420	0.72	69.8
5	2.19	56150	0.56	66.7	3420	0.74	74.75

E:- experiment
SE:-strain effective
SER:-displacement effective rate
D: - damage
Se:- stress effective
V:- velocity
Dt:- displacement
T:- temperature

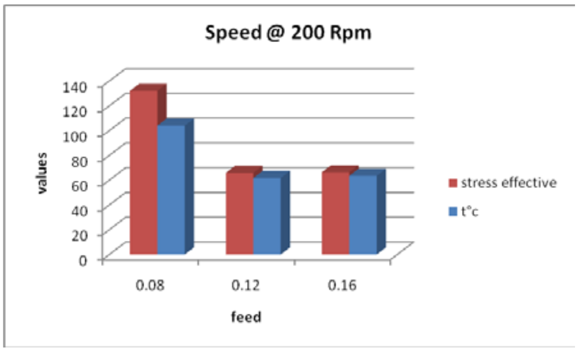

Figure 1. At constant speed with various feed

Figure 1 shows that the speed is constant at the rate of 200 rpm as well as different cutting feed force. With taking this, gives the responses of stress effective and temperature (t°c) parameters values.

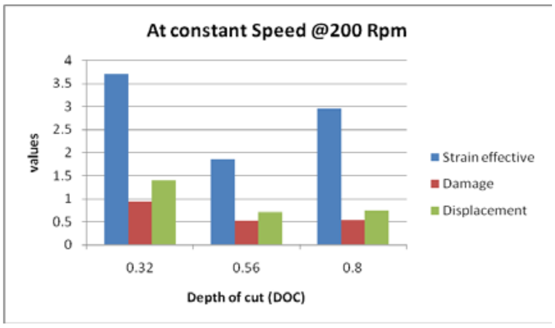

Figure 2. At constant speed with various DOC

Figure 2 shows that the speed is constant at the rate of 200 rpm as well as different Depth of cut (DOC). With taking this, gives the responses of Strain effective, Damage and Displacement parameters values.

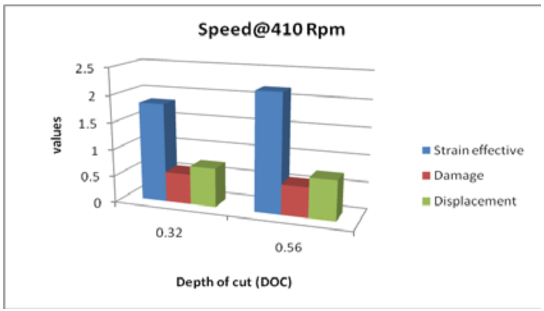

Figure 3. At constant speed with various DOC

Figure 3 shows that the speed is constant at the rate of 410 rpm as well as different Depth of cut (DOC). With taking this, gives the responses of Strain effective, Damage, and Displacement parameters values. The responses are main parameters which are mainly considered for the experimentation. It is clear from the figures that the variation of damage at various parameters is minimum as compared to displacement and strain effect. During machining temperature goes on increasing as the feed and doc increases.

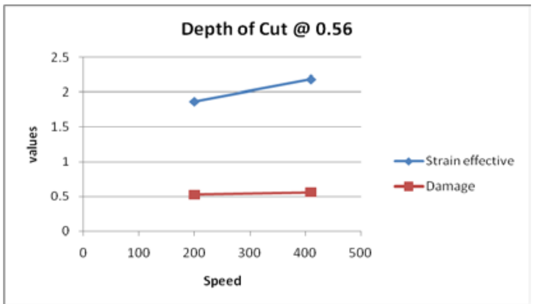

Figure 4. At constant DOC with various speed

Figure 4 shows that the Depth of cut is constant at the rate of 0.56 as well as different speeds. With taking this, gives the responses of Strain effective curve and Damage curve. Here, strain effective values and damage values are increasing along with increasing of speed.

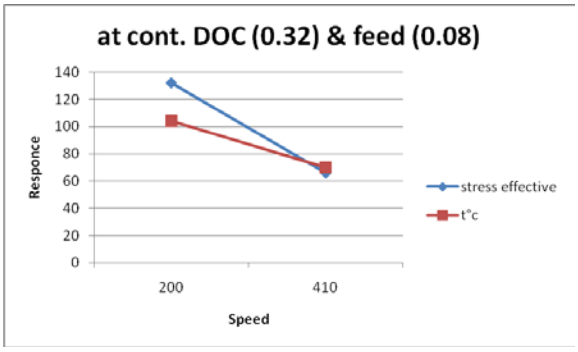

Figure 5. At constant DOC and feed with various speed

Figure 5 shows that the Depth of cut and feed is constant at the rate of 0.32 and 0.08 respectively. Here, different stress effective and temperature are decreasing the values along with increasing of speed.

Figure 4 and Figure 5 shows the responses of out put parameters with respect to input parameters at different rpm. When Depth of cut is small , it results in minimum damage to the tool material where as the strain is high in the workpiece material. There are two parameters which are varying with each other. According to time and insertion values, the result is given.

In this load prediction analysis Figure 6, input data and values are shown on above chart. According to given input values simulation is worked on load prediction diagram shown as below.

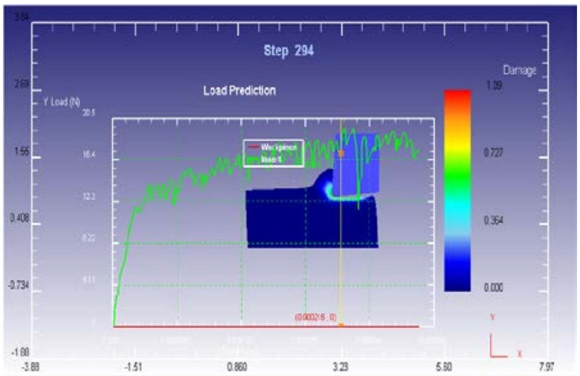

Figure 6. Load prediction simulation.

On the above simulation diagram Figure 6, the tool material is feed to job material. At the left side of the diagram, the load is given simultaneously as 0 to 20.5 N. And at the right side of the diagram, one scale is given to measure the temperature 0.000 to 1.09 to prevent from damage of machining. Finally, The green line of the diagram shows the Load prediction of the job material.

3.2 State variable analysis

Here, the state variable is analyzed through the above parameters Table 1 and Table 2. There are also two parameters found ie. State variable workpiece and state variable insert through dependent with Time and Insert parameters. Here, time is varying but insertion is constant.

With the shown Figure 6, the damage on the tool can be predicted as following the tool life and its failure. The representation on the X-Y coordinate provides the sketch of the tool and the workpiece. The workpiece being stationary and the shape to be machined, the toughness, hardness and the material composition of the both pair affect the machinability. Always the perfection on the finishing of the workpiece is desired taking care of the tool. Thus, high MRR with high tool life is to be taken care of.

3.3 Point tracking

Here, point tracking is also prediction process to choose the best path to machining on the workpiece through the tool material to find out the best path on job material. There is given three paths with two different input data values, chart and simulation diagram. These points are tracked by the help of deform

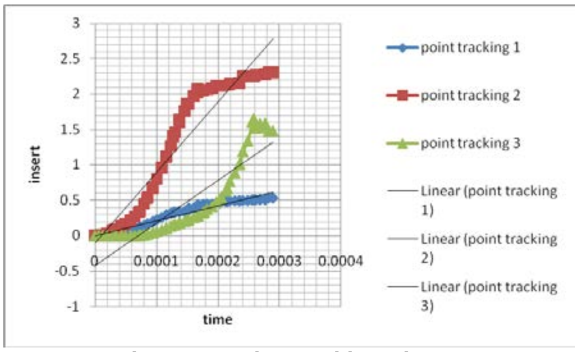

Figure 7. Point tracking chart 1

On the simulation diagram Fig Figure 7, there are three colored lines given and these line tracks for cutting the job material. These lines occurred the different strain values ie. 0 to 2.42 min/mm

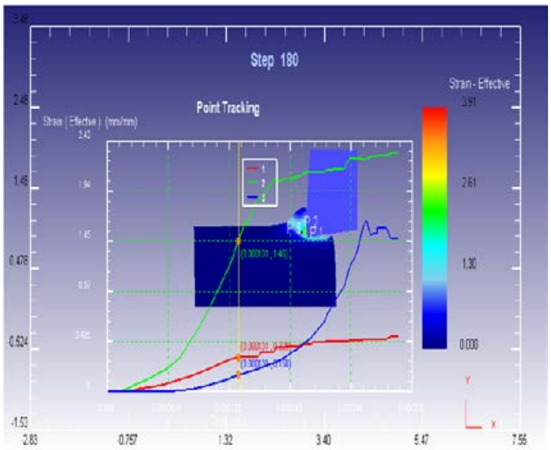

Figure 8. point tracking simulation 1

The diagram Figure 8 shows, three different colored lines. These lines are the different paths to point tracking with time and insert parameters. Here, strain effectiveness scale is showing as for these point tracking.

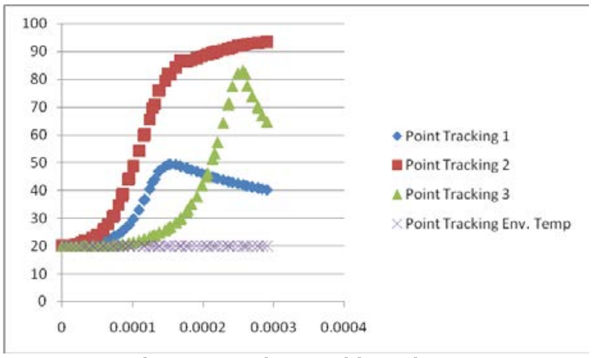

Figure 9. point tracking chart 2

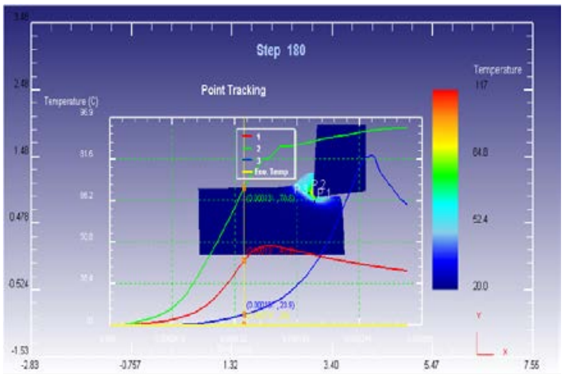

Figure 20. point tracking simulation 2

According to chart values, these values are simulated on point tracking diagrams through the help of Deformation 2D simulation software. The diagram Figure 10 shows, three different colored lines. These lines are the different paths to point tracking with time and insert parameters. Here, strain effectiveness scale is showing as for these point tracking

4. Conclusion:

- From this study, the machinability study has been performed with process variables are speed, depth of cut and feed along with responses are strain effective, displacement effective rate, damage, stress effective, velocity, displacement and temperature using simulation software DEFORM 2D.
- While at constant speed of 200 rpm and feed has been observed decrease of temperature up to a feed of 0.12 than increase. Similarly, strain effective increase with increase of feed.
- While at constant depth of cut 0.56 and speed has been observed that increase with increases of strain effective.
- From the statically variable analysis of point tracking at various points with a constant speed, feed and depth of cut determine strain effective and temperature distributions at selective points.

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