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An investigation of temperature rise based on process parameters on AL7075-T6 using RSM and FEA in orthogonal machining

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ABSTRACT -- The finite element method is used to simulate and analyze the orthogonal metal cutting process. Determination of the maximum temperature and temperature distribution of the cutting tool is important because of its controlling influence on tool life, as well as, the quality of the machined part. The present work deals with modelling and analysis to predict the temperature rise in terms of geometrical parameters such as nose radius of cutting tool insert and machining parameters such as cutting speed and cutting feed rate for machining AL7075-T6, using Response Surface Methodology (RSM). The temperature rise during orthogonal machining was measured by DEFORM-2D FEA software. The second order mathematical model in terms of process parameters was developed for predicting a temperature rise. The direct and interaction effect was graphically plotted which helps to study the significance of these parameters with temperature rise

Index Term-- Temperature rise; orthogonal machining; AL7075-T6; nose radius; Response Surface Methodology; Finite element simulation

INTRODUCTION:

Machining is the complex process in which many variables can affect the desired result. Among these temperatures is the main parameters which affect the tool life, tool wear, tool life, work piece surface integrity, chip formation mechanism and contribute to the thermal deformation of the cutting tool. The increase in the temperature of the work piece material in the primary deformation zone softens the material, thereby decreasing cutting forces and the energy required to cause further shear. High temperature variation in the work piece causes the thermal expansion in the material. Orthogonal cutting is defined as when the cutting tool generates a plane surface parallel to an original plane surface of the material being cut and is set with its cutting edge perpendicular to the direction of relative motion of the tool and work piece Recently various FEA numerical models were found to determine the temperature variation between the work piece and the cutting tool. In this paper, a second order mathematical model is developed using RSM to predict the temperature rise in turning operation for given values of tool nose radius, cutting speed and feed rate. And the analysis is carried out in finite element analysis DEFORM -2D software

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LITERATURE REVIEW:

C. Dinc et al predicted the three-dimensional finite difference-based model to predict temperatures in machining processes is presented. Heat balance equations in three-dimensions are solved analytically for chip, tool and work piece including the heat convection effect that is excluded in two-dimensional analysis.

Ming et al has estimated the transient tool-face temperature and heat dissipation in the workpiece during a slot milling process using surface temperature. Lazoglu and Altintas proposed an FDM based oblique cutting model for the prediction of tool and chip temperature in continuous and intermittent cutting operation. Fang and Zeng developed a 3D model of the oblique cutting process for the prediction of the temperature distribution in the work piece, tool and chip.

Kolachev and Talalaev analysed that decreasing the cutting forces and temperature in the cutting zone increases the tool life and the formation of the chip .A.G .Mamalis et al concludes that hard turning is considered to be a new machining process and finite element method has been extensively used for modelling machining operations Grzesik measured tool-work interface temperature when machining an AISI 1045 and an AISI304 coated tools using k type of thermocouple inserted in the work piece and reported friction on the flank face had a big impact on cutting speed .

Cotterrn et al measured the machined surface temperature with two thermocouples inserted into the work piece when machining aluminium 6082-T6 and results decreases in cutting force and machined surface temperature. Muller et al found that the temperature distribution depends on the heat conductivity and specific capacity of the tool and the work piece and the amount of heat loss based on radiation and convection. Gwo et al developed the model gives predictions of the breakout phenomenon as evaluated in the proposed simulated orthogonal machining tests

Less researchers have worked towards an RSM based methodology and we are going to consider the entire tool geometry, here the depth of cut is assumed as constant A second order mathematical model is developed using RSM to predict the temperature rise in turning operation for given values of tool nose radius, cutting speed and feed rate. These process parameters are optimized using genetic algorithms to obtain a minimum temperature rise. The experiments are going to be conducted on Al7075 – T6 Aluminium alloy jobs using TNMG inserts in JYOTHI CNC Lathe. Al7075 has high strength and excellent corrosion resistance among the available aluminium alloys, which enables it to be used in aerospace and defence equipment and the material composition are shown in

EXPERIMENTAL SETUP:

The plan of work is described as follows:

1. Identification and selection of influential process parameters that have an impact on the temperature rise during turning operation.
2. To setup the limits for the input parameters that affects the response.
3. Development of the FEA model and to predict the temperature distribution function.
4. Development of experimental design matrix for conducting the experiments.
5. Conducting the experiments to determine the temperature distribution for different combinations of input parameters.
6. Development of RSM based mathematical model to predict the temperature based on experimental data

DEFORM STEPS

The various steps involved in 2D deform software are given below:

1. Defining machining process data
2. Defining process environment conditions
3. Defining tool edge geometry
4. Select the cutting tool material
5. Set the Work piece geometrical data
6. Set the work piece material
7. Running the simulation
8. Post process output result

FINITE ELEMENT ANALYSIS

Finite element analysis is done using DEFORM-2D FEA software and fig 1 shows the output result of the obtained 2D FEA model.

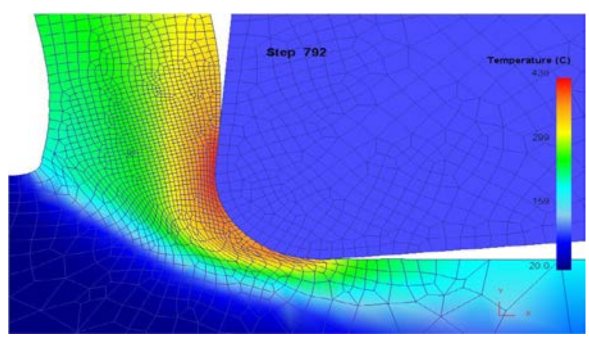

Fig 1. An example of Temperature rise obtained from the 2D FEA model

Table 1 Composition of Al7075

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Element	Mn	Si	Cr	Cu	Fe	Zn	Mg	Ti	Al
Composition %	0.3	0.4	0.18-0.3	1.2-2	0.5	5.1-6.1	2.1-2.9	0.2	88.11-90.87

Table 2: process variables (three factors ,five levels)

parameters	Factor levels				
	-1.682	-1	0	1	1.682
Nose radius, r (mm)	0.4	0.6	0.8	1	1.2
Cutting speed, Vs (rpm)	2000	2500	3000	3500	4000
Feed, fz (mm)	0.05	0.1	0.15	0.20	0.25

MODEL DEVELOPMENT

The experiment involves three parameters viz. tool nose radius, cutting speed and feed, each at five levels which is a 5^3 factorial design. The factor levels and the coded values for the parameters are shown in table 2.The design matrix for the experiment, observed temperature values, O_v and the predicted temperature values, P_v along with the corresponding percentage

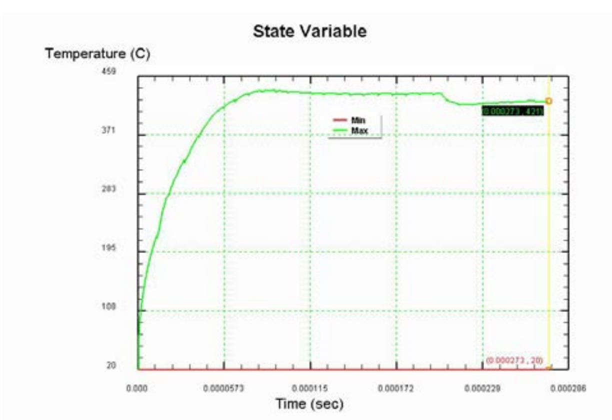


Fig 2 temperature vs time

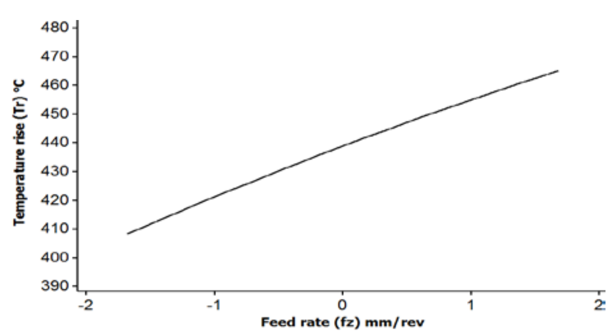
error are shown in Table 3. MINITAB 16 software is used to analyze the central composite experimental design and to perform the analysis of variance. The mathematical model for predicting temperature from the input parameters is developed from the observed experimental results. This model is expressed in equation 1

RESULTS AND DISCUSSION

The effect of input machining parameters on temperature rise is analysed using the developed mathematical model.

MAIN EFFECT OF THE PARAMETERS

The direct effect of each individual machining parameter on temperature rise is identified by keeping all input values at the middle level except the parameter under study.



R	*Vc*	*fz*	O_v	P_v	%error
-1	-1	-1	414	405.885	-1.96014
1	-1	-1	416	418.053	0.49351
-1	1	-1	436	429.767	-1.42959
1	1	-1	438	424.935	-2.98288
-1	-1	1	404	413.693	2.399257
1	-1	1	449	451.861	0.637194
-1	1	1	469	463.575	-1.15672
1	1	1	480	484.743	0.988125
-1.682	0	0	430	434.3675	1.015699
1.682	0	0	462	462.4031	0.087247
0	-1.682	0	405	399.5151	-1.35431
0	1.682	0	437	447.2536	2.346359
0	0	-1.682	397	410.4526	3.388556
0	0	1.682	476	467.3176	-1.82403
0	0	0	443	442.198	-0.18104
0	0	0	433	442.198	2.124249
0	0	0	445	442.198	-0.62966
0	0	0	448	442.198	-1.29509
0	0	0	438	442.198	0.958447
0	0	0	447	442.198	-1.07427

Table 3: Experimental design matrix with measured and predicted temperature values

$$T = 442.19 + 8.33r + 14.19V_c + 16.90f_z - 6.65V_c^2 + 6.50rf_z + 6.50V_c f_z \text{ -----(1)}$$

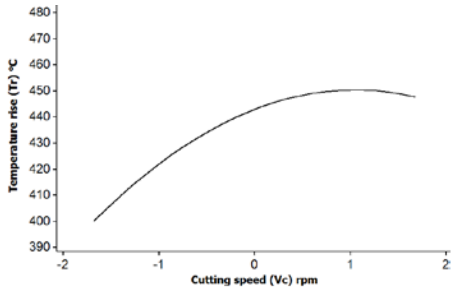


Fig.4.Cutting Speed Vs Temperature

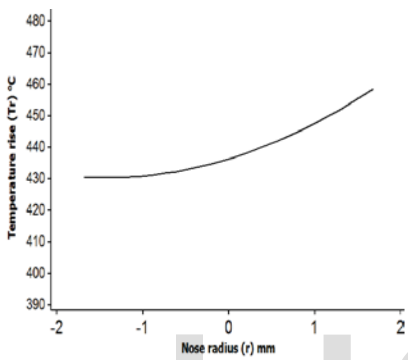


Fig 5. Nose Radius Vs Temperature

Fig 3 shows the direct effect of the feed rate on temperature rise and from the figure it is clear that the increase in the feed rate increases the temperature. It can be concluded that feed rate has a direct linear effect on temperature.

Fig 4 shows the direct effect of the cutting speed on temperature rise. From the figure, it is clear that with the increase in the cutting speed, the temperature increases at earlier stage directly and then it becomes stable until the speed reaches the maximum limit.

Fig 5 shows the direct effect of nose radius on temperature and here the temperature initially decreases to a minimum value at the beginning. With further increase in nose radius, temperature keeps on increasing until nose radius reaches the maximum limit.

INTERACTION EFFECT OF THE PARAMETERS

Interaction effects are the impacts created by the combined effects of multiple input parameters on the response, other than the effects produced by them individually.

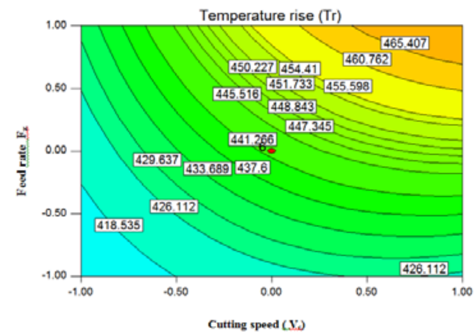


Fig.6.Cutting Speed Vs Feed Rate

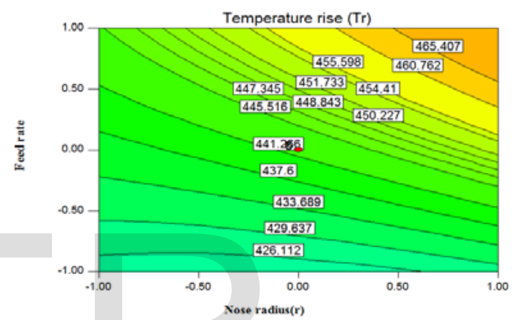


Fig.7.Nose Radius Vs Feed Rate

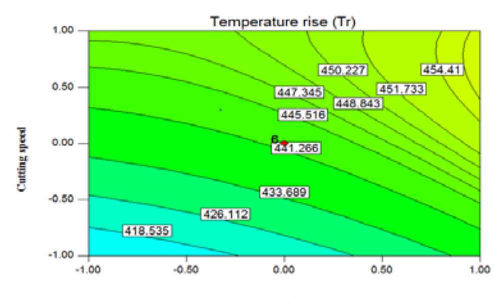


Fig.8.Nose Radius Vs Cutting Speed

The effects of interaction between the input parameters are shown in Fig 6, 7 & 8. It is found that the interaction between nose radius and feed rate and the interaction between cutting speed and feed rate have similar impact on the response (temperature rise). Therefore to minimize the temperature, the nose radius and feed rate combination and the cutting speed and feed rate combination have to be maintained at the minimum level.

MODEL VALIDATION:

The model is validated by comparing the predicted temperature rise value with the observed temperature rise. It is found that the determined model has a reliability of 99.69%.

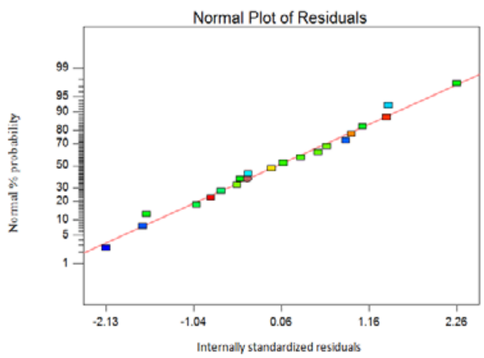


Fig 9.Standard Residuals Vs % Probability

Also the adequacy of the model is investigated by examination of residuals. Residuals are the difference between the predicted and observed values of the response. The residuals are analyzed for normality and the plot of residuals versus predicted values of response for each run. For the model to be adequate the normality test should result in a straight line and the residuals plotted against each run should not follow any structured pattern. The normality plot of the residuals is represented in Fig 9.

CONCLUSION:

In this paper finite element method is used to simulate and analyze the orthogonal metal cutting process. The maximum temperature and the temperature distribution in the material are determined from known values of tool nose radius, cutting speed and feed rate in CNC turning by employing 2D DEFORM software. This will assist in establishing the levels of input parameters to achieve the desired temperature distribution The direct and interaction effects of the input parameters are also analysed The predicted values of temperature are found to match closely with the observed values.

This work will be enable the operator to determine the levels of input parameters to be established for minimizing thermal defects caused by high speed machining. This will also be useful in designing the spindle for the machining operations.

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