International Journal of Engineering Research-Online
A Peer Reviewed International Journal
Articles available online http://www.ijoer.in; editorijoer@gmail.com

Vol.4., Issue.6., 2016
Nov-Dec.

RESEARCH ARTICLE

ISSN: 2321-7758

MODELLING AND ANALYSIS OF A LATHE SINGLE POINT CUTTING TOOL

MADALA SOUJANYA[1], Dr.CH.SREEDHAR[2]

[1]PG student, Department of Mechanical Engineering, A1 Global Institute of Engineering & Technology, Markapur, Andhrapradesh.

[2]Professor, Department of Mechanical Engineering,. A1 Global Institute of Engineering &Technology, Markapur Andhra Pradesh

ABSTRACT

A lathe is a machine tool which rotates the work piece on its axis to perform various operations such as cutting, turning, knurling and drilling with tools that are applied to the work piece to create an object which has symmetry about an axis of rotation. A cutting tool is any tool that is used to remove metal from the work piece by means of shear deformation.

Temperature at tool-chip interface of a single point cutting tool is determined, generated in different speed machining operations. Specifically, three different analyses are comparing to an experimental measurement of temperature in a machining process at slow speed, medium speed and at high speed. In addition, three analyses are done of a High Speed Steel and of a Carbide Tip Tool machining process at three different cutting speeds, in order to compare to experimental results produced as part of this study. An investigation of heat generation in cutting tool is performed by varying cutting parameters at the suitable cutting tool geometry. The experimental results reveal that the main factors responsible for increasing cutting temperature are cutting speed (v) and depth of cut (d) respectively. Various researches have been undertaken in measuring the temperatures generated during cutting operations. Investigators made attempt to measure these cutting temperatures with various techniques during machining.

Key words: Single point cutting tool, cutting speed , depth of cut, temperature , machining process structural analysis, FEM

1. INTRODUCTION

A large amount of heat is generated during machining process as well as in different process where deformation of material occurs. The temperature that is generated at the surface of cutting tool when cutting tool comes in contact with the work piece is termed as cutting tool temperature. Heat is a parameter which strongly influences the tool performance during the operation. We know the power consumed in metal cutting is largely converted into heat. Temperature being developed during cutting it is of much concern as a result heat are mainly dependent on the contact between the tool and chip, the amount of cutting force and the friction between the tool and chip. Almost all the heat energy produced is transferred into the cutting tool and work piece material while a potion is dissipated through the chip. During machining the deformation process is highly concentrated in a very small zone and the temperatures generated in the deformation zone affect both the work piece and tool. Tool wear, tool life, work piece surface integrity, chip formation mechanism are strongly influenced at high cutting temperatures and contribute to the thermal deformation of the cutting tool, which is considered as the largest source of error in the machining process.

There has been a considerable amount of research devoted to develop analytical and numeric models in order to simulate metal cutting processes to predict the effects of machining variable such as speed, feed, depth of cut and also tool geometry on deformations of tool. Especially, numerical models are highly essential in predicting chip formation, computing forces, distributions of strain, strain rate, temperatures and stresses on the cutting edge and the machined work surface. Advanced process simulation techniques are necessary in order to study the influence of the tool edge geometry and cutting conditions on the surface integrity especially on the machining induced stresses.

2. LITERATURE REVIEW

To provide a review of past research efforts related to single-point cutting tool and finite element analysis. A review of other relevant research studies is also provided. The review is done to offer insight to how past research efforts have laid the groundwork for subsequent studies, including the present research effort. The review is detailed so that the present effort can be properly tailored to add to the present body of literature as well as to justify the scope and direction of the present effort. *B. Fnides, M. A. Yallese, H. Aouici [1]* developed a work is to evaluate cutting pressures, resulting force and maximum temperature in hard turning of hot work steel AISI H11. This steel is hardened to 50 HRC, machined by a mixed ceramic tool (insert CC650 of chemical composition 70%Al_2O_3+30%TiC), free from tungsten on Cr-Mo-V basis, insensitive to temperature changes and having a high wear resistance. *Shijun Zhang, Zhanqiang Liu [2]* developed an analytical model with constant temperature at tool and chip interface of one-dimensional heat transfer in monolayer coated tools has been to investigate temperature distribution in metal cutting. *M. Hameedullah [3]* developed first and second order mathematical models in terms of machining parameters by using the response surface methodology on the basis of the experimental results. The experiment was turning of EN-31 steel alloy with tungsten carbide inserts using a tool-work thermocouple technique. *J. E. Jam,V. N. Fard [4]* determined the thermal contact conductance of the tool chip interface in the metal cutting process using an inverse procedure. An orthogonal cutting of the AISI 1045 steel is simulated by LS-DYNA finite element code. *P. D. Kamble [5]* studied the approaches for modelling the turning process for EN-24 type of steel. In this study, a Finite Element Analysis software Deform 3D is used to study the effects of cutting speed, feed rate, and type of alloy steel in temperature behaviour. *Deepak Bhardwaj [6]* studied three different rake angles in order to find out the variation in values of Vonmisses stress for the specified applied forces. In present study mesh is created in ANSYS and the boundary conditions are applied and the analysis is carried out for the applied constraints. *Komesh Sahu [7]* developed an optimization method of the cutting parameters (cutting speed, depth of cut and feed) in dry turning of AISI D2 steel to achieve minimum tool wear, low work piece surface temperature and maximum material removal rate (MRR). *Razik [8]* conducted three analyses using a High Speed Steel and of a Carbide Tip Tool at three different cutting speeds, in order to compare the experimental results produced. The experimental results reveal that the main factors responsible for increasing cutting temperature are cutting speed (v), feed rate (f), and depth of cut (d), respectively.

3. METHODOLOGY

3.1. DESIGN OF EXPERIMENT

In randomized complete block design, it is possible to reduce error variance by forming blocks such that the experimental units within the blocks are relatively more homogeneous with respect to the dependent variable of interest to the experimenter. The primary objective of creating the blocks is to eliminate from the experimental error the variation due to the differences between the blocks. The experimental units or the subjects correspond to plots and block comprises of k subjects that are fairly homogeneous with respect to a given variable. Here, each block will consist of k subjects matched on a given variable. Thus, the subjects within any block will be more homogeneous than the subjects that are selected at random. The objective of this local control is to create homogeneity within each of the r blocks and consequently heterogeneity between the blocks. The variation due to block differences is eliminated from the experimental error.

3.1.1 DESIGN OF EXPERIMENT FOR HSS TOOL

In our case, experimental results are the temperature formed at the cutting tool tip face when machining at different speed and depth of cut. Here we analyse the error using the temperatures obtained for HSS tool at a time 10 seconds after machining starts. The analysis carried out for a significance level of 0.01.The table of subjects of the design of experiment for HSS tool are summarized in Table 3.1

Table 3.1 Table of subjects of the design of experiment for HSS tool

Speed (rpm)	Depth of Cut (mm)			Total Sum
	0.1	0.4	0.7	
150	34	70	115	937
	33	72	116	
	32	70	114	
	35	70	115	
	34	72	116	
420	73	96	148	1451
	72	94	146	
	73	95	145	
	71	94	146	
	72	95	145	
710	81	123	165	2144
	82	125	169	
	83	125	168	
	80	124	169	
	82	126	167	
Total Sum	1098	1565	1869	**4532**

3.1.2 DESIGN OF EXPERIMENT FOR CARBIDE TOOL

Similarly here also we analyse the error using the temperatures obtained for Carbide tool at a time 10 seconds after machining starts. The analysis carried out for a significance level of 0.01.The table of subjects are summarized in table 3.2

Table 3.2 Table of subjects of the design of experiment for Carbide tool

Speed (rpm)	Depth of Cut (mm)			Total Sum
	0.1	0.4	0.7	
150	37	71	118	1006
	39	71	119	
	40	72	120	
	39	73	119	
	38	72	119	
420	75	102	153	1509
	76	102	153	
	77	103	154	
	75	104	153	
	76	104	155	
710	87	127	176	2239
	88	128	175	
	86	127	176	
	86	128	174	
	87	127	175	
Total Sum	1147	1662	1945	**4754**

3.1.3 REPEATABILITY TEST

The repeatability index (r_i) can be used to assess precision i.e. whether an observer makes consistent measurements and whether a trial varies.

$$r_i=(\text{MS between} - \text{MS error}) / (\text{MS between} + (n-1)\text{ MS error})$$

Informal terms to describe the measure of repeatability ri, from Martin and Bateson (1986) is summarized in table 3.3.

Table 3.3 Informal terms to describe the measure of repeatability

Index of repeatability (r_i)	**Term**
$r_i < 0.2$	Slight repeatability
$0.2 < r_i < 0.4$	Low repeatability
$0.4 < r_i < 0.7$	Moderate repeatability
$0.7 < r_i < 0.9$	High repeatability
$r_i > 0.9$	Very high repeatability

3.1.4 EXPERIMENTAL SETUP AND CONDITIONS

The experiment was conducted under dry conditions on a three jaw centre lathe. Lathe removes undesired material from a rotating work piece in the form of chips with the help of tool which is traversed across the work and can be fed deep in work. A hole was drilled on the face of work piece to allow it to be supported at the tailstock (Figure 3.1).

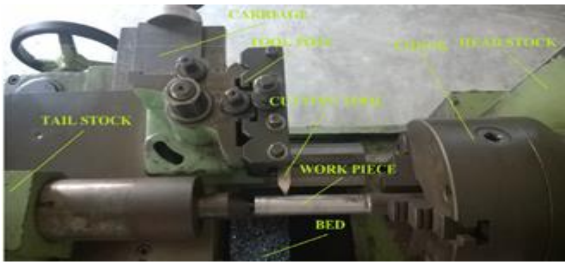

Figure 3.1 Experimental setup

The work piece used as cylindrical rod of Mild Steel (Ø23*63.7 mm). The cutting tool used as High

Speed Steel and Carbide Tip Tool (13*101.98 mm). The machining is carried out at different speed and depth of cut. Feed may be kept as constant. The settings of the main machining parameters are summarized in Table 3.4.

Table 3.4 Main machining parameters of the experiment

Parameters	Value
Feed (mm/rev)	0.52
Speed (rpm)	150, 420, 710
Depth of cut (mm)	0.1, 0.4, 0.7

We know that maximum temperature is on the tool chip interface during machining. So for measuring this temperature we use a Thermal imager, a non-contact temperature measurement device. Thermal imagers detect the infrared energy emitted, transmitted or reflected by all materials (at temperatures above absolute zero) and converts the energy factor into a temperature reading or thermo gram. A thermo gram is the thermal image displayed by the camera of the object which is emitting, transmitting or reflecting the infrared energy. Here Fluke TI32 IR Thermal Imager (Range -20 °C to +600 °C) is used for measuring the temperature on the cutting tool while machining (Figure 3.2). Stop watch is used for measuring the time for machining.

Figure 3.2 Fluke TI32 IR Thermal Imager

3.2. FINITE ELEMENT ANALYSIS OF TOOL

Finite element analysis of single point cutting tool is carried out by using ANSYS, a powerful general purpose finite element analysis package. Ansys is a finite element analysis package to numerically solve a wide variety of mechanical, structural and non-structural problems. These problems include static/dynamic structural analysis (both linear and non-linear), heat transfer and fluid problems as well as acoustic and electromagnetic problems.

In this project we carried out thermal analysis of a single point cutting tool using Ansys. Thermal analysis is used for determining the temperature distribution and quantities such as thermal distribution, amount of heat loss or gain, thermal gradient, thermal fluxes etc.,

3.2.1 MODELLING OF TOOL

The single point cutting tool has been solid modelled by using SOLIDWORKS, a solid modelling computer aided design software. Solid works is a solid modeller, and utilizes parametric feature-based approach to create models and assemblies. Parameters refer to constraints whose values determine the shape of or geometry of the model or assembly. Parameters can be either numeric parameter, such as tangent, parallel, concentric, horizontal or vertical etc. numeric parameters can be associated with each other through the use of relations

Table 3.5 Main dimensions of the tool and work piece.

	Cutting Tool	Work piece
Material	High Speed Steel Tungsten carbide	Mild Steel
Cross-section	13*101.98 mm Side and end cutting edge angles: 30° End relief angle: 20°	Ø23*63.7 mm

3.2.1.1 MODELLING OF HSS TOOL

The single point cutting tool (HSS) has been solid modeled by using SOLIDWORKS. The 3D and 2D views are shown in below (Figure 3.3

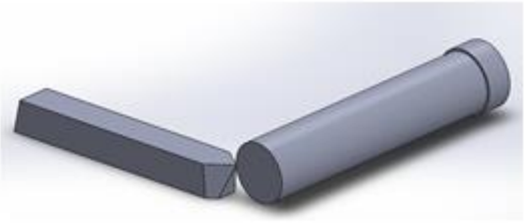

Figure 3.3 3D view of HSS model

3.2.1.2 MODELLING OF CARBIDE TOOL

The single point cutting tool (Tungsten Carbide) has been solid modeled byusing

SOLIDWORKS. The 3D and 2D views are shown in below (Figure 3.5 .

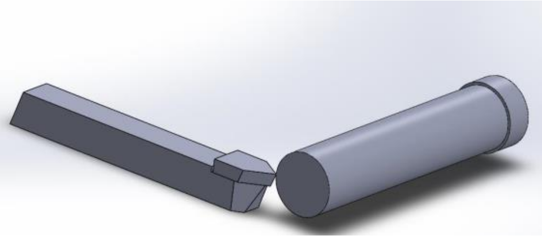

Figure 3.5 3D view of Carbide model

3.2.2.2 MATERIAL

The cutting material used is T15 super high speed steel. The temperature dependent properties of tool are summarized below in Table 3.6 and the other properties are also given below.

Table 3.6 Properties of T15 super high speed steel

Sl=. No	Temperature (°C)	Density (kg/m^3)	Thermal Conductivity (w/mK)	Specific Heat(J/kgK)
1	0	8190	19	418.68
2	50	8186	20	420
3	75	8183	22	425.36
4	100	8179	23	430.45
5	120	8177	25	436.25
6	175	8172	26	442.57
7	200	8168	28	445.68
8	220	8162	30	448.35

Coefficient of thermal expansion: 1.01*10-5 °C-1 (Ref temp: 22 °C)

Young's modulus: 2.07*105 Mpa

Poisson's ratio: 0.25

The work piece material used is mild steel. The various properties of mild steel are given below,

Density: 7850 kg/m3

Coefficient of thermal expansion: 1.2*10-5 °C-1 (Ref temp:20 °C)

Young's modulus: 2*1011 Pa

Poisson‟s ratio: 0.3

Thermal conductivity: 60.5 w/mK Specific heat: 434 J/kgK.

3.2.2.3 MESHING

The method used for meshing the cutting tool is Hex dominant method "giving a body sizing of 1.5 mm and for work piece is „Multi zone method‟ giving a body sizing of 2.5 mm. The meshed geometry is given in Figure 3.8.

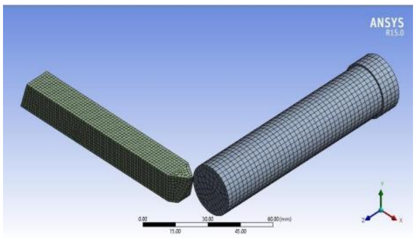

Figure 3.8 Meshed geometry of HSS tool

For mesh convergence study, different mesh element sizes are provided for cutting tool as well work piece. The objective of this study is to reduce the error as well as the computational time. The summarized study is given below in Table 3.7.

Table 3.7Mesh convergence study

Work piece element size [mm]	Cutting Tool element size [mm]	Number of nodes	Number of Elements	Max FEA Temp [°C]	Max Expt Temp [°C]	%error	Computational Time [Hrs]
4	3	13231	2971	80.2	**67.6**	15.71	74.6
3.5	2.5	18678	3975	78.9		14.32	102.2
3	2	25345	5340	72.1		6.241	105.65
2.5	**1.5**	**49197**	**11059**	**69**		**2.03**	**115.94**
2	1	144399	36793	68.8		1.744	140.45
1.5	0.5	725465	183714	68.7		1.601	163.2

3.2.2.4 LOAD AND BOUNDARY CONDITIONS

Structural loads and boundary conditions are applied as usual. Here we have four conditions.

1. Cylindrical support for work piece 2.Longitudinal displacement of tool (63.7 mm)

3. Tangential displacement of tool (0.1 mm, 0.4 mm, 0.7 mm)

4. Speed of rotation of work piece (150 rpm, 420 rpm, and 710 rpm).

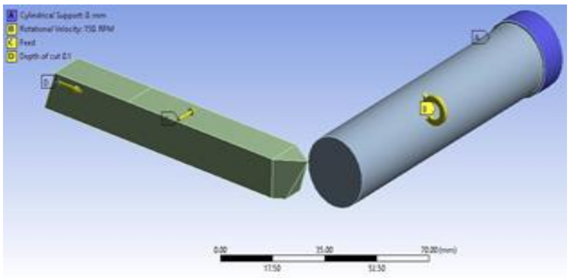

Figure 3.9 Load and boundary conditions for HSS tool.

Here the model is defined as frictional model. That is heat is generated due to contacting friction when machining. So we define a contact element and target element. In this case, cutting tool is contact element (CONTA175) and work piece is the target element (TARGE170) and a node to surface contact is obtained. The coefficient of friction is given as 0.5 and contact behaviour is asymmetric.

This gives fraction of frictional dissipated energy converted into heat.

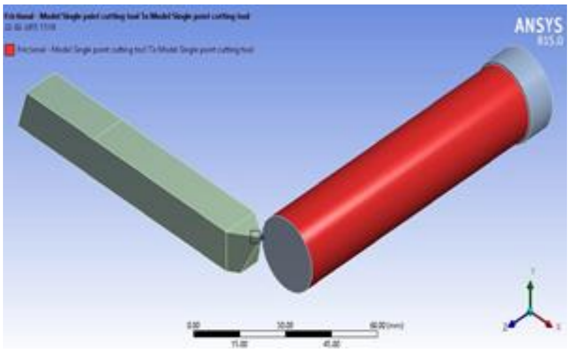

Figure 3.10 Frictional model of HSS tool

3.2.2.5 ANALYSIS SETTINGS

For time step controls, program controlled (automatic) time step are used. The step end times are 49 sec, 17.5 sec and 10.0 sec.

The initial time step may be given as 0.49 sec, 0.175 sec and 0.10 sec. The ranges for time step are given as, Minimum time step: 4.9*10-2 sec, 1.75*10-2 sec, 1.0*10-2 sec. Maximum time step: 4.9 sec, 1.75 sec, 1.0 sec.

3.2.3 FINITE ELEMENT ANALYSIS OF CARBIDE TOOL

3.2.3.1 GEOMETRY

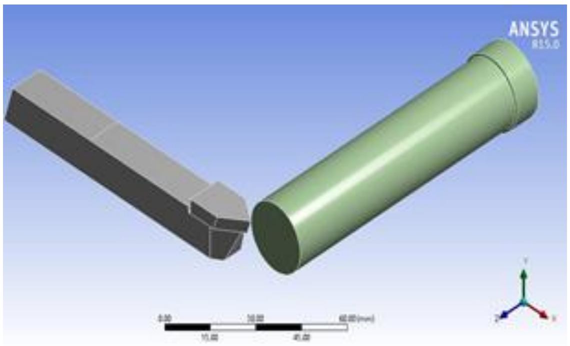

Figure 3.11 Geometry of Carbide tool

4. EXPERIMENTAL AND FINITE ELEMENT ANALYSIS RESULTS FOR CARBIDE TOOL

The temperatures obtained for carbide tool at various speed and depth of cut through experiment and FEA are summarized in Tables and graphs given below.

4.1 Temperature obtained through experiment at speed: 150 rpm, doc: 0.1 mm

Table 4.1 Temperature obtained through experiment at speed: 150 rpm, doc: 0.1 mm

Sl No	Time [sec]	Max Temp [°C]
1	0	32
2	10	38.6
3	20	45.6
4	30	55
5	40	62.8
6	**49**	**75.4**

From the graph it is clear that temperature increases when machining progresses. The temperatures obtained through FEA and experiment having almost same values. The percentage difference between maximum temperatures obtained at machining end time is only 2.10%.

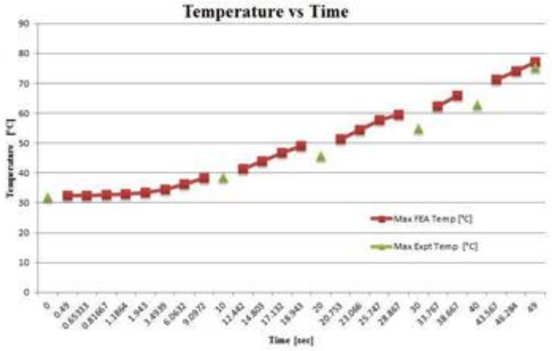

Figure 4.2 Comparison of temperatures at speed: 150 rpm, doc: 0.1 mm

4.2. TEMPERATURE OBTAINED AT SPEED: 150 rpm, doc: 0.4 mm DOC: 0.4 mm

Table 4.3 Temperature obtained through experiment at speed: 150 rpm, doc: 0.4 mm

Sl No	Time [sec]	Max Temp [°C]
1	0	61
2	10	71.8
3	20	83.2
4	30	93
5	40	100.8
6	**49**	**111.8**

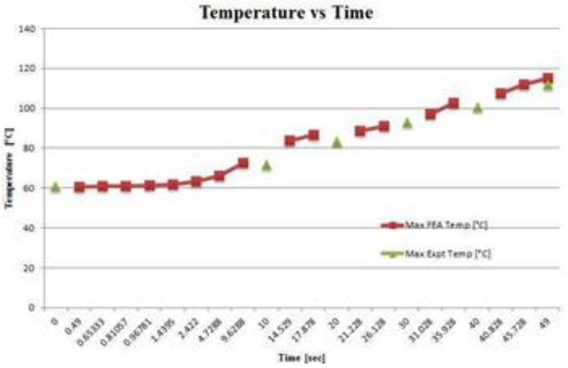

Figure 4.4 Comparison of temperatures at speed: 150 rpm, doc: 0.4 mm

From the graph it is clear that temperature increases when machining progresses. The temperatures obtained through FEA and experiment having almost same values. The percentage difference between maximum Temperatures obtained at machining end time is only 2.81%.

4. 3 TEMPERATURE OBTAINED AT SPEED: 150 rpm, doc: 0.7 mm DOC: 0.7 mm

Table 4.4. Temperature obtained through experiment at speed: 150 rpm, doc: 0.7 mm

S No	Time [sec]	Max Temp [°C]
1	0	101.2
2	10	119
3	20	130.2
4	30	138.8
5	40	151.2
6	**49**	**159.4**

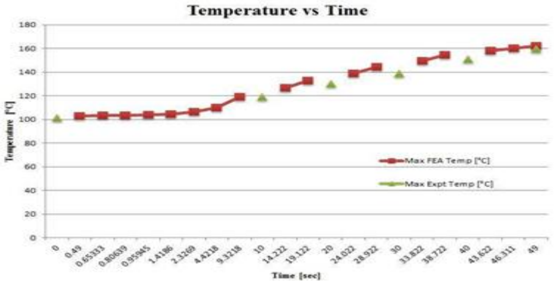

Figure 4.5 Comparison of temperatures at speed: 150 rpm, doc: 0.7 mm

From the graph it is clear that temperature increases when machining progresses. The temperatures obtained through FEA and experiment having almost same values. The percentage difference between maximum temperatures obtained at machining end time is only 1.64%

4.4 TEMPERATURE OBTAINED AT SPEED: 420 rpm, DOC: 0.1 mm

Table 4.5 Temperature obtained through experiment at speed: 420 rpm, doc: 0.1 mm

S No	Time [sec]	Max Temp [°C]
1	0	43.8
2	5	60.2
3	10	75.8
4	**17.5**	**82.8**

From the graph it is clear that temperature increases when machining progresses. The temperatures obtained through FEA and experiment having almost same values. The percentage difference between maximum temperatures obtained at machining end time is only 2.62%.

4. 5 TEMPERATURE OBTAINED AT SPEED: 420 rpm, DOC: 0.4 mm, DOC: 0.4 mm

Table 4.6 Temperature obtained through experiment at speed: 420 rpm, doc: 0.4 mm

S No	Time [sec]	Max Temp [°C]
1	0	71.4
2	5	85.8
3	10	103
4	**17.5**	**119.2**

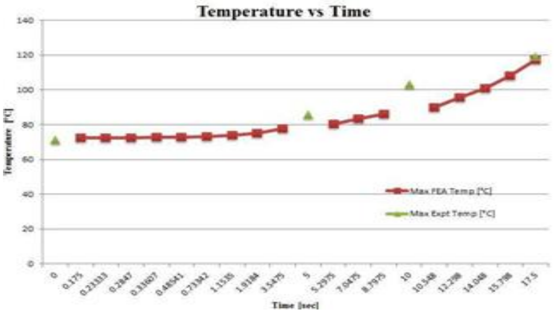

Figure 4.10 Comparison of temperatures at speed: 420 rpm, doc: 0.4 mm

From the graph it is clear that temperature increases when machining progresses. The temperatures obtained through FEA and experiment having almost same values. The percentage difference between maximum temperatures obtained at machining end time is only 6.36%.

4.7. PERCENTAGE DIFFERENCE BETWEEN MAX TEMP OBTAINED THROUGH EXPERIMENT FEA AND HSS TOOL

Table 4.8 Percentage difference between max temperatures obtained for HSS tool

S No	Feed (mm per rev)	Speed (rpm)	Machining Time (sec)	Depth of Cut (mm)	Max Expt. Temp (°C)	Max FEA Temp (°C)	Percentage Difference (%)
1	0.52	150	49	0.1	67.6	69	2.03
2				0.4	104.4	108	3.33
3				0.7	152.4	155	1.68
4		420	17.5	0.1	78.4	77	1.79
5				0.4	109.6	112	2.14
6				0.7	158.6	160	0.875
7		710	10	0.1	81.6	84	2.85
8				0.4	124.6	127	1.89
9				0.7	167.6	170	1.41

4.9.PERCENTAGE DIFFERENCE BETWEEN MAX TEMP OBTAINED THROUGH EXPERIMENT FEA AND HSS TOOL FOR CARBIDE TOOL

Table 4.10 Percentage difference between max temperatures obtained for Carbide tool

S No	Feed (mm per rev)	Speed (rpm)	Machining Time (sec)	Depth of Cut (mm)	Max Exp. Temp (°C)	Max FEA Temp (°C)	Percentage Difference (%)
1	0.52	150	49	0.1	75.4	77.02	2.10
2				0.4	111.8	115.03	2.81
3				0.7	159.4	162.05	1.64
4		420	17.5	0.1	82.8	85.025	2.62
5				0.4	119.2	117.04	6.36
6				0.7	167.6	169.06	0.86
7		710	10	0.1	86.8	90.027	3.58
8				0.4	127	129.04	1.58
9				0.7	175.2	174.06	0.65

5. CONCLUSION

It can be observed that an increase of the cutting speed produces an increase of the cutting temperature. This result is due to the fact that an increase of the cutting speed produces an increase of the cutting forces. More energy is needed to remove the material away increasing the cutting temperature.

It can be observed that an increase of the depth of cut produces an increase of the cutting temperature. When a material is plastically deformed, most of the energy is turned into heat since the material is subject to extremely severe deformations; being the elastic deformation the ones that represents a small part of the total deformation. Hence, the increase of depth of cut represents a bigger compression in the tool-work piece interface this will increase the energy supplied to the system during the cut of the material.

In both experiment and finite element analysis, the temperature formed during machining is more in carbide tool than in HSS tool. So the chances for tool wear or tool failure is more in carbide tool than in HSS tool at same cutting conditions.

REFERENCES

[1]. W.S. Lin, “The reliability analysis of cutting tools in the HSM processes”, Archives of Materials Science and Engineering, Volume 30, Issue 2, April 2008, Pages 97-100.

[2]. “Workshop Technology (Volume – II) Machine Tools,” by S. K. Hajra Choudhary, A. K. Hajra Choudhary, and Nirjhar Roy. 2007. Media Promoters & Publishers Pvt. Ltd., Mumbai.

[3]. “Manufacturing Technology (Volume – II) Metal Cutting & Machine Tools,” by P. N. Roy, 2008. Tata McGraw Hill Publications, New Delhi.

[4]. “Design Data Book for Machine Elements,” PSG Tech. Publications.

[5]. “Design Data for Machine Elements,” by B. D. Shiwalkar, 2005, Central Techno Publications, Nagpur.

[6]. “A Text Book of Machine Design,”, by R. S. Khurmi & J. K. Gupta, 1997, S. Chand & Company Ltd., New Delhi. [10] “Introduction to Finite Elements in Engineering,” by Tirupati 7. Chandrupatla and Ashok D. Belegundu, 2002. Prentice Hall of India Pvt. Ltd. New Delhi