OPEN ACCESS

International
Journal
Of Modern Engineering Research (IJMER)

Finite Element Analysis of Single Point Cutting Tool

S. H. Rathod[1], Mohd. Razik[2]

1Pursuing M.E. Mechanical Engineering, Department, Babasaheb Naik college of Engineering, pusad, India
2Assistant Professor, Mechanical Engineering, Department, Babasaheb Naik college of Engineering, pusad, India

Abstract: *In this project, temperature at tool-tip interface is determined, generated in high-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), feed rate (f), and depth of cut (d), respectively. It is also determined that change in cutting speed and depth of cut has the maximum effect on increasing cutting temperature. 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.*

*In this project, **"Fluke 62 max IR thermometer"** (Range -40 ^{0}C to 650 ^{0}C) is used for measuring temperature at tool-tip interface. Single point cutting tool has been solid modeled by using CAD Modeler Pro/E and FEA carried out by using ANSYS Workbench 14.5. Experimental work is done at "Khushi Engineering", Nagpur.*

By varying various parameters the effect of those on temperature are compared with the experimental results and FEA results. After comparison nearly 4% variation is found in between the results.

Keywords: *Single Point Cutting Tool (HSS) tool and Carbide tip tool (P - 30), Computer Aided Design (CAD), Centre lathe, Fluke 62 max IR thermometer (Range -40 0C to 650 0C), Finite Element Analysis, Solid Modeling.*

I. Introduction

Machining, the most widespread process for shaping metal, has become a very significant aspect of modern society and industry. The importance of the machining process is evident by the observation that nearly every device used by humanity in day-to-day life has at least one machined part or surface. From a materials viewpoint, high speed machining is a relative term, since different materials should be machined with different cutting speeds to insure acceptable tool life. Because of this difference and the fact that cutting speed determines whether a material will form continuous or segmented chips, one way to define high-speed machining is to relate it to the chip formation mechanism. Machining is a common fabrication technique where material removed from a part using a tool with a small, hard tip. Usually the material being cut is a metal, such as aluminum or steel. In order to fabricate a part quickly, a high cutting speed desired. These higher speeds, however, lead to a faster degradation of the tool tip, which requires that the tool tip replaced more frequently. Over the history of machining, guidelines and conventions have arisen based on empirical information of tradeoffs between cutting speed and tool replacement time. Machining is a term covering a large collection of manufacturing processes designed to remove material from a work piece.

II. Literature Review

The purpose of this chapter is 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.

Lower and Shaw et al.[1], developed analytical prediction model for the measurement of cutting temperature during machining. They concluded that the cutting temperature is the function of cutting speed and feed rate.

$\theta t = V^{0.5} \times t^{0.3}$

Where,

θt = Average cutting temperature

V = cutting speed

t = un-deformed chip- thickness or feed rate.

Stephenson [2], suggested that the temperature distribution in the tool might be obtained by using information about the changes in the hardness and microstructure of the steel tool. It is necessary to calibrate the hardness of the tool against the temperature and time of heating and samples of structural changes at corresponding temperatures. These methods permit measurement of temperatures to an accuracy of ± 25 ^{0}C within the heat-affected region.

Miller et al [3], developed Experimental techniques using modern, digital infrared imaging and successfully applied them during this study to gather cutting tool temperature distributions from orthogonal machining operations.

Abhang L.B. et al. [4], worked to measure the tool-chip interface temperature experimentally during turning of EN-31 steel alloy with tungsten carbide inserts using a tool-work thermocouple technique. Average chip-tool interface temperatures have been experimentally studied using the tool work thermocouple technique. Based on the parametric study. the developed empirical relation agrees well in velocity with the Shaw's non-dimensional model. It has been observed that increasing cutting speed, feed rate and depth of cut lead to an increase in cutting temperature.

Federico M. Aneriro et al. [5], Investigated the influence of cutting parameters (cutting speed, feed rate and depth of cut) on tool temperature, tool wear, cutting forces and surface roughness when machining hardened steel with multilayer coated carbide tools. A standard K-type of thermocouple inserted near the rake face of the tool was used to measure the interface temperatures. They concluded that the temperature near the rake face increases significantly when the depth of cut changes from 0.2 to 0.4 mm. The increase in contact length between chip and rake face could be responsible, since it grows, together with uncut chip cross-section.

Sullivan et al. [6], measured the machined surface temperatures with two thermocouples inserted into the work piece when machining aluminum 6082-T6. The results indicated that an increase in cutting speed resulted in a decrease in cutting forces and machined surface temperatures. This reduction in temperature was attributed to the higher metal removal rate that resulted in more heat being carried away by the chip.

S.K. Chaudhary et al. [7], Predicted cutting zone temperatures by natural tool work thermocouple technique, when machining EN 24 steel work piece and HSS with 10% cobalt as the cutting tool. The results indicated that an increase in cutting speed and feed rate resulted in an increase in tool wear and cutting zone temperature increases with the increase in the cutting speed. While in the whole range of feed the temperature increases with increase in feed rate.

Huda et al [8], developed a technique for measuring temperature at the interface between a cutting tool and a chip using two-color pyrometer with fused fiber coupler for the temperature measurement of the tool-chip interface in dry and wet turning.

H.Ay and Yang [9], used a technique with K thermocouple to analyze temperature variations in carbide inserts in cutting various materials such as copper, cast iron aluminum 6061 and AISI 1045 steel. They observed oscillations in temperature near the cutting edge, which were more marked for ductile materials and less in the hard machining materials. These observations were attributed to the chip formation and its contact with the work material.

Kashiway and Elbestawi [10], investigated the effect of cutting temperature on the integrity of machined surface. It has been shown that cutting temperature has a major effect on the integrity on the machined surface. The undesirable surface tensile residual stresses were attributed to the temperature generated during machining. Therefore, controlling the generated tensile residual stresses relies on the understanding of the effect of different process parameters on the cutting temperature.

B. Findes, et al [11], studied the influence of cutting speed, feed rate and depth of cut on cutting pressures, cutting force and on cutting temperature, when machining AISI H11 steel treated to 50 HRC work piece material with mixed ceramic tool. The results show that depth of cut has great influence on the radial cutting pressure and on cutting force. The cutting pressure and cutting force increase with an increase in depth of cut and feed rate. It was found that increase in cutting speed increases cutting zone temperature rapidly

W. Grzesik [12], His work related to create a FEM simulation model in order to obtain numerical solutions of the cutting forces, specific cutting energy and adequate temperatures occurring at different points through the chip/tool contact region and the coating/substrate boundary for a range of coated tool materials and defined cutting conditions. Results showing how the tool chip interfacial friction influences the temperature distribution fields as the effect of using coated tools are the main. A good agreement was achieved, especially for uncoated and three-layer coated tools, between predicted and experimental values of cutting temperatures.

W. Grzesik, M. Bartoszuk et al. [13], the aim of this study was to create a FEM simulation model in order to obtain numerical solutions of the cutting forces, specific cutting energy and adequate temperatures occurring at different points through the chip tool contact region and the coating/substrate boundary for a range of coated tool materials and defined cutting conditions.

III. Objective of Present Work

3.1 Project objective

The objective of the project is;

- To detect tool tip temperature by using “IR Thermometer” at various machining parameters
- Modeling by using PRO/E
- Finite Element Analysis by ANSYS 14.5
- Comparison of Experimental data with FEA data for the tool.

IV. Project Methodology

Since there are a large number of variables controlling the process, some Experimental models are required to represent the process. In order to achieve this, FEA analysis of the experimental results will have to be processed using the analysis (ANSYS). ANSYS is a computational technique that enables the estimation of the relative contributions of each of the control factors to the overall measured response. In the present work, only the significant parameters are used to develop relation between temperature and various parameters like speed, feed and depth of cut. These models are of great use during the optimization of the process variables.

4.1 Experimental results for HSS Tool

Table 4.1 : Various Results obtained experimentally Using HSS Tool

Exp. No.	Speed (v) (RPM)	Depth of cut (d) (mm)	Experimental Temperature (T in ^{0}C)
1.	540	0.5	143
2.		0.7	149
3.		1.0	156
4.		1.3	162
5.		1.5	165
6.	750	0.5	150
7.		0.7	154
8.		1.0	163
9.		1.3	169
10.		1.5	175
11.	950	0.5	166
12.		0.7	171
13.		1.0	180
14.		1.3	189
15.		1.5	200

4.2 Experimental results for Carbide Tool

Table 4.2 : Various Results obtained experimentally Using Carbide Tool

Exp.No.	Velocity (v) (RPM)	Depth of cut (d) (mm)	Experimental Temperature (T in ^{0}C)
1.	540	0.5	148
2.		0.7	152
3.		1.0	163
4.		1.3	170
5.		1.5	172
6.	750	0.5	155
7.		0.7	164
8.		1.0	168
9.		1.3	176
10.		1.5	181
11.	950	0.5	168
12.		0.7	176
13.		1.0	186
14.		1.3	197
15.		1.5	205

Table 4.3 : Heat Flux for HSS and Carbide

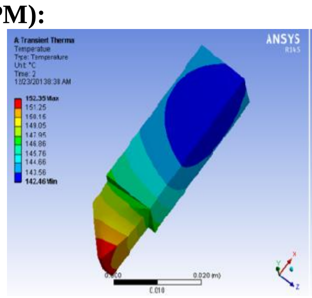
Sr. No.	Speed RPM	Area	Heat Flux For HSS	Heat Flux For Carbide
1	540	75	1823.066	1898.4
2		73.75	1945.89	1991.8
3		71.87	2106.85	2216.9
4		70	2260	2389.1
5		68.75	2350.4	2465.4
6	750	75	1928.53	2003.8
7		73.75	2022.5	2175.7
8		71.87	2216.9	2292.5
9		70	2373	2486
10		68.75	2514.7	2613.3
11	950	75	2169.6	2199.7
12		73.75	2282.9	2359.5
13		71.87	2484.2	2578.5
14		70	2695.8	2825
15		68.75	2925.6	3007.8

V. Finite Element Analysis of Tool (Thermal)

5.1 Transient Thermal analysis of tool

5.1.1 Finite Element Analysis of HSS tool at

Medium speed (V- 750 RPM):



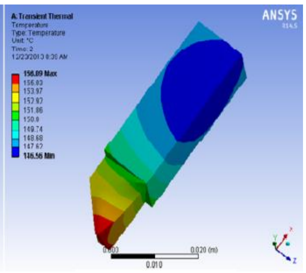


Fig. 5.1: HSS tool at Depth of cut 0.5 mm Fig.5.2: HSS tool at Depth of cut 0.7 mm

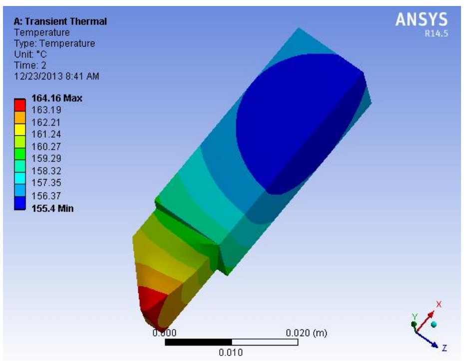


Fig. 5.3: HSS tool at Depth of cut 1.0 mm

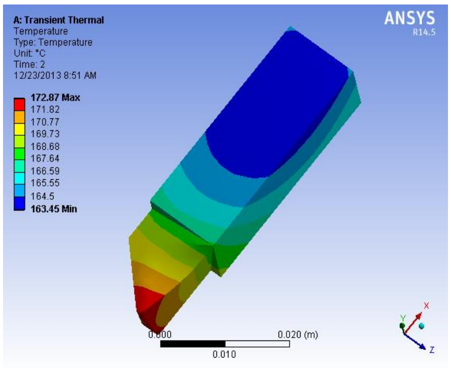


Fig. 5.4 : HSS tool at Depth of cut 1.3 mm

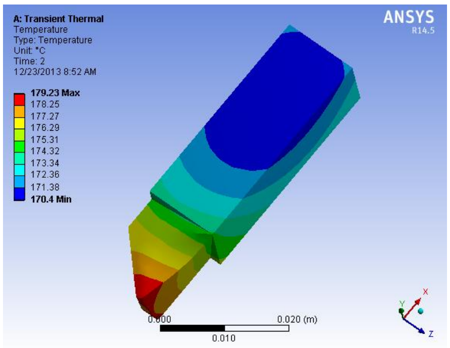


Fig. 5.5 : HSS tool at Depth of cut 1.5 mm

Speed (750)	DOC	0.5	0.7	1.0	1.3	1.5
RPM	Max^{m} Temp.	152.35	156.09	164.16	172.87	179.23

5.1.2 Finite Element Analysis of Carbide tool at High speed (V- 750 RPM):

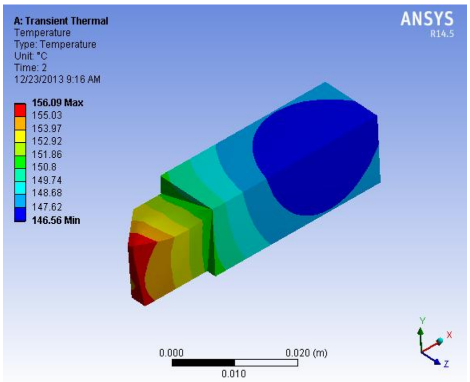


Fig. 5.6 : Carbide tool at Depth of cut 0.5 mm

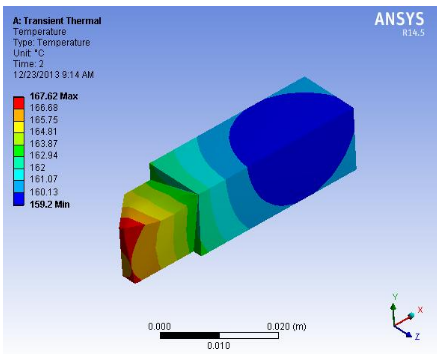
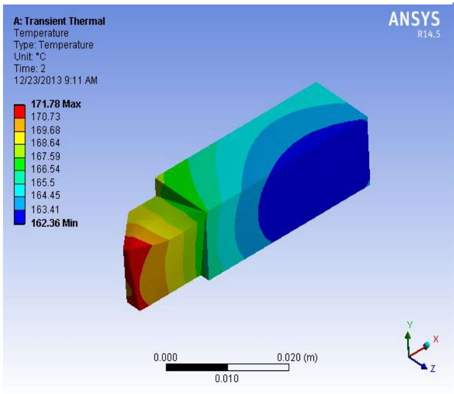


Fig. 5.7 Carbide tool at Depth of cut 0.7 mm



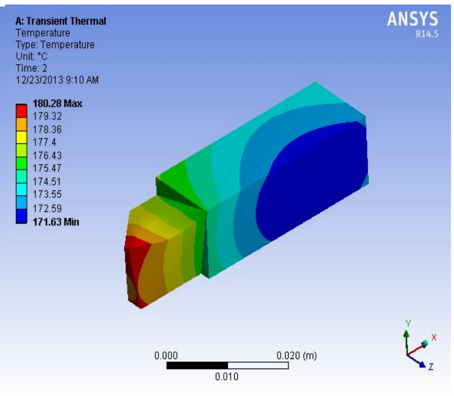


Fig. 5.8 : Carbide tool at Depth of cut 1.0 mm
Fig. 5.9 Carbide tool at Depth of cut 1.3 mm

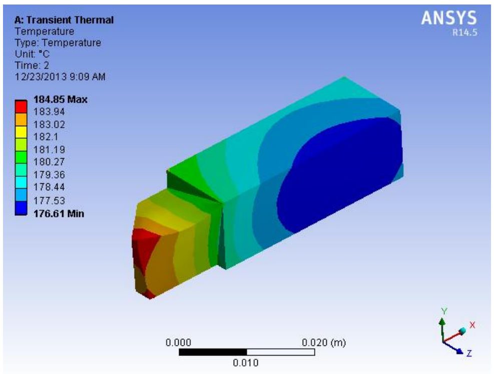


Fig. 5.10: Carbide tool at Depth of cut 1.5 mm

Speed (750) RPM	DOC	0.5	0.7	1.0	1.3	1.5
	Max^{m} Temp.	156.09	167.62	171.78	180.28	184.85

VI. Results and Discussion

Comparative results for HSS

Table 8.1 : Comparative Results obtained for HSS Tool

Exp. No.	Speed (v) (RPM)	Depth of cut (d) (mm)	Experimental Temperature (T in ^{0}C)	FEA Temperature (T in ^{0}C)	% Difference
1.	540	0.5	143	146.41	2.33
2.		0.7	149	150.15	2.10
3.		1.0	156	157.64	1.04
4.		1.3	162	165.03	1.84
5.		1.5	165	166.99	1.19
6.	750	0.5	150	152.03	1.335
7.		0.7	154	158.57	2.88
8.		1.0	163	166.06	1.84
9.		1.3	169	171.67	1.55
10.		1.5	175	179.99	2.77
11.	950	0.5	166	170.73	2.77
12.		0.7	171	174.94	2.55
13.		1.0	180	182.89	1.58
14.		1.3	189	192.25	1.69
15.		1.5	200	201.6	0.79

➢ **Effect of cutting speed for HSS tool**

As the cutting speed increase, increase in temperature occurs at tool tip interface.

Cutting speed increases from 540 RPM to 750 RPM change in temperature observed experimentally 4.66 %. While, results observed for FEA have 5.62%.

➢ **Effect of depth of cut on cutting temperature for HSS tool**

Keeping the speed constant if we increase the depth of cut, it is observed that with increase in DOC temperature at tool tip interface also increases.

For increase in DOC from 0.5 to 0.7 mm increase in temperature is 2.72% experimentally and 2.5 by FEA.

Comparative Results for Carbide

Table 8.2 : Comparative Results obtained for Carbide Tool

Exp. No.	Velocity (v) (RPM)	Depth of cut (d) (mm)	Feed (f) (mm / rev)	Expt. Temp. (T in ^{0}C)	FEA Temp. (T in ^{0}C)	% Difference
1.	540	0.5	1	148	150.54	1.68
2.		0.7	1	152	157.06	3.22
3.		1.0	1	163	166.3	1.98
4.		1.3	1	170	172.8	1.62
5.		1.5	1	172	175.93	2.23
6.	750	0.5	1	155	156.09	0.7
7.		0.7	1	164	167.62	2.16
8.		1.0	1	168	171.78	2.20
9.		1.3	1	176	180.28	2.37
10.		1.5	1	181	184.85	2.08
11.	950	0.5	1	168	171.78	2.20
12.		0.7	1	176	179.17	1.77
13.		1.0	1	186	188.43	1.28
14.		1.3	1	197	200.03	1.51
15.		1.5	1	205	207.04	0.98

➢ **Effect of cutting speed for Carbide tool**

Cutting speed increases from 540 RPM to 750 RPM change in temperature observed experimentally 4.51%. While, results observed for FEA have 3.55%.

➢ **Effect of depth of cut on cutting temperature for Carbide tool**

For increase in DOC from 0.5 to 0.7 mm increase in temperature is 2.63% experimentally and 4.15% by FEA.

VII. Conclusion

- From the results obtained experimentally and by FEA, the difference in temperature is not more than 4%.
- Thus, finally it can be observed that we must select the cutting parameters, which are cutting speed, feed rate, and depth of cut, in such a way so as to have the optimum temperature at the tool tip because of the heat generated, so that the minimum tool wear is encountered, and thus we could have the longest tool life and better machining economy.

REFERENCES

[1] Lowen E.G. and Shaw M.C, on the analysis of cutting tool temperatures, Transactions of the ASME, 001. 76 pp-217-231, (1954).

[2] D.A. Stephenson, Tool –work thermocouple temperature measurements: theory and implementation issues, Proceedings of winter Annual meeting of ASME, Anaheim CA. pp-18-95. November (1992).

[3] Miller Mark R., Mulholland George, Anderson Charles, Journal of Manufacturing Science and Engineering, vol. 125(2003), pp. 667-673.

[4] L. B. ABHANG and M. HAMEEDULLAHD department of Mechanical Engineering, Aligarh Muslim University, Aligarh, India “Chip-Tool Interface Temperature Prediction Model for Turning Process”, 2010.

[5] Federico M. Aheiro Reginalot, Coelho, Lincdnc, Brandao, Turning hardened steel using coated carbide at high cutting speeds. J.of the Braz. soc. of Mech. sci. and Engg., vol.xxx. no. 2 1109, (2008).

[6] Sullivan D.O., Cotterell M., Journal of Material Processing Technology, vol. 118(2001), pp. 301-308.

[7] S. K. Choudhary, G. Bartarya, Role of temperature and surface finish in predicting tool wear using neural network and design of experiments. Int. J. of machine tools and manufacture,43, 747-753, (2003).

[8] Huda Mahfudz Al, Yamada Keiji, Hosokawa Akira, Ueda Takashi, Journal of Manufacturing Science and Engineering, vol. 124(2002),pp. 200-207.

[9] H. Ay, W. J Yang, Heat transfer and life of metal cutting tools in turning, Int, J. Heat and mass transfer, 41, 613-623, (1998).

[10] Kishawy, H. A. Elbestawi, M. A, Effect of edge preparation and cutting speed on surface integrity of die materials in hard machining, ASME Int. Eng. Congr, Exp. Manf.sci, Techno, 269-276, (1998).

[11] [11] B. Fnides, M. A. Yallese, H, Aouici, Hard turning of hot work steel AISI H11: Evaluation of cutting pressure, resulting force and temperature, ISSN1392-1207, Mecanika, Nr.4 (72), 2008.

[12] Grzesik, W, Experimental investigation of the cutting temperature when turning with coated Index able inserts .Int.J, of Machine tools and manufacture, 39 pp 355-369,(1999).

[13] W. Grzesik, M. Bartoszuk and P. Niesłony, 13 International scientific conference, (2005).

[14] P.C. Sharma, "A Text Book of Production Engineering", S. Chand and Company Ltd. Delhi,

[15] Hajra Choudhary, "Workshop Technology", Tata McGraw-Hill *Publishing* Co. Ltd., New Delhi,

[16] M GOSTIMIROVIC, P KOVAC and M SEKULIC, "An inverse heat transfer problem for optimization of the thermal process in machining", *Sadhana* Vol. 36, Part 4, pp 489–504. Indian Academy of Sciences, August 2011.

[17] P. L. Ballani, Data book of heat transfer, Thermal Engineering, Khanna publication, 7th Reprint, 24th Edition, pp 249, 272, 2012.

[18] Mahesh Rathore , "Heat Transfer", Tata McGraw-Hill Publishing Co. Ltd., 914, 2010.