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Experimental Analysis and Measurement of Chip-Tool Interface Temperature in Turning of Aluminium Alloy

Alimoddin Patel[1], Rajendrakumar Tated[2]

[1]*Associate Professor, Dept. of Mechanical Engg. College of Engineering. Osmanabad, Maharashtra, India*
[2]*Professor, Dept. of Mechanical Engg. Matoshri College of Engineering and Research Center, Nashik, Maharashtra, India*

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Abstract - *During metal cutting, heat is generated at the cutting tool tip is a important factor for the performance of the tool and quality of the finished product. The effect of the cutting temperature, particularly when it is high, is mostly affect to both tool and work piece. The machining and tool life can be improved by the knowledge of cutting temperature on the tool tip. In this paper, we evaluated the variation of different parameters on cutting temperature. We done set up of an experiment to measure the temperature developed on tool tip, during turning operation in a center lathe, under different parameters. The metal cutting parameters considered are cutting speed, feed rate and depth of cut at constant tool nose radius. In this experiment, we used an assembly of K type thermocouple with digital temperature indicator for measuring the temperature. The tool used is of high carbon tip, cast iron shank and work piece is used cylindrical aluminium alloy rod. Aluminium alloy is used because it has large variety of applications, light in weight. corrosion resistance, good electrical and thermal conductivity, ductility and non magnetic. More research work is required on aluminium alloy material. From the data collected during the experiment, we found the effects of different cutting parameters on temperature developed on tool tip. The obtained results are tabulated and analyzed graphically.*

***Key Words*: Cutting tool, Depth of cut, Feed rate, Machining, Parameters, Speed and Thermocouple.**

1. INTRODUCTION

During a cutting process the mechanical energy due to plastic deformation developed at primary shear plane and at chip-tool interface, is converted into heat. The chip and environment dissipate large amount of this heat, but the remaining heat is conducted into the work piece and cutting tool. However, this small quantity of heat conducted into tool is enough to create high temperatures near tool cutting edge. These high cutting temperatures strongly influence tool wear, tool life and work piece surface integrity. Also, the high cutting temperature helps in reducing the magnitude of the cutting forces and cutting power consumption to some extent by softening or reducing the shear strength of the work material. Hence, it is important to study the effect of cutting temperatures on tool and work piece.

Temperature distribution in the work piece, chip and cutting tool is nothing but temperature variation of particular point which is moving in primary deformation zone or primary to secondary deformation zone or primary to tertiary deformation zone due to conduction and convection of heat in an orthogonal metal cutting.

The cutting temperature magnitude is more or less influenced by all machining parameters like: work material (specific energy requirement, ductility, thermal properties), process parameters (cutting velocity, feed, depth of cut), cutting tool material (thermal properties, wear resistance, chemical stability), tool geometry (rake angle, cutting edge angle, clearance angle, nose radius), In this paper, we studied the effect of cutting parameters.

2. HEAT GENERATION DURING MACHINING

In the metal cutting process, a tool performs the cutting action by overcoming the shear strength of the work piece material. This generates a large amount of heat in the work piece resulting in a highly localized thermo-mechanically coupled deformation in the shear zone. Temperatures in the cutting zone considerably affect the stress–strain relationship; fracture and the flow of the work piece material. The main regions where heat is generated during the orthogonal cutting process are shown in Fig.1.1

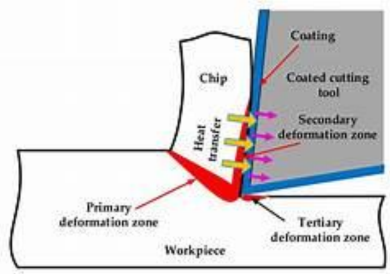

Fig.1.1 Sources of heat generation in orthogonal cutting process .

Firstly, heat is generated in the primary deformation zone due to the plastic work done at the shear plane. The local heating in this zone results in very high temperatures, thus softening the material and allowing greater deformation. Secondly, heat is generated in the secondary deformation zone due to work done in deforming the chip and in overcoming the sliding friction at the tool-chip interface zone. Finally, the heat generated in the tertiary deformation zone, at the tool work piece interface, is due to the work done to overcome friction, which occurs at the rubbing contact between the tool flank face and the newly machined surface of the work piece. Heat generation and temperatures in the primary and secondary zones are highly dependent on the cutting conditions while heat generation in the tertiary zone is strongly influenced by tool flank wear.

3. LITERATURE SURVEY

Julien Artozoul *et.al* [2] applied infrared thermography measurement technique for measurement of tool chip interface temperature in orthogonal cutting . J.C. Heigela *et. al* [3], Daniel Soler *et. al* [5], J.C. Heigel et. al [13], did work on various turning operations on different materials, an infrared camera is used to observe the radiant temperature of the tool–chip interface during machining.

Mehul Gosaia *et. al* [1] , Kuan-Ming Li *et. al* [6], Bogdan P. NEDI et. al [7], Jun Shinozuka et. al [10], Abdil Kus *et. al* [11], Ajay Goyal, *et. al* [12], Takeshi Yashiro *et. al* [15], Arun Kumar et. al [16],did work on various turning operations on different materials and concluded that, the tool-work thermocouple technique is the best method for measuring the average chip-tool interface temperaturee

Sushil D. Ghodam *et. al* [8] and L.B.Abhang *et. al* [9] did work on the principle of temperature measurement by thermocouple, it is that, when two dissimilar metals come in contact, with each other one is called the hot junction and the cold junction and are maintained at two different temperatures, an electromotive force (emf) is produced across these two junctions due to Seebeck effect. The emf generated is a function of the materials used for the thermocouple as well as the temperatures of the junctions. in the machining processes, a emf is generated in thermocouple is converted into temperature by using digital temperature indicator, then the temperature of tool was measured by digital temperature indicator. Akhil C S *et. al* [4] was used K type thermocouple for measurement of temperature.

L. B. Abhang *et.al* [9] conducted chip-tool interface temperature prediction model for turning process of EN 31 steel alloy material and three various cutting speed, of 39 m/min,112 m/min and 189 m/min feed rate .06 mm/rev, .10 mm/rev and .15 mm/rev and depth of cut .2 mm,.4 mm and .6 mm with tool nose radius .4 mm for EN-31 steel alloy material of work piece also did work on prediction of temperature at chip tool interface during turning process. In this research, the metal cutting parameters considered are cutting speed, feed rate, depth of cut and tool nose radius. It can be seen that the cutting speed, feed rate and depth of cut are the most significantly influencing parameters for the chip-tool interface temperature followed by tool nose radius. The results show that increase in cutting speed, feed rate and depth of cut increases the cutting temperature while increasing nose radius reduces the cutting temperature and analyzed the tool-chip interface temperature by first and second order predictions models which was established by experimental data. They did dry turning of EN-31 steel alloys with tungsten carbide inserts (CNMA 120404, CNMA 120408, CNMA 120412) tools. They had done tests for cutting speed of 39 m/min, 112 m/min and 189 m/ min at a constant feed rate of 0.06 mm/rev first and then method was repeated for feed rate of 0.10 mm/rev and 0.15 mm/rev. Experiment done for constant value of depth of cut of 0.2 mm and tool nose radius of 0.4 mm. Effect of cutting speed on cutting temperature (depth of cut=0.2 mm, tool nose radius=0.4 mm) Experiment results shows an increase in temperature of 174% from initial, when cutting speed increases from 39 m/min to 189 m/min.

4. METHODOLOGY

A setting is done for measurement of temperature at the tool tip during turning operation on Centre Lathe. Temperature measuring device consists of an assembly of K type thermocouple with digital temperature indicator. The tool being used in the experiment is high carbon steel tip with cast iron shank. A probe of the thermocouple is inserted in tool tip such that , it touches the tool tip, then it is soldered on the shank of the tool . The negative and positive end of the thermocouple is connected to the corresponding terminals of tool tip and digital temperature indicator In this arrangement the temperature at the tip of the tool will develop an emf in the thermocouple which will be displayed in the digital temperature indicator. The tool is fixed on the tool post and the work piece is fixed on the three jaw chuck. The digital temperature indicator reading is taken for different machining conditions by varying the cutting parameters like cutting feed, depth of cut, cutting speed etc.

4.1 COMPONENTS

4.1.1 Centre Lathe : The experimental apparatus to measure the cutting temperature on the tool is built on the centre lathe which is used for turning process. Turning is a metal cutting process in which the work piece is rotated and a single point cutting tool of hard material is brought to the surface of work piece resulting in removal of excess material in the form of chips as shown in fig 4.1.

Specifications of Center Lathe (V bed light duty center lathe machine, Bed length = 1500vmm, Motor = 2.5 HP, Max. Speed = 1410 RPM, Max, swing diameter = 200 mm, Make: Heera Machine Tools, Vavdi, Rajkot.)

Fig 4.1 Setup for temperature measurement using thermocouple on lathe machine

- **4.1.2 Work Piece:** Aluminium alloy rod of 30 mm cylindrical shape is selected as a work piece for the experiment. The Aluminium alloy work material is selected because it has wide applications, light in weight. corrosion resistance, good electrical and thermal conductivity & ductility non magnetic as shown in fig 4.2.

Fig 4.2 Work piece

4.1.3 Cutting Tool: We measured the temperature on the cutting tool during turning operation. The high carbon tip and cast iron shank tool is used for this experimentationas shown in fig 4.3.

Fig 4.3 Cutting tool with thermocouple inserted

4.1.4 Artificial Thermocouple: Nickel-Chromium V/s Nickel-Aluminium K-Type thermocouple is used for the measurement of temperaturet. It is capable of measuring temperature ranging from -200 to 1260 ˚ C. The thermocouple measures temperature and generates corresponding emf. This emf generated is converted to temperature by using digital temperature indicator.as shown in fig 4.4. The themocouple is calibrated before reading.

Fig 4.4 Thermocouple and digital temperature indicator

4.1.5 Digital Temperature Indicator : The readings from thermocouple are in the form of emf and for measuring these emf we are using a digital temperature indicator with digital display as shown in fig 4.4.

4.2 EXPERIMENTATION PROCEDURE:

1. Thermocouple probe is soldered on the most adjacent point of the cutting tool tip .
2. The tool is fixed on tool holder of center Lathe.
3. The work piece is fixed at center of lathe machine by by adjusting the three jaws chuck.
4. The one end of thermocouple is fixed on the tool tip and the other end is connected to the digital temperature indicator.
5. The parameters are considered feed rate in mm/rev, depth of cut in mm and cutting speed in rev/min.
6. Cutting speed can be varied by changing the gears .
7. Depth of cut is adjusted by using cross slide.
8. Feed rate is selected by adjusting the pitch values.
9. By adjusting the different feed rates, cutting speeds and depth of cuts, temperature is measured by digital temperature indicator.
10. The same procedure is repeated at different values of feed rate, depth of cut and cutting speed.
11. Five minute time were taken to bring the tool to cool back to initial state of atmospheric temperature after each turning operations .
12. Graphs were plotted between the temperature vs cutting speed for the various parameters.

5. RESULT AND DISCUSSION

Three process variables are selected by L. B. Abhang *et.al* [9] for EN 31 steel alloy, we are selected same process variables and their levels for experimentation of aluminium alloy as shown in Table 5.1 and and composition of aluminium alloy is as shown in Table 5.2.

The experiment of measuring cutting temperature during machining was completed successfully using artificial K type thermocouple with digital temperature indicator. The feed rate and cutting speed is made constant and the values of temperature are measured with temperature indicator at three different depths of cuts, the feed rate is made constant by adjusting the pitch values. The experiment is repeated at three different feed rate and cutting speed and the obtained values are in table 5.3.

Table 5.1 Process variables and their levels

S N	Parameter	Symbol	Level 1 (Low) -1	Level 2 (Medium) 0	Level 3 (High) +1
1	Cutting speed (Rev/min)	v	39	112	189
2	Feed rate (mm/rev)	f	0.06	0.10	0.15
3	Dept of cut (mm)	d	0.2	0.4	0.6
4	Tool nose radius (mm)	r	0.4	0.4	0.4

Table 5.2 Chemical Composition of aluminium alloy

Comp.	Si	Fe	Cu	Mn	Mg	Cr	Zn	Ti	Al
%	.4 to .8	.7	.15 to .4	.8 to 1.2	.8 to 1.2	.04 to .35	.04 to .35	15	79.9 to 81.6

Table 5.3 Obtained values

S N	Speed (v) rev/min	Feed (f) mm/rev	Depth of cut (d) mm	Tool nose Radius (r) mm	Tool Chip interface temperature in ° C
01	-1	-1	-1	0.4	27
02	-1	-1	0	.4	31
03	-1	-1	+1	.4	33
04	-1	0	-1	.4	39
05	-1	0	0	.4	52
06	-1	0	+1	.4	57
07	-1	+1	-1	.4	33
08	-1	+1	0	.4	45
09	-1	+1	+1	.4	58
10	0	-1	-1	.4	32
11	0	-1	0	.4	34
12	0	-1	+1	.4	37
13	0	0	-1	.4	37
14	0	0	0	.4	37
15	0	0	+1	.4	39
16	0	+1	-1	.4	42
17	0	+1	0	.4	50
18	0	+1	+1	.4	66
19	+1	-1	-1	.4	34
20	+1	-1	0	.4	37
21	+1	-1	+1	.4	44
22	+1	0	-1	.4	36
23	+1	0	0	.4	40
24	+1	0	+1	.4	43
25	+1	+1	-1	.4	44
26	+1	+1	0	.4	45
27	+1	+1	+1	.4	53

5.1 Effect of cutting conditions on chip-tool interface temperature:

5,1.1 Effect of varying cutting speed and depth of cut at constant 0.06 mm/rev feed rate on cutting temperatures: Chip-tool interface temperature is closely related to cutting speed & Shows the effect of cutting speed on the cutting temperatures (chip-tool interface temperature). With increase of cutting speed, friction increases, this induces an increase in temperature in the cutting zone, the temperature measurement by tool-work thermocouple indicates that for a speed of 39 rev/min, the maximum temperature is 33° C When cutting speed increases from 39 rev/min to 189 rev/min the increase in temperature in cutting zone of 44 ° C. If cutting speed increases then chip-tool interface temperature increases as shown fig 5.1

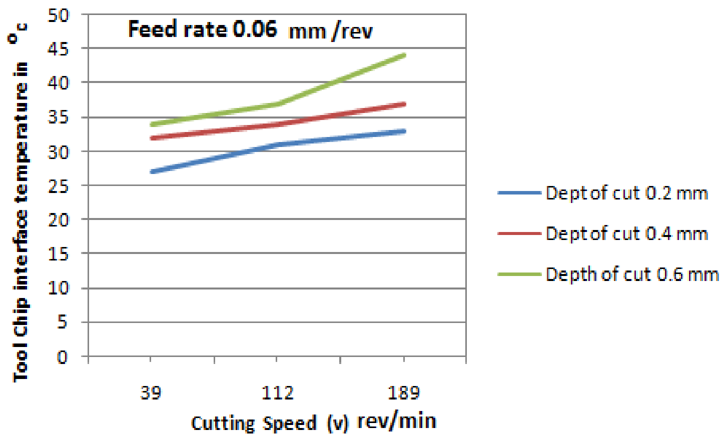

Fig 5.1 Effect of cutting speed and depth of cut at constant feed rate on cutting temperature (Feed rate 0 .06 mm/rev)

5,1.2 Effect of varying cutting speed and depth of cut at constant 0.1 mm/rev feed rate on cutting temperatures:

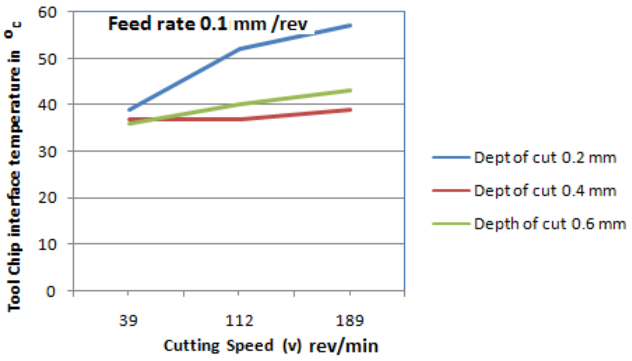

Fig 5.2 Effect of cutting speed and depth of cut at constant feed rate on cutting temperature (Feed rate 0 .1 mm/rev)

As shown in fig 5.2 the temperature measurement by tool-work thermocouple indicates that for a speed of 39 rev /min, the maximum temperature is 57 ° C . When cutting speed increases from 39 rev/min to 189 rev/min, there is decrease in temperature at cutting zone of 43 ° C. It is observed that, for 0.2 mm depth of cut the chip-tool interface temperature more as compared to 0.6 mm depth of cut but cutting speed increases then tool chip interface temperature increases.

5.1.3 Effect of varying cutting speed and depth of cut at constant 0.15 mm/rev feed rate on cutting temperatures: As shown in fig 5.3 the temperature measurement by tool-work thermocouple indicates that for a speed of 39 rev/min, the maximum temperature is 58 ° C When cutting speed increases from 39 rev/min to 189 rev/min their is decrease in temperature in cutting zone of 53 ° C It is observed that at maximum speed at same depth of cut and temperature is low but cutting speed increases then chip-tool interface temperature decreases.

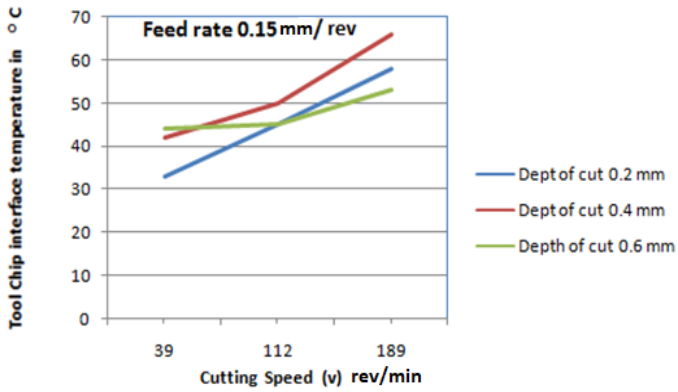

Fig 5.3 Effect of cutting speed and depth of cut at constant feed rate on cutting temperature (Feed rate 0 .15 mm/rev)

6. CONCLUSIONS

Chip-tool interface temperature is closely related to cutting speed. With increase in cutting speed, friction increases, this induces an increase in temperature in the cutting zone. With the increase in feed rate consequently friction increases and chip-tool interface temperature increases.

If the depth of cut increases, the section of chips involves the increase in temperature i.e. if dept of cut increases the chip-tool temperature increases.

If friction in chip-tool increases which leads to an increase in temperature. The maximum temperature developed in the cutting tool tip during machining was found to be 66° C. By carrying out proper measuring and applying suitable methods to reduce the developed temperature during machining operation can improve the quality of the work piece and can enhance the life of the cutting tool.

REFERENCES:

1) Mehul Gosaia, Sanket N. Bhavsarb,, Experimental Study on Temperature Measurement in Turning Operation of Hardened Steel (EN36), Procedia Technology 23 (2016) 311 – 318, 3rd International Conference on Innovations in Automation and Mechatronics Engineering, ICIAME 2016.
2) Julien Artozoul, Christophe Lescalier, Olivier Bomont, Daniel Dudzinski, Extended infrared thermography applied to orthogonal cutting: Mechanical and thermal aspects, Applied Thermal Engineering 64 (2014) 441-452.
3) J.C. Heigel E. Whitenton B. Lane M.A. Donmez V. Madhavan W. Moscoso-Kingsley, Infrared Measurement of the Temperature at the Tool-Chip

Interface While Machining Ti-6Al-4V, Journal of Materials Processing Technology ,PROTEC 15027.

4) Akhil C S, Ananthavishnu M H, Akhil C K, Afeez P M, Akhilesh R, Rahul Rajan, Measurement of Cutting Temperature during Machining,, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 13, Issue 2 Ver. I (Mar. - Apr. 2016), PP 108-122.
5) Daniel Soler , Patxi Aristimuño, Ainhara Garay, Pedro J. Arrazola, Uncertainty of temperature measurements in dry orthogonal cutting of titanium alloys, Infrared Physics & Technology 71 (2015) 208–216..
6) Kuan-Ming Li, Chia Wang, Wei-Ying Chu, An improved remote sensing technique for estimating tool–chip interface temperatures in turning, Journal of Materials Processing Technology 213 (2013) 1772–1781.
7) Bogdan P. NEDI , Milan D. ERI, Cutting temperature measurement and material machinability, thermal science: Year 2014, Vol. 18, Suppl. 1, pp.S259-S268.
8) Sushil D. Ghodam, temperature measurement of a cutting tool in turning process by using tool work thermocouple, ijret: International Journal of Research in Engineering and Technology EISSN: 2319-1163 | PISSN: 2321-7308
9) L.B.ABHANG* and M. HAMEEDULLAH, Chip-Tool Interface Temperature Prediction Model for Turning Process, International Journal of Engineering Science and Technology Vol. 2(4), 2010, 382-393
10) Jun Shinozuka, Habibah Binti JAHARADAK, Measurement of the temperature distribution at the tool-chip interface by using a cutting tool with seven pairs of built-in micro Cu/Ni thermocouples, *Advanced Materials Research ISSN: 1662-8985, Vol. 1136, pp 586-591.*
11) Abdil Kus, Yahya Isik, M. Cemal Cakir, Salih Coşkun, and Kadir Özdemir, Thermocouple and Infrared Sensor-Based Measurement of Temperature Distribution in Metal Cutting, Published online 2015 Jan 12. doi: 10.3390/s150101274.
12) Ajay Goyal,Suresh Dhiman, Shailendra Kumar, Rajesh Sharma, A Study of Experimental Temperature Measuring Techniques used in Metal Cutting, Jordan Journal of Mechanical and Industrial Engineering Volume 8 Number 2, April. 2014 ISSN 1995-6665 Pages 82 – 93.
13) J.C. Heigel, E. Whitenton, B. Lanea, M.A. Donmez, V. Madhavan, W. Moscoso-Kingsley, Infrared measurement of the temperature at the tool–chip interface while machining Ti–6Al–4V, Journal of Materials Processing Technology 243 (2017) 123–130.
14) José Díaz-Álvarez, Alberto Tapetado ,Carmen Vázquez and Henar Miguélez, Temperature Measurement and Numerical Prediction in Machining Inconel 718, Sensors 2017, 17, 1531; doi:10.3390/s17071531.
15) Takeshi Yashiro , Takayuki Ogawa , Hiroyuki Sasahara, Temperature measurement of cutting tool and machined surface layer in milling of CFRP, International Journal of Machine Tools & Manufacture 70 (2013) 63–69.
16) Arun Kumar, Sukhdeep S. Dham, A Review on Modeling of Temperature Distribution at Tool Workpiece Interface during Machining Process , International Journal of Innovative Research in Science, Engineering and Technology (A High Impact Factor & UGC Approved Journal) vol. 6, Issue 8, August 2017.

AUTHORS

Alimoddin Patel
Associate Professor, Dept. of Mechanical Engg. College of Engg. Osmanabad, Maharashtra, India

Dr. Rajendrakumar Tated
Professor, Dept. of Mechanical Engg. Matoshri College of Engg and Research Center, Nashik, Maharashtra, India