International Journal of Research (IJR) Vol-1, Issue-5, June 2014 **ISSN 2348-6848**

Thermal and Tool Wear Studies On Mild Steel Turning

Pramod Kumar N[1],Avinash N V [2],Sudheer K V[3]and Umashankar K S[4]

Abstract:

The present works involves the study of thermal and wear behaviour of tool and work interface. Experiments were conducted on a Turn master 35 automatic lathe. Various cutting forces, temperature at tool tip, thickness and weight of chips formed during machining along with the tool wear data were recorded. The influence of cutting parameters was studied. Based on the experimental data plots are obtained. Finite element analysis was done using ANSYS software tool and was used to find the tool tip deflection, counterplots. Thermal analysis was done to determine the temperature distribution over machining interface. Good agreement was found between the predicted and measured cutting forces.The analysis provides new insight into the chip formation and temparature distribution over tool tip and work interface in mild steel turning. As turning of mild steel rod using HSS is one among the major machining operations in manufacturing industry and tool wear results obtained would significantly contribute to the cutting parameters optimization during manufacturing of some of the parts for automobile and other structural related sectors.

Keywords:

Finite element analysis, Tool deflection , Tool wear, Cutting force, Machining

[123] *PG Students., Dept. of Mechanical Engineering, KVGCE, SULLIA, DK – 574327*
VTU, Belgaum. Karnataka, India, [1]E-mail:pramodnk90@gmail.com
[4]Professor., Dept. of Mechanical Engineering
KVGCE, SULLIA, DK – 574327, VTU, Belgaum, Karnataka, India ,[4]E-mail:ukskvgce@gmail.com
[2]E-mail:nvavinash50@gmail.com, [3]E-mail:sudheerkv21@gmail.com

Introduction

Machining operations comprise a substantial portion of the world's manufacturing infrastructure [1,2]. They create about 15% of the value of all mechanical components manufactured worldwide[3]. Because of its great economic and technical importance, a large amount of research has been carried out in order to optimize cutting process in terms of improving quality, increasing productivity and lowering cost.

Tool wear influences cutting power, machining quality, tool life and machining cost. When tool wear reaches a certain value, increasing cutting force, vibration and cutting temperature cause surface integrity deteriorated and dimension error greater than tolerance The life of the cutting tool comes to an end. Then the cutting tool must be replaced or ground and the cutting process is interrupted[4,5, 6]. The cost and time for tool replacement and adjusting machine tool increases cost and decreases the productivity[2]. Hence tool wear relates to the economic of machining and prediction of tool wear is of great significance for the optimization of cutting process

Machining of metals is still not completely understood because of the highly non-linear nature of the process and the complex coupling between deformation and temperature fields [1]. Metal cutting can be associated with high temperatures in the tool-chip interface zone and hence, the thermal aspects of the cutting process strongly affect the accuracy of the machining process [2]. The deformation process is highly concentrated in a very small zone and the temperatures generated in the deformation zones affect both the tool and the workpiece. High cutting temperatures strongly influence tool wear, tool life, workpiece surface integrity, chip formation mechanism and contribute to the thermal deformation of the cutting tool, which is considered, amongst others, as the largest source of error in the machining process [1]. Measuring temperature and the prediction of heat distribution in metal cutting is extremely difficult due to a narrow shear band, chip obstacles, and the nature of the contact phenomena where the two bodies, tool and chip, are in continuous contact and moving with respect to each other. The ever-increasing demand on cost reduction and improving quality of final products are driving metal cutting research into new areas. As for high speed machining (HSM) [3], it has become a key technology of particular relevance to the aerospace, mould and die and automotive industries. In HSM, cutting speed has a predominant effect on the cutting temperature and the heat transfer mechanism. As cutting speed increases, the cutting process becomes more adiabatic and the heat generated in the shear deformation zone cannot be conducted away during the very short contact time in which the metal passes through this zone. Consequently, highly localized temperatures in the chip occur. Therefore, it appears that in HSM, where the process is nearly adiabatic, the effect of the thermal phenomenon should become more important. The metal cutting is a coupled of thermo-mechanical process. During the process, the heat generation occurs as a result of plastic deformation and friction along the tool–chip and tool–work piece interface [4]. The maximum temperature occurs at the tool– chip interface[5]. The tool–wear and fracture or tool failure considerably increases at higher temperatures. Temperature rise in machining has a controlling influence on the cutting parameters. Many parameters depend on the temperature field during cutting tool life, mechanics of chip formation, surface quality, cutting forces, cutting speed, process efficiency etc. A lot of efforts have been made to measure the temperatures at the tool-chip interface zone, chip, cutting tool and the work piece [4]. A review of the common experimental techniques designed for temperature measurement in metal cutting processes reveals that these techniques can be classified as direct conduction, indirect radiation, and metallographic.

In the metal cutting process, the tool performs the cutting action by overcoming the shear strength of the workpiece material. This generates a large amount of heat in the workpiece 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 workpiece material [4]. Generally, increasing temperature decreases the strength of the workpiece material and thus increases its ductility. It is now assumed that nearly all of the work done by the tool and the energy input during the machining process are converted into heat.

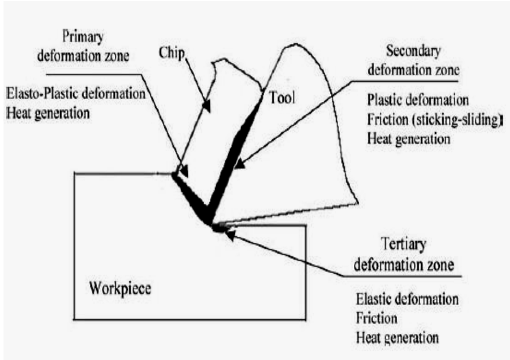

Figure 1. Sources of heat generation in the orthogonal cutting process [5].

The main regions where heat is generated during the orthogonal cutting process are shown in Fig. 1 [5]. Firstly, heat is generated in the primary deformation zone due to 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 workpiece 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 workpiece. 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.

The radiation techniques are non-contact thermo graphic methods designed to measure the surface temperature of a body based on its emitted thermal energy [4]. It is available for temperature field measurement (infrared thermography), including photo camera with films sensitive to infrared radiation and infrared camera, and for temperature point measurement (infrared pyrometer) [5]. The development of new kinds of tools and new materials has expanded the experimental field. This has resulted in a renewed interest in the study of the phenomena of wear. This renewed interest is highlighted by examples of tool wear investigations in different application fields: It is clear that, in a given field, the wear criteria chosen alone should be used to judge reliably when the tool must be removed from service for renewal of the cutting edge [7]. The wear can be defined as the loss of material from the cutting edge due to mechanical or chemical factors associated with the cutting process [8]. Wear minimization has been pursued by different means. An ideal cutting material has to combine high hardness and wear resistance with good toughness and chemical stability, but no material has ever shown all these properties together at their best combination.

Materials and Methods Used

Mild Steel Bar

In the present work Mild Steel is used as a work material to estimate the HSS single point cutting tool wear. Mild SteelBright Mild Steel Chemical Composition (0.16 % Carbon, 0.70% Manganese, 0.40% Silicon, 0.040% Phosphorus, 0.040% Sulphur), As turning of mild steel rod using HSS is one among the major machining operations in manufacturing industry.The machining of general purpose steel bars suitable for preparing lightly stressed components including studs, bolts, gears and shafts. Often specified where weld ability is a requirement. Mild steel can be hardened to improve wear resistance. Bright mild steel has more consistent hardness, and increased tensile strength.

Figure 2. MS-Rods used for Experiment

Experimentation

The cutting tests were performed using a Turn master 35 lathe. A strain gauge dynamometer was used to measure the cutting forces. Cutting conditions were feed rate 0.24 mm/rev, 4 different values for depth of cut (0.5, 1.0, 1.5, 2.0) and 4 different cutting speeds (180rpm, 280rpm, 450rpm, 710rpm). Tool geometry are nose angle 60^o, End relief angle 30^o, Face angle 0^o. Mild Steelrod of 32mm diameter was taken as work materials for experiment.

Figure 3. HSS Tool Used for Tests

Figure 4. Electronic Balance (Lc= 0.0001gm)

A lathe was utilized, fitted with a HSS tool. The other parameters were selected in order to obtain prompt treatment and to identify the most appropriate method to analyze the forces. HSS tool is ground to standard tool face angles and end relief angle and fixed on the Dynamometer for the force acquisitions are shown in Fig 5.

Figure 5. Lathe Tool dynamometer Setup

Figure 6. Tool dynamometer Output

A Lathe tool Dynamometer was used to measure the cutting forces. The cutting forces were measured according to the three principal directions, cutting force, tangential and normal respectively. An Infrared thermometer is used to measure the Cutting temperatures at tool tip and work surface. Tool wear measurements were made by the loss of the material from the active cutting edge due to the factors associated with the cutting process. Tool wear or tool material loss was measured using Electronic balance of least count 0.0001gms. Tool material loss was measured after turning every 150mm length of work material for different speeds and depth of cut values. All measured parameters are summarized and relations between them are plotted.

Results And Discussions

The relation between the tool wear & cutting forces with cutting speed, depth of cut shown in the below graph, along with other cutting parameters the variation of temperature developed at tool tip also plotted. The fig 7, 8, 9 shows Variation in Cutting force, Tangential force, Natural force on lathe tool while machining with four set of cutting speeds & different depth of cut combinations for Mild Steel turning. Force values increases with increase in cutting speed as well as depth of cut values.

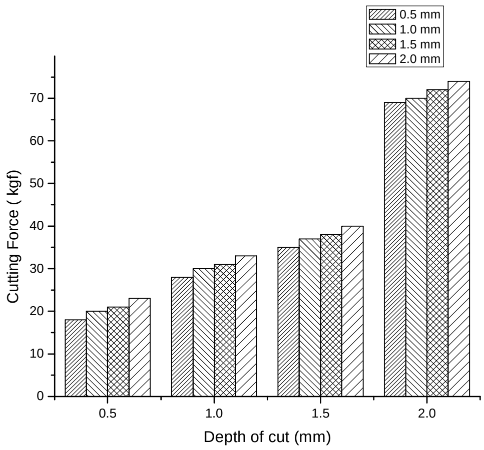

Figure 7. Cutting force (Fx) Values

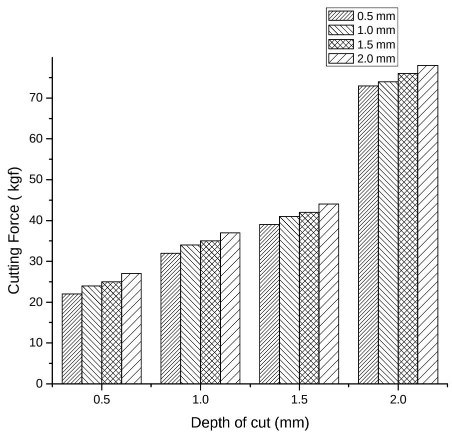

Figure 8. Tangential force (Fy) Values

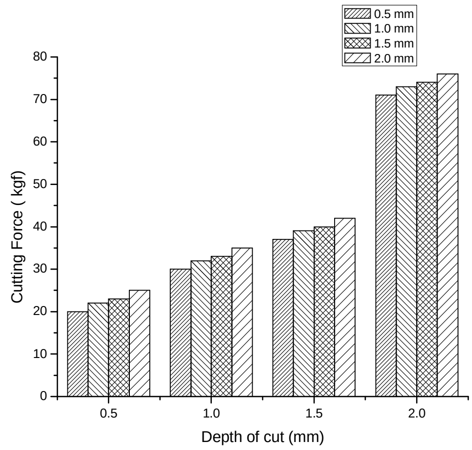

Figure 9. Natural force (Fz) Values

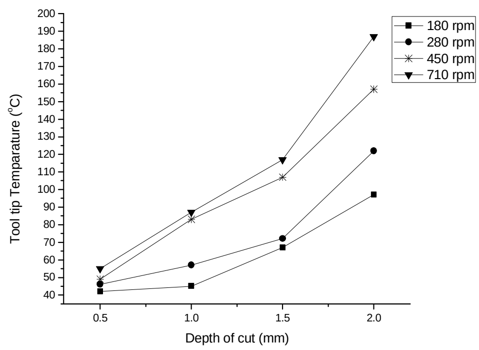

Figure 10. Temperature developed in Turning

The Fig.10, Shows the variations in temperature developed at tool tip while machining with different cutting speed & depth of cut combination for Mild Steel rod. From the graph it is clear that temperature developed at tool tip increases with the increase in machining speed and depth of cut values. The temperature developed at tool tip is maximum for 2.0 mm depth of cut and 710 rpm combination.

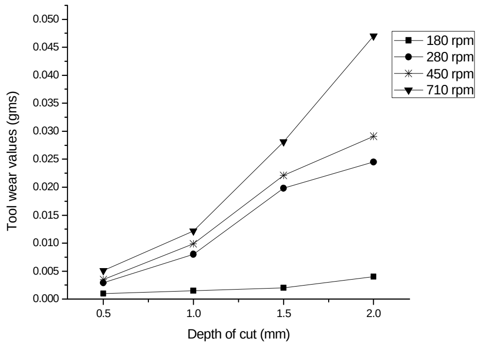

Figure 11. Tool wear values for turning

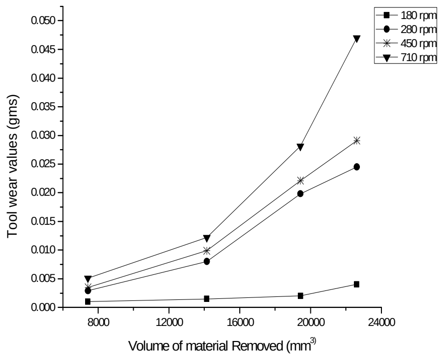

Figure 12. Tool wear Vs Volume of material removed

The Fig 11 and 12 shows values of tool wear while machining with different cutting speed & depth of cut combination for Mild Steel turning. From the graph it is clear that tool wear is increases with temperature developed at tool tip with the increase in cutting speed. Tool wear is minimum for 0.5mm depth of cut and it increases as we machine with higher depth of cut values.

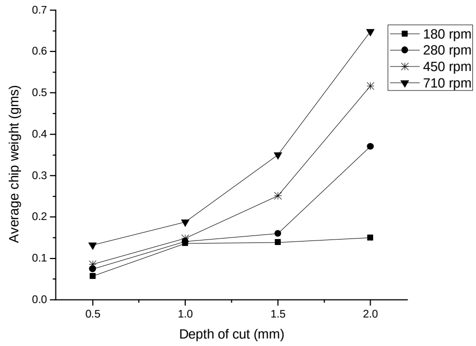

Figure 13. Chip weight variation

Fig.13 Shows the weight of chips formed during machining of mild steel, the chip length increases with machining speed and hence weight of chips. Weight of chips increases for higher machining speed and depth of cut values and it influence on tool wear.

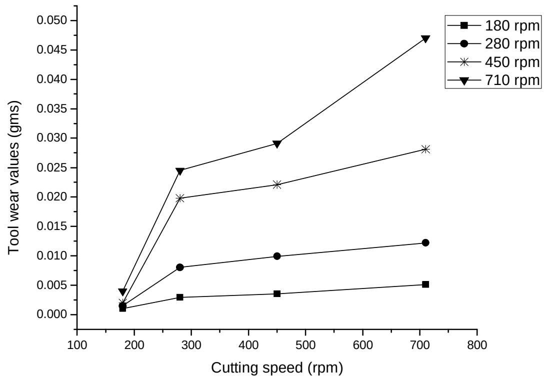

Figure 14. Tool Wear for different machining

Fig 14., shows that tool wear value is minimum for cutting speed range of (400-450) rpm for Mild Steel turning. To avoid high tool wear while machining Mild Steel it is advised to run machine in the range of (180-300) rpm by giving moderate depth of cut and feed values. From the experiment on machining it is found that cutting speed has significant effect on the temperature developed as well as the tool wear. The depth of cut plays a influence on cutting force, and an insignificant influence on tool wear.

Modeling And Comparisions

In this present work a practical high speed lathe tool taken as a case study. A 2D lathe tool model was plotted and the keypoints are developed for lathe tool. The modeling is done on Solid 3D modeling & ANSYS 10.0 software tool. Fem element taken for the Thermal analysis is, 3D Brick 8 node 45, Thermal analysis is done by taking some of basic assumptions. Temperature at tool tip $=187^{o}C$, Room temperature $=29^{o}C$, Air as convection medium and thermal properties of HSS lathe tool and Mild Steel are considered for analysis.

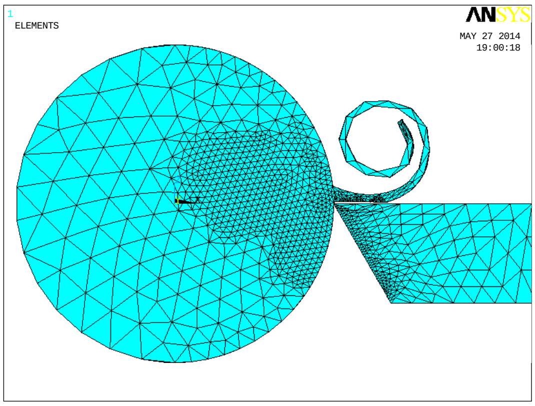

Figure 15. Tool work Model meshed Elements

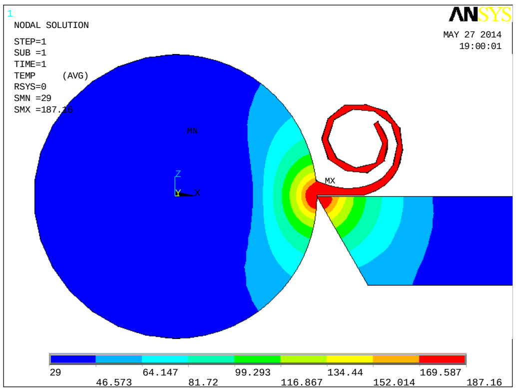

Figure 16. Temperature Distribution Tool-Work

Fig 15 and 16 Shows meshed finite element model of tool work interface and temperature distribution counter plots respectively. The model is created using solid 3D modeling software then exported on to ANSYS environment and meshed with optimum number of elements. Fig 17 shows distribution of temperature over tool-workpiece interface. The counterplots shows temperature is maximum at tool tip and tool work interface and it decreases with distance from the tool work interface.

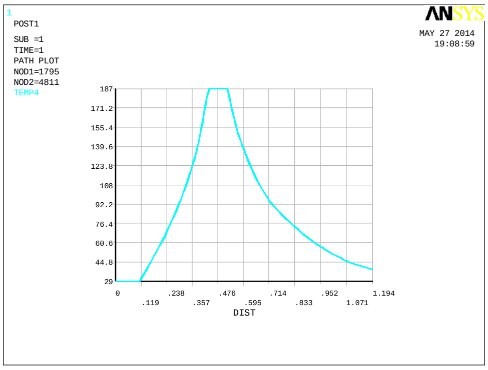

Figure 17. Temperature Distribution at Machining interface

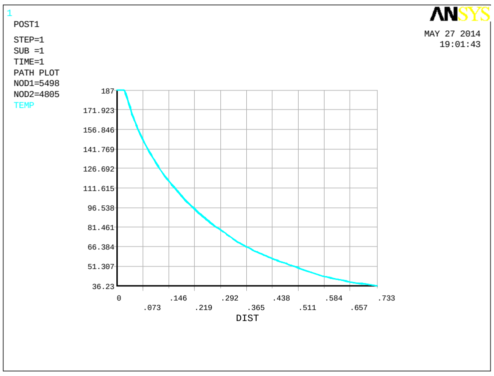

Figure 18. Temperature Distribution over tool tip surface

Fig 17 and 18 shows temperature distribution graphs for machining interface and tool tip region. From the fig 17. it is seen that maximum temperature region (0.4mm-0.5 mm) is at tool work interface and the work piece is at its maximum temperature (0.25mm). From the graph the temperature developed is clearly seen for tool surface as well as Tool-Machining interface.

Conclusions

The Mild Steel turning operation provided some useful results in relation to machining parameters, which will be useful in developing turning process optimization with respect to power consumption and tool life. Good agreement was found between the predicted and measured cutting forces.The finite element model provides new insight into the chip formation and temparature distribution over machining interface while turning the mild steel. The focus should be on choosing an appropriate combination of machining parameters, which will be helpful in manufacturing automobile and other structural parts contributing to the cost reduction in the overall production process.

REFERENCES

1. G. Sutter, L. Faure, A. Molinari, N. Ranc, V. Pina, “An experimental technique for the measurement of temperature fields for the orthogonal cutting in high speed machining” *Int. J. Mach. Tools Manufac.* 43 (2003) 671–678
2. E.K. Levy, C.L. Tsai, M.P. Groover, “Analytical investigation of the effect of tool wear on the temperature variations in a metal cutting tool” *Trans. ASME J. Eng. Ind.* 98 (1976) 251–257.
3. A.J. Shih, “Finite element simulation of orthogonal metal cutting” *ASME J. Eng. Ind.* 117 (1995) 84–93.
4. J.S. Strenkowski, J.T. Carroll, “A finite element model of orthogonal metal cutting” *ASME J. Eng. Ind.* 107 (1985) 349–354.
5. J.A. Ghani, M. Rizal, M.Z. Nuawi, M.J. Ghazali, C.H.C. Haron, “Monitoring online cutting tool wear using low-cost technique and userfriendly GUI,” *Wear,* 2619– 2624, 271, 2011.
6. M.B. Da Silva, J. Wallbank, “Cutting temperature: prediction and measurement methods -a review”, *J. Mater. Process. Technol.* 88 (1999) 195–202.
7. R. Komanduri, Z.B. Hou, “Thermal modelling of the metal cutting process-part III: temperature rise distribution due to the combined effects of shear plane heat source and the tool-chip interface frictional heat source”, *Int. J. Mech. Sci.* 43 (2001) 89–107.
8. Hogmark S, Olsson M. “Wear mechanisms of HSS cutting tools”. *SME Tech Paper* 2005:1–14.
9. Y.B. Guo, C.R. Liu, “3D FEA modeling of hard turning” *ASME J. Manuf. Sci. Eng.* 124 (2002) 189–199.
10. Da Silva, M.B. and Wallbank,“Cutting temperature: prediction and measurement methods -a review”, *J. Mater. Process. Technol.* 88: 195-202.
11. Kadirgama, K., Abou-El-Hossein, K.A., Mohammad, B., Habeeb A. A. and Noor, M.M.. “Cutting Force prediction model by FEA and RSM when machining Hastelloy C-22HS with 90º holder”. *Int. J. Scientific & Ind. Res,* 67(6): 421-427(2008)