

Simulation of the Effect of Cutting Angle in Lathe Process on Distribution of Cutting Temperature

By Amrifan Saladin Mohruni

PAPER • OPEN ACCESS

Simulation of the Effect of Cutting Angle in Lathe Process on Distribution of Cutting Temperature

2

To cite this article: T Ismail *et al* 2020 *J. Phys.: Conf. Ser.* **1500** 012029

2

View the [article online](#) for updates and enhancements.

You may also like

2

- [WAN MATVEEVICH VINOGRADOV \(on seventieth birthday\)](#)
Yu V Linnik and A G Postnikov

- [Performance of micro-drilling of hard Ni alloys using coated and uncoated WC/Co bits](#)

Philip A Primeaux, Bin Zhang and W J Meng

- [Comparative analysis of speed and cutting results of st-37 soft steel using HSS and carbide chisel knife](#)
Harling Vina N. Van



244th Electrochemical Society Meeting

October 8 – 12, 2023 • Gothenburg, Sweden

50 symposia in electrochemistry & solid state science



Deadline Extended!
Last chance to submit!

New deadline:
April 21
submit your abstract!

Simulation of the Effect of Cutting Angle in Lathe Process on Distribution of Cutting Temperature

Ismail T¹, Amrifan SM², Irsyadi Y³, Riman S⁴, Rahmad H⁵,

^{1,2,3,4,5} Mechanical Engineering, Engineering Faculty of Sriwijaya University,
Jln Raya Palembang - Inderalaya Km 32, Indonesia

E-mail: ismailthamrin@ft.unsri.ac.id

Abstract. Lathe machining process (turning) is one of the metal cutting operation is the most widely used. At the time of the cutting process almost all cutting energy is converted into heat through friction between the chisel and the workpiece, as well as the destruction of molecular or atomic bonding in the field of shear (shear plane). The heat produced will be distributed in workpiece surface, chisel edge, and chip. High cutting temperatures as a result of friction between the chisel and workpiece, will have an impact on the wear rate of the active surface of the plastic deformation chisel and chip. Cutting temperature can be measured in various ways, either directly or indirectly. However, in its application, direct measurement will find it difficult to reach the area of the cutting temperature. The difficulty is due to the relatively narrow measurement range, disturbance of movements machinery and hindered by chip that formed during the machining process is done. To overcome this we can do indirectly measuring process for measuring the temperature of the cutting. Indirect measurement can be done by simulation or modelling. This research uses Tungsten carbide as a cutting tool and AISI 4340 as the workpiece in the simulation process. FEM-simulation software used in this research is SolidWorks 2014 and Abaqus / CAE 6.14. Simulations were performed to analyze the influence of the temperature distribution of the corner cutting that occurs during cutting.

1. Introduction

Cutting tool of tungsten carbide material for manufacturing processes mainly in small and medium industrial workshops are still widely used. This is because this type of cutting tool is ductile, easily sharpened, easily available and the price is relatively cheap. tungsten carbide tool has the properties of hot hardness (hardness at high working temperature) and recovery hardness (hardness at room temperature after the tool experiences high working temperature).

Along with its use, the tool will wear from time to time due to friction between the cutting edge and workpiece [1]. The friction of the chisel to the workpiece causes the temperature around the chisel and the workpiece to increase, resulting in the transfer of heat from areas with high temperatures to areas with lower temperatures. We can simulate the rate of heat transfer using the 2014 Solidworks program and Abaqus / CAE 6.14 so that it can be analyzed for various purposes.



The purpose of this research is to Applying SolidWorks Simulation and Abaqus / CAE 6:14 to analyze the temperature in the machining process and analyzing the temperature distribution that occurs in the cutting edge types of tungsten carbide with workpiece AISI4340 with Orthogonal cutting force.

Cutting temperature is one of the key factors to be investigated in process optimization [2].

2. Literature Review

The turning process is basically a process of changing the shape and size of the workpiece by cutting the workpiece with a cutting tool so that the workpiece is cylindrical [3].

The position of the workpiece gripped by the chuck and rotates in accordance with the machine axes and the tools will quietly move to the right or left direction of the axis of the machine. On conventional lathes, the main shaft rotation generally graded, the rules have been standardized, eg, 630, 710, 800, 900, 1000, 1120, 1250, 140, 1600, 1800, and 2000 rpm. For CNC lathes, with variable motor rotation, or with a variable transmission system, the main shaft rotation speed is no longer graded but continuous [4].

In the lathe machining process, product size is determined first and then the edge of tool had to throw most workpiece material up to the size of the workpiece is achieved. This is inseparable from the basic elements of the machining process.

Cutting style is a method of positioning directions between the working tool (cutting tool) with the workpiece to be used during the machining process. There are two types of cutting force, namely orthogonal cutting and Oblique cutting [3].

Orthogonal cutting is a cutting system with relative motion between the cutting edge and the workpiece forming a 90° cutting angle or that is named with the main cutting angle. The direction of the resulting chip will be perpendicular to the cutting edge and shaped like a short spiral coil. The main cutting angle has a role that are determine the width and thickness of the chip before being cut off, determine the length of contact between chip and the tool plane, determine the amount force [4][5].

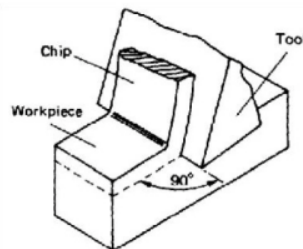


Figure 1. Orthogonal Cutting [3]

According to Möhring H C et al [6], high cutting temperatures and other factors such as high pressure and friction, will have an impact on the wear rate of the active surface of the tool and the plastic deformation of the tool. Even if the cutting temperature reaches the crystallization area of the microstructure of the metal tool arrangement can change. As a result, the tool undergoes changes in mechanical properties that can result in tool breakage and poor machining results. The cutting temperature can be measured in various ways, both directly and indirectly.

Direct measurement can be done using a variety of tools such as a thermocouple temperature gauge, infrared thermometer and pyrometer [7]. However, in its application, direct measurement will find it

difficult to reach the area of the cutting temperature. The difficulty is due to the relatively narrow measurement area, interference from machine movements and obstructed by the furrow formed during the machining process. To overcome this, we can make an indirect measurement process to measure the cutting temperature. Indirect measurements can be done by simulation or modeling.

Putz M et al [8] explained that during the cutting process, almost all cutting energy is converted into heat through the friction process between chips and tools and between tools and workpieces, and the destruction of molecules or atomic bonds in the shear plane.

There are three sources of heat generated during the cutting process, the three heat sources include are : 1. The heat generated when the tool changes shape (works) on the metal. chip forming region in this area is plastically deformed and broken / breaking in metal machining processes are performed. This area covers all the surface flow, the underlying source of the first heat source (Q1). 2. Friction on the cutting face, which is the friction area between the rake and the surface of the cutting tool, underlying the second heat source (Q2). 3. Friction on the tool flank, ie the friction area between the surface of the cutting tool and the workpiece which is machined with the cutting speed underlying the third heat source (Q3).

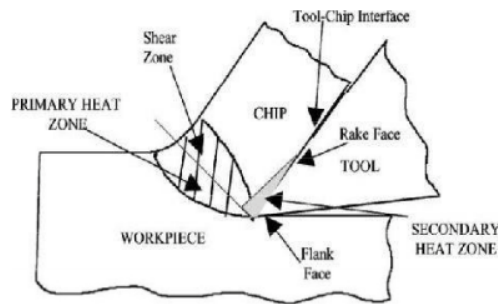


Figure 2. Region of heat generation in turning [9]

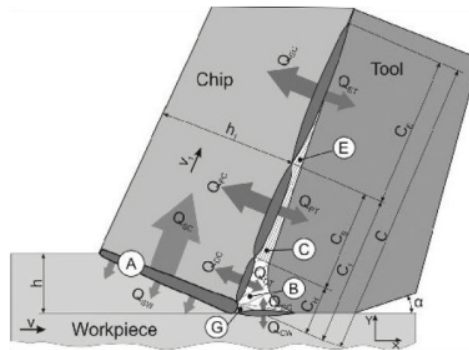


Figure 3. Heat flows in cutting process [6]

The cutting tool temperature can be measured using the formula:

$$\theta_E = \frac{C \cdot k_s \cdot v^{(1-2m)} \cdot A^{(m)} \cdot t^{\frac{1}{2}(2-2m)}}{\lambda_w \cdot C_{vw}} \quad (1)$$

As in equation (1) Where θ_E : Tool temperature ($^{\circ}\text{C}$); m : 0,22; k_s : specific cutting force; v : cutting speed; A : chip cross section (cm); λ_w : workpiece heat conductivity ($\text{J}/\text{cm} \cdot ^{\circ}\text{C}$); C_{vw} : Specific volumetric heat of the workpiece ($\text{J}/\text{cm}^3 \cdot ^{\circ}\text{C}$). **The following** formula is used to get the specific volumetric heat of the workpiece.

$$C_{vw} = \rho_w \cdot C_w \quad (2)$$

As in equation (2) Where ρ_w : Specific weight of workpiece (g/cm^3); C_w : specific heat of workpiece ($\text{J}/\text{g} \cdot ^{\circ}\text{C}$)

Lathe is a machine that is generally made of metal and is used to form workpieces by cutting, where the main motion rotates. Generally turning is used to form cylindrical objects. In figure 1. There are some basic elements you need to know; cutting speed, feeding rate, time

5 Finite Element Method FEM is the numeric technique **1** most often used in metal machining, other numerical methods are Finite Differences Method (FDM) and Boundary Elements Method (BEM). In the finite element method the basic principle is the replacement of a continuum with finite elements forming a mesh; this procedure is called discretization. Each finite element is simpler in geometry and therefore easier to analyze the actual structure [10].

Finite element methods is one method approach by replacing the domain of the problem with a collection of simple subdomains called finite elements. The shape and size of subdomains can vary to illustrate complex shapes. There are two characteristics that distinguish finite element methods from numerical methods, i.e 1. This method uses an integral formulation to produce an algebraic equation system. 2. This method uses continuous functions to approach unknown parameters.

The meshfree method is a specific class of numerical simulation algorithms to simulate physical phenomena. Traditional algorithm simulation relies on grid or mesh while the meshfree method uses the geometry simulation approach in its calculations. This has become one of the advantages of the meshfree method compared to conventional methods. Research methodology

SolidWorks is not only used for solid modeling, but SolidWorks can also be used for the FEMSimulation process. Until now SolidWorks has increasingly been used for design and generation of tools (CAD-CAM). In recent years, SolidWorks has upgraded the FEM-Simulation module, formerly called Cosmosworks.

Now the FEM SolidWorks module is called SolidWorks Simulation, in which there are several types of sub modules that can be selected depending on the characteristics of the system to be simulated. So the design phase, tool generation, analysis (CAD-CAM-CAE) can already be done in the same system, so that compatibility or compatibility is guaranteed. In addition, the operation of SolidWorks Simulation is easier compared to certain other CAE software, so that it can be used by people who are not experts in the finite element method.

SolidWorks Simulation has several types of sub models that can be selected according to the research to be conducted, such as Static, Thermal, Frequency, Buckling, Drop Test, Fatigue, Pressure Vessel Design, Design Research, Submodeling, Nonlinear, and Dynamic Linear [11].

3 A software tool for finite element analysis and computer assistive techniques, originally released in 1978. The name and logo of this software is based on the abacus calculation tool.

3. Result and discussion

The main components being used in this research are hardware and software. Hardware that being used is Intel Corei7-2630QM CPU @ 2.00GHz 2.00 GHz with 4.00 GB memory and 750 GB HDD.

Meanwhile the softwares that used are Solidwork 2014 and Abaqus/CAE 6.14

3.1. The analysis results with 3 different rake angle variants of 5, 10 and 15

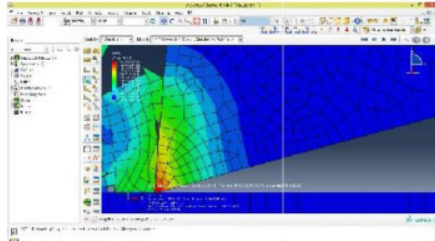


Fig 4a. Temperature distribution at cutting angle of 5°

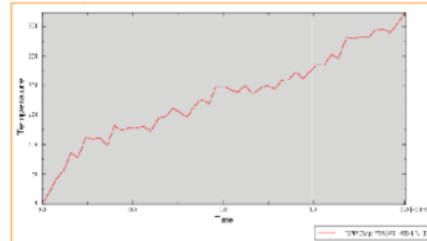


Fig 4b. Temperature graphic at cutting at cutting angle of 5°

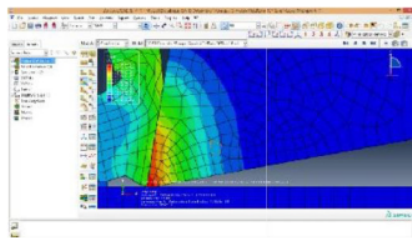


Fig 5a. Temperature distribution at cutting angle of 10°

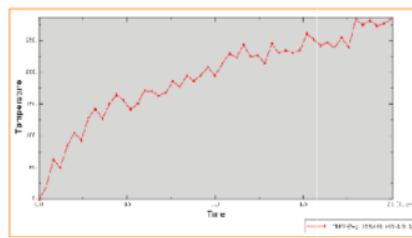


Fig 5b. Temperature graphic at cutting angle of 10°

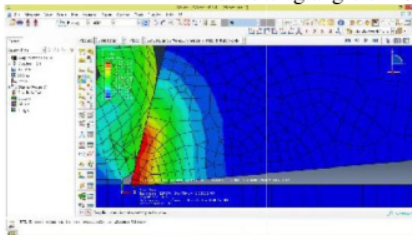


Fig 6a. Temperature distribution at cutting angle of 15°

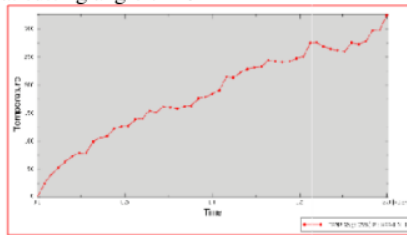


Fig 6b. Temperature graphic at cutting angle of 15°

3.2. Analysis Using Abaqus/CAE 6.14

For FEM-Simulation analysis the turning process of turning on SolidWorks 2014 could not be done, this happened because there was no tangent modulus (ETAN) value. The author is looking for references to the modulus tangent value in the FEA forum, and many errors are indeed caused by the absence of the modulus tangent value. For example for certain materials in SolidWorks 2014 there are tangent modulus values, but for custom materials, such as the FCD 500 AISI 4340 there is no tangent modulus value. Therefore the analysis is continued using Abaqus / CAE 6.14.

For analysis of FEM-Simulation lathe machining process (turning) using Abaqus / CAE 6:14 can be done by adding Johnson Cook parameters.

From the results of the analysis conducted on 3 variants of the cutting angle we can see in figures 4a through figure 6a, that the smaller the cut angle value (rake angle) the greater the temperature value, and vice versa the greater the cut angle value (rake angle) the greater the temperature value. The difference in temperature results from variations in the cutting angle is due to the small cutting angle which will cause the contact area between the chip and the tool to become narrower so that it slows down the heat dissipation rate and the tool temperature becomes higher. And also because this angle gives the flue side to remove the chip (chips) although this will only be seen if the cutting is done under a microscope.

The cutting angle also affects the level of surface roughness, where the smaller the cutting angle is used, the higher the level of surface roughness. And the higher the level of surface roughness will certainly affect the temperature generated friction between the tool and the workpiece.

4. Conclusions and recommendations

From the research that has been done, the researchers draw the following conclusions: 1. SolidWorks 2014 cannot be used for FEM-Simulation of turning and chip formation. 2. For turning process with AISI 4340 workpiece type material, the result of the chip that will be formed is discontinuous. 3. The greater the value of rake angle (positive position), the temperature value will be smaller, the smaller the value of rake angle (positive position), the temperature value will be even greater.

Suggestions to be conveyed by researchers for further development and better results from this research, it is recommended to use the results of experiments and compare them with simulation results

References

- [1] Chinchanikar S and Choudhary S K 2014 *Procedia Material Science* Vol 6 (2014) 996-1005
- [2] Karaguzel U, Bakkala M, Budak E 2016 7th HPC – Conference on High Performance Cutting, *Procedia CIRP* 46 (2016) 173 – 176.
- [3] Boothroyd G and Knight W A 1989. Fundamentals of Machining and Machine Tools. 2nd ed. MARCEL DEKKER, INC
- [4] Rochim, T., 2007. Manufacturing Process, Book 1 : Process Clarification, Force & Power. Publisher : ITB. Bandung
- [5] Lo S P 2000 *J. Mat. Proc. Tech.* 105: 143-151.
- [6] Möhring H C et al 2018 *CIRP Annals - Manufacturing Technology* 67 (2018) 61–64 [7] Gosai Mehul and Bhavsar S N 2016 *3rd ICIAME Procedia Technology* 23 (2016) 311 – 318
- [8] Putz M et al 2017 *16th Conf on Model of Mach Operations Procedia CIRP* 58 (2017) 97 – 103
- [9] Sullivan D O and Cotterell M 2001 *J. of Mat Proc & Tech* 118 (2001) 301-308
- [10] Markopoulus A P 2013. Finite Element Method in Machining Processes. Manufacturing and Surface Engineering *Springer Briefs in Appl Sci and Tech* DOI 10.1007/978-1-4471-4330-7
- [11] Gao Y et al 2017 *Procedia CIRP* Vol. 58 (2017) 204 – 209

Simulation of the Effect of Cutting Angle in Lathe Process on Distribution of Cutting Temperature

ORIGINALITY REPORT

7%

SIMILARITY INDEX

PRIMARY SOURCES

- 1 link.springer.com 56 words — 2%
Internet
- 2 Yen-Sen Wang, Hong-Ping Tsai, Evans Ching-Song Yang, Ya-Chin King, Steve Chen, Charles Ching-Hsiang Hsu. "A Body-Effect-Assisted NOR-type (BeNOR) Multilevel Flash Memory", Japanese Journal of Applied Physics, 2001 51 words — 2%
Crossref
- 3 en.wikipedia.org 27 words — 1%
Internet
- 4 F. Akbar. "Predictive modelling of average heat partition in high speed machining of AISI/SAE 4140 steel", International Journal of Machining and Machinability of Materials, 2009 22 words — 1%
Crossref
- 5 Angelos P. Markopoulos. "Finite Element Method in Machining Processes", Springer Science and Business Media LLC, 2013 15 words — 1%
Crossref
- 6 Chungchoo, C.. "A computer algorithm for flank and crater wear estimation in CNC turning operations", 14 words — 1%

International Journal of Machine Tools and Manufacture, 200210

Crossref

EXCLUDE QUOTES OFF

EXCLUDE BIBLIOGRAPHY ON

EXCLUDE SOURCES < 1%

EXCLUDE MATCHES OFF