Journal of Material Science and Mechanical Engineering (JMSME)
Print ISSN: 2393-9095; Online ISSN: 2393-9109; Volume 2, Number 1; January-March, 2015 pp. 70-73
© Krishi Sanskriti Publications
http://www.krishisanskriti.org/jmsme.html

Study of Effect of Feed on Cutting Coefficients in Turning

Manikandan H.[1], T.C. Bera[2] and Suraj K. Patil[3]

[1]*Research Scholar, Department of Mechanical Engineering Birla Institute of Technology and Science Pilani*
[2]*Department of Mechanical Engineering Birla Institute of Technology and Science*
[3]*Department of Mechanical Engineering Birla Institute of Technology and Science Pilani*
E-mail: [1]manikandan.h@pilani.bits-pilani.ac.in, [2]tcbera@pilani.bits-pilani.ac.in, [3]h2013129@pilani.bits-pilani.ac.in

Abstract—*During turning operation which is one of the most common and versatile machining process, cutting force plays a major role in metal cutting process affecting tool-workpiece vibration and part quality. Main aim of the research work is to develop a mechanistic model of the cutting forces and to study the mechanistic constant used in turning operation. The proposed model can be used for the reliable estimation of the cutting forces establishing relationship between various force components (cutting force and feed force) and uncut chip thickness. The accurate estimation of cutting force is required to control chatter vibration and to improve part accuracy specially machining of thin-walled components.*

1. INTRODUCTION

Turning is a continuous metal cutting process in which a non-rotary cutting tool moves linearly parallel to job axis while workpiece rotates about its own axis. Generally, this operation is carried out on lathe machine tool. Turning is one of the most common and versatile machining operation practiced in various industries such as aerospace, automotive, biomedical, die-mold making industries etc. There are lot of research work attempted regarding the development of cutting force model using various approaches such as analytical, numerical and mechanistic [1-6]. The first one is analytical approach which facilitates to establish mathematical relationship between cutting forces and various mechanical aspects such as cutting tool geometry, friction, process parameters, mechanical behaviour of workpiece materials etc. The second one is numerical approach which deals with fundamental mechanics and physics of metal cutting concentrating tool tip contact zone and interaction of tool-workpiece pair. The third one is mechanistic approach which is semi-analytical in nature dealing with a series of experiments between machining parameters and cutting forces. This approach takes into account the geometrical characteristic of metal cutting process and empirical cutting constants obtained from the experiments for a specific tool-workpiece pair. Each one of them has their own merits and demerits. The present research attempt mainly focused on the development of a mechanistic cutting force model in turning operation due to reliable and accurate prediction of cutting forces along with less calibration time. This approach considers the geometrical characteristic of metal cutting process and determines the empirical cutting constants from a series of experiments for a specific tool-workpiece pair. Although mechanistic model is very specific for a tool-workpiece pair, the calibration time of cutting constant is very short and it incorporates complex tool geometry into metal cutting process. It has enough capability to predict accurate cutting forces for a wide range of cutting conditions subject to a tool-workpiece pair. Therefore, an attempted has been made in the present work to identify and determine the specific cutting constants for estimating accurate cutting forces for turning of Al 6351 T6 material.

Henceforth, this paper is organized as follows: In section 2, the proposed approach is described to identify and determine the specific cutting constants for cutting force model of turning. Using the specific cutting constant, cutting force model is developed and detail description has been given in section 3. Section 4 deals with experimental setup and machining conditions selected for the present work. Section 5 illustrates the results and discussions of the proposed method. Finally, conclusion based on the present study has been summarized in section 6.

2. MECHANISTIC APPROACH IN ORTHOGONAL CUTTING

The mechanistic approach can be defined as a combination of both analytical as well as experimental approaches. In mechanistic approach, instantaneous chip thickness is calculated analytically from geometry of tool-workpiece interactions and specific cutting constants are determined experimentally at various chip thickness values. Later, empirical relationships are established among geometrical parameters obtained from the process geometry of turning.

Mechanistic model considers that cutting force is proportional to the chip cross-sectional area or effective cutting area. The constant of proportionality is known as cutting force coefficient or cutting constant or cutting pressure constant. The cutting force constant depends on several factors such as tool and workpiece material, tool geometry. Due to these significant factors, cutting force constant is difficult to quantify in many cases. Therefore, a reliable method is required to identify and determine the cutting pressure constant. A direct calibration method is used to determine the same. A series of machining tests are conducted to establish the cutting force coefficients over a range of cutting conditions [3].

3. DETERMINATION OF SPECIFIC CUTTING CONSTANT

The specific cutting constant is directly related to the mechanics of metal cutting and tool-workpiece interaction which is shown from the Fig. 1. To obtain the magnitude of cutting force, the cutting constant is multiplied with effective area of cutting. This effective cutting area depends on true radial depth of cut and true feed or actual uncut chip thickness. Cutting force component and feed force component can be obtained from the following equations.

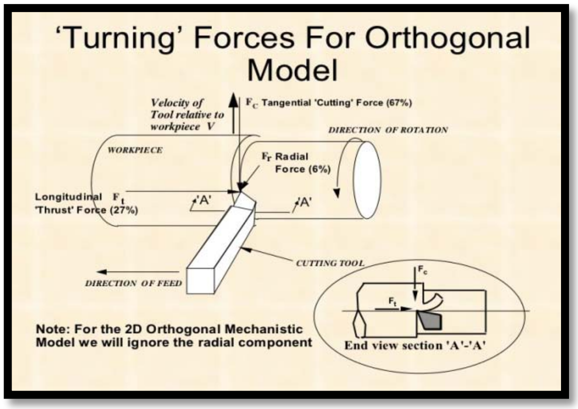

Fig. 1: Schematic diagram of turning [6]

$$F_C = K_c . A_c \ldots\ldots\ldots (Eq. 1)$$

$$F_F = K_f . A_c \ldots\ldots\ldots (Eq. 2)$$

Where F_C is cutting force component and F_F is feed force component, A_c is effective cutting area, K_c and K_f are constants for cutting force and feed force respectively. The effective cutting area also depends on actual uncut chip thickness and true depth of cut which can be calculated from the following equation.

$$A_c = t_c . w \ldots\ldots\ldots Eq. 3$$

Where t_c is true feed or actual uncut chip thickness and w is true depth of cut. These cutting constants are function of true feed or actual uncut chip thickness. Many researchers [1-3] are expressed the mechanistic constants as non-linear function of uncut chip thickness in more general form given below:

$$K_c = K_C (t_c)^p \ldots\ldots\ldots Eq\ 4$$

$$K_f = K_F (t_c)^q \ldots\ldots\ldots . Eq\ 5$$

Where K_C is the specific constant for cutting force and

K_F is the specific constant for feed force. The p and q are other constants.

4. EXPERIMENTAL SETUP

All machining experiments are performed on a conventional lathe equipped with piezoelectric dynamometer (Kistler) based cutting force measurement set up shown if Fig.2.

Fig. 2: Experimental setup

The workpiece material and cutting tool selected during machining experiments are Aluminum 6351-T6 and carbide insert (TNMG 16 04 08 CQ) respectively. The pre-machined hollow cylindrical workpiece is produced from rectangular components using roughing operation prior to final cut. The one end of cylindrical workpiece is attached to the square base mounted on four jaw chuck and other end is free which is shown in Fig. 3.

Fig. 3: The workpiece mounted on four jaw chuck

The length of cylindrical workpiece is 75 mm from the square base. The outer and inner diameter of the workpiece is 55 mm and 49 mm respectively and thickness is 3 mm. Orthogonal cutting tests are performed with constant depth of cut which is equal to the thickness of the hollow cylinder. DYNOWARE software was used to process the data recorded during the cutting for 30 seconds for each experiment.

5. RESULTS AND DISCUSSIONS

Each experiment is performed on the same experimental setup by varying feed rate keeping depth of cut and cutting speed constant. According mechanistic approach, geometrical characteristic of metal cutting process is incorporated in the present study. Depending on the machining conditions, effective cutting area has been calculated based feed per revolution and depth of cut. The magnitudes of cutting forces are taken from recorded data obtained from DYNOWARE commercial package for the given machining condition. Later on, cutting constants are calculated for given machining conditions for a specific tool-workpiece pair. The cutting conditions, calculated values of mechanistic constants and cutting forces are given in the table-1 below.

Table 1: Cutting conditions and results

Cutting Conditions			Measured Average cutting forces		A=feed xDOC	Mechanistic Cutting Constants		Avg chip thickness (Tc)= feed
Rpm (rev/min)	feed (mm/rev)	Depth of cut (mm)	F_z (N)	F_x (N)		K_r	K_t	
147	0.04	3	650.8	940.7	0.12	7833.33	5423.33	0.04
	0.08	3	695.5	893.7	0.24	3723.75	2897.16	0.08
	0.12	3	808.7	959.6	0.36	2665.55	2246.38	0.12
	0.16	3	899.2	1051	0.48	2189.58	1873.33	0.16
190	0.04	3	574.7	771.8	0.12	6431.66	4789.16	0.04
	0.08	3	656.7	820.6	0.24	3419.16	2736.25	0.08
	0.12	3	725.5	874.4	0.36	2428.88	2015.27	0.12
	0.16	3	784.8	913.7	0.48	1903.54	1901.458	0.16
247	0.04	3	426.3	623.9	0.12	5199.66	3552.5	0.04
	0.08	3	505.4	683.5	0.24	2847.916	2105.83	0.08
	0.12	3	606.2	773.3	0.36	2148.055	1683.88	0.12
	0.16	3	661.6	806.8	0.48	1680.83	1357.33	0.16
320	0.04	3	360.1	515.5	0.12	4537.5	3000.83	0.04
	0.08	3	446.7	594.9	0.24	2478.75	1861.25	0.08
	0.12	3	515.7	669.1	0.36	1858.61	1432.5	0.12
	0.16	3	590.4	700.2	0.48	1458.75	1197.08	0.16

After determination of cutting constants, they are expressed as a non-linear function of the uncut chip thickness using best fitted method. The Fig. 4. represents the graph for cutting constant and uncut chip thickness.

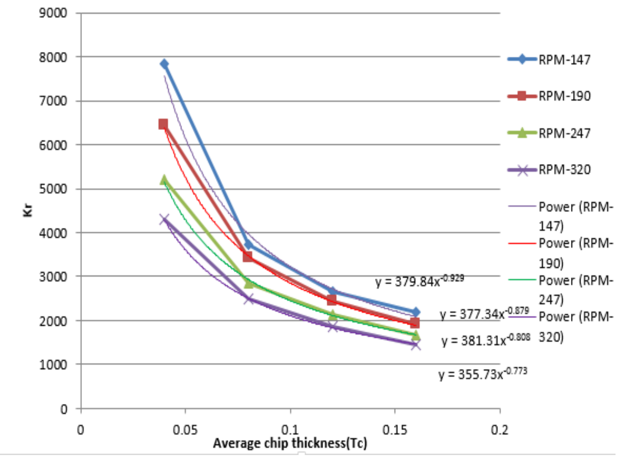

Fig. 4: Graph for cutting constant and uncut chip thickness for various rpm.

From the above graph, it can be clearly observed that the magnitude of the cutting constant decreases with increase uncut chip thickness. As uncut chip thickness is function of feed rate, cutting constants are also dependent on feed rate. When feed rate increases the section of sheared chip thickness increases because the metal resists the rupture more and requires larger efforts for chip removal [5]. Hence the cutting force also increases as the feed rate increases. The calculated values of specific constants are given in the table 2.

Table 2: The values of specific constants.

RPM	Non-linear relationship between Kr & Tc	Non-linear relationship between Kt and Tc
147	$Kr = 379.84Tc^{-0.929}$	$K_t = 442.22Tc^{-0.769}$
190	$Kr = 377.34Tc^{-0.879}$	$Kt = 389.65Tc^{-0.777}$
247	$Kr= 381.31Tc^{-0.808}$	$Kt = 395.2Tc^{-0.677}$
320	$Kr= 355.73Tc^{-0.773}$	$Kt = 373.02Tc^{-0.644}$

6. CONCLUSION

In the present study, mechanistic cutting constants are found out for given pair of tool-workpiece combination. The relationship between cutting constants and uncut chip thickness is successfully established to develop cutting force model. A general relation has been established between mechanistic constant and uncut chip thickness in non-linear form within an acceptable range of error for the specific range of cutting speeds. The accurate estimation of cutting force is required to process control, process characterization and to enhance machining performance specially for machining of thin-walled components.

7. ACKNOWLEDGEMENT

The authors thank and acknowledge the Science and Engineering Research Board (SERB), Department of Science and Technology, Government of India for financial support to carry out this research work (Project No: SERB/ET-0003/2013).

REFERENCES

[1] Fernández-Abia A. I., Barreiro. L., and Lopez de Lacalle, L. N., " Behavior of austenitic stainless steels at high speed turning using specific force coefficients", International Journal of Advanced Manufacturing Technology, 62, January 2012, pp. 505-515.

[2] Olvera D., Urbicain, G., Lopez de Lacalle N., Olvera D., and Campa F. J., "On the research of cutting coefficients in machining annealed Inconel 718 with ceramic tools", The Annals of DUNAREA DE JOS University of Galati, Fascicle V, 2009,pp.175-180.

[3] Endres W.J., DeVor, R. E., Kapoor S. G., "A dual-mechanism approach to the prediction of machining forces, Part 1: Model development", Transactions of the ASME Journal of Engineering for Industry, 117, November 1995, pp.526-533.

[4] Huang Y., and Liang S. Y., "Modeling of cutting forces under hard turning conditions considering tool wear effect", Transactions of the ASME, Journal of Manufacturing Science and Engineering , 127, May 2005, pp.262-270.

[5] Malagi R. R., and Rajesh B. C., " Factors influencing cutting forces in turning and development of software to estimate cutting forces in turning", International journal of engineering and innovative technology, 2, July 2012, pp. 37-43.

[6] Altintas Y., "Manufacturing automation, metal cutting mechanics, machine tool vibrations, and CNC design" Cambridge University Press, January 2012.