International Journal on Emerging Technologies (Special Issue on ICRIET-2016) **7**(2): 173-176(2016)

ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

Introduction to Metal Cutting

Adarsh Adeppa
Department of Mechanical Engineering, BKIT Bhalki, Karnataka, INDIA

(Corresponding Author: Adarsh Adeppa)
(Received 29 September, 2016 Accepted 25 October, 2016)
(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: Metal cutting is the most used production processes in the industry. The process is very flexible and can be used for production of parts with complex geometry and fine tolerances. Despite of the importance of this process, it is one of the production processes least examined. Detailed knowledge of the cutting processes is required in actually meeting these requirements. Cutting force is the main factor for the study of cutting process. Force modeling in metal cutting is important for tool life estimation, chatter prediction, and tool condition monitoring purposes. The cutting forces generated in metal cutting have a direct influence on heat generation, tool wear or failure, quality of machined surface and accuracy of the work piece.

Key points: cutting forces, tool, performance

I. INTRODUCTION

Machining is a term that covers a large collection of manufacturing processes designed to remove unwanted material, usually in the form of chips, from the work piece. Machining is used to convert castings, forgings, or preformed blocks of metal into desired shapes, with required size and finish specified to fulfill design requirements. The majority of industrial applications of machining are in metals. Theoretical analysis of cutting process is complex still the application of these processes in the industrial world is widespread. The primary chip formation processes are listed below, with alternative versions in parentheses. Each process is performed on one or more of the basic machine tools. For example, drilling can be performed on milling machines, lathes, and some boring
machines:

1. Turning (boring, facing, cutoff, taper turning, form cutting, chamfering, recessing, thread cutting).
2. Shaping (planing, vertical shaping)
3. Milling (hobbing, generating, thread milling)
4. Drilling (reaming, tapping, spot facing, counter boring, countersinking)
5. Sawing (filing)
6. Abrasive machining (grinding, honing, lapping)
7. Broaching (internal and surface)[2].

II. AN OVERVIEW OF THE TURNING OPERATION

Turning is a metal cutting process used for generation of cylindrical surfaces. Typically, the work piece is rotated on the spindle and the tool is fed into it radialy, axially or both the ways simultaneously to give required surface. The term turning, in general sense refers to generation of any cylindrical surface with a single-point tool. More specifically it is often applied just to the generation of external cylindrical surfaces oriented primarily parallel to the work piece axis. The generation of surfaces oriented primarily perpendicular to the work piece axis is called facing. In turning the direction of the feeding motion is predominantly axial with respect to the machine spindle. In facing a radial feed is dominant. Tapered contoured surfaces require both modes of tool feed at the same time, often referred to as profiling. The principle used in all machine tools is, that the material is removed by providing a suitable relative motion between the work piece and the cutting tool. The primary motion is the main motion provided by a machine tool to cause a relative motion between the tool and the work piece so that face of the tool approaches the work piece material. Usually the primary motion absorbs most of the total power required to perform a machining operation. The feed motion is defined as a motion that may be provided to the tool or work piece by the machine tool which when added to the primary motion, leads to repeated or continuous chip removal and the creation of the machined surface with the desired geometric characteristics.

III. CUTTING FORCES

The knowledge of cutting forces developing in the various machining processes under given cutting factors is of great importance, being a dominating criterion of material machinability, to both: the designer-manufacturer of machine tools and user.

Furthermore, this prediction helps in the analysis of optimization problems in machining economics, in adaptive control applications, in the formulation of simulation models used in cutting databases. In this regard, cutting forces being a substantial dependent variable of the machining system has been investigated by many researchers in various cutting processes through formulation of appropriate models for their estimation. These models are analytical, semi-empirical and empirical relationships, which connect cutting factors to forces. The analytical models are based upon the theory of mechanics of cutting, orthogonal or oblique but they are complicated and mostly, they demand a-prior knowledge of response magnitudes, as shear angle and friction angle.

Cutting force components. In orthogonal cutting, the total cutting force F is conveniently resolved into two components in the horizontal and vertical direction, which can be measured using a force measuring device called a dynamometer. If the force and force components are plotted at the tool point instead of at their actual points of application along the shear plane and tool face, we obtain a convenient and compact diagram[9].

Factors influencing estimation of cutting forces. The cutting forces in metal cutting depend upon several factors. The influence of each factor is discussed below in brief.

Work material- The cutting forces vary to a great extent depending upon the physical and mechanical properties of the material. Tangential force can be determined by multiplying the chip cross-section with the specific cutting resistance offered by the work material, which is found to be decreasing with increasing chip thickness and increases with increase in tensile strength and hardness of the material being cut. [11]

Cutting speed- The tangential force ‘Fc’ varies with increase in cutting speed. It will be noted that the cutting forces first increase with increase in cutting speed and on further increase in speed reach a maximum value and start decreasing and become fairly stabilized at higher speed ranges. Theinitial rise in cutting force up to about 70 m/min is due to the effect of built-up edge which does not occur at high speeds. Cutting forces at high speeds beyond 70 m/min decreases because of high temperature involved which tend to make the material plastic. [11]

Feed rate- The tangential component of cutting force is greatly influenced by the feed rate. It has been observed that cutting force changes linearly with feed at higher speeds, but at slower speeds the change is exponential.

Depth of cut- The tangential component ‘Fc’ increases in the same proportion as the depth of cut, if the ratio of depth and feed is more than four.

Tool approach angle- The chip size is dependent upon the approach angle. The tangential component ‘Fc’ is more or less constant within the range 900 to 550 and increases slightly for approach angles less than 550. Axial component ‘Fc’ maximum for approach angle of 900 and decreases with decrease in approach angle. Radial component ‘Fr’ minimum for approach angle of 900 and increases with decrease in approach angle. [11]

Side rake angle- All the three components of cutting forces decreases as side rake angle changes from –ve value to +ve value; the tangential component alone being predominant for +ve side rake angles and other two being negligible. However for higher –ve vales, both ‘Fc’ and ‘Ff’ are considerable and thus result in vibrations. For negative side rake angle component ‘Fc’ increases due to higher plastic deformation of chips and increased friction in the tool-chip interface. This type of variation is not so marked at higher speeds as at lower speeds. [11]

Back rake angle- It controls the direction of chip flow either away from or towards the work piece depending upon whether it is +ve or –ve. The vertical component Fr increases slightly as the back rake angle increases from –ve value to +ve value. [11]

Flank wear- The tangential component ‘Ff’ as well as ‘Fc’ and ‘Fr’increase considerably with increase in flank wear. [11]

IV. LITERATURE REVIEW

Suleyman Yaldıza *et al* [1]. in this study, a turning dynamometer that can measure static and dynamic cutting forces by using strain gauge and piezo-electric accelerometer respectively has been designed and developed. The orientation of octagonal rings and strain gauge locations has been determined to maximize sensitivity and to minimize cross-sensitivity. The developed dynamometer is connected to a data acquisition system. Cutting force signals were captured and transformed into numerical form and processed using a data acquisition system consisting of necessary hardware and software running on MS-Windows based personal computer. The obtained results of machining tests performed at different cutting parameters showed that the dynamometer could be used reliably to measure cutting forces.

Morten F. Villumsen, *et al* [6]. In their study they have used Finite Element Method, A Lagrangian approach is used for prediction of cutting forces in metal cutting. The analysis which predicted the best agreement between force output from analysis and force output measured from experiments and at the same time, predicted a realistic chip formation was found. The cutting force and thrust force were predicted and compared with forces measured during experiments. The cutting force ‘Fx’ was overestimated by 104% and the thrust force ‘Fz’ was over estimated by 60%.

Y. Huang, S.Y. Liang [7] in this approach they have used the effect of tool thermal property for modeling of the cutting forces. To model the effect of tool thermal property on cutting forces, this study modifies Oxley's predictive machining theory by analytically modeling the thermal behaviors of the primary and the secondary heat sources. The model prediction is compared to the published experimental process data of hard turning AISI H13 steel (52 HRC) using either low CBN content or high CBN content tools. But the proposed model and finite element method (FEM) both predict lower thrust and tangential cutting forces and higher tool–chip interface temperature when the lower CBN content tool is used, but the model predicts a temperature higher than that of the FEM.

Bandit Suksawat [8] described application of ANN for classification chip form type and tangential cutting force prediction is presented. The machining condition consisting of cutting speed, feed rate and cutting depth are determined as input parameters of BPNN input layer for classification chip form and tangential cutting force in cast nylon turning operation with a single point high speed steel tool . From the results, it can conclude that ANN is effective for classification chip form and cutting force prediction with 86.67% and 91.130% of accuracy, respectively.

Xiaoli Li [9] in this paper proposes a new method to measure the cutting forces in turning using inexpensive current sensors and the cutting force model. First, the relationship between the various factors, which affect the performance of the spindle and feed drive systems, and the models of the spindle and feed drive systems are analyzed. Then, some reliable and inexpensive Hall-effect current transducers are employed to sense the current signals of the ac servomotor in a computer numeric control (CNC) turning center; the tangential (Ft) and axial (Fa) cutting forces in turning are estimated by applying a neuro– fuzzy technique. Finally, the normal cutting pressure (Kn) and effective friction coefficient (Kf) are calculated through the cutting mechanical model, so the axial cutting forces (Fr) can also be estimated based on the model of cutting force. Experimental results demonstrate that the method proposed can measure tangential, axial, and radial cutting forces with an error of less than 10%, 5% and 25%, respectively.

V. METHODS OF ESTIMATING CUTTING FORCES

Merchant's orthogonal cutting model [3, 10]

The first analytical model for cutting force was developed by Merchant [10]. His model was based on the shear plane where shear force was a maximum and chips were formed by the shearing action. Following are the assumptions with regards to Merchant's orthogonal cutting model

1. Work moves with a uniform velocity.
2. The surface where the shear occurs is plane.
3. The tool is perfectly sharp and there is no contact along the clearance surfaces.
4. The cutting edge is a straight line which extends perpendicular to the direction of motion and generates plane surface as the work moves past it.
5. The stresses on the shear are uniformly distributed.
6. Uncut chip thickness is constant.
7. A continuous chip is removed without any built up edge [10].

Empirical models for cutting process [10]. Very few empirical models for metal cutting have been proposed. Most of the empirical models are generally machine and material specific. Those kinds of models are developed to use in industry for different predictions from cutting forces to tool wear. Empirical equations are generally complex relationship between most of the process variables to be fitted from a small number of tests results. The main problems with empirical models are that they lack the description of physical process and have limited ability to generalize the models to different machining conditions and materials. Some of the empirical methods have been described below from an open literature review. Power law regression methods, relating the turning forces of cutting to the different cutting condition were presented by Waldorf. Again, Zorev developed a force model where he reported that the shear stress be proportional to tensile stress by a set of empirical constants. He also reported that coefficients of friction along the rake face and chip flow direction were both related through an analytical equation with some empirical constants [10].

Finite element analysis of machining process. Metal cutting process is one of the most complex tasks due to large number of constraints affecting the process from different disciplines, such as metallurgy, elasticity, plasticity, heat transfer, vibration, fracture mechanics, contact mechanics, and lubrication. Due to the complexity of the process, numerical approaches have been developed and adopted to replace the direct experimental approach which is time consuming and expensive. Among the numerical techniques, finite element methods are the most common. With the advancement of the computer technology, finite element methods are successfully used to model and analyze complex problems such as metal cutting ,metal forming, contact mechanics, fracture mechanics, etc. With the help of different finite element software the machining process was studied by:

1. Formulating material properties as a function of strain, strain rate, and temperature.
2. Modeling chip tool interface as a function of either sticking or sliding friction.

3. Analyzing the functions, global variables like cutting force, feed force, chip geometry, local stress, strain, and temperature distribution in the work piece can be calculated.

VI. CONCLUSION

In the present work it is important to estimate cutting forces in turning using above methods. These methods estimates the cutting force within an error of 15%. The results obtained shows that cutting forces increases with increase in feed rate and depth of cut and there is no much effect of cutting speed on cutting forces. Cutting forces are less at positive tool rake angle compared to tools with negative rake angle. The values obtained from the software are compared with experimental results which are within acceptable limit. It can be concluded here that by developing software it is possible to estimate cutting force by software which will save the time and it is the cost effective method because experimentation to measure the cutting force is costly.

REFERENCES

[1] Suleyman Yaldiz "Development and Testing of a Cutting Force Dynamometer for Milling" Journal of Polytechnic Vol. **8** No: 1 pp. 61-68, 2005.
[2] ASM Handbook. Published in 1989 as Volume 16 of the 9th Edition Metals Handbook.
[3] V C Venkatesh and S Izman "Precision Engineering" Tata mcgraw-Hill Publishing Company ltd., New Delhi
[4] G. Petropoulos, I. Ntziantzias, C. Anghel, "A predictive model of cutting force in turning using taguchi and response surface techniques" 1st International Conference on Experiments/Process/SystemModeling/Simulation/Optimization 1st IC-epsmso Athens, 6-9 July, 2005.
[5] Valery Marinov, Manufacturing Technology.
[6] Morten F. Villumsen, Torben G Fauerholdt "Prediction of Cutting Forces in Metal Cutting, using the Finite Element Method, A Lagrangian Approach" LSDYNA Anwenderforum, Bomberg 2008.
[7] Y. Huang, S.Y. Liang "Cutting forces modeling considering the effect of tool thermal property—application to CBN hard turning " International Journal of Machine Tools & Manufacture **43** (2003) 307–315.
[8] Bandit Suksawat "Chip Form Classification and Main Cutting Force Prediction of Cast Nylon in Turning Operation Using Artificial Neural Network" International Conference on Control, Automation and Systems 2010 Oct. 27-30.
[9] Xiaoli Li "Development of Current Sensor for Cutting Force Measurement in Turning" Journal of IEEE transactions on instrumentation and measurement, vol. **54**, no. 1, February 2005.
[10] Snahungshu Sikder "Analytical model for force prediction when machining metal matrix composites" University of Ontario Institute of Technology.
[11] R. K. Jain "Production Technology " Khanna Publishers 7th edition New DelhiK.