Influence of cutting parameters on cutting forces

M. Bourdim, A. Bourdim, S. Kerrouz

Abstract— The turning is machining operation used in industrial manufacturing processes to obtain specific characteristics of machined work piece such as part geometry, surface roughness, etc. Cutting process create movements between the cutting tool and the work piece, which can affect the cutting forces between the tool and the work piece. The cutting forces depend on tool geometry and its material, work piece material, feed rate and cutting. These cutting forces could lead to reduced productivity, since lowered cutting speeds have a negative effect on the work piece surface. In this work we present an approach based on the study of cutting forces applied on the surface of work piece by Lathe tool is measured using experimental setup. The forces works on the work piece applies in three directions as longitudinal, axial and lateral directions.

Keywords— Turning, work piece, cutting forces, feed, productivity
.

I. Introduction

THE turning is one of the most important manufacturing processes in the field of engineering production. If the cutting process is unstable, the amplitude of vibrations can start increasing exponentially until a value similar to chip thickness is reached.

leads to destructive oscillating cutting forces which create vibration marks on the machined surface. This drastically shortens cutting tool and machines durability, can cause cutting tool breakage and early lathe spindle bearing wear [1]. Cutting forces generated during metal cutting have a direct influence on generation of heat and thus accuracy of work piece, quality of machined surface and tool wear. The knowledge of cutting forces for different cutting parameters helps the designer-manufacturer for increasing the efficiency of machine tools. The cutting forces depend upon tool geometry, work piece material, feed rate, depth of cut, cutting speed etc [2]. It is believed that the forces acting on the tool form a parallelepiped shown in Fig. 1.

The force components acts against tool are “Cutting Force Fc”, this force has primary effect on motion and has (70%-80%) of total force over the operation and used to calculate power for machining. “Feed Force Ff”, this force works in the direction of feed motion. Cutting forces changes linearly with feed at high speed but change is exponential at slower speed. “Thrust Force Fp”, thrust force works in the direction perpendicular to “feed force Ff”, this force has lesser effect compared to the other two forces. In cutting process, among the cutting factors that influence the cutting force, the present study is based on the three parameters.

Calculations cutting forces cannot produce accurate results due to complex tool configurations and cutting conditions of metal cutting operations for unknown factors and stresses [3], [4]. So experimental measurement is unavoidable. The researches results that tool breakage, tool wear and work piece deflection are strongly related to cutting force.

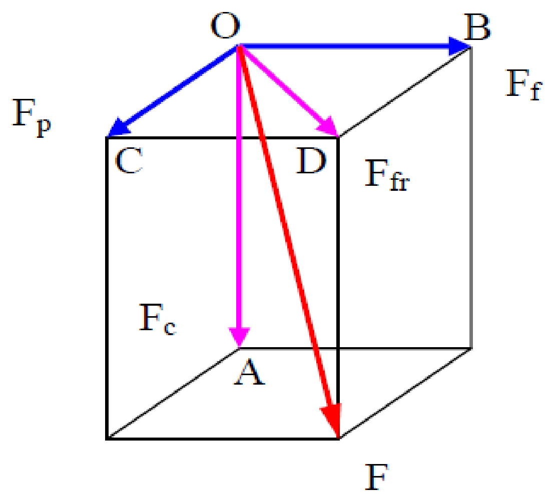

Fig. 1 cube efforts

II. Knowledge of Cutting Forces

One of the most important technical data that affect a machining process is the cutting force, which is the basis of the power required for cutting. These facts the knowledge of cutting forces is a greater need. In metal removal operations, many research were carried out in the past and many are continuing for the purpose of decreasing production cost and manufacturing parameters without reducing product quality.

It was seen in all works on cutting forces by chip removal methods that the acting forces directly influence cutting parameters such as cutting speed, feed rate, depth of cut, tool rake angle and tool life, so various force measuring methods have been developed. For this purpose, it is well known.

Cutting tools are insistently subject to pressure and opposing stresses during cutting even though their cutting

This work was supported by the laboratory water and work in their environment under one’s supervision university abou bek Belkaid of Tlemcen,Algeria.

M. Bourdim is with the Relizane University center Algeria (phone: +213558702785; e-mail: mokhtar_61@ yahoo.fr).

A. Bourdim, Mechanical Engineering Department University of Tlemcen Algeria (e-mail: bourdim56@yahoo.fr).

S. Kerrouz. is with the Relizane University center Algeria, (e-mail: kerrouzsiham@gmail.com).

edges are sufficiently sharp while machining metallic and nonmetallic materials. Many researchers spent effort to determine optimum tool cross-sections and their ideal rake angles to withstand cutting forces.

Various dynamometer design techniques have been used in force measurement based on strain measurement and ring theory [5],[6] mechanical force measurement device with three axis [7], dynamometers with dial gage, piezoelectric dynamometer with three part [6],[8], sensor integrated intorotary tool [9],[10], dynamometer included load cells based on strain measurement [11].

There have been many studies concerning the effect of cutting parameters and rake angle on the cutting forces. The influence of machining parameters such as cutting speed, feed rate, etc. for different materials [7],[11], determining cutting forces effect on tool wear [12],[13] have been investigated. The influence of tool rake angle on cutting force and stresses was studied. All results yielded from all these studies have been evaluated.

III. PRICIPLES

In turning, determination beaches stable cutting parameters "cutting speed Vc," "feed rate f," "depth ap," is based on the variation of specific cutting forces, calculated by. Refer to "(1)," "(2)" and "(3),"

$$Kc = \frac{Fc}{f.ap} \quad (1)$$

$$Kf = \frac{Ff}{f.ap} \quad (2)$$

$$Kp = \frac{Fp}{f.ap} \quad (3)$$

With "Kc, Kf and Kp the specific cutting forces," due to the "cutting force Fc," the "advance force Ff," and the "penetration force F p".

Experiments were performed using the method of experimental designs that allows both to reduce the number of tests, and investigating a large number of factors, but also to detect possible interactions between factors [14].

The obtained results of machining test at different cutting parameters showed that Dynamometer could be used reliably to measure cutting forces. It can be used to measure three force components in a cutting process that are "feed force Ff," "thrust force Fp," and main "cutting force Fc," [15].

After each 100 mm cutting length oneach sample, measurements were taken. In order to keep all conditions constant, each experiment was performed with unworn tool.

The process of experiment will be carried out by changing the different cutting parameters (spindle speed, feed and depth of cut) to measure cutting force.

A. Machine tool, cuttingtool and cutting parameters

The fig. 2 represents the entire apparatus used for both test series. A tour REALMECA T400 digital control power 7.5 kilowatts is used to perform the shooting test.

The machining is to conduct Roughing passes on the piece to study.

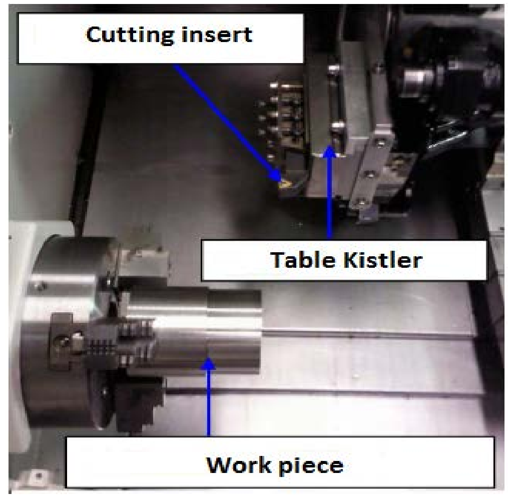

Fig. 2 experimental device

The cutting conditions were determined according to the requirements and recommendations of Sandvik, see Table I.

Table I. Cutting conditions adopted

Cutting speed	$100 \leq Vc \leq 400$ mm/min
Feed rate	$0{,}1 \leq f \leq 0{,}45$ mm/rev
Depth of cut	$0{,}6 \leq ap \leq 1{,}2$ mm

The cutting tool is formed of a triangular plate irreversible titanium carbide coated type TNMG 16 04 08 and a door designation tool SOGIMO 90 ° 20W3K10 a following geometry:

$$\psi = 95°; \ \alpha = 6°, \ \gamma = -6° .$$

B. Work piece material to be machined

The material is machined from steel C45, used in industry (aeronautics, automotive, engineering,…). These are steel bars, obtained by drawing, of "(100 mm) diameter," and "length (140 mm)," the chemical composition of the selected work piece is shown as follows: C, 0.45; Si, 0.22; Mn, 0.66; P, 0.027; S, 0.032; Cr, 0.26; Ni, 0.15; Mo, 0.02; Cu, 0.18.

IV. RESULTS AND DISCUSSION

Figs. 3 present developments "specific efforts Kc and Kp Kf," depending on the cutting speed and the speed of the chip.

These graphs show the same changes accordingly in the following analyze are made from the cutting speed. Thus, determination of the stable cutting range is based on "the specific cutting force Kc," this parameter is sensitive to the cutting speed. Observation Fig. 3. A, distinguishes three areas of evolution specific efforts.

De same as before observing the curve in Fig. 3. A, shows a significant trend reversal of the “specific cutting force Kc,” from (200 m / min). The cup near the “cutting speed Vcmin,” ensure speed and potential disruptions due to the machining system (vibration, auto-generation of surfaces ...).To set the minimum stable “cutting speed Vcmin,” the speed of (200 m / min) was considered because it represents the speed of the nearest section of the shoulder point “specific cutting force Kc,”. “Minimum speed Vcmin,” the minimum speed is obtained with a (15%) increase is “minimum speed Vcmin (230 m / min),” the increase of (10-15%) is generally used to satisfy the stability of speed of the nearest section of the shoulder point “specific cutting force,”.

The “minimum speed Vcmin,” is obtained with a (15%) increase is “minimum speed (Vcmin = 230 m / min),” the increase of (10-15%) is generally used to satisfy the stability of the cup near the “minimum speed Vcmin,” ensure speed and potential disruptions due to the machining system (vibration, auto-generation of surfaces ...).

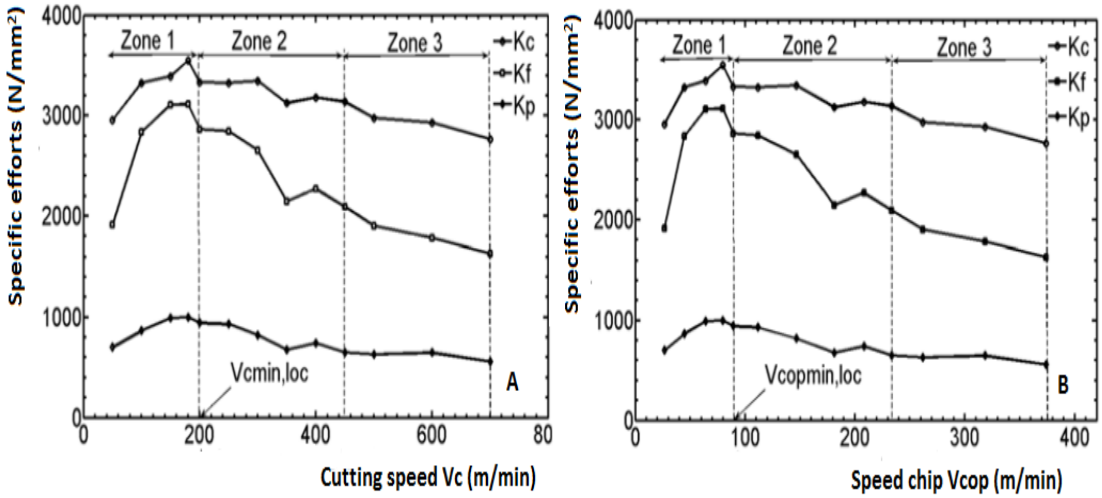

Fig. 3 evolution specific efforts, a) of the cutting speed, b) on the speed chip

Figs.4, 5, 6 illustrate the variations of effort based on “advance f,” for three cases of “cutting depth (ap = 0.8 to 1.1 and 1.4 mm) ,” and a “cutting speed (Vc = 250 m / min),”. Overall, these figures show a linear increase in the forces as a function of advance.

It is the “penetration forces Fp,” are the weakest and “cutting forces Fc,” the strongest. The slopes of change in “cutting force Fc,” and “penetration Fp,” are more significant than that of the “feed force Ff,” in fact, a variation of (0.1 to 0.3 mm / rev) for feeding respectively induces a variation of 116% on the “cutting force, 100%),” of the “penetration force and (25%),” of the “effort in advance in the case of a “depth of cut of (0.8 mm) ,”. The slope of the evolution of the “feed force Ff,” as a function of the feed speed is practically the same for the “pass depths of (0.8 and 1.1 mm),” with a slight difference to the “depth of from (1.4 mm),” This means that for low depths of cut“ the variation of the feed rate has no significant effect on the feed force. Observing Fig. 5, shows that for small advances (f ≤ 0.15 mm / rev), the change in advance has no influence on the penetration effort when the depth of cut varies. As against advances (f> 0.15 mm / rev), a difference is noticeable on the effort of penetration by varying the depth of cut.

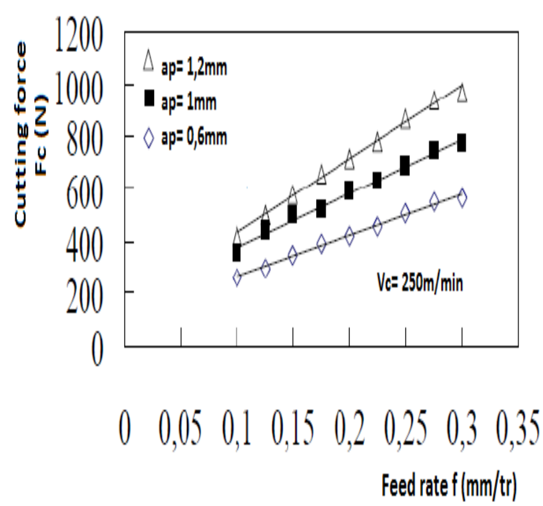

Fig. 4 evolution cutting forces

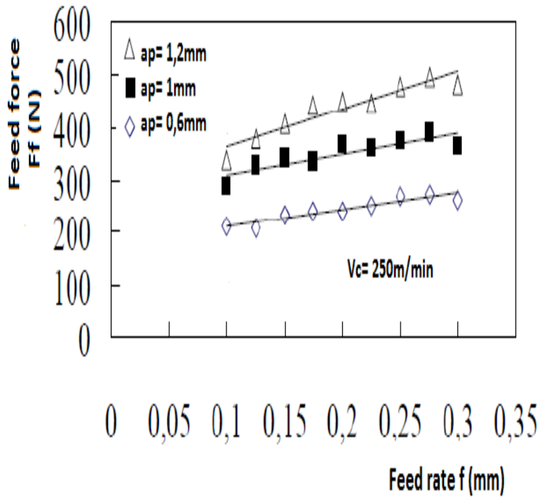

Fig. 5 evolution feed forces

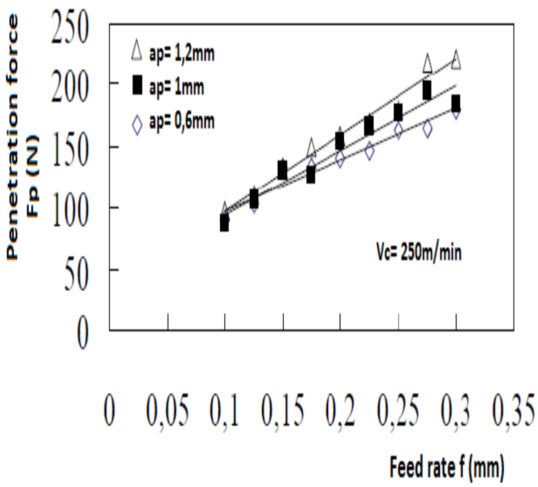

Fig. 6 evolution penetration forces

Fig. 7 shows the evolution of efforts (Fc, Ff, Fp) depending on the depth of cut. It shows that the increase in depth of cut induces an increase in the cutting force and the feed force. By against the increased depth of cut has no significant effect on the penetration force as also shown in Fig. 6.

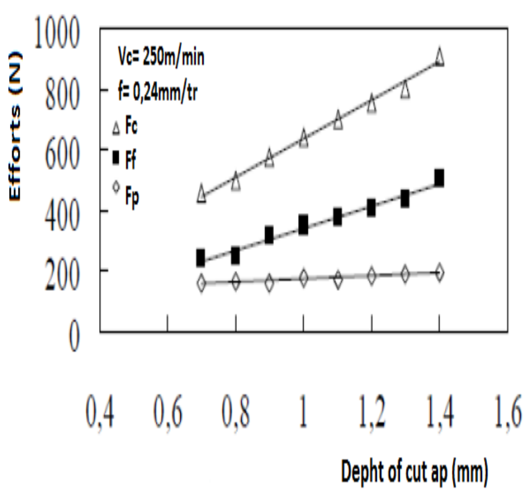

Fig. 7 Evolution of efforts depending on the depht of cut (ap)

V. CONCLUSIONS

The results showed that the cutting speed and feed rate are the two most influential parameters on efforts coupe. These cutting forces increase depending on the cutting speed for the range of cutting speeds of 50 to 200 m / min for a couple (f ap) given. Beyond 200 m / min, efforts decrease depending on the cutting speed: this is the effect of thermal softening of the material.

It has been noticed that a wear of the edge simultaneously induced jumps efforts cutting mainly the cutting force and the feed force.

ACKNOWLEDGMENT

The authors thank to staff of the technological hall Abou Bekr Belkaid Universityof of Tlemcen Algeria, for its support when performing experiments.

References

[1] Y. C. Shin, S. A. Coker, "*Surface roughness measure by ultrasonic sensing for in process monitoring*. Journal of Engineering for industry, vol.117, ph. 439, 1995.

[2] S. Han, "Mechanisms and modeling of white layer formation in orthogonal machining of steels. PhD thesis, George W. Woodruff *School of* Mechanical Engineering, Georgia Institute of Technology, 2006.

[3] M. Remadna, "Le comportement du système usinant en tournage dur. Application au cas d'un acier trempé usiné avec des plaquettes CBN Nitrure de Bore cubique)," PhD thesis, Institue Nationale des Sciences Appliquées de Lyon, 2001.

[4] A. Molinari, M. Nouari, "*Modeling of tool wear by diffusion in metal cutting*," 2002, pp 135-149.

[5] J. C. Chen, R. A. Smith, "*Experiment design and analysis in understanding machining mechanisms*," Journal of Industrial Technology, vol.13, No. 3, 1997, pp 15-19, 1997.

[6] A.J. Shih, "*Finite element analysis of the rake angle effects in orthogonal metal cutting*," International Journal Mechanical and Sciences. vol .38, No. 1, 1996, pp 1–17.

[7] M.C. Shaw, Metal Cutting Principles, Oxford University Press, London, (1984).

[8] M. Santochi, G. Dini, G. Tantussi, M. Beghini, Sensor integrated tool for cutting force monitoring, Cirp Ann. Manuf. Technol. 46 (1) 49–52, 1997.

[9] K.N. Strafford, J. Audy, Indirect monitoring of machinability in carbon steels by measurement of cutting forces, J. Mater. Process. Technol. 67 (1–3) 150–156, (1997).

[10] N. Otmanboluk, I. Ay, Z. Aksoy, Orthogonal-ring dynamometer design for measuring cutting forces in turning operations, in: Proceedings of the Material and Production Symposium, University of Dokuz Eyl¨ul, Denizli, (1987).

[11] W.L. Jin, P.K. Venuviod, X. Wang, Optical fibre sensor based cutting force measuring device, Int. J. Mach. Tools Manuf. 35 (6) 877–883, (1995).

[12] A.J. Shih, Finite element analysis of the rake angle effects in orthogonal metal cutting. Int. J. Mech. Sci. 38 (1) 1–17, (1995).

[13] L.J. Plebani, J.J. Fu, Entropy based method for characterizing dynamic cutting forces and tool wear in face milling processes, In Proceedings of the Industrial Engineering Research Conference, IEE,Norcross, GA, USA, 1993 , pp. 365–369.

[14] B. Yardimoglu, L. Boyar, "Experimental investigation of cutting forces in chip removal operations," Part 5, in: Proceedings of ,the National Machine Tool and Manufacturing Congress, Ankara, (1992)..

[15] X. Dai, G.H. Gautschi, Next generation of cutting force dynamometers. in: Proceedings of the International Symposium on Test and Measurement, International Academic Publishers, Beijing, China, 1997, pp. 615–616

[16] J.W. Youn, M.Y. Yang, H.Y. Park, "Detection of cutting tool fracture by dual signal measurements," Int. J. Mach. Tools Manuf. 34 (4) 507–525, 1994.

[17] A.A. Hamid, Y. Ali, "Experimental determination of dynamic forces during transient orthogonal cutting," J. Mater. Process. Technol. 55 (3–4) 162–170, 1995.