Effect of Cutting Parameters on Feed Cutting Force and Estimation of Feed Cutting Force in Dry Orthogonal Turning

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***Abstract*—Turning is a metal cutting process used for generation of cylindrical surfaces and shaft design. The process is associated with generation of extensive stresses and plastic deformations which influences cutting forces in the direction of feed. This feed cutting force is the background for the evaluation of the necessary power in machining. They are also used for dimensioning of machine tool components and the tool body, chip formation and machining system stability. With the inclusion of cutting parameters, studying feed cutting force in turning becomes expensive and cumbersome for local lathe users. Here an attempt is made to simplify the method of measuring and estimating feed cutting force and the effect selected cutting parameters has on the feed cutting force, in order to address a local problem in turning process.**

***Keywords*— Turning Process, Feed Cutting Forces, Cutting Parameters and Dynamometer**

I. INTRODUCTION

Turning operation is one of the most important, frequently practiced and unavoidable machining operations for the components used in shaft design and fabrication. It 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 radically, 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. Orthogonal turning is a turning process whereby the cutting tool edge is set at right-angle to the direction of movement.

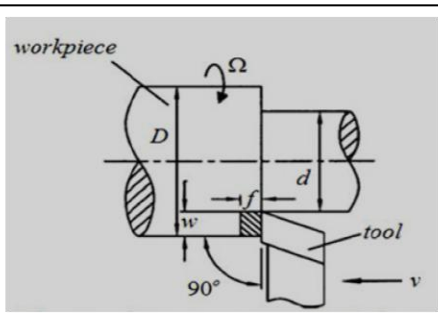

Fig. 1. Orthogonal turning with cutting parameters [1]

Fig. 1 is the diagram of an orthogonal turning process with cutting parameters. For an orthogonal turning operation, the force components can be measured in three directions. The force component acting on the tool in the direction parallel with the direction of feed, i.e., direction parallel to the axis of the workpiece is referred to as the feed force *Fx* [2]. This force acts perpendicularly to the main cutting force *Ft*, while the third component *Fr* is the radial force acting in the direction tending to push the tool away from the workpiece [2]. It is the smallest of the force components in orthogonal turning and for the purpose of simplicity of cutting force analysis in turning process, it is usually ignored.

A large amount of studies has been directed towards the prediction and measurement of cutting forces generated during turning process as done by Thomas & Beauchamp, (2003), Kurt, Sürücüler & Ali (2010), Axinte, Belluco & De Chiffre (2001) and Ezeanyagu (2015). That is because the cutting forces generated during turning operation have a direct effect on the stability of the system, tool wear, quality of machined surface and accuracy of the work piece. Theoretical cutting force calculations failed to produce accurate results due to the complexity of machining operations. Therefore experimental measurement of the cutting forces became unavoidable. Within the last hundred years, many force measuring devices, known as dynamometers have been developed, capable of measuring tool forces with increasing accuracy.

In these dynamometers, experimental cutting force measurement is mainly based on elastic deformation of the materials. The mathematical relationship connecting cutting force and cutting parameters like depth of cut and feed rate is given by Kienzle and Victor (1957) in their model as:

$$F_x = CA \quad (1)$$

where *C* is the specific cutting resistance, a material-tool dependent property. *A* is the undeformed chip area rewritten as:

$$A = w f_x \quad (2)$$

fx is the chip thickness or feed rate and *w* is the width of chip or depth of cut of the tool system

$$F_x = Cw f_x \quad (3)$$

II. EXPERIMENT AND DISCUSSION

To determine the effect of depth of cut and feed rate on feed cutting force, cutting tests were done on the Dean Smith & Grace Lathe System having maximum power of 4.0 *Kw*, using Brazed Carbide cutting tools and a spring type cutting force Dynamometer to measure cutting forces. Work piece used is of mild steel material of 35mm diameter and 280mm long. Before the actual test, the outer surface of the work piece were machined in order to minimize the roll forming effects such as the outer surface hardness. Experimentation is carried in a dry condition. Fig. 2 shows the experimental set up.

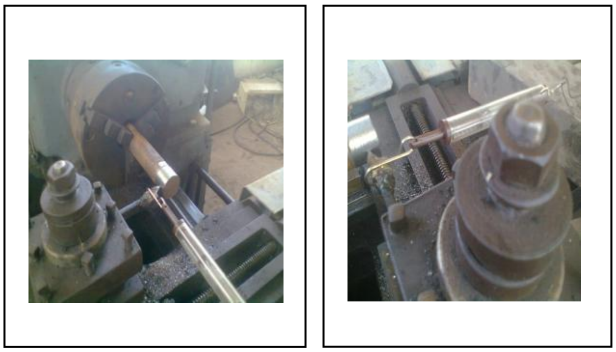

Fig. 2. Dry orthogonal turning of mild steel sample and cutting force measurement on tool using dynamometer [7]

A. *Effect of depth of cut on feed cutting force*

Cutting Parameters: Spindle speeds = 90 *rpm*, 450 *rpm*, 660 *rpm*, 950 *rpm*, 1000 *rpm*, 1150 *rpm*, 1200 *rpm*, 1230 *rpm*. Feed rate = 0.64 *mm/rev* .

Table I: Experimental and Estimated Feed Cutting Force Values at Different Depth of cut

Depth of cut (mm)	Experimental feed cutting force (Newton)	Estimated feed cutting force (Newton)	Error (%)
0.10	246.6	246.3	0.13
0.15	248.1	247.6	0.20
0.20	250.2	249.0	0.47
0.30	253.4	251.7	0.67
0.60	257.0	260.0	1.15
0.95	266.7	269.5	1.04
1.20	275.0	276.4	0.51
1.50	288.1	284.6	1.21

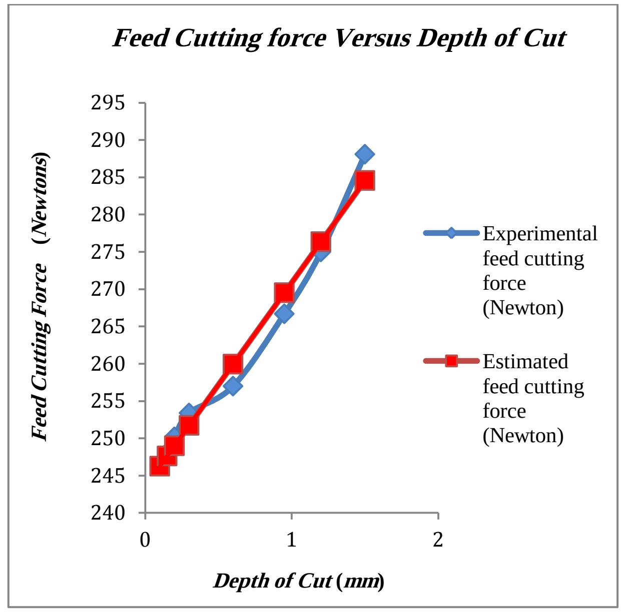

Fig. 3. Feed cutting force versus depth of cut

The results in Fig. 3 shows the generation of feed cutting forces according to the depth of cut. With the increase in the depth of cut, the tool indents more into the workpiece and the width of cut *w* becomes reasonably high. This effect increases the chip section in contact with the tool and in turn increases cutting forces in the feed direction to cut the chip. Therefore feed cutting forces increases as the depth of cut increases.

B. *Effect of feed rate on feed cutting force*

Cutting Parameters: Spindle speeds = 90 *rpm*, 450 *rpm*, 660 *rpm*, 950 *rpm*, 1000 *rpm*, 1150 *rpm*, 1200 *rpm*, 1230 *rpm*. Depth of cut = 1.5 *mm*.

Table II: Experimental and Estimated Feed Cutting Force Values at Different Feed rates

Feed rate (mm/ rev)	Experimental feed cutting force (Newton)	Estimated feed cutting force (Newton)	Error (%)
0.076	86.4	118.4	27.03
0.080	96.4	119.7	19.47
0.150	144.0	142.8	0.83
0.160	163.2	146.1	10.48
0.300	220.8	192.3	12.91
0.320	240.1	198.9	17.16
0.610	278.6	294.6	5.43
0.640	288.1	304.5	5.39

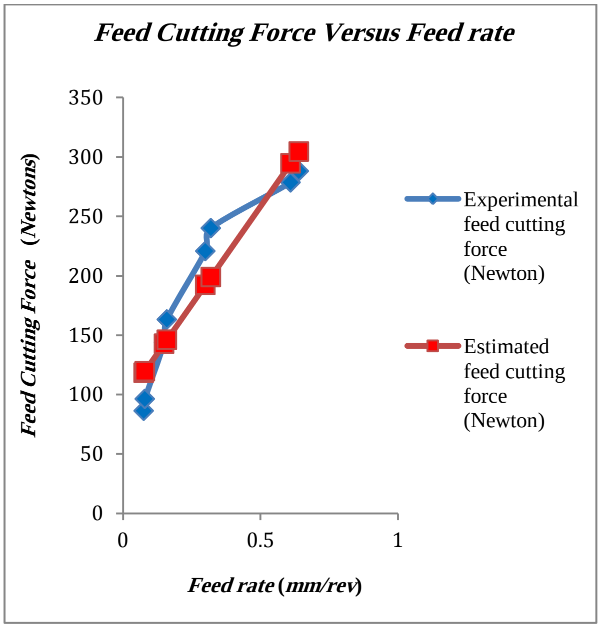

Fig. 4. Feed cutting force versus feed rate

The results in Fig. 4 shows the generation of feed cutting forces according to the feed rate. With the increase in feed rate the section of the sheared chip thickness increases because the workpiece resists rupture more and requires larger force for chip removal. Therefore feed cutting force increases as the feed rate increases.

III. ACKNOWLEDGMENT

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IV. CONCLUSION

From the results gotten above, it can be concluded that feed cutting force increases as the depth of cut and feed rate increases. The percentage error between the experimental and estimated feed force values is minimal and in the acceptable range, hence the developed method can be used by local lathe tool users for the estimation of feed cutting force and to know the effect of cutting parameters on feed cutting force in turning operation.

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