ISSN 2250-3153

Analysis of variation of Cutting Forces With Respect to Rake and Shear Angle

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Abstract **–** Metal machining process is one of the fundamental areas where manufacturing industry prospers.Themajor parameters that control the quality of the job within the tolerance limits are speed, feed and depth of cut and other process parameters that affect the machining. In this paper an effort has been made to study the effect of rake angle on cutting forces for a single point cutting tool. Different experiments are carried out to identify the variation in cutting force with the variation in rake angle.

Keywords: Rake Angle, cutting forces, dynamometer, merchants circle analysis, Profile projector

I. INTRODUCTION

The modern world demands high productivity to meet the ever growing demand, an increase in productivity requires involvement of all production operations, activation of all the available manufacturing facilities. In order to involve all the technological operations, optimum technological processes, optimum tool selection, suitable combination of tool-workpiece material and determination of optimum cutting variables and tool geometry must be considered. The tool geometry has an important factor on cutting forces and cutting forces are essential sources of information about productive machining. … [1]

The amplitude and frequency of cutting forces and torque are used in calculating the required power as well optimal planning of individual machining operations based on physical constraints. During cutting process, the cutting tool penetrates into the workpiece due to the relative motion between tool and workpiece. The cutting forces are measured by the dynamometers designed for different working principles on a measuring plane in the Cartesian coordinate system.

In this study, the influence of rake angle and shear angle on the cutting force is investigated. The experiments are carried out on a lathe and cutting force components are measured in the process using a dynamometer.

A. Rake Angle

Rake Angle (α), the angle between the tool face and the plane normal to the surface of the cut through the tool cutting edge .Rake angle is a parameter used in various cutting and machining processes, describing the angle of the cutting face relative to the work. There are two rake angles, namely the back rake angle and side rake angle, both of which help to guide chip flow. Depending on the direction of the slope on the tool they are defined as positive, negative, and zero rake angles. … [1]

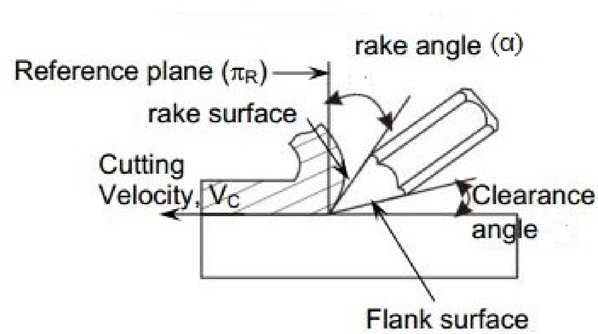


Figure (1): Rake angle of a single point cutting tool in action

Generally positive rake angle makes the tool more sharp and pointed. On the other hand it reduces the strength of the tool, as the small included angle in the tip may cause it to chip away. It also reduces cutting forces and power requirements. Positive rake angle helps in the formation of continuous chips in ductile materials and also help in eliminating the formation of a built-up edge. … [1]
Negative rake angle, by contrast make the tool blunter, increasing the strength of the cutting edge but also increases the cutting forces. Though it increases friction,

ISSN 2250-3153
resulting in higher temperatures yet it improves the surface finish. … [1]

A zero rake angle tool is the easiest to manufacture, but has tendency to a larger crater wear when compared to positive rake angle as the chip slides over the rake face. Recommended rake angles can vary depending on the material being cut, tool material, depth of cut, cutting speed, machine, and setup. Rake angles for drilling, milling, or sawing are often different. … [1]

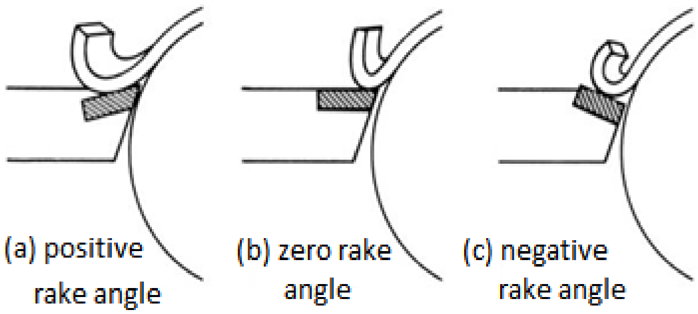


Figure (2): Types of Rake angle on single point tool

B. Cutting ForceComponents:

In orthogonal cutting, the total cutting force (Fc) is conveniently resolved into two components in the horizontal and vertical direction, which can be directly measured using a force measuring device called a dynamometer. Also a small radial force will generate in zdirection which are shown in figure (3). … [1]

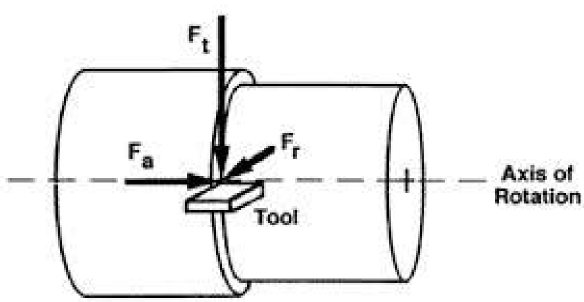


Figure (3): cutting components

II. WORK MATERIAL, CUTTING TOOL and METHOD:

AISI 1018 steel has been used as the work piece material to conduct all the experiments. These type of materials are extensively used in the industrial applications. Samples were prepared from cylindrical bar with diameter of 25mm, prior to the experiments the specimens were turned with 1 mm cutting depth in order to remove the outer layer, which could appear discontinuous or unexpected hardening distribution due to theirextrusion production process. The chemical composition and mechanical properties of the selected work piece material are listed in table (1)

Table (1): Main Composition of AISI 1018 steel

Carbon	0.17%
Silicon	0.27%
Manganese	0.80%
Phosphorus	0.050% max
Sulphur	0.050% max

Table (2): Properties of AISI 1018 steel

Finish	Bright Drawn
Yield Strength (MPa)	340-600
Tensile Strength (MPa)	430-750
Elongation %	12 min
Hardness (HB)	120-220

Single point HSS (High speed steel) cutting tools were used in all the experiments. New tools were used for all experiments to ensure that tool condition is same in all the cases. Different rake angles were ground on each tool with the help of a tool cutter and grinder machine and the rake anglesis measured using profile projector as shown in figure (5).

ISSN 2250-3153

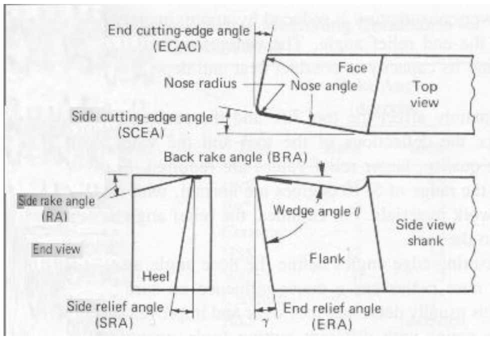


Figure (4): Tool Geometry of single point cutting tool

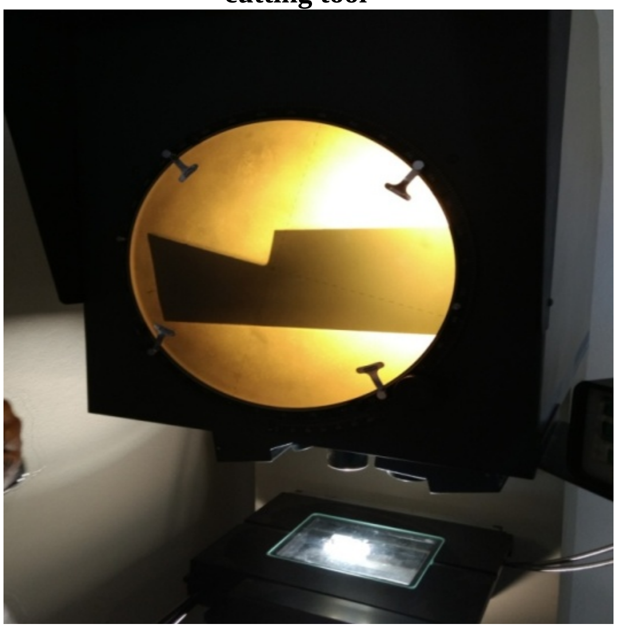


Figure (5): Measurement of rake angle using profile projector

The various tool rake angles are: 0^O, 5^O, 10^O, 17^O, 18^O, 20^O, $25^O$and a constant clearance angle was used. While turning a ductile material by a sharp tool, the continuous chip would flow over the tool's rake surface and in the direction apparently perpendicular to the principal cutting edge. Practically, the chip may not flow along the orthogonal plane but this assumption is made for an ideal case.

The experiment were carried out by the use of lathe, dynamometer , and a couple of tools each having different rake angle ground on the rake face .The shear angle wasestimated by keeping the depth of cut (t) , feed (f), and speed (N in RPM) constant and subsequently measuring chip thickness(t_c). In order to measure the forces generated while machining, a dynamometer was used and the cutting force components were measured.

Here the side rake angle, end cutting angle, side cutting angle, end clearance angle, side clearance angle *are*kept constant. The work piece for each experiment would have the same diameter (25mm) and a constant machining length. The experimental setup is shown in figure (6) and figure (7);

Figure (6): Experimental setup

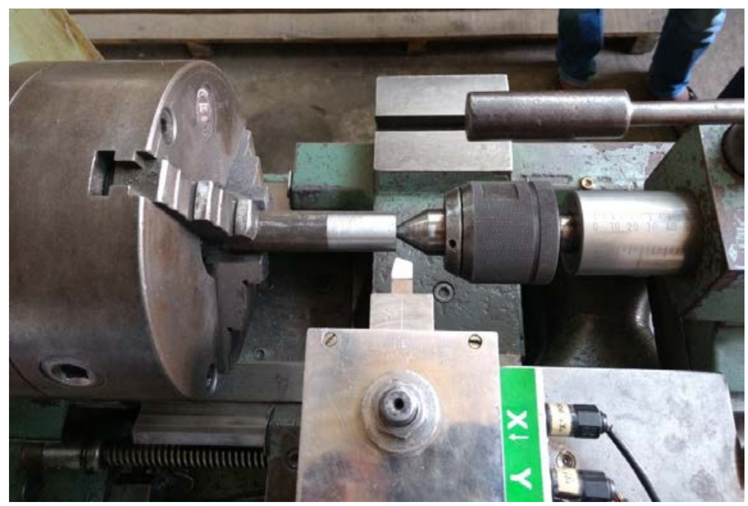


Figure (7): work piece and tool placed in setup along with dynamometre

III. RESULTS AND DISCUSSIONS

Below, the observations of the cutting forces, with respect to the rake angle and shear angle are tabulated in table no. (3)

Table no. (3): Comparison of experimental and theoretical data

Sno.	Rake angle (α)	Chip thickness (t_c)	Chip thickness ratio (r_t)	Shear angle (ϕ)	Experimental cutting Forces (N)			
					F_x	$F_y(F_c)$	F_z	$F_{theoritical}$
1	0°	0.74	0.6757	33.88	29.4	29.4	117.6	29.4
2	5°	0.76	0.65	34.46	49	58.8	68.6	58.19
3	10°	0.55	0.9	46.41	39.2	58.8	117.6	55.98
4	17°	0.87	0.57	38.18	9.8	19.6	137.2	18.43
5	18°	0.88	0.56	32.78	29.4	58.8	68.6	57.1
6	20°	0.75	0.66	38.7	19.6	39.2	29.4	42.03
7	25°	0.51	0.98	56.6	29.4	88.2	117.6	80.77

Here,

Shear angle is estimated using therelation,

$$\Phi = \mathrm{Tan}^{-1}\left(\frac{r\cos\alpha}{1 - r\sin\alpha}\right)$$

Where,

r is chip thickness ratio and α is rake angle

Variation of experimental cutting forces, Fy in particular with respect to rake angle is illustrated in the graph shown in figure (8);

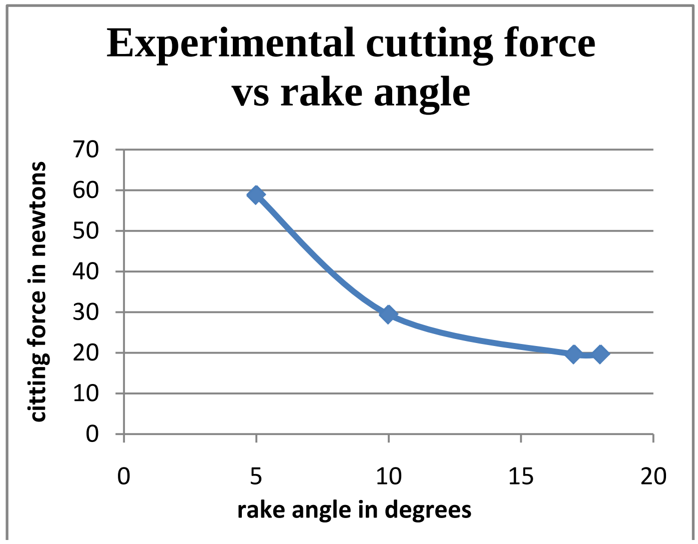


Figure (8): graph showing variation of cutting force (F_c) with respect to rake angle

The theoretical approach to calculate cutting forces is given by merchant'sforce analysis. Pictorially the merchant's circle is shown in figure 9…[5]

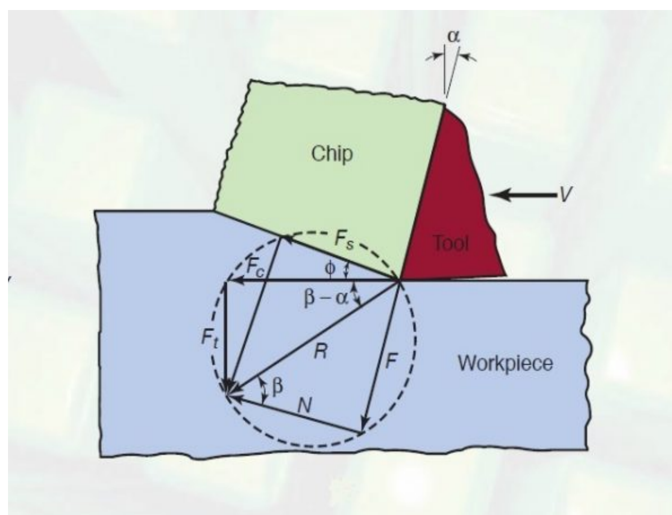


Figure (9): Merchant's circle for Force Cutting Analysis

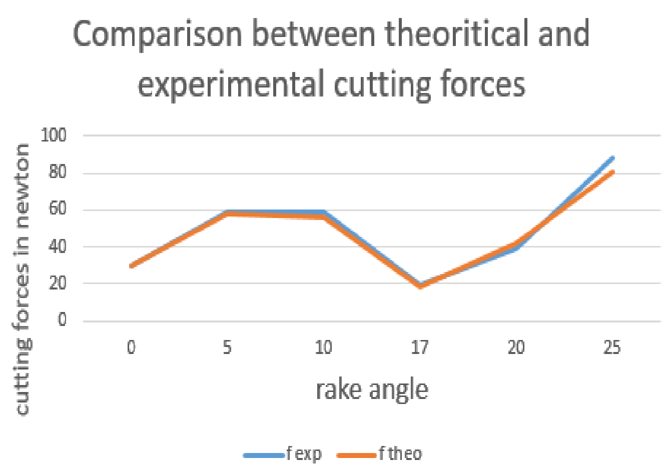
From the figure (8) it is evident that

$$\frac{F_c}{\cos(\beta - \alpha)} = \frac{F_t}{\sin(\beta - \alpha)}$$

Therefore,

$$F_c = F_t \cot(\beta - \alpha)$$

Using the above equation the theoretical cutting force is calculated and the corresponding values are tabulated in table no (3) above. A comparison between theoretical cutting force and experimental cutting force is shown in figure (9). Here the β value is assumed to be 45°.



IV. CONCLUSION

The cutting forces are also calculated using merchant's force analysis and the values were compared with experimental results. From the table and graph it is observed that the theoretical and experimental results are in good agreement with a standard deviation of 5-10%, which may be attributed to the inherent variability of parameters of machining, materials,vibrations, atmosphere, and operator's skill etc.

Further a decreasing pattern of cutting force initially up to an angle of18^{O} is observed, beyond which there is an increase in cutting force. This could be due to increase in vibrations of the tool as the tool nose becomes weaker due to increase in positive rake angle.

V. ACKNOWLEDMENTS

We are thankful to the management of MUFFAKHAM JHA COLLEGE OF ENGINEERING AND TECHNOLOGY, Hyderabad and the technical staff for supporting this research work and preparation of specimens and testing etc.

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