INTERPRETATION OF SIDE RAKE ANGLE WITH CUTTING FORCE AND SURFACE FINISH IN TURNING – AN EXPERIMENTAL APPROACH

***Prashanth T[1], C.R. Prakash Rao[2] , N.Nagaraja[3].**

[1,2,3]Dept. of Mechanical Engineering, Global Academy of Technology, Bangalore, India.

ABSTRACT

Cutting tools for metal cutting have many shapes, each of which are described by their angles or geometries. Every one of these tool shapes has a specific purpose in metal cutting. The primary machining goal is to achieve the most efficient separation of chips from the work piece. For this reason, the selection of the right cutting tool geometry is critical. This paper presents an experimental investigation on the cutting tools having varied side rake angles and its strength and suitability on metal cutting application. Different side rake angle tools were taken for testing on EN8 material. A HSS cutting tools with -2˚,-4˚,-6˚,-8˚,-10˚,-12˚,0˚,2˚,4˚,6˚,8˚,10˚,12˚ side rake angles keeping 0˚Back rake angle were used for turning the specimen under dry conditions. The Surface texture is measured using SJ201P, MITUTOYO Make surface roughness measuring instrument. The cutting force and feed force and thrust forces measured using turning tool dynamometer. Micro chipping and macro chipping if any were recorded using a tool makers Microscope. The results indicated that the 12˚ positive side rake angle tool shown least cutting force and 12˚ negative side rake angle tool shown highest cutting force.

Key words: Side rake angle, Cutting force, Surface finish, feed per revolution, Dry machining.

1. Introduction

A cutting tool intended for high production machining process should be amply strong and rigid, it should have optimum geometry for the given process in terms of strength , be keenly sharpened , with a high class of finish, producible in manufacture and convenient to use .(14) Several angles are important when introducing the cutting tool edge into a rotating work piece. These angles include (refer Fig 1):

- Back rake angle
- Side rake angle
- End cutting edge angle
- Side cutting edge angle
- Relief angles
- Lip angle
- Nose angle
- Tool nose radius

Machining at higher chip cross section is opted during turning in order to achieve high production. Components manufacturing includes both roughing and finishing operation. During roughing high depth of cut and high feed rates were preferred in order to reduce cycle time. A +ve rake angle tool consumes less forces, hence for a given capacity of the machine can be used for higher material removal rates.

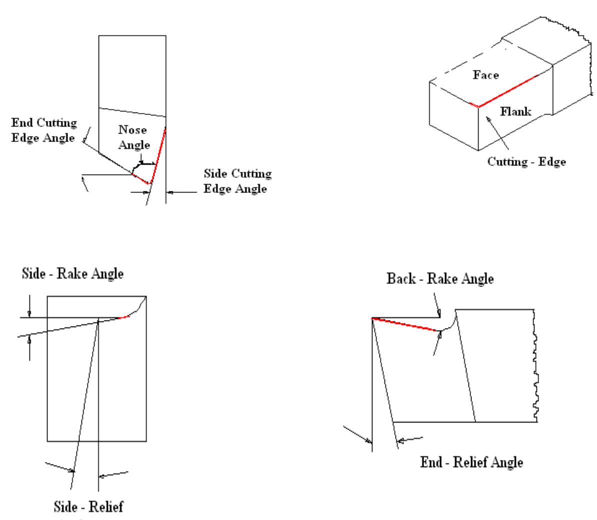

Fig 1: Cutting Tool Nomenclature

A cutting tool may become ineffective due to different modes of failures such as flank wear, crater wear, Micro chipping, Chipping at the main cutting

***Corresponding author: E-mail: prash_t@yahoo.com**

edge, chipping at the Nose, Nose wear, Comb cracks and Transverse type of thermal cracks.

2. Literature Survey

The geometry of cutting tools has a significant effect on machining performance. It is generally found that there is an optimal tool geometry for maximum cutting tool life. (2 to 6). The basic tool geometry is determined by the rake angle of the tool. The primary machining goal is to achieve the most efficient separation of chips from the work piece. For this reason, the selection of the right cutting tool geometry is critical (1 to 6). The neutral, positive, and negative rakes are considered for experiment. There are two rake angles: back rake and side rake. In most turning and boring operations, it is the side rake that is the most influential. This is because the side rake is in the direction of the cut. The other major effect of rake angle is its influence on cutting force (1). A negative rake tool increases cutting force and cutting temperature which results in accelerated wear (7to12). A cutting tool with a positive rake angle reduces cutting forces by allowing the chips to flow more freely across the rake surface. Finally, it was found that rake angle was effective on all the cutting force components (13 to 16). It is understood that less work is done on the effect of Side rake angle with cutting force and surface finish in turning.

3. Experimental Studies

3.1 Cutting Tool and Machining Parameters:

Cutting tools of various side rake angles were selected for the experimentation. The HSS cutting tools were ground in tool and cutter grinding machine. Forces exerted on the tool were measured using turning tool dynamometer. The data acquired from the dynamometer were digitized using anlog to digital converter. The Surface texture is measured using SJ-201P, MITUTOYO Make surface roughness Tester. Before taking the readings on tested sample the instrument is calibrated by means of adjusting the detector gain so that the instrument can yield correct measurements. This is done by measuring a supplied precision roughness specimen. The measuring range of 12.5 mm is used during calibration and measuring of tested specimens. The readings were tabulated are the average absolute value of the profile excursions from the mean line that is Ra. Over five consecutive readings were taken, and an average is computed.

The following are the cutting tool parameters considered during experimentation:-

1. Back rake angle : – 0^0
2. Nose radius kept sharp.
3. Cutting speed kept constant at 120 m/min during the test.
4. Depth of cut : – 2mm.
5. Feed per revolution used during experiment: – 0.1 mm.
6. Side rake angles -2˚,-4˚,-6˚,-8˚,-10˚,-12˚, 0˚, 2˚,4˚,6˚,8˚,10˚,12

3.2 Material Used for testing cutting tool :-

EN8 grade of steel was used conforming to the following specifications.

carbon	silicon	Manganese	Sulphur	Phorous	Hardness (BHN)
0.35-0.45%	0.05-0.35%	0.6-1%	0.06% max	0.06 % max	180 -200

Table 1: Chemical Composition Steps involved in conducting the test on EN8 work piece with the cutting parameters of the tool and the machining conditions as discussed,

1. EN8 material of diameter 100 mm and a length of 300 mm was selected for the machining operation between centers.
2. After skinning the material, cutting tools with different side rake angles were fastened on the tool post.
3. Each tool were tested for surface finish and cutting force, feed force and thrust forces at the parameters mentioned in table 2 and then observed for cutting tool edge condition.
4. The same procedure was repeated to verify the result.
5. The Edge condition of the cutting tool was monitered using a Tool makers microscope.

4. Results and Discussions

The following table (Table No. 2) shows the data pertaining to the surface finish and force measurement at various side rake angles.

From the fig. 1 it is observed that the cutting force decreases as the positive side rake angle increases. It was found no difference in Cutting force between 0˚ and 2˚, however as positive side rake angle increases 4˚ to 12˚ in step of 2˚ significant reduction in cutting force is observed. The readings were tabulated in table no. 2

are the average of five consecutive force measurement tests.

Table No. 2: Experimental Results

Sl.No.	Feed /Rev	Side rake angle	Surface finish , Ra in um	Cutting force in N	Feed force in N	Thrust force in N
1	0.1	0˚	5.79	2780	740	37
2	0.1	2˚	5.86	2780	730	34
3	0.1	4˚	5.39	2740	680	28
4	0.1	6˚	5.12	2700	630	25
5	0.1	8˚	4.86	2536	600	22
6	0.1	10˚	4.51	2394	560	18
7	0.1	12˚	3.97	2037	514	17
8	0.1	0˚	5.79	2780	740	37
9	0.1	-2˚	5.94	2810	740	33
10	0.1	-4˚	6.12	2840	765	34
11	0.1	-6˚	6.24	2970	810	35
12	0.1	-8˚	6.54	3120	890	30
13	0.1	-10˚	6.98	3240	940	30
14	0.1	-12˚	7.83	3486	960	30

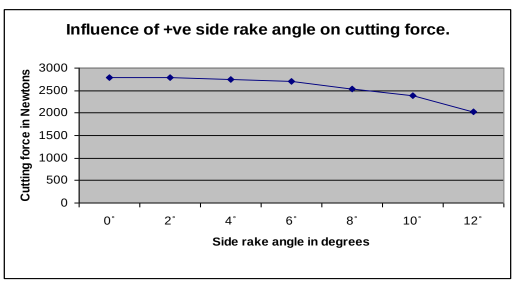

Fig.1 Influence of positive Side Rake Angle on cutting force

Similarly from the fig. 2 it is observed that the feed force decreases as the positive side rake angle increases. The difference in the feed force between 0˚ and 2˚ was marginal, however as positive side rake angle increased from 4˚ to 12˚ in step of 2˚ significant reduction in feed force is observed.

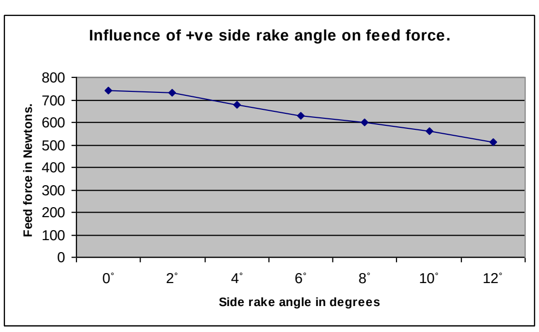

Fig.2 Influence of positive Side Rake Angle on feed force

From the fig. 3 it is observed that the surface texture is improved as the positive side rake angle increases. The difference in the Surface finish obtained between 0˚ and 2˚ was marginal, however as positive side rake angle increased from 4˚ to 12˚ improvement in surface texture observed.

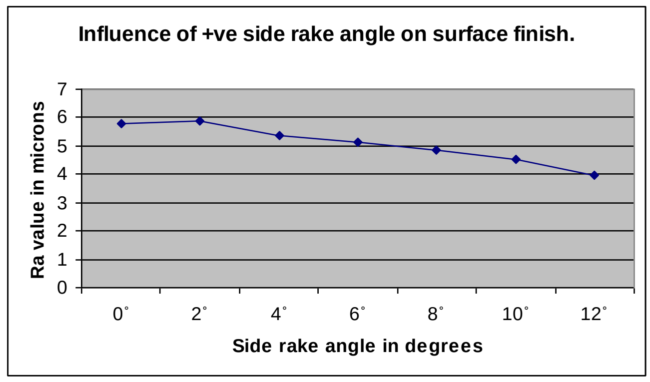

Fig.3 Influence of positive Side Rake Angle on surface finish

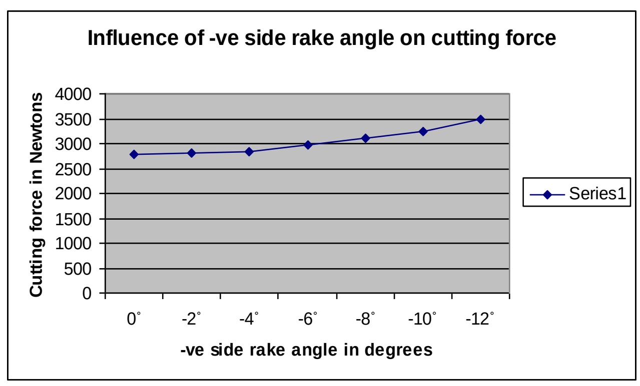

Fig. 4 Influence of negative Side

From the fig. 4 it is observed that the cutting force increases as the negative side rake angle increases. Experiment conducted from 0˚ to 12˚ in step of 2˚, as the rake angle increased towards negative increase in cutting force is observed .

Rake Angle on cutting force

From the fig. 5 it is observed that the deteriation of surface texture observed as the negative side rake angle increases. The difference in the Surface finish obtained between 0˚ to 12˚ is tabulated. The deteriation in the Surface finish observed between 0˚ and -6˚ was less when compared to -8˚ and -12˚ rake angle cutting tool.

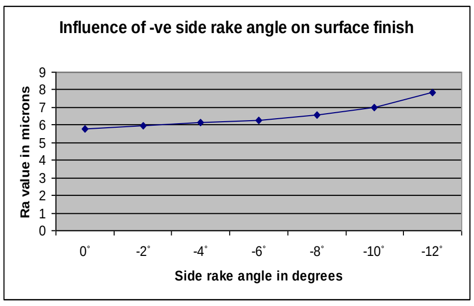

Fig. 5 Influence of negative Side Rake Angle on surface finish

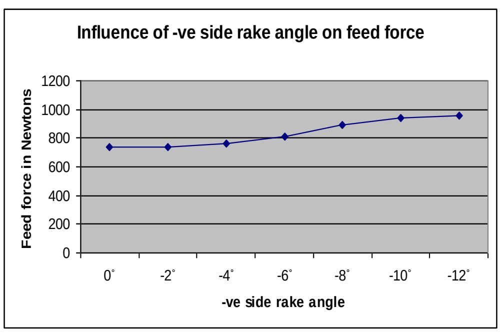

Fig. 6 Influence of negative Side Rake Angle on feed force

From the fig. 6 it is observed that the feed force increases as the negative side rake angle increases. It was found no difference in Cutting force between 0˚ and 2˚, however as negative side rake angle increased from 4˚ to 12˚ in step of 2˚, significant increase in feed force is observed.

6. Conclusions

Based on the work carried out at different side rake angles the following conclusions are drawn:

1. Cutting force >Feed force >Thrust force at all combinations.
2. As side rake angle increases towards positive the Cutting force decreases.
3. As side rake angle increases towards positive the Feed force decreases.
4. As side rake angle increases towards negative the Cutting force increases.
5. As side rake angle increases towards negative the Feed force increases.
6. Side rake angle is having impact on surface.
7. It is observed that +12˚ rake angle cutting tool shown least forces and -12˚ rake angle cutting tool shown maximum forces.
8. Surface finish achieved by using +12˚ rake angle cutting tool is of higher order when compared to other tools.
9. Hence, we can conclude that cutting tool with +12˚ rake angle is ideal for machining centers and CNC Machines where available H P is limited.
10. It is also observed that +12˚ side rake angle tool produced very good surface finish.

6. References

1. *J.H.Lee, S.J.Lee , One –step-ahead prediction of flank wear using cutting force., International journal of Machine Tools & Manfacture 39 (1999) 1747-1760.*

2. *S.Kaldor,A.D.A.,M.O.D.,Rafael/Israel – Submitted by S.Malkin(1), Technion/Isreal , A common Denominator for Optimal Cutting tool Geometry. Annals of the CIRP Vol.35/1/1986, pages 41-44.*

3. *Tom Floyd, Diagnose Insert Failure and cure premature tool wear. Manufacturing engineering, October 1992, pages 37-38.*

4. *Dr.N.Nagaraja, Prashanth T, C.R.Prakash Rao , Effect of Nose angle on strength of cutting tool- An experimental approach. NATCOM 2006, SIT, TUMKUR.*

5. *I.S.Jawahir, P.X.Li, R.Gosh, E.L.Exner , A New parametric Approach for the Comprehensive Tool wear in Coated Grooved Tools. Annals of the CIRP Vol.44/1/1995,pages 49-54.*

6. *V.C.Venkatesh, M. Satchithanandam, a Discussion on Tool life Criteria and Total Failure causes. CIRP Vol 29/1/1980, pages19-22.*

7. *Dr. Edmund isakov, Kennametal Inc. Edited by Stephen Mraz. The mathematics of machining, American machinist, august 1996, pages 37,38*

8. *S.V.Subramanian, S.S.Ingle and D.A.R.Kay. Design of coating to minimize Crater wear, Coating Technology, 61/ (1993), pages 293-299.*

9. *M.V.Kowstubhan and P.K.Philip. On the tool life equation of TiN-coated high speed steel tools. Wear, september 11 1990,143 (1991) pages 267-275.*

10. *W.Konig, R.FRITSH, D.Kammermeier, New Approaches to Characterizing the performance of coated cutting Tools. In CIRP Vol 41/1/1992. Page no. 49-54.*

11. John F. Kahles, Machinability Data Requirements for Advanced Machining Systems. CIRP Vol 36/2/1987, PP523-529.

12. W.Grzesik , Experimental investigation of the cutting temperature when turning with coated indexable inserts. International journal of Machine Tools & Manufacture 39 (1999) 355-369.

13. Cutting tool geometries, “Society of Manufacturing Engineers”,www. smeindia.org, pages 1-5.

14. M.A.Davies, Y.Chou,C.J.Evans , On Chip Morphology, Tool wear and Cutting Mechanics in finish Hard Turning, CIRP Vol 45/1/1996 PP77-82.

15. Milton C Shaw, Metal Cutting principles, Oxford University Press.

16. Geoffrey Boothroyd, Winston A. Knight, Fundamentals of machining and machine tools, Third edition, Taylor and Francis group (CRC).