Mathematical Calculation of Effects on Tool Setting on Tool Cutting Angle

Dipak Ranjan Jana, and Tarni Mandal

Abstract— **Accuracy of machined component is one of the most critical considerations for any manufacturer. Many key factors like cutting tool and its setting angle, machining conditions, resolution of the machine tool and the type of work place etc., play an important role. However, once these are decided upon, the consistent performance of the machine tool depends upon its ability to accurately position the tool tip vis-à-vis the required work piece dimension. Hence in this study the effect on Tool setting on cutting angle has been mathematically demonstrated.**

Solution has also been given for questions such as "Why we align the centre" and "For what height, deviation of tool when set, then what change in tool angle should be done so as to get the result in such a way that there will be no effect on tool and work piece and we can get the greater accuracy of job in turning operation."

***Index Terms*— Tool Geometry, Chip-forming, Chip-breaking, Accuracy**

I. Introduction

As we know that cutting tool angle plays a vital role in surface finish and also to get most desirable finish. We should match the centre of work piece with respect to the tool to make concentric. As far as matching of centre is concerned, we should have correct data/datum that can provide informations that for what variation, the center alignment shall be done. Hence how much tool angle should change as per defined in idle condition has also to be considered. Tool wear in hard turning not only modifies the cutting edge geometry but also increases cutting force and cutting temperature significantly, which, in turn, influence the residual stress profile on the machine surface. Therefore, wears in cutting edge is crucial during hard turning. Temperature is one of the major factor which influences flank wear.

II. Literature Review

The wear mechanism of tin coated carbide and uncoated cerment tools were investigated for various combination of cutting speed, feed rate, and depth of cut for end milling of hardened AISI H13 tool steel. At low speed, feed rate and depth of cut, SEM (scanning electron microscope) investigation has shown that both inserts experience uniform and gradual ware on the flank face, and diffusion and oxidation have also been observed [1]. Performance of P10 Tin coated carbide tool during the end milling of AISI H13 tool steel at high cutting speed, feed rate, and depth of cut on the tool life were studied experimentally. Hence the result shows that the tool life is highly affected by the feed rate and depth of cut [2]. Effect of cutting speed on tool performance in milling of B4Cp reinforced aluminum metal matrix composites was investigated with the help of five different cutting speed at constant feed rate of 0.26 mm/Z were used in order to determine the effect of cutting speed on tool wear and tool wear mechanism[3]. Comparison between constant force and constant rate of feed in materialographic cut-off machines, surface quality in relation to cutting speed, force and rate of feed has been studied, where this study shows that while cutting work piece of varying shape, the most uniform surface is obtained by using a constant rate of feed and this combined with high cutting speed will produce surface with the least and most uniformed information [4]. The influence of feed rates and cutting speeds on the cutting forces, surface roughness and tool chip constant length during face milling were studied where in the study, three components of the cutting forces developed during face milling AISI 1020 and AISI 1040 steel work piece were measured[5]. The effect of cutting speed and cutting tool geometry on machinability properties of nickel base inconel 718 as per alloy has been investigated. Hence it is machined under dry cutting condition by using digitally controlled computer lathe with ceramic cutting tool in two different geometries and three different material qualities [6] Some effect of cutting edge preparation and geometric modifications when turning INCONEL 718 ^{TM} at high cutting speeds where this paper evaluates the performance of some inserts subjected to modifications on the edge geometric form and preparation, when turning, at high cutting speed, on a nickel base alloy, INCONEL 718 ^{TM}, hardened by solution and precipitation(44HRc)[7]. Influence of the critical cutting speed on the surface finish of turned steel base have been studied where variables such as feed rate and the tools of nose radius and cutting speed can provide a control on the quality and the surface finish in a given machining process [8]. Effect of federate, work piece hardness and cutting edge on sub surface residual stress in the hard turning of bearing steel using chamfer hone cutting edge geometry has been projected through numerical analysis that hone edge puts chamfer cutting edge and aggressive feed rate help to increase both Compressive residual stress and penetration depth[9]. Effect of cutting speed on the performance of Al2O3 based ceramic was the worst performing tool with respect to tool wear and the best with respect to surface finish. Tin coated Al2O3 + TiCN mixed ceramic tool is the most suitable one for turning modular cast iron, especially at high cutting speeds [10]. An experimental study of the effect of cutting speed on chip breaking study concluded that due to

Dipak Ranjan Jana is with National Institute of Technology, Jamshedpur, India. (E-mail: drjana_nitjsr@yahoo.co.in)
Tarni Mandal is with National Institute of Technology, Jamshedpur, India. (E-mail: tmandal-nitjsr@rediffmail.com)

the effect of cutting speed on minimum feed for chip-breaking, when machining a continuous chip-forming material, chip-breaker with a wide application range should be selected[11].

In our literature review, it was observed that no work has been carried out related to the alignment of the center of the work piece with respect to tool and for what variation in centre alignment, how much tool angle should be changed as per defined in idle condition (Concentric). Hence a mathematical demonstration has been shown for the same to obtain most the desirable finish.

III. Machine Specifications

Machine Specifications

MAZAK QUICK TURN 15 N, 3 AC – 415V, 50/60HZ

Size (Height):- 1810 mm.
Floor Space Required (Width * Length):- [2360 * 2570] mm.
Machine Weight (In Kg.): 4400 Kg.
Shape of Bed: Horizontal
Bed Width: 340 mm.
Positioning Accuracy: 0.008 mm[X – axis]
0.013 mm[Z – axis]
Repetitive Positioning Accuracy: ± 0.002 mm. [X – axis]
± 0.003 mm. [Z – axis]
Cutting Speed (CS) is measure in surface meter/minute
= (Diameter in mm * π) * RPM / 1000
Cutting speed is required for Lathe operations without using a cutting fluid.
Cutting speed and feed is influenced by
- Cutting tool material
- Work piece material
- Geometry of the cutting tool
- Use of chip breaker
- Desired tool life
- Cutting fluid used
- Type of the cut(Rough/Finish)
- Rigidity of m/c & tool with respect to work.

TABLE 1: TOOL ANGLE FOR HIGH-SPEED STEEL TOOL AND VARIOUS MATERIALS

Turning and Boring

Material to be machining		Roughing	Finishing	Screw-Thread Cutting
Low-carbon steel 0.05 to 0.30% C	m/min	27	30	10-12
High-carbon steel 0.06 to 1.7% C	m/min	15	21	6-8
Brass	m/min	45	91	15-18
Aluminum	m/min	60	105	15-21

Material	Side Clearance Angle, degrees	Side Clearance Angle, degrees	Back Rack Angle, degrees	Front Clearness Angle, degrees
Steel 1020	12	14	16	8
Medium Steel 1035	10	14	16	8
Medium C. Steel 1090	10	12	8	8
Screw Steel X I 112	12	22	16	8
Cost Iron	10	12	5	8
Aluminum	12	15	35	8
Brass	10	0	0	8
Monal Metal	15	14	8	12
Plastic	12	0	0	8
Fiber	15	0	0	12

Carbide tool requires slightly greater cutting angle those shown in Table 1 because of the brittleness of the material. Side-Cutting-Edge angle of 5 to 20 degrees are recommended for those cutters. As we know that cutting tool angle plays a vital role in surface finish and also to get most desirable finish, we should match the centre of workpiece and tool i.e. to make them concentric. As far as matching of centre is concerned, we should have data that for what variation in centre alignment, how much tool angle should be changed as per defined in idle condition (concentric). A mathematical demonstration has been shown here for the alignment of the centre of the job with respect to the tool and also for keeping the centre at certain height what change in angles should be done, so that we will get approximately same results, nonetheless cutting forces are different.

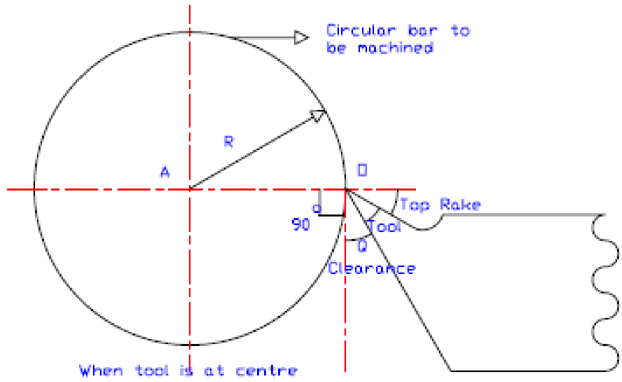

Figure 1: Machining while tool is at the center

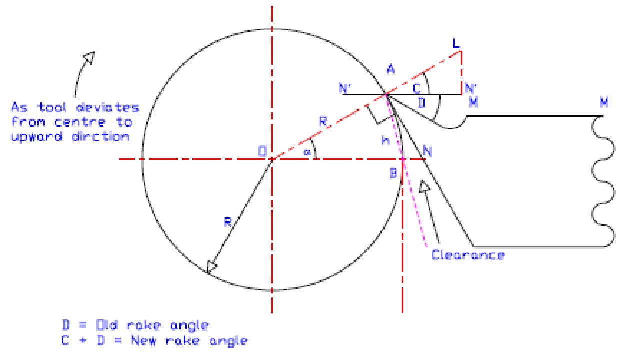

Figure 2: Machining while tool is at an angle α to the center

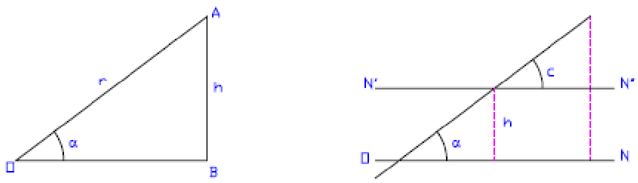

Figure 3: Tool Geometry

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Let h = height of deviation from centre

α = angle of deviation

Then from Δ OAB, we get,

Sin α = h / r

∴ α = $\sin^{-1}$ (h / r)

It is obvious that change in clearance

= previous clearance – α [given, α = $\sin^{-1}$ (h / r)]

& new rake= previous rake + $\sin^{-1}$ (h / r)

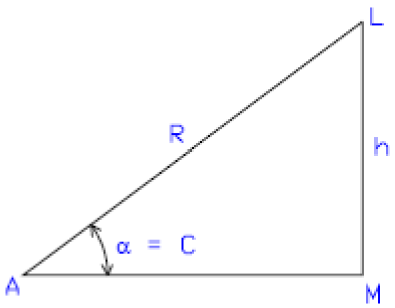

Figure 4: Tool Geometry

Sin α = h / R

Here we see that while the clearance angle is decreasing by α, rake is increasing by the same amount. The tool is being set at certain height (h) from the centre of the Work Piece. So after composing work-piece & tool with respect to new top rake angle, it will be equal to previous top rake plus the amount of angle formed at the centre of work-piece, when the tool is being deviated towards top direction. But clearance angle will be decreasing by the same amount as top rake increases, because clearance angle is always measured at the tangent, where tool tip point rests at the work-piece.

Let 'h' be the height of deviation of the tool from centre of work-piece. α is the angle formed at the centre of work-piece. As per construction α = C and correspondence angle, the amount reduce in clearance angle will be equal to 'C', where 'D' is the old top rake angle. So, new top rake angle will be equal to (C + D). Now previous clearance is 'C'. So, new clearance will be previous clearance (Q) – Increase in top rake angle i.e. (Q – C). Hence, finally it is obvious that if clearance angle decreases, then tool face will be in contact with workpiece, then rubbing will start and surface finish will be deteriorated. For h amount (height from centre) and angle α, tool clearance angle should be

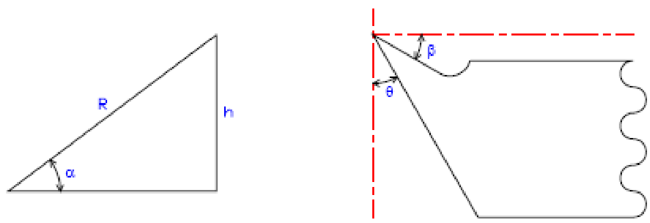

Figure 5: Tool Geometry and Machining

New Clearance or Required Clearance,

θ1 = θ + α = θ + Sin-1 (h / R) and

β1 = β – Sin-1 (h / R)

IV. Conclusion

Hence we can conclude that for what height, deviation of tool when set, then what change in angle of tool should be set to get the correct result, where effect on tool and work-piece will not occur. Hence, we can get the greater accuracy of job/ work.

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