International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056
Volume: 03 Issue: 02 | Feb-2016 www.irjet.net p-ISSN: 2395-0072

In metal turning, effect of tool rake angles and lubricants on cutting tool life and surface finish: A Review

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Abstract - *Turning is a widely used metal removal process in manufacturing industry that Involves generation of high cutting forces and temperature. With variation in rake angles and Lubrication techniques, becomes critical to minimize the effects of these forces and temperature, on life of cutting tool and Surface finish of the work. In metal industry, the use of coolant has become more problematic in terms of both workpiece quality, employee health and environmental pollution. On this account it has become necessary to investigate the effects of cutting Parameters and lubricants on tool life and surface finish. This paper describes a review of basic terms and visualizations of the major components of the cutting tool geometry and lubrication techniques in turning process. The parameters like rake angle, depth of cut, feed rate, temperature, cutting speed and role of coolant implementation techniques are taken in to account so as to predict their effects on tool life and surface roughness of the work.*

Key Words: Rake angle, depth of cut, cutting speed, tool wear, dry, wet and minimum quantity lubricant (MQL)

1. INTRODUCTION

Useful production time and energy are being wasted during regrinding or re-sharpening of cutting/turning tools during machining operations. The quest for profit maximization in manufacturing process makes it necessary for engineers and scientist to explore the optimum processes which requires less time and minimum energy for maximum output. [1] Turning is a machining process to produce parts cylindrical in shape by a single point cutting tool on lathes. The primary motion of cutting in turning is the rotation of the work piece, and the secondary motion of cutting is the feed motion. [2] Cutting tools in metal machining have many kind of shapes which are described by their angles or geometries. Selecting the correct angles of cutting tools in rotating workpiece is very important. These angles include the angle of inclination, rake angle, effective rake angle, lead or entry angle and tool nose radius. Rake angle and clearance angle are the most significant for all the cutting tools. [3]

It should be properly selected for performance evaluation criteria such as:

- ❖ Surface finish
- ❖ Lower Temperature at Cutting zone
- ❖ Less Tool wear and Long Tool life etc. [15]

The tool geometry effects on turning performance parameters are mentioned in Figure1.

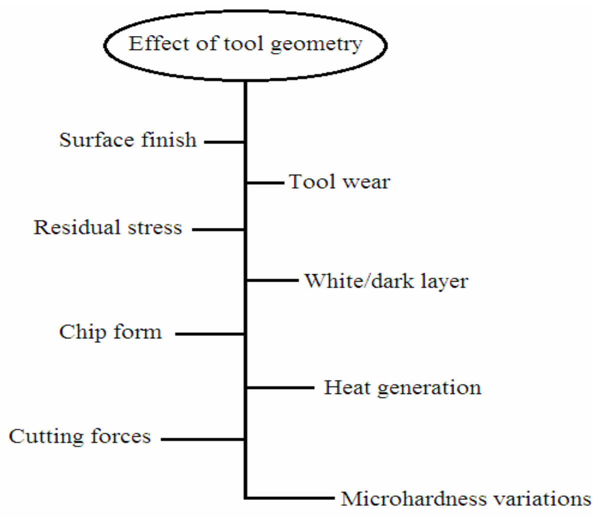

Fig -1: Effect of tool geometry on performance parameters in turning [4]

For effective production, many researches were carried out in the past and many are continuing for the purpose of decreasing production cost and manufacturing parameters without reducing product quality. The various cutting parameters mainly described are:

- ❖ Rake angle
- ❖ Tool life
- ❖ Machinability
- ❖ Depth of cut
- ❖ Cutting speed
- ❖ Tool wear
- ❖ Surface finish
- ❖ Lubricants

1.1 Rake angle

Tool rake angle is one of the important geometrical parameters, directly affecting zone deformation, chip break formation, cutting force, tool wear and machined surface quality. Thus in order to avoid this problem, correct rake angle can reduce tool wear and can get a good surface finishing. [3]Cutting tool angle plays a vital role in surface finish and also to get most desirable finish. [5]

There are following three types of rake angles are:-
Positive
Negative
Zero [6]

- Generally, positive rake angles:

Make the tool more sharp and pointed. This reduces the strength of the tool, as the small included angle in the tip may cause it to chip away.
Reduce cutting forces and power requirements.
Helps in the formation of continuous chips in ductile materials.
Can help avoid the formation of a built-up edge.

- Negative rake angles, by contrast:

Make the tool more blunt, increasing the strength of the cutting edge.
Increase the cutting forces.
Can increase friction, resulting in higher temperatures.
Can improve surface finish.

- A zero rake angle is the easiest to manufacture, but has a larger crater wear when compared to positive rake angle as the chip slides over the rake face. [7]

1.2 Tool life

During machining operation, the cutting edge of the tool gradually wears out and at certain it stops cutting metal. After a certain degree of wear, tool has to be re-sharpened to make use of it. [12] This is the period of cutting with the tool measured between regrinding. It is simply the time between regrinding or re-sharpening of tools. [8] The period which tool cuts satisfactorily are called life. Thus it results in poor surface finish or dimensional in accuracy. Tool life is the period between two consecutive tool replacements. [13]

1.3 Cutting Tool

Cutting tools must be made of a material harder than the material which is to be cut, and the tool must be able to withstand the heat generated in the metal cutting process. Also, the tool must have a specific geometry, with clearance angles designed so that the cutting edge can contact the workpiece without the rest of the tool dragging on the workpiece surface.[16]

1.4 Depth of cut

Cutting speed and feed rate come together with depth of cut to determine the material removal rate, which is the volume of work piece material that can be removed per unit time. [6] The depth of cut has a proven effect on tool life and cutting forces; it has no significant effect on surface roughness except when a small tool is used. Therefore, a larger depth of cut can be used to save machining time when machining small quantities of workpieces. On the other hand, combining a low depth of cut with a higher cutting speed prevents the formation of a built-up edge, thereby aiding the process by yielding a better surface finish. [19]

1.5 Cutting speed

Cutting speed is the relative speed between the cutting tool and the surface of the work piece. [6] Cutting speed has no major impact on surface roughness. It affects the surface roughness when operating at lower feed rates, which leads to the formation of a built-up edge. Higher speeds are important in yielding accurate results. [18]

1.6 Cutting forces

Cutting tools are insistently subject to pressure and opposing stresses during cutting even though their cutting 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. [10]

1.7 Tool wear

The various regions of tool wear are identified as flank wear, crater wear, nose wear, chipping of the cutting edge, plastic deformation, and catastrophic failure (Kalpakjian and Schmid, 2001). Temperature is one of the factors that influence in tool wear. [3] Metal cutting friction influences the cutting power, machining quality, tool life, and machining cost. When tool wear reaches a certain value, increasing cutting force, vibration and cutting temperature, it causes deteriorated surface integrity and dimension error greater than tolerance.[17] (Yulian et al., 2012) in their work highlighted that when the temperature increase, the wear is also increase gradually.[3] Generated heat goes from the cutting zone into the chips, tool, workpiece and into the environment, during which, the decrease of the hardness of tool's cutting elements, cutting wedge deformations, the loss of the tool cutting ability and its bluntness occur.[15]

1.8 Surface finish

In today's manufacturing industry, special attention is given to dimensional accuracy and surface finish. The surface quality is an important performance criterion to asses' machinability of any material. [15] In order to achieve a high surface quality, the machine parameters and the tool geometry must set at proper specifications. [3] As the negative rake angle is increased, the surface roughness value increase and it will make the surface finish rougher. The effect of rake angle is more effective rather than cutting speed on determine the surface finish (Gunay, 2007). He showed that by using ANOVA analysis, the negative rake angle gives poor surface finish compare to positive rake angle in machining of AISI 1040 steel. The study was carried out to study the effect of tool wear and surface finish by applying different rake angle and to define which angles are the most suitable in reducing tool wear and improving surface finish during machining process.

1.9 Coolants

The major needs in machining are high material removal rate, good work surface finish and low tool wear. These objectives can be achieved by reducing tool wear using proper cooling system of the tool during machining [14].In many cutting operations, fluids are used to cool and lubricate both the cutting tool and the work piece. Such fluids are called coolants. Lubrication reduces friction thus, decreases the heat generated and the power required for a given cut.[1] Lubrication becomes critical to minimize the effects of these forces and temperature on life of cutting tool and, Surface finish of work.[8] High temperature in cutting zone has been traditionally tried to control by using cutting fluids. The coolant effect reduces temperature in cutting zone and the lubrication action decreases cutting forces. [14] In metal industry, the use of coolant has become more problematic in terms of both workpiece quality, employee health and environmental pollution. In this work, chip tool interface temperature was measured for three different lubricant conditions such as dry, wet, and Minimum quantity lubrication.[8] Variations in cutting force, cutting temperature, chip thickness and surface roughness are studied under different machining and coolant conditions. The results indicate that there is a considerable improvement in machining performance under MQL machining compared to dry and wet machining. [9]

2. AIMS OF WORK

The aims and objectives of the present study are as follows:-

- To study the effect of different rake angles on metal turning process.
- To study the effect of lubricants on cutting forces, temperatures and surface roughness.
- To evaluate appropriate rake angle for turning process to maximize the tool life.

3. LITERATURE REVIEW

Mustafa Gunay, Ihsan Korkut, Ersan Aslan, Ulvi Seker 2004 [10] , study the effect of tool rake angle on main cutting force for machining rotational parts by sharp cutting tools. A special dynamometer was designed and produced to measure the forces for this purpose. Main cutting force (Fc) was measured for eight different rake angles ranging from negative to positive and five cutting speeds while depth of cut and feed rate remaining constant. And he observed that main cutting force was reduced by increasing rake angle in positive and was increased by increasing rake angle in negative values.

K.V. Santha Kumari, Dipak Ranjan jana and Anjani Kumar, 2010 [5], works on Effect of tool setting on tool cutting angle on turning operation. In this study the effect on Tool setting on cutting angle has been mathematically demonstrated. Lastly solution has been given that “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.

M. Dogra, V.S. Sharma, J. Dureja, 2011 [4], study the review on effect of tool geometry variation on finish turning. This article presents a survey on variation in tool geometry i.e. tool nose radius, rake angle, groove on the rake face, variable edge geometry, wiper geometry and curvilinear edge tools and their effect on tool wear, surface roughness and surface integrity of the machined surface.

Engr. Kaisan Muhammad Usman, 2012 [1], study the effects of tool rake angle on tool life in turning tool. In their work tool life was studied under different rake angles of 0, 5, 10, 15, and 20-degree at a constant clearance (Relief angle) of 8-degree were used to turn bright mild steel on the lathe machine, with a high speed steel of 18mm side as cutting tool and soluble oil was used as coolant. And observed that, the rake angle of 20-degree gave the longest tool life as well as the best surface finish and yielded continuous chips formation.

K. Dharma Reddy, Dr. P. Venkataramaiah, 2012 [8] done Experimental investigation on responses in turning of aluminium with carbide tipped tool at different coolant conditions. In his experiment chip tool interface temperature was measured for three different lubricant conditions such as dry, wet, and minimum quantity lubrication. Later has been proved to be a feasible alternative to the conventional cutting fluid system. In the present work 10% boric acid by weight mixed with base oil SAE 40 is used as a MQL in turning process. Variations in cutting force, cutting temperature, chip thickness and surface roughness are studied under different machining and coolant conditions. The results indicate that there is a considerable improvement in machining performance under MQL machining compared to dry and wet machining.

Z. Karim, S.A.S.Azuan, A. Yasir, 2013 [3], study on tool wear and surface finish by applying positive and negative rake angle during machining. In their study the experiment was conducted by using conventional lathe machine and aluminium alloy Al6061 as the workpiece. The machining parameters were kept constant while the rake angles were varied from positive to negative values. At every 200mm tool travel distance, the flank wear and surface roughness values were measured using Microscope Motic Images Plus and Handysurf surface roughness tester respectively. The experimental result shows that the higher the rake angle used during machining, the higher the value of the flank wear. The surface roughness value however shows a reducing trend with the increase of rake angle. This result can be used by machine operators to assist them in considering the optimum value of rake angle to get the best value of surface roughness with minimum flank wear.

Kapil Sharma, Dalgobind Mahto, S.S. Sen, 2013 [6] done review in metal turning, effect of various parameters on cutting tool. This paper describes a review of basic terms and visualizations of the major components of the cutting tool geometry in orthogonal turning process. The parameters like rake angle, depth of cut, feed rate, temperature and cutting speed are taken in to account so as to predict their effects on tool life. Their influences on cutting forces and tool geometry have also been referred. The results obtained from the literature survey it is found that:-

- ❖ The cutting force decreases as the tool rake angle increases.
- ❖ With increase in feed rate, this tends increase in cutting force.
- ❖ The increase in absolute value of negative tool rake angle and cutting speed these results in the decrement of tool chip friction.
- ❖ The tool tip temperature increases with an increase in cutting speed.

Kapil Sharma, Dalgobind Mahto, S.S. Sen, 2013 [7] works in metal turning, influence of rake angle on cutting tool life. In this research work the effect of rake angles on tool life has been studied. The various rake angles used are,0,1,3and 6 while the other parameters like depth of cut, feed rate, cutting speed ,clearance angle were kept constant. All the experiments were carried out on mild steel with High Speed Steel (HSS) as cutting tool. It may be concluded that choosing 6 rake angle, gives maximum tool life other than 0, 1 and 3 degrees.

Ashutosh Verma , Prof. Suman Sharma, 2014 [2] examine the analysis of cutting forces for different work materials and tool material: Effect of rake angle in turning process. The aim of this work is to study experimentally the influence of tool rake angle, work piece material type and tool material on the main cutting force during a turning process. EN 31, MS, Aluminum specimens have been used as work piece materials; High Speed Steel and Carbide tools are used as tool materials. The experiments have been obtained with constant cutting speed (550 rpm), depth of cut and feed rate with five different tool rake angles (0-16-degree) .The experimental results show that main cutting force has the maximum value at the EN 31 specimen, average value at the MS specimen and the lower value at the Aluminum specimen.

Kundan Kumar Singh, Mayank Joshi, Anurag Bahuguna, Rajesh Pant, 2014 [9], studied the effect of rake angles and material properties on chip formation: A Review. Study shows that rake angle which can give the longest tool life was then selected and observed that rake angle having value of 20-degree as well as the best surface finish and yielded continuous chips formation. This paper looks at the process of chip formation in metal cutting as being dependent not only on the work piece material but, even on the micro and macro structures of the work piece materials.

4. CONCLUSIONS

As analyzing the literature reviews, following results were concluded...

- ❖ Cutting force can be reduced by increasing the rake angle in positive degrees.
- ❖ MQL (minimum quantity lubrication) may considerable improve the machining performance compare to dry and wet machining.
- ❖ Surface roughness value shows an inverse relation with the rake angle. When the rake angle is increased, the value of surface roughness will decrease.
- ❖ Rake angle of 20-degree gave the longest tool life as well as the best surface finish and yielded continuous chips formation.
- ❖ Cutting force having different values for different work and tool materials.

REFERENCES

[1] Engr. Kaisan Muhammad Usman, “Effects of tool rake angle on tool life in turning tool,” International journal of scientific & engineering research, vol.3, 4. April. 2012, ISSN. 2229-5518.

[2] Ashutosh Verma and Prof. Suman Sharma, “Analysis of cutting forces for different work materials and tool material: Effect of rake angle in turning process,”International journal of scientific research, vol.3, 7. July. 2014, ISSN. 2277-8179.

[3] Z. Karim, S.A.S.Azuan and A. Yasir, “A study on tool wear and surface finish by applying positive and negative rake angle during machining,” Australian journal of basic and applied sciences, 7(10): 46-51, 2013, ISSN. 1991-8178.

[4] M. Dogra, V.S. Sharma and J. Dureja, ”Effect of tool geometry variation on finish turning – A Review, Journal of engineering science and technology,”review 4 (1) (2011) 1-13 , Received 4-october-2009; Revised 19-october-2010; Accepted 20-December-2010

[5] K.V. Santha Kumari, Dipak Ranjan Jana and Anjani Kumar, “Effects of tool setting on tool cutting angle on turning operation,” Asian research publishing network [

ARPN] Journal of engineering and applied sciences, vol. 5, may. 2010, ISSN. 1819-6608.

[6] Kapil Sharma, Dalgobind Mahto and S.S. Sen, "In metal turning, effect of various parameters on cutting tool: A Review," International journal of application or innovation in engineering & management (IJAIEM), Vol. 2, 8. Aug. 2013, ISSN. 2319-4847

[7] Kapil Sharma, Dalgobind Mahto and S.S. Sen, "In metal turning, influence of rake angle on cutting tool life," International journal of application or innovation in engineering & management (IJAIEM), Vol.2, 11. Nov. 2013, ISSN. 2319-4847

[8] K. Dharma Reddy and Dr. P. Venkataramaiah, "Experimental investigation on responses in turning of aluminium with carbide tipped tool at different coolant conditions," International journal of mechanical engineering and technology (IJMET), vol. 3, May-Aug. (2012), ISSN. 189-199 ISSN 0976-6340 (Print), ISSN 0976-6359 (Online)

[9] Kundan Kumar Singh, Mayank Joshi, Anurag Bahuguna and Rajesh Pant, "Effect of rake angles and material properties on chip formation: A Review," International journal of engineering science and innovation technology (IJESIT), vol. 3, 6. Nov. 2014, ISSN. 2319-5967

[10] Mustafa Gunay, Ihsan Korkut, Ersan Aslan and Ulvi Seker, "Experimental investigation of the effect of cutting tool rake angle on main cutting force," Journal of materials processing technology, 166(2005) 44-49, Received 10 September 2003; received in revised form 22 December 2003; accepted 20 July 2004

[11] Charles R. H. (1971), "Machine tools and process for engineers," McGraw Hills Inc., Chapter 8,10

[12] B.R.Dabhi and K.V.Parmar, "A review paper on latest trend on face milling tool," International Journal of Advance Engineering and Research Development , vol. 2, 1. January. 2015, ISSN (Online): 2348-4470 ISSN (Print) : 2348-6406

[13] Production Technology, Khanna Publication by R. K. Jain.

[14] Yahya Isik, "An Experimental Investigation on Effect of Cutting Fluids in Turning with Coated Carbides Tool," Journal of Mechanical Engineering 56(2010)3, Paper received: 02.04.2009 Paper accepted: 00.00.2010

[15] Amol N, Varade and Kamlesh P. Kadia, "An investigation of temperature, surface roughness and material removal rate during hard turning of EN19 material-A Review," IJIRST-International journal for innovative research in science and technology, vol.1, 8. January. 2015, ISSN(online): 2349-6010

[16] Patrick Adebisi Olusegun Adegbuyi, Ganiyu Lawal, Oluwatoyin Oluseye and Ganiyu Odunaiya, "Analysing the effect of cutting fluids on the mechanical properties of mild steel in a turning operation," American journal of scientific and industrial research, 2010, ISSN: 2153-649X

[17] Nexhat Qehaja, Kaltrine Jakupi, Avdyl Bunjaku, Mirlind Bruci and Hysni Osmani, "Effect of machining parameters and machining time on surface roughness in dry turning process," 25- DAAAM Intenational Symposium on Intelligent Manufacturing and Automation, DAAAM-2014.

[18] Lambert and B. K. (1983), "Determination of metal removal rate with surface finish restriction." Carbide and Tool Journal, 1983, 23, 16–19.

[19] Kwon, W.T and Choi, D. (2002). "Radial immersion angle estimation using cutting force and pre-determined cutting force ration in face milling." International Journal of Machine Tool and Manufacture, 42, 1649–1655.

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