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A Study on Tool Wear and Surface Finish by Applying Positive and Negative Rake Angle during Machining

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Abstract: Cutting tools for metal cutting have many shapes, each of which are described by their angles or geometries. Several types of angles are important when introducing the cutting tool's edge into a rotating workpiece. This paper proposes the study of tool wear and surface finishing by applying the positive and negative rake angle during machining. 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.

Key words: Tool wear, surface finish, rake angle, flank wear, surface roughness

INTRODUCTION

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. In this work, different positive and negative rake angle will be applied to know the effect of rake angle towards tool wear and surface finish.

Rake angle:

Cutting tools in metal machining have many kind of shapes which are described by their angles or geometries. Every one of these tool shapes has a specific purpose in metal cutting. 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. The concept of rake angle and clearance angle is shown in Fig. 1.

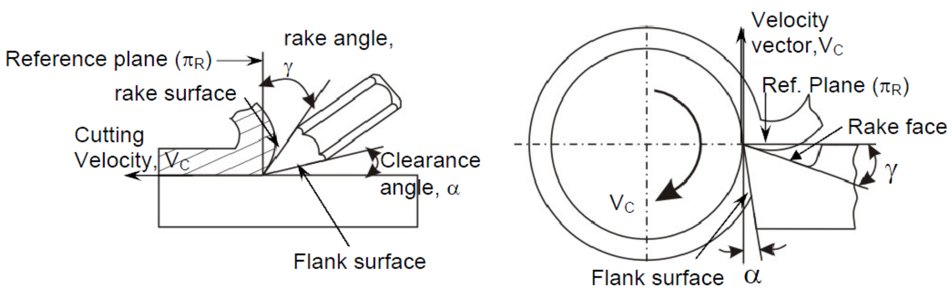

Fig. 1: Rake and clearance angles of cutting tools (Astakhov, *et al*., 2008)

Rake angle (γ) is the angle of inclination of rake surface from reference plane. Clearance angle (α) is the angle of inclination of clearance or flank surface from the finished surface. Rake angle is provided for ease of chip flow and it can be positive, negative or even zero as shown in Fig. 2.

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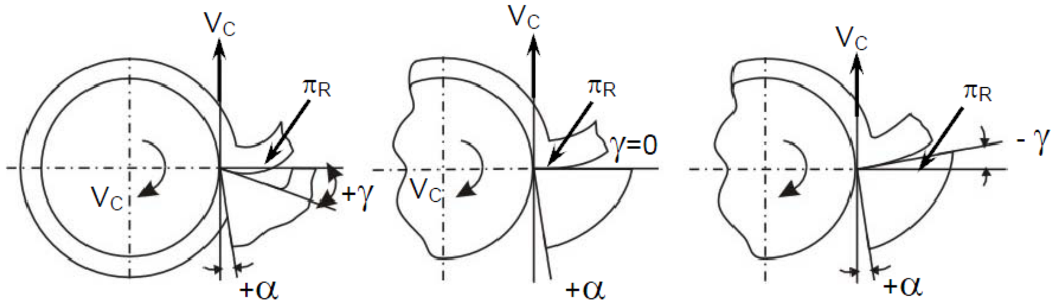

Fig. 2: Three possible type of rake angle

Different set-up in rake angle provides different advantage in turning machine process. Positive rake angle helps reduce cutting force and thus cutting power requirement (Dogra *et al.*, 2011). Negative rake set-up is to increase the edge-strength and life of the tool. Finally, zero rakes advantage is to simplify design and manufacture of the form tool (Astakhov, *et al*., 2008).

Tool Wear And Flank Wear:

Tool wear can be defined as the amount of volume loss of tool material on the contact surface due to the interactions between the tool and work piece. Tool wear is one of the most important and complex aspects of machining operation (Kalpakjian and Schmid, 2001).

Generally, tool life can be determined by tool failure modes. 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. (Yulian *et al*., 2012) in their work highlighted that when the temperature increase, the wear is also increase gradually.

Flank wear usually occurs due to the rubbing action on both at the major and minor cutting edges during turning cutting process. Flank wear is often used to define the end of effective tool life. Flank wear has been studied extensively and generally attribute to the main factors (Kalpakjian, 2001).

Yulian *et al*., (2009) claimed that flank wear increase gradually as cutting speed and rake angle increase. This also agreed by (Thamizhmanii *et al*., 2007) that had conducted research on tool wear and surface roughness in turning AISI 8620 using coated ceramic tool. They found that flank wear increased when the cutting speed and feed rate and depth of cut was increased. This is due to abrasive action between the tool cutting edge and workpiece and temperature generated between cutting edge and the work piece. Flank wear also influences in the surface roughness both by CBN and PCBN cutting tools (Thamizhmanii *et al*., 2008).

Surface finish:

Surface finish is one of the important aspects in turning operation. In order to achieve a high surface quality, the machine parameters and the tool geometry must set at proper specifications (Farhad *et al*., 2011). The most significant effect on surface roughness is feed rate. Therefore, the proper selection of feed rate will contribute the optimization in surface roughness (Islam *et al*., 2011). The important turning parameters considered in their research are cutting speed and feed rate. Besides, they also agreed that rake angle, side cutting edge angle and end cutting edge angle are considered as tool geometry specifications.

Metin, (2008) conducted studies on the machinability of AL2O3 particle reinforced aluminium alloy composites concluded that coating cutting tool resulted in better performance compare to HX tool. The coatings decreased tool wear and gives a better surface finish performances.

As the negative rake angle is increased, the surface roughness value increase and it will make the surface finish rougher (Yulian *et al*.,2009). The experiment also proved that to get smooth surface finish, cutting speed and feed rate must be increased.

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.

Experimental Set-Up And Procedures:

The experiment was performed by using conventional turning machine Ramo C33 manufactured by Ramo Industries. The machine was operated at the fix cutting speed 120m/m, feed rate 0.5 min/rev and dept of cut 2.0 mm. The tool bit used was Miranda High Speed Steel (HSS) with tool holder 20mm x 20mm x 125mm. The hardness for the tool bit is M42 that is 64-67 HRC with the end bevel equal to15°. This insert is based from the

0.80% Carbon, 1.50% Tungsten, 8.00% Molybdenum, 4.00% Chromium, 1.00% Vanadium and Hardness Rockwell C is about 63 to 65%.

All three HSS tool bit need to be sharpen into specific angle approximately 21° before grinding into positive and negative rake angle. The tool bits were grinded into 5°, 10° and 15° positive rake angle and -5°, -10° and -15° negative rake angle. The workpiece used in this work is aluminium alloy Al6061 with 50 mm diameter and 250mm length.

To measure the flank wear, tool bit is removed from the machine holder after every step of machining process placed under microscope to observe and determine the area of flank wear. The value of flank wear was determined by capturing the image under microscope as shown in Fig. 3(a) using software called Motic Images Plus version 2.0ML. This software allows users to verify the right position of flank wear and determine the correct length of the flank wear that occur on the cutting tools. The length of flank wear is measured three times and the highest reading is taken as the final data. The measurement of the flank wear is performed for cutting process with another different rake angle. The surface finish is measured base on the average surface roughness, *Ra*, and it was measured using Handysurf surface roughness tester as shown in Fig 3 (a) and (b).

(a) (b)

Fig. 3: (a) Microscope Motic Images Plus version 2.0ML (b) Handysurf surface roughness tester

RESULTS AND DISCUSSION

The result of flank wear and surface roughness with the relation between flank wear with length of cutting process are on Table 1.

Table 1: Result of flank wear for positive rake angle

Run	Length Of Cutting Process (mm)	Flank Wear (mm)			Average Of Surface Roughness		
		5˚	10˚	15˚	5˚	10˚	15˚
1	200	0.1913	0.1913	0.2003	1.24	1.14	1.03
2	400	0.1983	0.1995	0.2223	1.26	1.18	1.1
3	600	0.2124	0.2215	0.2362	1.27	1.21	1.08
4	800	0.2312	0.2357	0.2569	1.27	1.26	1.11
5	1000	0.2587	0.2532	0.2712	1.34	1.29	1.11
6	1200	0.2674	0.2694	0.2805	1.39	1.32	1.15

The result from Table 1 is plotted in Fig. 4 and Fig. 5. From Fig. 4, when positive rake angle increase from 5˚ to 15˚, the value of flank wear also increase. At the cutting length equal to 600 mm for example, the value of flank wear equal to 0.2124 mm, 0.2215 mm and 0.2362 mm for 5˚, 10˚ and 15˚ rake angle respectiv ely. The flank wear is at maximum value when the rake angle equal to 15˚. It happen because change of the rake angle had caused the clearance angle to be changed accordingly, i.e. when the rake angle was increased to certain degrees, the clearance angle was also decreased with the same degree (Hendri Yanda, *et al*.). This is also in agreement with the previous findings that the smaller the clearance angle, the bigger the contact area between the clearance face and the work piece (Stephenson, *et al*. and Yanda, *et al*.). Small changes in clearance angle will greatly influence the wear mechanism and consequently the tool life (Coelho, *et al*.). The plot of flank wear versus cutting length shows a linear relationship with similar slope which indicate similar rate of wear in the cutting tool.

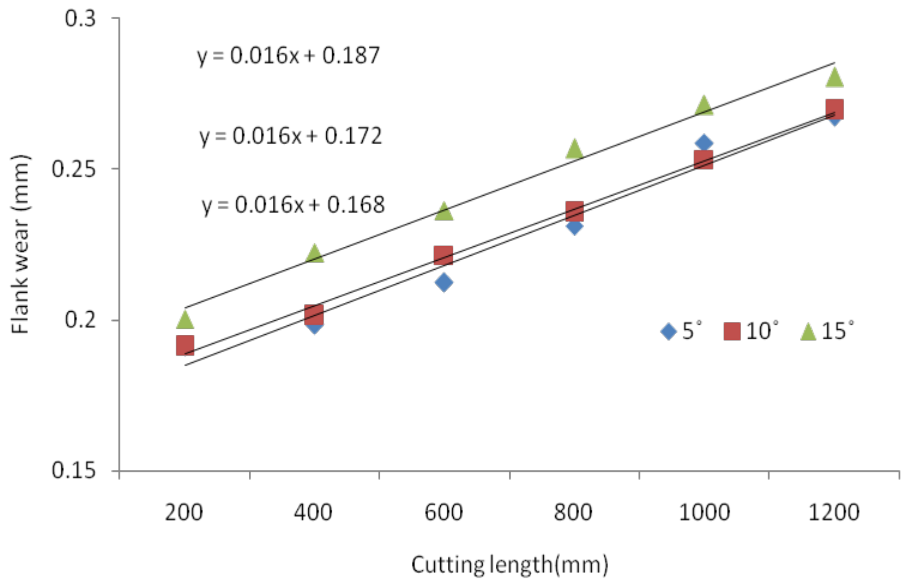

Fig. 4: Flank wear versus cutting length for positive rake angle

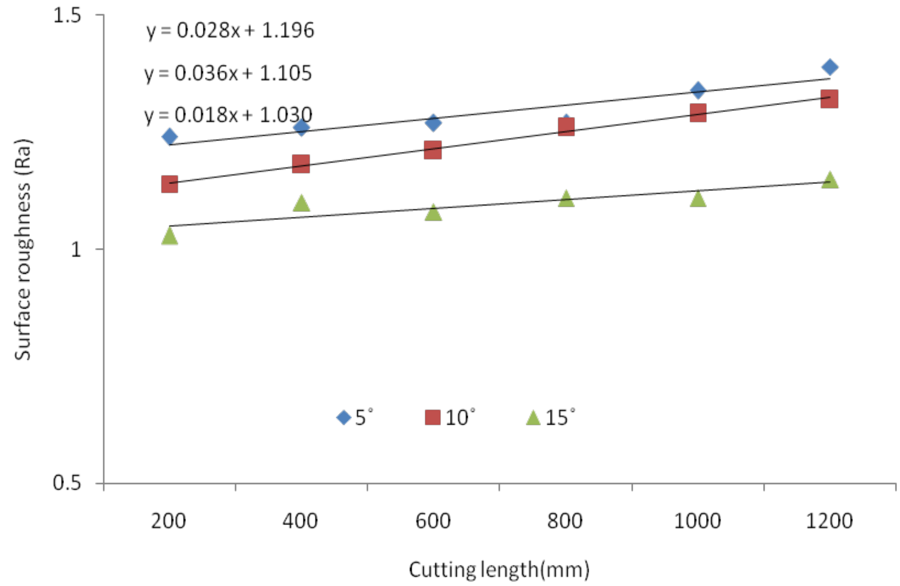

Fig. 5: Surface roughness versus cutting length for positive rake angle

In Fig. 5, surface roughness value decrease with respect to the increase in the rake angle. According to (Tejinder et. al., 2010) the rake angle and nose radius play important in determine the surface roughness. They conclude that when the rake angle increases, the surface roughness decrease. At cutting length equal to 1000 mm for example, the value of surface roughness equal to 1.34, 1.29 and 1.11 for 5˚, 10˚ and 15˚ rake angle respectively. The plot of surface roughness versus cutting length shows a linear relationship with slightly different value of slope which indicate slightly different rate of surface roughness change with respect to the increase of cutting length.

Table 2: Average of surface roughness for negative rake angle

Run	Length of cutting process (mm)	Flank wear (mm)			Average of surface roughness		
		-5˚	-10˚	-15˚	-5˚	-10˚	-15˚
1	200	0.1815	0.1913	0.2103	1.05	1.13	1.21
2	400	0.1983	0.2014	0.2323	1.08	1.15	1.23
3	600	0.2124	0.2215	0.2562	1.11	1.18	1.25
4	800	0.2312	0.2357	0.2769	1.14	1.2	1.27
5	1000	0.2587	0.2532	0.2912	1.15	1.23	1.3
6	1200	0.2674	0.2694	0.3105	1.16	1.27	1.31

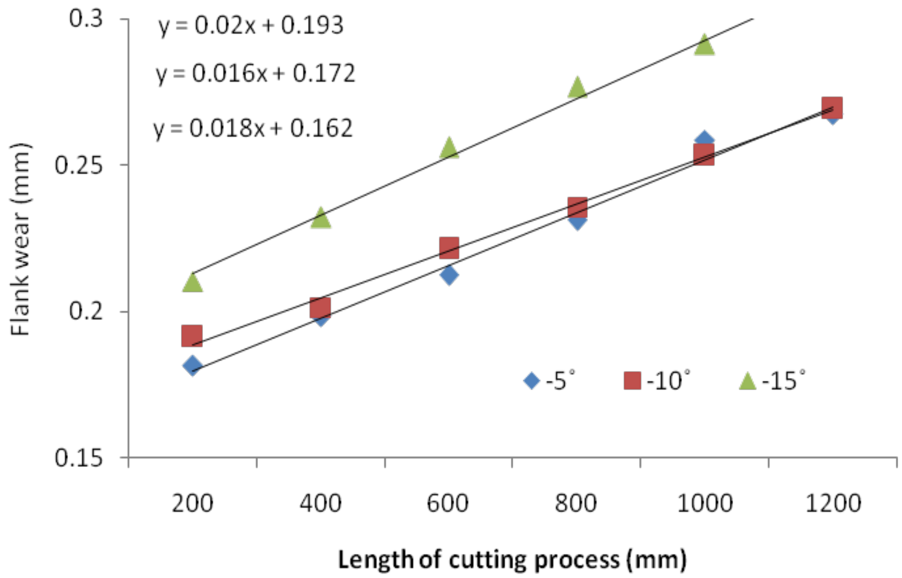

Fig. 6: Flank wear versus cutting length for negative rake angle

The result from Table 2 is plotted in Fig. 6 and Fig. 7. From Fig. 6, when positive rake angle increase from -5˚ to -15˚, the value of flank wear also increase. At the cutting length equal to 400 mm for example, the value of flank wear equal to 0.1983 mm, 0.2014 mm and 0.2323 mm for -5˚, -10˚ and -15˚ rake angle respectively. The plot of flank wear versus cutting length shows a linear relationship which indicates the rate of wear in the cutting tool is proportional to the cutting length.

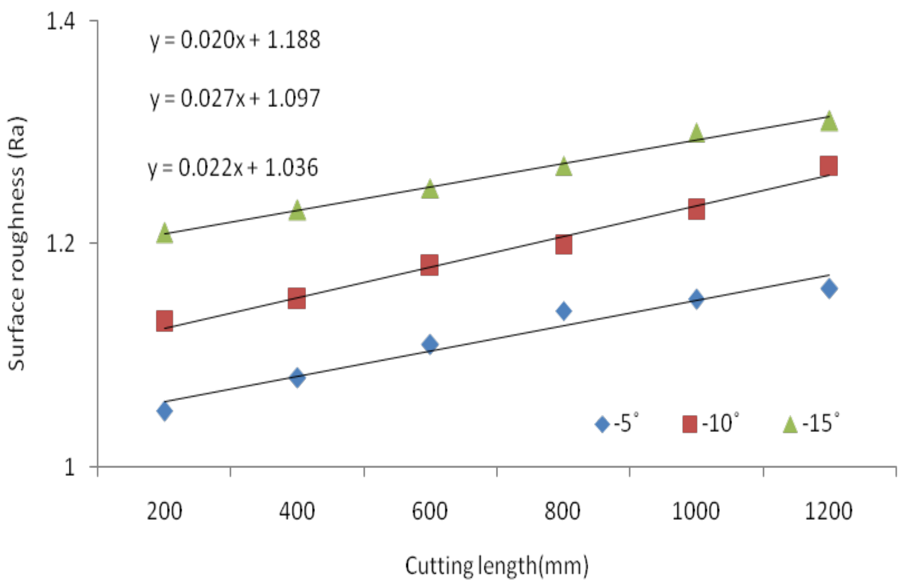

Fig. 7: Surface roughness versus length of cutting for negative rake angle

In Fig. 7, surface roughness value increase with respect to the increase in the rake angle. At cutting length equal to 200 mm for example, the value of surface roughness equal to 1.05, 1.13 and 1.21 for -5˚, -10˚ and -15˚ rake angle respectively. The plot of surface roughness versus cutting length shows a linear relationship with slightly different value of slope which indicate slightly different rate of surface roughness change with respect to the increase of cutting length.

Conclusion:

In this work, the effect of different rake angle toward flank wear and surface roughness was successfully performed and recorded. From the tool wear result, the flank wear increase with respect to the increase of positive rake angle or negative rake angle. The flank wear is at maximum value when the rake angle equal to

15˚. The plot of flank wear versus cutting length shows a linear relationship with similar slope which indicate similar rate of wear in the cutting tool. Base on the data that were recorded through the experiment as summarized in Table 1 and Table2, negative and positive rake angle give very close values of flank wear. Thus, It can be concluded that the negative and positive rake angle give the same effect to flank wear during machining process. Surface roughness value shows an inverse relation with the rake angle. When the rake angle is increased, the value of surface roughness will decrease. The result in this work can be used in optimizing machining parameter setting to get the best value of surface roughness with minimum flank wear.

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