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Effect of Cutting Parameters on Wear and Surface Roughness of Stainless Steel (316L) Using Milling Process

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Abstract

Flank wear width is generally recognized as the key indicator for tool life. In the milling process, several factors that influence on the wear of the tool(the material of workpice, the tool material, cutting conditions, the shape of a tool, machining time). In the experiments stainless steel 316L was used and cutting parameter with constant cutting tool type, cutting feed ,depth of cut and four spindle speeds(350,550,930 and 1100) rpm. The cutting tool wear was measured using optical microscope. The results showed an increase in cutting speed lead to decreases surface roughness (2.648,2.285,1.878 and 1.526) μm respectively with constant machine parameter and give indicating for tool wear which increase with the increase roughness of production surface.

Key words: tool wear, milling process ,tool life flank wear, surface roughness.

Introduction and review

Tool wear is the change of shape of the tool from its original shape, loss of tool material and influences cutting power, machining quality, tool life and machining costs. When tool wear reaches a certain value, increasing cutting force, vibration and rise of cutting temperature cause surface integrity deterioration and dimensional error. The methods to measure tool wear can be largely divided into direct and indirect measuring methods. The direct measuring method measures the cutting edge of the tool using a machine vision system and optical microscope. The indirect measuring method measures the degree of tool wear by processing the signals generated in the cutting process with use signal of cutting force, spindle torque,…etc. This method has a problem of accuracy depending upon signal processing and analysis [1] .The use direct optical microscopes to measure wear in end milling tool given more accuracy. Davim.P, et al. [2] have investigated the influence of cutting parameters on the tool flank wear and surface roughness in finish turning of hard steel. Flank wear of ceramic tool has been observed with a scanning electron microscope (SEM). Similar measuring techniques have been performed by Lajis.G.Turnad,et.al [3] in end milling of hardened steel. This method is also used by current standards(ISO 8688-2.1989) Tool life testing in milling used optical microscope[4]. Jozic Sonja and Topic, S [5]study the influences of cutting speed,feed per tooth, radial depth of cut and time of inserts engagement on flank wear in peripheral milling process have been examined. Down milling is more favorable compared to the up milling because increase production and reduce machine time, but increase wear, so the material removal rate in down milling is greater than in up milling. Numan M. Durakbasa, et al.[6] study the tool wear for cutting end milling by using 3D digital microscope monitors high quality recorded images easily, The captured images of the uncoated and coated cutting tools were analyzed using the image processing technique. Establishing tool life criteria based on the value of the flank or the clearance face of the cutter.

Surface roughness

Surface roughness parameter is one of the main parameters in milling processes. It plays the major role to optimize the process of producing smooth machined surface. In milling processes , various machining strategies can be applied to improve machined surface qualities. The selection of the most appropriate machining strategy for a given work piece is of great importance to the quality of productivity part [7]. Surface roughness are influenced by machining parameters, such as feed rate, spindle speed and depth of cut as well as non-controlled factors, such as non-homogeneity of work-piece and tool, tool wear. It has been shown that both controlled and non-controlled parameters cause relative vibrations between the cutting tool and the work piece [8] .

Flank wear form

On general lines for milling operation the standard ISO 8688 describes the main wear patterns and localizations, as shown in Figure (1) [4].

The Flank wear (VB)is defined as the loss of particles along the cutting edge, that is, in the intersection of the clearance and rake faces as shown in Figure(2), being observed and measured in the clearance face of end milling [4].

- **Uniform flank wear (VB1):** Wear land which is normally of constant width and extends over those edges as shown in Figure (1) [4].
- **Non-uniform flank wear (*VB*2):** irregular wear in several zones of the cutting edge as shown in Figure (1) [4].
- **Localized flank wear (VB3):** wear usually found in specific points. One type that is placed just in the depth of cuts line, the notch wear (*VBN*) as shown in Figure (1)[4].

Experimental work

Machine used

The experimental work has been performed on universal milling (KNUTH) model (MF1), It has the following specification listed in the Table (1).

Work piece Material

Stainless steel (316L) workpieces with a hardness of HV 170(Kg/mm^2) are used, the chemical composition which is examined in center organization for standardization and quality control/Baghdad and the mechanical properties are given in Tables (2)and (3) respectively.

Cutting Tools

The 4-flute types of end milling cutting tools are used with the geometry Properties and chemical composite as listed in the Table (4) and (5) respectively.

Machining Condition

1- Spindle speed:- four different spindle speeds (350,550,930 and 1100) rpm are used .The cutting speed is mostly determined by the material to be cut as listed in Table (6) ,and the material of the tool to find the right speed.

2- Feed rate: - The feed rate depends speed and depth of cut, finish desired and many other variables to calculate the desired feed, in this work used (50)mm/min.

3- Depth of cut: - the depth of cut depends on all the machine conditions above, in this work used axial depth of cut a_a= 2mm and radial depth of cut a_r =2.25 mm as shown in Figure (3).

4-Dry cutting :- the cutting fluid(oil or water) reducing tool wear with increase cutting speed and other condition.

5-Down Cut Milling:- causes an increase in material removal with increase temperature and increase wear compared with up cut milling.

Experimental test

To achieve slot cutting , The experiments were done using a cube with dimensions of (125*50*50) mm. In this experiment straight line was cut with multi pass and with different machining time in workpiece as shown in Fig.(3).

Results and discussion

Tool Wear Measurement

The following steps are achieved in order to measure the flank wear region:

1. The cutting process starts due to down milling using the end milling cutting tool.
2. The cutting conditions are selected as mentioned above.
3. The flank wear was measured using micro scale and optical microscope, as shown in Figure(4) and (5), for different machining time .

The test is repeated for the other spindle speed as shown in Table (7).

Table (8) and Figure (6) show the effect of cutting speed in the tool wear. Show increase cutting speed with increase flank wear with constant feed rate, Radial depth and machining time used Table (8).

Surface Roughness Measurements

Using surface roughness (Ra) tester brand “Mar Surf PS1” USA made, shown in Figure (7), the parameter (R_a) is chosen because it is simple and widely used as a parameter for the surface roughness indicator.

For explains the effect of machining time in tool wear and surface roughness use new tool (tool No.5) and machining tool No.5 with the same cutting parameter of tool No.4 with speed, depth and feed, but only increase the machining time from 30 min to 35 min noted that increase of heat of tool, vibration in the machine and tool damage immediately as shown in Figure (8) with a surface roughness measurement 4.821 µm and flank wear increase above ISO 8688-2 range and occurs catastrophic failure wear type. Figure (9) shows decrease surface roughness with increase cutting speed using constant feed and Radial depth while Figure (10) show increase surface roughness with increase flank wear using constant feed, radial depth and different machining time. Because the change of shape of the tool from its original shape, loss of tool material and influences cutting power, machining quality, tool life.

Conclusion

In this work, the results that are obtained from the experimental work include the following points:

- The roughness Ra grows from 1.526 to 2.648 for the chosen cutting conditions with growth in flank wear from 0.31 to 0.41 mm.
- The increase in cutting speed V from 20 to 62 m/min at constant feed= 50 mm/min

and depth a=2.25 mm lead to an increase in roughness from 0.22 to 0.31 μm.

- Surface roughness are playing an important role as an indication of wear increasing parametric in end milling, considering the change in the parameters of roughness, which relate to the consideration of the wear of tools.
- Possible to give higher speed with growth in the flank wear of teeth on the back surface, correct the speed to the decrease related to this increase in roughness. This leads to an increase in tool life.

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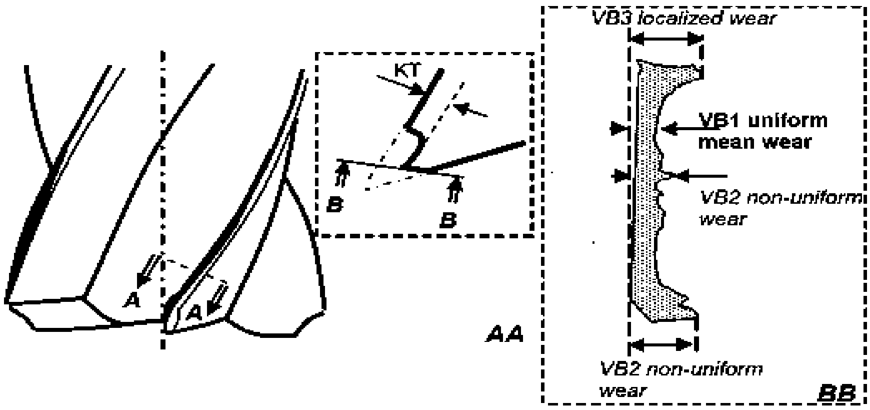

Figure 1: Wear of end milling tools [4]

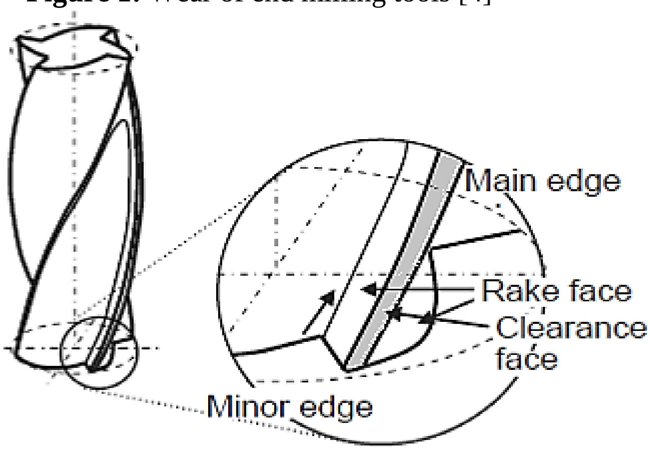

Figure 2: Basic geometry of end milling tools [4]

Table 1: Specifications of machine used.

Spindle speed	(80-4500) rpm	Travel –z	370mm
Feed rate	(27-816)mm/min	Motor main drive	3hp
Travel- x	670mm	Travel –y	290mm

Table 2: Chemical compositions of workpiece material**.**

Material	C %	Si %	Mn %	P %	Co %	Cr %	Mo %	Ni %	V %	Fe %
Weight%	**0.008**	**0.29**	**1.68**	**0.02**	**0.23**	**18.5**	**2.08**	**11.7**	**0.07**	**Balance**

Table 3: Mechanical properties of work material at room temperature

Property	Values
Reduction in area(%)	55
Elongation(%)	45
Elastic modulus (GPa)	200
Tensile strength (MPa)	550
Yield strength (MPa)	200

Table 4: Geometry Properties of Cutting Tools**.**

Cutting tool	Material	Mill diameter (mm)	Shank diameter (mm)	Flute length(mm)	Overall length (mm)
4-flute	HSS Titanium Nitride Coated (TiN)	18	18	23	92

Table 5: Chemical composition of Tool (HSS Titanium Nitride Coated (TiN).

Material	C%	W%	Mo%	Cr%	V%
M2	**0.85**	**6.00**	**5.00**	**4.00**	**2.00**

Table 6: listed Conversion from the rotational speed of cutting speed

Spindle speed (r.p.m)	Convert law	Cutting Speed (m/min)
350	$Vc = \frac{\pi DN}{1000}$	20
550		31
930		53
1100		62

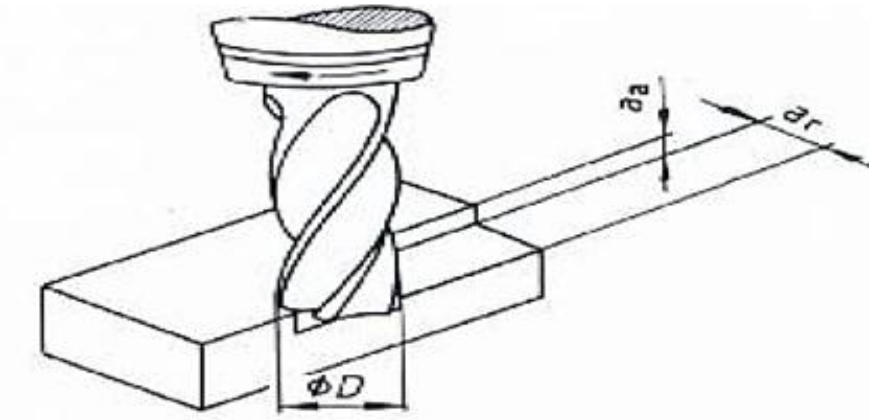

Figure 3: Show dawn milling ($a_a < a_r$)

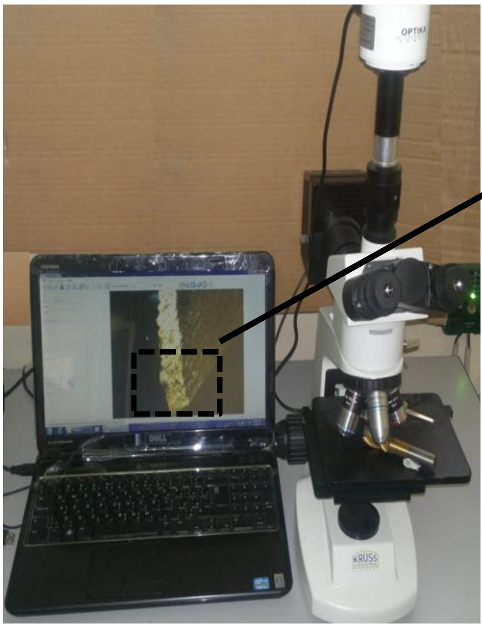

Figure 4: optical microscope Using in research

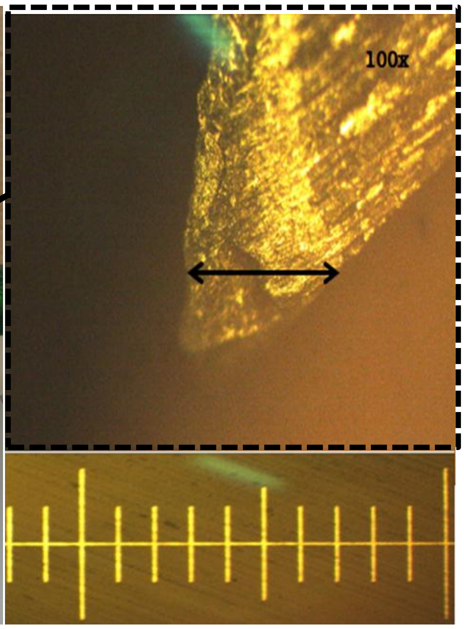

Figure 5: measure flank wear using micro scale for tool(1) at time 69min

Table 7: machining parameters used and the result of flank wear measured

Tool No.	Cutting speed *Vc (m/min)*	Depth of cut a_r *(mm)*	Feed *f* *(mm/min)*	Machining Time *t (min)*	Wear (mm)
1	20	2.25	50	69	0.41
2	31			53	0.36
3	53			40	0.33
4	62			30	0.31

Table 8: machining parameters used and the result of flank wear measured

Tool No.	Cutting speed *Vc (m/min)*	Depth of cut a_r *(mm)*	Feed *f* *(mm/min)*	Machining Time *t (min)*	Wear (mm)
1	20	2.25	50	30	0.22
2	31				0.25
3	53				0.27
4	62				0.31

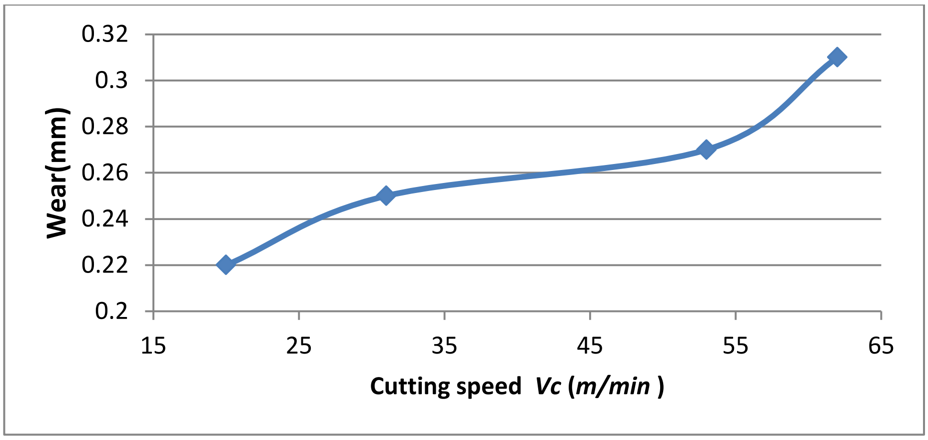

Figure 6: The Relationship between Wear and Cutting Speed

Figure 7: The Surface Roughness Tester

Table 9: Machining Parameters Used And Result Of Surface Finish Measured

Tool No.	**Cutting speed** *Vc (m/min)*	**Depth of cut** a *(mm)*	**Feed** *f (mm/min)*	**Machining Time** *t (min)*	**Surface *Roughness*** R_a (μm)
1	20	2.25	50	69	2.648
2	31			53	2.285
3	53			40	1.878
4	62			30	1.526

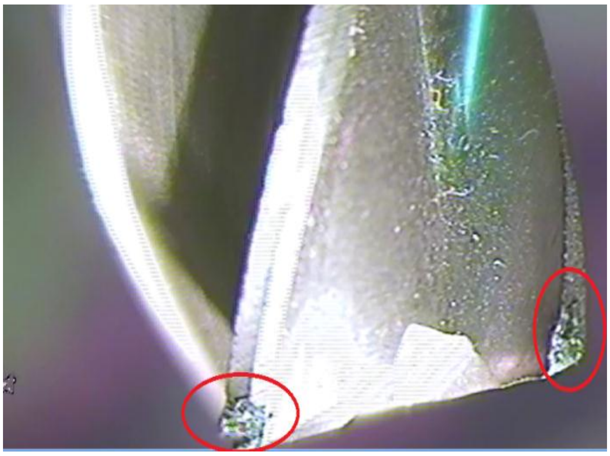

Figure 8: Shown the Catastrophic Failure Wear Type

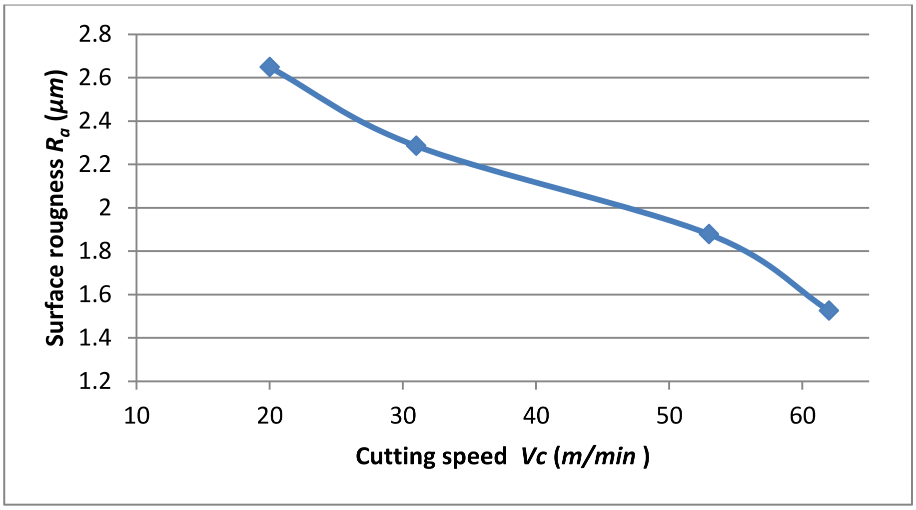

Figure 9: The Relationship between Cutting Speed and Surface *Roughness*

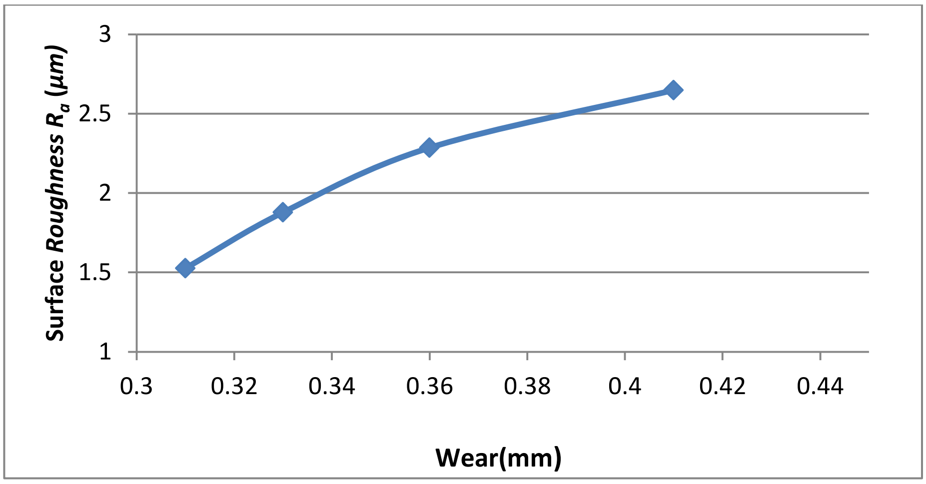

Figure 10: The Relationship between Wear and Surface *Roughness*

تأثير ظروف القطع على البلى والخشونة السطحية للفولاذ المقاوم للصدا (316L) باستعمال عملية التفريز

علي عبار خليف **مصطفى عادل عبد الله**

الجامعة التكنلوجية /هندسة الانتاج والمعادن

الخلاصة:

عرض البلى الجانبي يعتبر كمؤشر رئيسي لمعيار عمر الاداة. في عملية التفريزهنالك عدة عوامل تؤثرفي بلى الاداة هي مادة العدة المشغلة,ظروف التشغيل ,شكل الاداة المستعملة وزمن التشغيل.الجانب العملي استعمل الفولاذ المقاوم للصدا (316L) وظروف قطع من ادة قطع وتغذية وعمق ثابت ولكن استعمال اربع سرع دوران(550350, 930و1100) دورة بالدقيقة.ان البلى في عدة القطع تم قياسه باستعمال مجهر ضوئي والنتائج اظهرت ان زيادة سرع القطع تؤدي الى نقصان في خشونة السطح (1.526, 1.878,2.285,2.648) مايكرون بثبوت ظروف القطع (والتي تعطي مؤشر لبلى الاداة والذي يزداد بزيادة الخشونة للسطح المشغل .