Experimental Research on Effect of CNC Machining Parameters on Surface Roughness of Workpieces

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Abstract: The surface roughness of a mechanical part is one of the accuracy of parts processing. A Cutting parameter in CNC machining is a important factor that would affect the surface roughness of parts. From an experimental point of view, the writers have studied the influence of the cutting amount on the surface roughness in CNC machining, and the result could be used to guide the machining.

1 INTRODUCTION

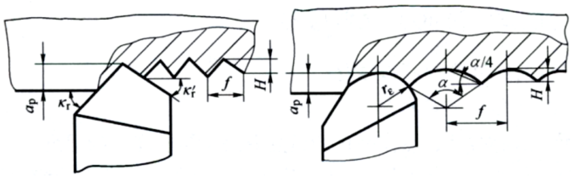
The term surface roughness refers to the smaller pitch of the machined surface and the unevenness between peaks and valleys. The lower the surface roughness is, the smoother the surface is. The surface roughness of a part is a parameter that characterizes the micro-geometry of the part surface, to measure the accuracy of the part surface. According to GB/T 1031-2009"Surface Structure Profile Method Surface Roughness Parameters and Its Value", the arithmetic average deviation Ra and the contour maximum height Rz are used as the evaluation parameters in the sampling length. When used, the part' surface roughness will affect its wear resistance, fatigue strength, corrosion resistance and tolerances and fits and so on.

In the cutting process, the surface roughness of the workpiece will be affected by a lot of factors, such as cutting amount, tool geometric parameters, workpiece material, cutting fluid, vibration during cutting, formation of built-up edge or not, and so on. In the numerical control machining process, some influence factors are fixed relatively, such as the workpiece material, cutting fluid, vibration and built-up edge. The others are need to be selected according to different processing conditions, such as and the cutting amount and tool geometric parameters etc. The standard tools are used in CNC machining. When a certain tool type is selected, the geometric parameters are also determined. So as to the actual cutting parameters，then there is only one is actually to be selected，that is the cutting amount in the actual machining process.

The cutting amount includes the cutting speed vc，the back engagement of the cutting edge ap, and the feed amount f and so on. When increasing one of them， the cutting efficiency will be more and influence by the tool condition and the machine tool performance. Because changing the cutting amount parameters will affect the quality of the part machining surface, so it is more important for us to study the relationship between the cutting parameters and the surface roughness of the workpiece for ensuring the quality of the NC machining while improving the cutting efficiency.

2THE THEORETICAL CAUSE OF SURFACE ROUGHNESS

The term theoretical roughness is the tool surface geometry and the workpiece surface roughness caused by cutting motion. That is residual areas formed between the contours of the adjacent tool paths due to the geometry of the tool during machining. Here，we take turning processing as an example as shown in Figure 1.



(a) (b)

Figure 1 Surface area remaining on turning workpiece.

The value of surface roughness in cutting process is mainly based on the height of the cutting residual area. When tools with corner radius r_ε=0, the height of the workpiece surface remained (Referring to Figure 1a).

$$H = \frac{f}{\cot\kappa_r + \cot\kappa_r'} \qquad (1)$$

Where f - Feed amount (mm/r);

κ_r - Lead angle (≠90°);

κ'_r - Deflection angle (≠90°).

When tools with corner radius r_ε≠0, the height of the workpiece surface remained (Referring to Figure 1b).

$$H \approx \frac{f^2}{8r_\varepsilon} \qquad (2)$$

Based on the above equations (1) and (2) , the height of the residual area can be reduced by decreasing f 、 κ_r 、 κ'_r orincreasing r_ε.

Certainly, the microscopic geometric deformation generated on the workpiece surface is more than the theoretical roughness in the actual cutting process, because of the friction between the tool and the workpiece surface, the plastic deformation of the workpiece surface, and the high frequency vibration in the process system.

3THE ESTABLISHMENT OF AN EXPERIMENTAL MODEL

It is long for theoretical and experimental research on the influence of the three factors of cutting amount on the roughness of the workpiece surface. It is shown that the amount of feed has a significant effect on the value of the surface roughness by a lot of studies and the Long-term production. That is the value of the surface roughness will increase after the feed increases. And the effect of cutting speed on the surface roughness of the workpiece is related to the formation of built-up edge in the cutting process. When cutting plastic material in the medium-speed (vc =20-40m/min)，the built-up edge is easy to be formed, then the surface roughness value of the workpiece increases；While in low-speed or high-speed, it is not and the roughness value of workpiece surface is less；The effect of the amount of the back engagement of the cutting edge on the workpiece surface roughness is not very obvious. Of course, the results are based on ordinary metal cutting process. CNC cutting machining is similar to it, but it still has some specific features. Here, the actual conditions of modern CNC cutting processing is be used to determine the corresponding experimental methods and parameters in the paper.

We intend to machine the workpiece with CNC machining and CNC milling separately, then measure the value of the surface roughness of the workpiece, and finally analyze the measurement data and results from them in this experiment. Based on the actual production habits, the parameters are set as follows:

①CNC turning: Specimenφ18×40，Q235； 93 degree turning tool ； ap(mm)0.1,0.2,0.5,1.0 ； f(mm/r)0.05,0.08,0.10,0.12,0.20 ； n(r/min)500,800,1000,1200；

② CNC milling: Specimen 64×16 ， Q235 ； φ80End mill，φ20、φ16、φ10 End mill，R5Ball end mill；ap(mm)0.1，0.2，0.3，0.5，1.0，2.0；F(mm/min)50， 100， 200， 300；n(r/min)500， 800，1000，1200，1800，2000.

4THE EXPERIMENTAL DATA

After machining, wetested specimen in the way of contour contact measurement using a 2205 Surface Roughness Gauge. The data are listed in Table 1 and Table 2 (Excerpts) respectively. The 2205 Surface Roughness Gauge can measure multiple surface roughness parameters. This experimental is only based on the most widely used contour arithmetic average deviation Ra.

Table 1: Surface Roughness Measurement Results of CNC Lathe Machining Test Pieces (Extract).

No.	n r/min	V_c m/min	f mm/r	a_p mm	Ra um
01	500	28.26	0.15	0.5	2.632
02	500	28.26	0.15	1.0	2.143
03	500	28.26	0.20	0.5	4.243
04	500	28.26	0.20	1.0	3.479
05	800	45.22	0.12	0.5	3.359
06	800	45.22	0.12	1.0	2.981
07	1000	56.52	0.08	0.2	3.033
08	1000	56.52	0.08	0.1	3.066
09	1000	56.52	0.10	0.2	3.507
10	1000	56.52	0.12	0.2	3.548
11	1200	67.82	0.05	0.2	2.797
12	1200	67.82	0.08	0.2	3.240

Note: Spindle speed n, feed amount f, and the back engagement of the cutting edge a_p refer to the common CNC turning parameters selection.The cutting speed Vc is a converted value (Vc=πdn/1000).

Table 2 :Surface Roughness Measurement Results of NC Milling Test Pieces (Excerpt).

No.	R mm	n r/min	V_c m/min	F mm/min	a_p mm	Ra um
01	40	800	200.96	50	0.3	0.596
02	40	1000	251.20	50	0.3	0.677
03	40	1500	376.80	100	0.3	0.500
04	40	2000	502.40	100	0.2	0.708
05	40	800	200.96	100	2.0	0.933
06	40	500	125.60	200	1.0	1.048
07	40	800	200.96	200	2.0	1.262
08	8	1000	50.24	100	0.5	0.273
09	8	1000	50.24	200	0.5	4.410
10	8	2000	100.48	100	0.5	2.486
11	6	500	18.84	200	1.0	1.576
12	6	500	18.84	300	1.0	3.996
13	5	1500	47.10	200	0.2	1.944
14	5	1800	56.52	100	0.2	2.049
15	5	2000	62.80	100	0.1	1.532
16	5	2000	62.80	200	0.1	2.962

Note: Spindle speed n, feed speed F, and the back engagement of the cutting edge ap refer to the common CNC milling parameters selection.The cutting speed Vc is a converted value (Vc=2πRn/1000).

5THE ANALYSIS OF DATA

There are 83 valid samples of CNC turning and milling. Some data are eliminated by taking into account the effects of random errors and measurement errors during cutting. After studying the conclusions are as follows:

① The feed or feed rate has a significant effect on the workpiece surface roughness. Under the same cutting conditions, the workpiece surface roughness value will increase while the feed or feed rate increases. Referring the number 02, 03 and 08, 09 and11,12 in Table 1; the 05, 07 and 11 ,12 and15 ,16 in Table 2.In Fig. 2 and Fig. 3 are the measured results of the surface roughness of the workpieces of the CNC turning; In Fig. 4 and Fig. 5 are the CNC milling.

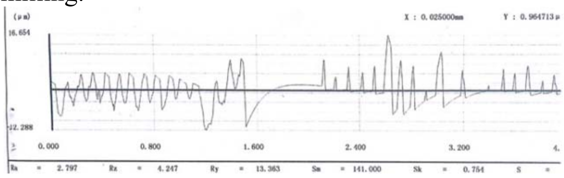


Fig. 2 Surface roughness measurement results of CNC turning workpiece 11(n1200,f0.05,ap0.2).

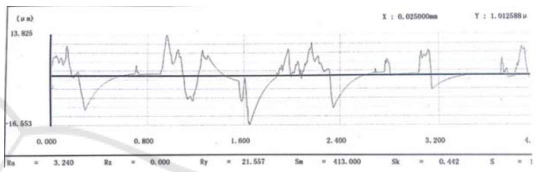


Fig. 3 Surface roughness measurement results of CNC turning workpiece 12(n1200,f0.08,ap0.2).

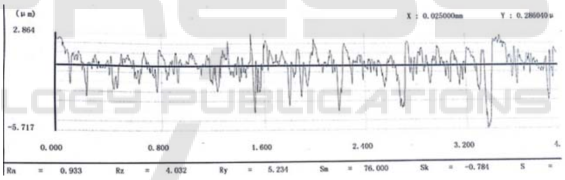


Fig. 4 Surface roughness measurement result of NC milling workpiece 05(R40，n800,F100,ap2).

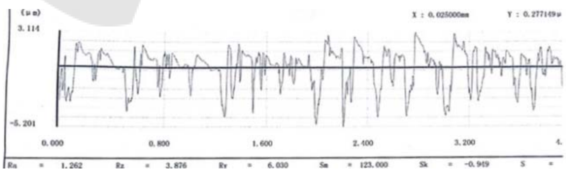


Fig. 5 Surface roughness measurement result of NC milling workpiece 07(R40，n800,F200,ap2).

②The parameter back engagement of the cutting edge has not a significant effect on the value of the surface roughness of the workpiece. When in the same condition in addition to the back engagement of the cutting edge, the surface roughness value of the workpieces keep unchanged basically either CNC turning or milling. Referring 01,02 and 03,04 in Table 1, the value the of surface roughness of the workpiece decreases when the back engagement of the cutting edge increases, because of the affecting by the turning radius of tool cutting edge of the turning tool.

③ The cutting speed has an effect on the surface roughness of the workpiece, but it is less than the feed or feed rate. During in high-speed, the value of the surface roughness of the workpiece decreases when increasing the cutting speed, referring to 14,15 in Table 2, and 14, 15 and 02, 03, 04.when the cutting speed Vc> 200m/min, the average value of the surface roughness of the workpiece is some 0.628μm; and when Vc = 50~60m/min, the value is about 2.122μm. However, if the spindle speed of the machine tool is too high, the value of the surface roughness of the workpiece will increase due to the accuracy of the machine itself and the effects of cutting vibration,. Such as when the spindle speed of the economical CNC lathe reaches 1200r/min and the CNC milling machine reaches 2000r/min.

6CONCLUSIONS

After CNC machining and milling, we tested the value of the surface roughness of the sample pieces and then study the effects on them by the cutting parameters (the cutting speed vc, the back engagement of the cutting edgeap, the feed f) in this experiment, the conclusions are as follows:

①The feed has a significant effect on the value of the surface roughness of the workpiece. the more the feed, the bigger the value.

②The cutting speed effects on the value of the surface roughness of the workpiece. the more the speed, the less the value during high-speed cutting.

③ Theback engagement of the cutting edge has little effect on the value of the surface roughness of the workpiece.

④Usually, if to make the value of the workpiece surface roughness Ra= 1.6 ~ 3.2μm, the ideal turning amount in CNC turning: vc = 30 ~ 60m/min, ap = 0.5 ~ 1.0mm, f = 0.05 ~ 0.12mm / r; In CNC milling: vc = 20 ~ 100m/min, ap = 0.2 ~ 2.0mm, F = 50 ~ 200mm/min. When a large diameter end is sued in CNC milling, and F = 50 ~ 100mm/min, the Ra is up to 0.8μm.

⑤When the spindle speed of the machine tool is too high, the value of the surface roughness value of the workpiece will increase due to machine tool accuracy and cutting vibration. Otherwise, if theback engagement of the cutting edge is too small, the value will increase due to the influence of the turning radius of tool cutting edge.

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