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Some Results on the Factor of the Surface Details When Turning C40 Steel Current

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Abstract: *This article presents some results of surface hardening (HV) experiment on machining C40 steel on CNC lathe. The experiment was conducted to investigate the effect of cutting mode (cutting volume - S, cutting speed - V and cutting depth - t) according to the experimental design of the center of rotation with 20 experimental points, and then identifying surface hardness for each sample. The experimental data help build the interaction graph of each pair of cutting conditions to the surface hardness. The data are also used to build the regression coefficient showing the relation between the surface hardness and the parameters of the cutting mode . The results show that all parameters S, V, t have a significant influence on HV. Specifically the cut depth t has the greatest influence on HV, followed by the influence of V and S; The interaction effect of the parameter of cutting mode on HV is quite complex. When increasing the value of S, V, t parameters, the interaction between them may increase or decrease HV.*

Keywords: *Cutting mode; surface hardness*

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I. Introduction.

In machining, turning is the most commonly used machining method for machining of various surface types (cylindrical face, conical face, thread surface, shaping face, ...). In a workshop, lathes account for 25 to 35% of the total number of equipment in the cutting workshop while the workload of the turning method accounts for about 40% of the total machining volume.

The quality of the product after turning is evaluated through many parameters including dimensional precision, geometric shape precision, and surface quality. Surface hardness is a parameter of surface quality affecting the workability of the machine parts. Surface hardness of the machine parts depends on many factors including material, cutting tools, cutting mode, and smooth technology. The group of parameters of the cutting mode has a great influence on the surface hardness of the machine parts.

In this study, some results of surface hardening were investigated in C40 steel milling. C40 steel is commonly used in machine construction and particularly in machining.

II. Experimental effect of cutting mode to hardening surface

2.1. Experimental system

2.1.1. Laboratory machine

The machine used in this study is a CNC lathe with the DOOSAN - LYNX220 symbol (Figure 1). The machine has some basic specifications

Fig 1. Lathe DOOSAN - LYNX220

- Maximum workpiece diameter: 320mm.
- Maximum workpiece length: 525mm.

- Movement in X direction: 175mm.
- Z directional shift: 550mm.
- Spindle motor: 11KW.
- Knife holder: 12 knives are automatically changed.

2.1.2. Sample for experiment

The experimental specimen was C40 steel with the length of 150mm, diameter ∅25. Prior to testing, samples were processed with the cutting mode of semi-fining, which is the cut mode of actual production.

2.1.3. Instrumentation

Surface hardness was measured using a JHR-30C gauge (Fig. 2).

Fig 2. Hardness Testing Machines JHR-30C

The machine has some basic specifications as follows:
- Load capacity: (15 ÷ 45) Kgf
- Resolution: 0.1HR.
- Response time: 1-60s.
- Working range: 170mm.
- Automatic measurement range conversion (via PC connection): HRC, HRB, HRA, HV, HK, HBW.

The experiment was carried out with changing cutting mode and the following fixed parameters which were chosen according to their value in published studies on the technology of optics [1], [2], [3].
- Turning tool: using right shoulder blade, cutting piece is hard metal T15K6, with front angle γ = 70, back angle α = 120.
- Coolant solution: emuxil oil 10%, in the form of irrigation.

2.2. Experimental matrices

Experimental design of mixed center of rotation (CCD) was selected in this study. This is the most commonly used experimental design in empirical research [4] and has been used by many scientists in experimental research on machining [5], [6], [7], ...

In a CCD-encoded test, each test variable receives 5 levels: -1, 0, 1 and 2 along the axis (-α and + α) [4]. α is the distance from the center point (level 0) to the point along the axis, determined by the following formula [4]:

$$\alpha = \sqrt[4]{n_F} \quad (1)$$

This is the original experiment score $n_F = 2^k$, when the number of input variables k = 3 then $n_F = 2^3 = 8$. Therefore, $\alpha = \sqrt[4]{n_F} = \sqrt[4]{8} = 1.68$.

The value of the variables at the experimental levels selected according to the studies on [1], [2], [3], [6] are given in Table 1.

Table 1. Value at the levels of the experimental parameters

Parameter	Symbols, units	Experimental levels				
		-1.68	-1	0	1	1.68
Cut Feed	S(mm/rev)	0.07	0.10	0.15	0.20	0.23
Spindle Speed	V(m/min)	15.91	50	100	150	184.09
Step depth	t(mm)	0.12	0,15	0,2	0,25	0.28

For the number of experiments in the matrix: the CCD experiment matrix will have the original experiment, 2k = 2.3 = 6 experiment points along the axis and should select 5 ÷ 6 points for the center experiment (at level 0) [4]. Thus, the CCD matrix for the three input variables with a choice of 6 pilot sites will consist of 20 experimental sites, set up by the Minitab 18 software as shown in Table 2.

Table 2. Experimental matrix form CCD

TT	S	V	t
1	0	0	-1.68
2	-1	1	1
3	0	-1.68	0
4	1	-1	1
5	0	0	1.68
6	1	-1	-1
7	-1	1	-1
8	-1.68	0	0
9	1.68	0	0
10	0	0	0
11	0	0	0
12	0	0	0
13	0	0	0
14	0	0	0
15	-1	-1	1
16	1	1	1
17	0	0	0
18	0	1.68	0
19	1	1	-1
20	-1	-1	-1

2.3. Experimental results

The experiment was carried out in the order of the points in Table 2 with the value of the variables at the level shown in Table 1. At each test site was conducted on three samples of C40 steel. On each sample, hardness at three different points was measured, then the average of consecutive measurements was calculated. The results are shown in Table 3.

Table 3. Experimental results

TT	S	V	t	Hardness (HV)
1	0	0	-1.68	285.99
2	-1	1	1	367.00
3	0	-1.68	0	306.00
4	1	-1	1	353.20
5	0	0	1.68	336.12
6	1	-1	-1	311.02
7	-1	1	-1	312.52
8	-1.68	0	0	324.65
9	1.68	0	0	367.56
10	0	0	0	338.03
11	0	0	0	338.00
12	0	0	0	337.92
13	0	0	0	338.01
14	0	0	0	337.88
15	-1	-1	1	324.12
16	1	1	1	319.00
17	0	0	0	338.00
18	0	1.68	0	336.12
19	1	1	-1	334.12
20	-1	-1	-1	285.24

Minitab 18 software was used to analyze the results in Table 3. The results are presented in Figure 3, Figures 4, 5 and Table 4

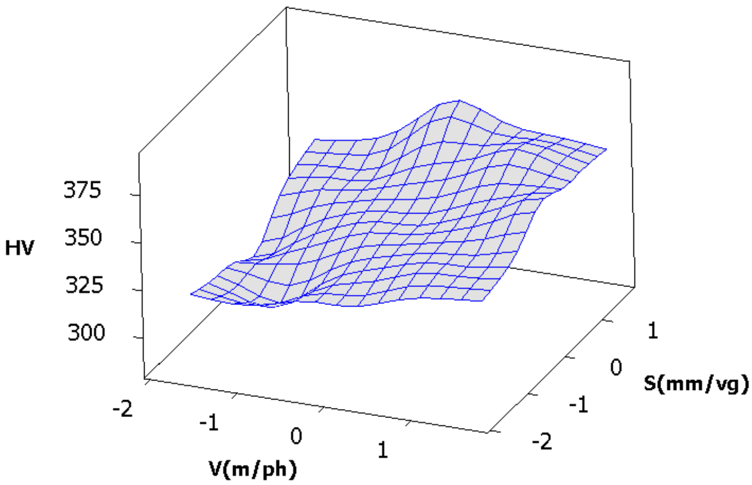

Fig 3. Interactive effects of V and S to HV

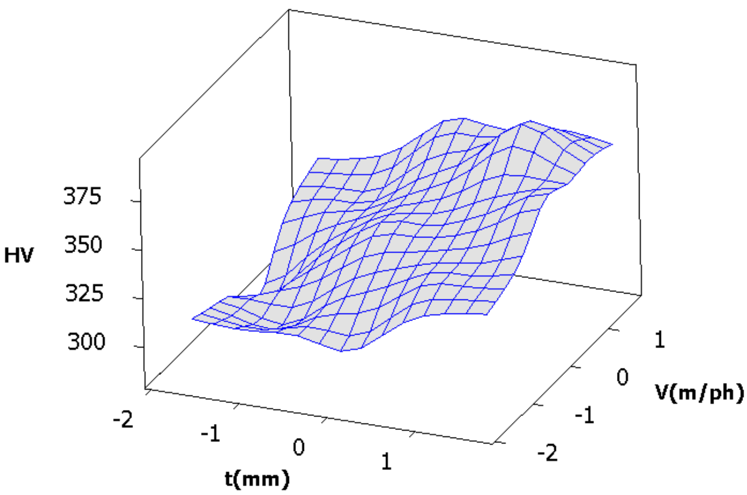

Table 4. Interactive effects of t and V to HV

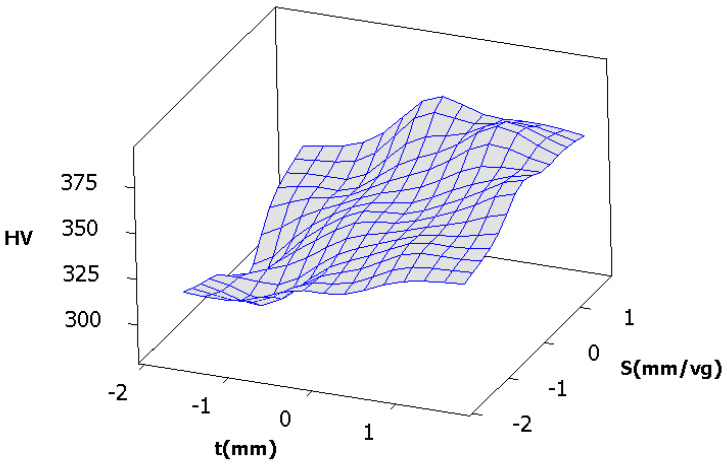

Fig 5. Interactive effects of t and S to HV

Table 4. Analysis results by software Minitab 18

Response Surface Regression: HV versus S(mm/vg), V(m/ph), t(mm)

The analysis was done using coded units.

Estimated Regression Coefficients for HV

Term	Coef	SE Coef	T	P
Constant	338.033	0.008070	41887.879	0.000
S(mm/vg)	12.707	0.005354	2373.243	0.000
V(m/ph)	16.355	0.005354	3054.646	0.000
t(mm)	23.952	0.005354	4473.457	0.000
S(mm/vg)*S(mm/vg)	2.888	0.005212	554.133	0.000
V(m/ph)*V(m/ph)	-1.740	0.005212	-333.826	0.000
t(mm)*t(mm)	-4.209	0.005212	-807.527	0.000
S(mm/vg)*V(m/ph)	-1.012	0.006996	-144.733	0.000
S(mm/vg)*t(mm)	0.788	0.006996	112.570	0.000
V(m/ph)*t(mm)	3.538	0.006996	505.672	0.000

S = 0.0197867   PRESS = 0.0297358
R-Sq = 100.00% R-Sq(pred) = 100.00% R-Sq(adj) = 100.00%

As can be seen from Figures 3, 4, 5 and Table 4:
- All S, V and t parameters have a significant influence on HV (because the probability value P is much smaller than the significance level α, usually $\alpha = 0.05$).
- Through the coefficient of regression (Coef), it is shown that the cutting depth t has the greatest influence on HV, followed by the influence of V and S (since the regression coefficient of t is 23.952 which is higher than the regression coefficients of V and S with the values of 16.355 and 12.707 respectively).
- The pairing of the cutting mode parameters (V * S, V * t and S * t) has a complex impact on HV, which corresponds to the value of the cut mode parameters examined in this study. When increasing the value of the parameters S, V, t, the interaction between them may increase or sometimes decrease the value of HV. For example, the effect of t on HV is greater than that of V but the effect of S *t on HV is smaller than that of of V * t.

Table 4 illustrates the relationship between HV and cutting parameters:

$$HV = 338{,}033 + 12.7069.S + 16{,}3553.V + 23{,}9519.t$$
$$+2{,}8883.S^2 - 1{,}7399.V^2 - 4{,}2089.t^2 - 1{,}0125.S.V + 0{,}7875.S.t + 3{,}5375.V.t \quad (2)$$

III. Conclusions

The experimental study using CCD test matrix was carried out to investigate the effect of cutting mode on the surface hardening when turning C40 steel mills. the following conclusions are drawn:
1. All parameters S, V, t have a significant influence on HV. The cutting depth t has the greatest influence on HV, followed by the degree of influence of V and S.
2. The effect of interaction of cutting parameters on HV is quite complex. When increasing the value of S, V, t parameters, the interaction between them can increase or sometimes decrease the value of HV.

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