Experimental Investigation of the influence of the Cutting Conditions on the Surface Roughness in Hole turning the SCM400 Steel

Nguyen Hong Son, Hoang Xuan Thinh, Nhu-Tung Nguyen, and Do Duc Trung

Abstract—This paper presented the experimental results about investigation of the influence of the cutting conditions on the surface roughness when hole turning the SCM400 steel. Three cutting parameters that have mentioned in this study included cutting speed, axial feed rate, and cutting depth. The experimental design was chosen following the orthogonal matrix and added the center experiment points. The analyzed results show that the axial feed rate has the greatest degree of impact on the surface roughness. And, the second and third factors have negligible effect on the surface roughness that are cutting speed and cutting depth, respectively. These results will guide the determination of the cutting conditions in order to machining the part surface with roughness that was ensured the setting requirement. Finally, the directions for further research were also mentioned in this paper

Index Terms—Cutting Condition, Hole Turning, SCM400 Steel, Surface Roughness.

I. INTRODUCTION

In machining processes, turning is the machining method that is used very commonly. In a factory, the number of lathe machines is usually about 25 ÷ 35% of the total tool-machine. The amount of work that was done by turning method is about 40% of the total machining process volume [1].

For hole surfaces with the high requirement of accuracy, the common methods are used that are the inner grinding, grinding, boring, sharpening, turning, etc. In particular, turning is arguably the most popular method, allowing processing of many different diameter sizes and this method is suitable for many types of production than the rest of the methods. Research on turning technology has been carried out by many scientists, many of whom have focused on controlling the turning processes to machining the part surfaces with the small surface roughness.

Muhammad Munawar et al. [2] conducted an experimental study on grinding the AISI 1018 steel when changing parameters including the rake angle of the cutter, radius of the cutter nose, cutting speed, feed rate, and cutting depth. Their research has shown that with a knife with a positive rake angle and a small cutter nose radius, the machining surface had a small roughness. In addition, they also commented that if a large feed rate and a low cutting speed that created the machining surface with a small roughness.

Yves Beauchamp et al. [3] experimentally investigated the effect of cutting conditions on the surface roughness when hole turning the AISI 1026 steel by two types of tool with different tool nose radius and tool length. The two values of the tool nose radius and the two values of the tool length that were used are 0.3969mm, 0.7938mm and 65.09mm, 95.25mm, respectively. Then, they concluded that using a cutting tool with a small length will reduce surface roughness compared to a large length cutting tool; Cutting speed, feed rate, and tool nose radius have little effect on the surface roughness.

Shen-Jenn Hwang and Yi-Hung Tsai [4] conducted an experimental study on the hole turning process of the 15-5PH stainless steel by using TiAlN cutting insert when changing the value of cutting speed, feed rate, cutting depth, and the concentration and temperature of the cool lubricant. Then they came up with some conclusions: (1) all of these parameters have a significant effect on the surface roughness; (2) in order to machining the part surface with the smallest roughness, the optimal value of the coolant concentration parameters, the coolant temperature, the feed rate, the cutting depth and the cutting speed were 25%, 220C, 0.25 mm/rev, 0.15 mm and 16 m/min, respectively.

K. Venkata Rao et al. [5] investigated the effect of cutting mode parameters (cutting speed, tool load) on the vibrations of workpiece, surface roughness, and the removal efficient when machining the AISI1040 steel with a piece of PVD coated tungsten (PVD coated tungsten carbide) with two values of nose radius of 0.4 mm (piece of DNM150604) and 0.8 mm (piece of DNM150608). When considering only the surface roughness criteria, they concluded that the feed rate is the most influential parameter.

However, in another study, K Venkata Rao et al. [6] also investigated the effect of cutting mode on the surface roughness and vibrations of the part when turning the AISI 1040 steel with a piece of PVD coated (PVD coated tungsten carbide), then they commented that in cutting mode parameters, the cutting speed has the greatest effect on surface roughness.

S.K. Choudhury et al [7] conducted the experiments on the middle carbon steel to determine the influence of some technological parameters on the surface roughness. The

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technological parameters adjusted in each of their experiments include the cutting speed, cutting depth and tool diameter. The results of their study indicated that the cutting depth has the greatest effect on the surface roughness, followed by the degree of influence of the cutting speed. The tool diameter has a smaller degree of the influence on the surface roughness than the degree of the influence of the cutting speed and feed rate.

Through some of the studies mentioned above, the studies of hole turning processes have been done by many scientists. In most of these studies, the authors focused on the study of technological conditions (cutting mode parameters, technological system parameters, etc.) to machine the detailed surface with a small roughness. However, in response to different machining conditions, especially, when considering the type of workpiece materials, the degree of influence of the cutting conditions on the roughness is very different. This suggests that, in order to machine the part surface with small roughness, it is necessary to conduct the experimental research in each specific machining condition.

In this paper, the experimental research is conducted to investigate the influence of cutting speed, feed rate, and cutting depth on the surface roughness on hole turning process of the SCM400 steel.

II. EXPERIMENTAL METHOD
A. The workpiece material
Experimental workpiece material is SCM400 steel. This is a type of material that is widely used in manufacturing the gears, pump shafts, hand tools, the parts in the fields of thermoelectricity, oil and gas industry, marine, etc. Before performing the experiments, the workpieces were heat treated to reach 50÷52 HRC hardness. The properties of workpiece are the density: 7.85 kg/cm3, the thermal expansion coefficient: 12.2 μm/m, and the thermal conductivity: 42.6 W/mK. The workpieces dimension are the outer diameter of 75 mm, the inner diameter of 52 mm, and the length of 20 mm as shown in Fig. 1. The chemical compositions of the SCM400 steel are listed in Table I.

![Fig. 1. Experimental sample](Image)

**Table I. Chemical Composition of SCM400 Steel**

<table>
<thead>
<tr>
<th>Com.</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>Cr</th>
<th>Mo</th>
<th>P</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.38~0.43</td>
<td>0.15~0.35</td>
<td>0.6~0.85</td>
<td>0.9~1.2</td>
<td>0.15~0.3</td>
<td>≤0.03</td>
<td>≤0.03</td>
</tr>
</tbody>
</table>

B. Cutting Insert
The cutting inserts were used in this study that were coated by PVD coating technology. The cutting insert has the symbol DNC250 1EA19C28 0.4R. This is a product of KORLOY company (Korea). This type of cutting insert is widely used in hard turning technology (processing materials after heat treatment).

C. Set-Up Machine and Surface roughness Tester
Experiments were performed on the Doosan Lynx 220L CNC lathe at Hanoi Industry of University. The detail is illustrated in Fig 2.

![Fig. 2. Testing Machine](Image)

The surface roughness Tester is TESA RUGOSURF 10 Roughness Gauge (Fig. 3). At each experimental, three samples were tested, each sample was measured the surface roughness three times, the average of surface roughness at each experiment was used to analysis the influence of cutting conditions on surface roughness.

![Fig. 3. Setting of surface roughness measurement](Image)

D. Experimental plan
In this study, in order to investigate the influence of cutting mode parameters including the cutting speed, feed rate, and cutting depth on the surface roughness, the experimental plan was built in the form of orthogonal matrix that is $2^k$ type (with k is the number of input parameters, k = 3), then adding 3 experiments at the central points.

**Table II. The Experimental Matrix**

<table>
<thead>
<tr>
<th>No</th>
<th>Code factors</th>
<th>Machining parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>v</td>
<td>f</td>
</tr>
<tr>
<td>1</td>
<td>-1</td>
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<tr>
<td>2</td>
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</tr>
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</tr>
<tr>
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</table>

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The experiment matrix with 11 experimental positions was built using Minitab 16 software. After being rearranged in the standard form, the experiment matrix is presented in Table II. All experiments were carried out under the condition of using cool lubricant Dromus B, and the sprinkler method with a flow of 125 liters/min.

### III. RESULTS AND DISCUSSIONS

The experimental results were investigated and listed in Table III. Using Minitab 16 software to analyze these experimental results, with the significance level $\alpha$ was chosen by 0.05, the influence of cutting parameters on the surface roughness was determined and shown in Fig. 4, Fig. 7.

<table>
<thead>
<tr>
<th>No</th>
<th>Code values</th>
<th>Machining parameters</th>
<th>$R_a (\mu m)$</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>$v$</td>
<td>$f$</td>
<td>$t$</td>
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</table>

The Fig. 4 showed that with three cutting parameters (cutting speed, feed rate, depth of cut), the feed rate has most significant influence on the surface roughness. The second parameter that effects on the surface roughness was depth of cut. The cutting speed and depth of cut as well as the interaction between parameters have little influence on the surface roughness.

The effect of cutting parameters on the surface roughness was described in Fig. 5 to Fig. 7. It is very clear that surface roughness increase with increasing of feed rate. This result is similar the result of the change in the surface roughness that were mentioned in the several works such as [5]. This trend can be explained as following: When the feed rate increases, that makes the un-deformed chip thickness increasing. Besides, the un-deformed chip thickness is directly proportional to the surface roughness. So, that makes the surface roughness increasing.

The surface roughness values exhibited increasing tendency with increasing of axial depth of cut from 0.05 mm to about 0.175 mm. But, when the axial depth of cut increases from 0.175 mm to about 0.3 mm, the surface roughness values decreases. In this study, the effect of cutting speed on the surface roughness was quit small.

![Fig. 4. Pareto graph about the effect of cutting parameters and the interaction between them on the surface roughness](image)

![Fig. 5. Effect of the interaction between f and v on the surface roughness](image)

![Fig. 6. Effect of the interaction between t and v on the surface roughness](image)

![Fig. 7. Effect of the interaction between t and f on the surface roughness](image)

**IV. CONCLUSIONS**

In this study, an experimental method was carried out to investigate the influence of cutting conditions on the surface roughness. Depending on the analyzed results, the conclusions of this study can be drawn as follows.

- The feed rate and depth of cut has a great influence on the surface roughness. The cutting speed affects not much on the surface roughness.
- When increasing the value of the feed rate, the surface roughness will increase.
- The surface roughness increases with increasing of axial depth of cut from 0.05 mm to about 0.175 mm. The surface roughness decreases when the axial depth of cut increases from 0.175 mm to about 0.3 mm.
- Based on the obtained results from this study, the determination of the optimal value of the cutting mode parameters to machining the part surface with the requirement of roughness that will be the next researches.

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