

## **THE INFLUENCE OF THE DEPTH OF CUT ON THE TWO- WAY APPLICATION OF CUTTING FLUIDS**

### **ABSTRACT**

The depth of cut is one of the important parameters of machining. It influences a great number of factors of machining like the surface finish, the tool wear, the temperature/heat, energy/power consumption etc. It is of course obvious that the depth of cut affects the rate of heat generated and consequently the temperature in various degrees depending on the conditions of machining, the material etc. So, in order to reduce the negative effect of high temperature which is as a result of the large heat generated due to high rate of friction at the workpiece – tool interface, cutting fluids and lubricants are used. This research focused on the effect of the depth of cut on the two-way application of cutting fluids. The angle of feeding was varied from 30° to 180°. The feed rate was 0.75 mm/rev and the speed was 125 rpm. It was established that the two-way application of the cutting fluids was most effective in terms of the surface finish when the depth of cut was 2 mm and at angle of 150°. In other words, the lowest surface roughness (8.41 µm) was obtained at this angle and depth of cut. In fact the lowest surface roughness (highest surface quality) and temperature were achieved under all the feeding angles except angle 30° and when the depth of was 2 mm. However, the tool wear values were lowest when the depth of cut was 1.0 mm as compared to other values of depth of cut used. Therefore, the recommended values for

the depth of cut are 1 mm and 2 mm in terms of the surface quality and tool wear obtained respectively.

**KEY WORDS:** Surface Roughness, Tool Wear, Temperature, Feeding Angle, Depth of Cut.

## 1.0 INTRODUCTION

Out of tolerance in cutting processes can produce a number of problems like surface finish and geometrical deformation [1-2].

Depth of cut is one the cutting parameters that influence the quality of the surface finish of the work piece, the rate of the tool wear and the heat generated (temperature) at the cutting zone. The temperature at the cutting zone is factor of the friction at the workpiece – tool interface. The higher the friction, the higher the heat generated and consequently the higher the temperature. Increase in the depth of cut usually lead to increase in the friction the tool-workpiece interface.

The depth of cut is thickness of the layer of metal removed in one cut or pass measured in a direction perpendicular to the machined surface [3].

Cutting speed, feed and depth of cut are considered to be the main independent variables in cutting processes. Their increase will lead to increase in the cutting force, power and temperature and consequently leads to high rate of tool wear and poor surface finish. [4, 5]

Therefore, in other to reduce the negative effect of the temperature, cutting fluids/lubricants are applied.

There are various cutting fluids (CF) available such as the emulsion mineral oil, synthetic [6-7], but the choice of particular CF depends on a number of factors like the material of workpiece, the operation type, etc. [8]. The effectiveness the CF depends to a large extent on

the method of its feeding. The method of CF feeding employed for this research work was a two-way application of cutting fluids method [9].

Nevertheless, variation in the depth of cut will affect the surface finish, the tool wear (tool life) and surface integrity, the temperature at cutting zone irrespective of the type of CF used and the method of application. According SO Yakubu and CO Izelu [9], the two-way application of cutting fluid was found to be effective in turning processes. Therefore, it was considered important to investigate how the depth of cut would influence the effectiveness of the two-way application of cutting fluids in terms of the surface finish the tool wear and temperature.

## 2.0 MATERIALS AND METHOD

### 2.1 Materials and equipment

The material used for the investigation was a medium carbon steel. Its chemical composition is presented in the table 2.1 below. The cutting fluid was soluble oil mixed with water to form a milky colour. The cutting tool used was cemented carbide tool insert type T107 and grade YG8. The equipment used were the non contact temperature measuring apparatus, the centre lathe machine model XL 400, digital vernier caliper, surface roughness tester type SR16.

Table 2.1 – Chemical Composition of the workpiece

| MATERIAL            | ELEMENT, % |      |      |      |       |      |      |      |      |      |      |      |
|---------------------|------------|------|------|------|-------|------|------|------|------|------|------|------|
| Medium Carbon Steel | C          | Si   | Mn   | P    | Fe    | Ni   | Cr   | Mo   | Cu   | V    | Pb   | Al   |
|                     | 0.38       | 0.22 | 0.49 | 0.01 | 98.73 | 0.03 | 0.04 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 |

64

## 65 2.2 Experimental Procedures

66 The experiment was conducted on lathe machine model XL400. The experimental set up is  
67 shown in figure 2.1. The experimental test was carried out under the following process  
68 variables (conditions): feed rate = 0.75, Speed of cutting = 125 rpm, Depth of cut was within  
69 the range of 1 – 2 mm and the CF feeding angles were from 30° – 180°. Each experiment was  
70 conducted for 1 hour 40 minutes (100 minutes) at an interval of 20 minutes. The parameters  
71 determined were the surface roughness, tool flank wear and the temperature at the cutting  
72 zone. After every 20 minutes the average values of readings taken from three different points  
73 on the workpiece and the tool were recorded. The surface roughness values were measured  
74 with an Insize surface roughness tester model ISR-16 at three different points on the  
75 machined surface and the average value was recorded. The Tester was placed parallel on the  
76 workpiece surface and then the power button was put on and the stylus travelled a certain  
77 distance giving the readings of the surface texture. The tool flank wear was measured with  
78 the aid of an Insize Digital Vernier Caliper Model SR44. The reading was conducted thus:  
79 the initial and the final heights were taken and the differences were recorded. This was  
80 repeated thrice and the average value was recorded as the tool flank wear after every 20  
81 minutes. The overall averages after machining for 1 hour 40 minutes i.e. 100 minutes were  
82 recorded in the tables 3.1 – 3.6. The temperature was measured with the help of a German  
83 non contact temperature measuring instrument (Therma Twin) model TN408LC. The  
84 temperature was measured during the operation at three different points on the workpiece and  
85 at three different positions of the cutting zones. Thereafter the average values were recorded  
86 after every 20 minutes of machining. The grand averages after every 100 minutes of

machining were recorded in the 3.1 to 3.6 respectively. The temperature was measured in Degree Celsius.

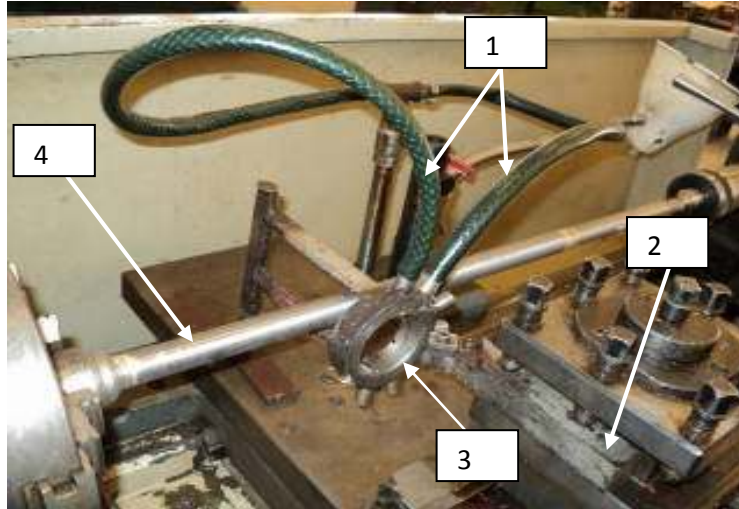


Fig.2.1 Experimental Set Up

1 – CF hoses, 2 – Cutting Tool, 3 – Two-way CF feeding Device, 4 – Workpiece

However, presented in 3.1 – 3.6 are the average values of the measured parameters at the end of one (1) hour forty (40) minutes machining.

## 3.0 RESULTS AND DISCUSSION

### 3.1 Results

Conditions of Machining: Feed ( $f$ ) = 0.75mm, Spindle Speed ( $V$ ) = 125rpm, Depth of Cut = 1 – 2.0 mm, CF feeding angles =  $30^\circ$  –  $180^\circ$

102 Table 3.1. Results of the surface finish, tool wear and temperature at a feeding angle 30°

| Depth of Cut, mm | Feeding Angle = 30°        |               |                 |
|------------------|----------------------------|---------------|-----------------|
|                  | Surface Roughness (Ra), µm | Tool Wear, mm | Temperature, °c |
| 1.0              | 9.63                       | 0.03          | 25.36           |
| 1.5              | 11.55                      | 0.43          | 31.83           |
| 2.0              | 9.79                       | 0.07          | 27.50           |

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104 Table 3.2. Results of the Surface Roughness, Tool Wear and Temperature at Feeding angle 60°C

| Depth of Cut, mm | Feeding Angle = 60°        |               |                 |
|------------------|----------------------------|---------------|-----------------|
|                  | Surface Roughness (Ra), µm | Tool Wear, mm | Temperature, °c |
| 1.0              | 9.91                       | 0.035         | 27.36           |
| 1.5              | 11.08                      | 0.38          | 31.63           |
| 2.0              | 8.63                       | 0.06          | 26.11           |

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106 Table 3.3. Results of the Surface Roughness, Tool Wear and Temperature at Feeding angle 90°C

| Depth of Cut, mm | Feeding Angle = 90°        |               |                 |
|------------------|----------------------------|---------------|-----------------|
|                  | Surface Roughness (Ra), µm | Tool Wear, mm | Temperature, °c |
| 1.0              | 9.57                       | 0.04          | 27.03           |
| 1.5              | 11.29                      | 0.34          | 31.48           |

|     |      |      |       |
|-----|------|------|-------|
| 2.0 | 8,76 | 0.07 | 25.81 |
|-----|------|------|-------|

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108 Table 3.4. Results of the Surface Roughness, Tool Wear and Temperature  
109 at Feeding angle 120°C

| Depth of Cut, mm | Feeding Angle = 120°          |               |                 |
|------------------|-------------------------------|---------------|-----------------|
|                  | Surface Roughness<br>(Ra), µm | Tool Wear, mm | Temperature, °c |
| 1.0              | 9.36                          | 0.04          | 27.20           |
| 1.5              | 10.96                         | 0.39          | 31.30           |
| 2.0              | 8.92                          | 0.05          | 26.25           |

110

111 Table 3.5. The results of the Surface Roughness, Tool Wear and Temperature at Feeding angle  
112 150°C

| Depth of Cut, mm | Feeding Angle = 150°          |               |                 |
|------------------|-------------------------------|---------------|-----------------|
|                  | Surface Roughness<br>(Ra), µm | Tool Wear, mm | Temperature, °c |
| 1.0              | 9.24                          | 0.04          | 27.02           |
| 1.5              | 10.68                         | 0.33          | 29.73           |
| 2.0              | 8.41                          | 0.05          | 26.11           |

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116 Table 3.6. The results of the Surface Roughness, Tool Wear and Temperature at Feeding angle  
117 180°C

| Depth of Cut, mm | Feeding Angle = 180°          |               |                 |
|------------------|-------------------------------|---------------|-----------------|
|                  | Surface Roughness<br>(Ra), µm | Tool Wear, mm | Temperature, °c |
| 1.0              | 9.29                          | 0.04          | 26.08           |
| 1.5              | 10.25                         | 0.44          | 31.83           |
| 2.0              | 8.53                          | 0.06          | 26.20           |

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### 119 3.2 Discussion

120 The effect of the depth of cut on the two-way application of cutting fluids was quantified with  
121 quality of the surface finish in terms of the surface roughness, the tool wear rate (tool life) and  
122 the temperature. The depth of cut was varied from 1.0 mm to 2.0 mm while the CF feeding angle  
123 was also varied from 30° to 180°.

124 Irrespective of the cutting fluids (CF) feeding angle, it was established that as the depth of cut  
125 was increased from 1.0 mm to 1.5 mm, the surface roughness, tool wear and the temperature  
126 increased. Definitely as the temperature at the cutting zone rose, it was expected that it would  
127 lead to a rise in the tool wear rate and consequently the surface roughness. In other words the  
128 tool life and the surface quality of the machined workpiece decreased.

129 However, when the depth of cut was increased from 1.5 mm to 2.0 mm, interesting results were  
130 obtained. The obtained values for the surface roughness, the tool wear and the temperature were  
131 lower than those got when the depth of cut was 1.0 mm and 1.5 mm respectively for all the  
132 angles of CF feeding. This was particularly obvious for the surface roughness values. In fact the

lowest surface roughness values were achieved when the depth of cut was 2.0 mm and it was 8.41  $\mu\text{m}$ . But the situation was not exactly the same in terms of the tool wear rate and the temperature for the same depth of cut. The obtained values for tool wear at this depth of cut (i.e. 2.0 mm) for all the angles of CF feeding were only lower than those obtained when the depth of cut was 1.5 mm. However, the tool wear values were higher than those got when the depth of cut was 1.0 mm under any given angle of CF feeding.

On the contrary, temperature decrease was observed under 2.0 mm depth of cut as compared to 1.0 mm when the angle of CF feeding was  $60^\circ$ ,  $90^\circ$ ,  $120^\circ$  and  $150^\circ$  respectively. The temperature was only higher when the feeding angle was  $30^\circ$  and  $180^\circ$  (tables 3.1 and 3.6) respectively. But comparing the temperature values to those obtained when the depth of cut was 1.5 mm, the values were all lower irrespective of the CF feeding angle.

It is worthy to note that the lowest surface roughness values (the highest surface quality) were obtained when the CF feeding angle was  $150^\circ$  for all the three values of the depth of cut (1.0, 1.5, & 2.0 mm). The only exception was when the depth of cut was 1.5 mm and the feeding angle was  $180^\circ$ . The same thing applied to the tool wear values except when feeding angles were  $30^\circ$  and  $60^\circ$  respectively and the depth of cut was 1.0 mm.

The cutting zone temperature did not change significantly except when the depth of cut was equal to 1.5 mm. However, relatively low temperature was achieved under the depth of cut equal to 2.0 mm. This may be due to the absence of self excited vibration and/or any other vibrations which has facilitated a very smooth turning process. It may also have been attributed to a better penetration of cutting fluids at the cutting zone which led to better cooling and consequently a reduction in the temperature.

#### 4. CONCLUSIONS

The depth of cut influenced the performances of the two-way application of cutting fluid in different ways. Based on the values of the depth of cut used, the following conclusions were deduced from the analysis of the results:

- i. The surface roughness and the tool wear and the temperature values were relatively the same when the depth of cut was 1.0 mm and 2.0 mm respectively. Whereas the highest tool wear, surface roughness and temperature values were recorded when the depth was 1.5 mm irrespective of feeding angle. In other words, the performance of the two-way application of the CF was at its lowest when the depth of cut was 1.5 mm.
- ii. Tool wear rate was very high at the depth of cut equal to 1.5 mm compared to the other values of the depth of cut irrespective of the feeding angle. The differences in the values of the surface roughness, tool wear and the temperature when the depth of cut was 1.0 and 2.0 mm in comparison with those obtained at the depth of cut equal to 1.5 mm for any feeding angle were high. For instance, the surface roughness, the tool wear and the temperature were  $9.63\text{ }\mu\text{m}$ ,  $0.03\text{ mm}$  and  $25.36^{\circ}$  respectively when the feeding angle was  $30^{\circ}$  and depth of cut was  $1.0\text{ mm}$  as against  $11.55\text{ }\mu\text{m}$ ,  $0.43\text{ mm}$  and  $31.83^{\circ}$  respectively when the depth of cut was  $1.5\text{ mm}$  for the same feeding angle.
- iii. The minimum negative effect of the depth of cut on the effectiveness of the two-way application of the cutting fluids was achieved when the feeding angle was  $150^{\circ}$ . All the three determined factors (surface roughness, tool wear & temperature) were at their lowest at this angle.

iv. The cutting zone temperature did not change significantly except when the depth of cut was equal to 1.5 mm. However, relatively low temperature was achieved under the depth of cut equal to 2.0 mm. This may be due to the absence of self excited vibration and/or any other vibrations which has facilitated a very smooth turning process. It may also be attributed to a better penetration of cutting fluids at the cutting zone which led to better cooling and consequently a reduction in the temperature.

v. The lowest surface roughness value was achieved when the depth of cut was 2.0 mm and the feeding angle was  $150^{\circ}$ . However, the lowest tool wear and temperature values were got when the depth of cut was 1.0 mm and the feeding angle was  $30^{\circ}$ .

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