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# Design and Construction of a Cutting Fluid Two-Way/Multi-Feeding Device for Turning Operation

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## Authors' contributions

*This research work was carried out in collaboration with author COI. Author SOY conceived the idea, designed the study and managed the literature searches. He performed the experiments and statistical analysis. He also wrote the first draft of manuscript. Author COI did the construction of the device and assisted in the design of the study. The two authors wrote the protocol together. All the authors read and approved the final manuscript.*

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## ABSTRACT

The effectiveness of a Cutting Fluid (CF) depends to a large extent on the method of its feeding. Therefore, a new device was developed to feed cutting fluids to the cutting area under lathe machining and specifically for turning process. The device can be used as a two-way or multi CF feeding mechanism depending on the number of nozzles used simultaneously for the application of the CF to the cutting zone. The material used for the construction of the device is low carbon steel, except the nozzles and the nozzle base that were made from brass. The device was tested as a two-way cutting fluid feeding mechanism to apply CF (soluble oil) to the cutting zone during the turning of high carbon steel material with a tungsten carbide cutting tool. The experiments were conducted on centre lathe machine model XL400. The results of the experiment indicated that the two-way application of CF is more effective in terms of its reduction in the tool wear, surface roughness and temperature as compared with the standard one-way application of CF. The average values of surface roughness (Ra), the Tool wear ( $\lambda$ ) and Temperature (T)

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were 8.62 $\mu$ m, 0.12mm and 27.12 $^{\circ}$ C respectively for two-way application of CF as against 9.67 $\mu$ m, 0.15mm and 30.48 $^{\circ}$ C for standard one-way application of CF. In other words the surface quality was increased by 11%, the tool life was prolonged approximately by 20% and the temperature was reduced by 11% with the two-way application of CF. Thus, the advantage of a two-way CF feeding mechanism over the standard one-way was ascertained. Dry Turning was also conducted for comparison purpose and naturally, the two-way application of CF showed tremendous advantage over the dry turning for the three parameters (Temperature, Surface Roughness and Tool wear) investigated. The temperature, Surface Roughness and Tool Wear for Two-way application of CF were 27.12 $^{\circ}$ C, 8.62 $\mu$ m, and 0.12mm as against 50.84 $^{\circ}$ C, 29.25 $\mu$ m and 1.24mm for dry turning respectively.

*Keywords: Cutting Fluid (CF); two-way application of CF; one-way application CF; surface roughness; tool wear; CF feeding; nozzle.*

## 1. INTRODUCTION

It is a well known fact that lathe machining, turning in particular, is accompanied with high temperature as a result of a lot of the heat generated [1,2]. High temperature causes a high rate of tool wear and subsequently may lead to its frequent replacement and poor surface finish of the machined work piece. Therefore, cutting fluids/lubricants (CF) are usually applied to reduce the temperature and friction at the cutting – workpiece interface which thereby prolongs the tool life and improve surface finish.

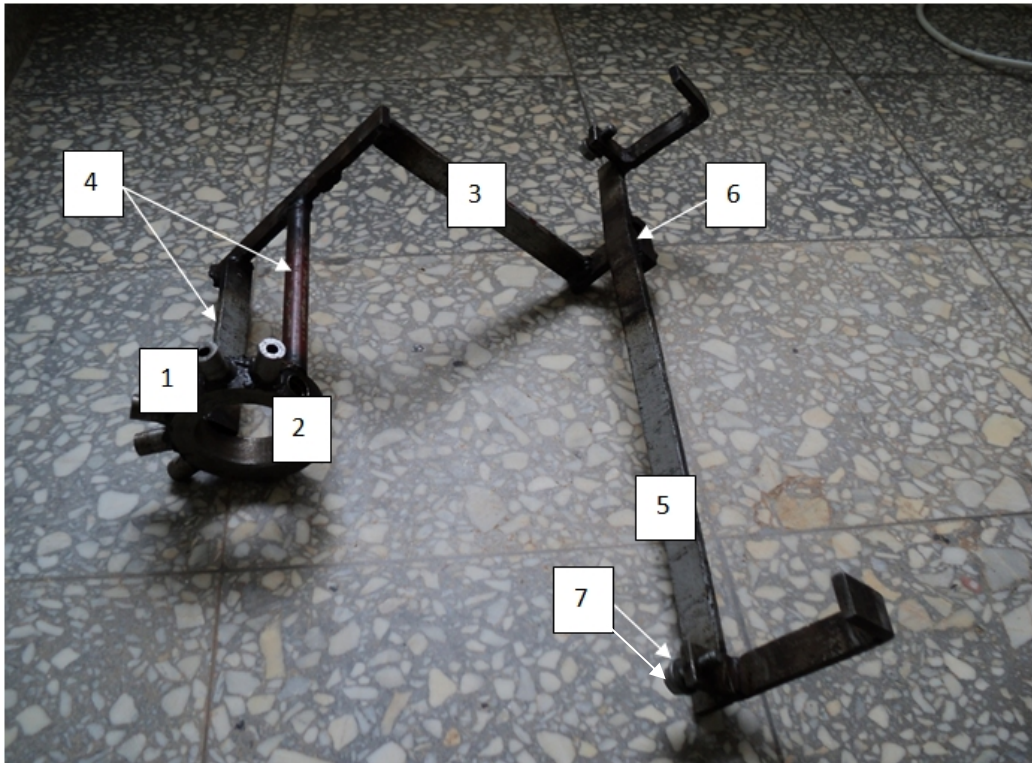
The traditional method of feeding the cutting fluids (CF) is one (vertical) way. That is, the CF feeding device traditionally has only one nozzle through which the CF is fed to the cutting zone. However, some other metal cutting machine tools possess multi-CF feeding mechanisms. An example of such machine tools is the milling machine [3,4]. Investigations also revealed that the application of Ionized Gaseous Medium (IGM) as CF from a distance of about 40mm to the cutting zone is effective in reducing the temperature of the cutting zone and cutting forces [5].

Nonetheless, there is little or no literature available on two-way/multiple-way application of CF in metal cutting, most especially in lathe machining processes. Thus, this was the reason for carrying out this research.

## 2. MATERIALS AND METHODS

The device is presented in the Fig. 1. below.

The material selected for the design and construction of the device was commercial low carbon steel. The reason for this choice was that low carbon steel is readily available and comparably cheaper than other materials. Moreover, it served the purpose for which it is meant for. i.e. feeding the cutting area with CF. The material used for the nozzle and its base was brass. This was, because brass possesses higher corrosion resistance than steel. A hole of 4.5mm diameter (Fig. 7) was drilled through the nozzle. The bolts, washers and nuts 7 were standard parts purchased. The nozzles were inserted into another brass material of cylindrical shape (Nozzle Base) to the depth of 8mm and then epoxy was used to rigidly fix them and seal the surface. The hanger was made from low carbon steel material also. The nozzle is illustrated in Fig. 6 below.



**Fig. 1. Cutting Fluid two-way/multiple feeding device for Turning Processes**

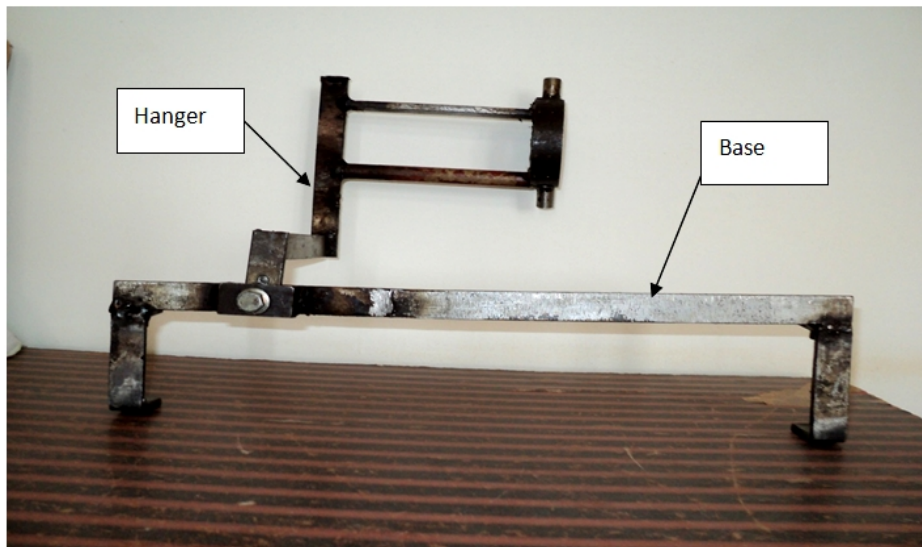
1- Nozzles, 2-Nozzle holder, 3- L- Shape hanger, 4- Bars (connecting the nozzle holder to the hanger), 5- Base of the hanger, 6 – Flange (movable along the hanger base), 7- Bolts, Nuts and Washers

## 2.1 Device Construction and Component Description

- **The nozzles** 1 is made of brass and positioned at angle  $30^\circ$  to each other (Fig.7). Each nozzle is 12mm diameter and 20mm length. A hole of 4.5mm diameter was made through the nozzle to a depth of 30mm i.e. 10mm into its base. The hole was made through the whole length of the nozzle (i.e. a through hole).
- **The nozzle base/holder** 2 is the cylindrical component of the device which has 77mm outer diameter and 52mm internal diameter. That is, the thickness of the hollow cylinder was 12.5mm while its width was 20.5mm. A 13mm diameter hole was bored into the cylindrical base to a distance of 8mm into which the nozzle was inserted. A hole of 3mm diameter was drilled at an inclined angle through the cylinder from a depth of 4.5mm from where the first 13mm diameter bored hole ended. A cross section of this is presented in Fig.7.
- **The hanger and base** 3 & 5 were made of low carbon steel. The hanger was welded to the base which was fixed to the tool post with the aid of bolts and nuts. For easy adjustment of the nozzle hanger to facilitate cross (transverse) movement of the nozzle, a groove was bored on one side of the hanger base 5 and with the aid of the flange 6, the nozzle hanger is moved freely along the bore groove on hanger base.



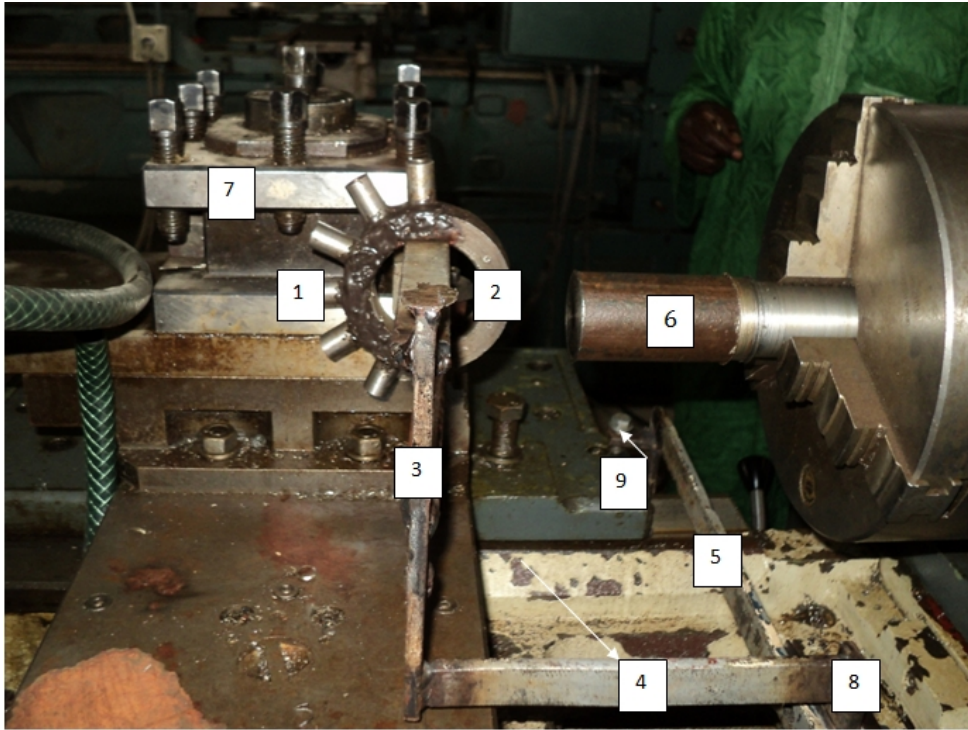
**Fig. 2. Nozzles and nozzle holder**



**Fig. 3. The hanger and its base**

## **2.2 Testing of Device**

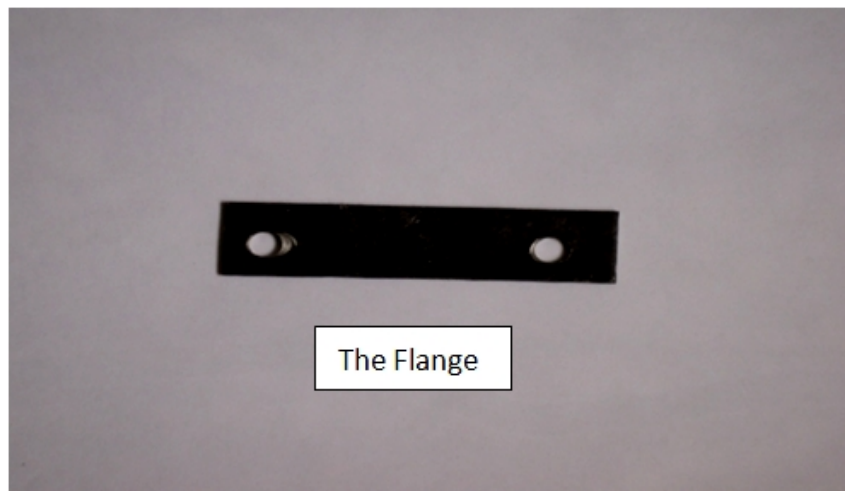
The efficiency of the device was tested on lathe machine. The experimental set up was as shown in Fig. 4.



**Fig. 4. Experimental set up**

1 – Nozzles; 2 – Nozzle holder; 3,4 – L- Shape hanger; 5 – Hanger base; 6 – Work piece; 7 – Tool post; 8 – Flange; 9 – Bolts and nuts

The experiment was conducted under the following conditions: Cutting speed (Spindle speed) = 180 rpm, Depth of cut = 1.5mm, Feed rate = 0.75mm/rev, angle of CF feeding = 30°



**Fig. 5. Flange**

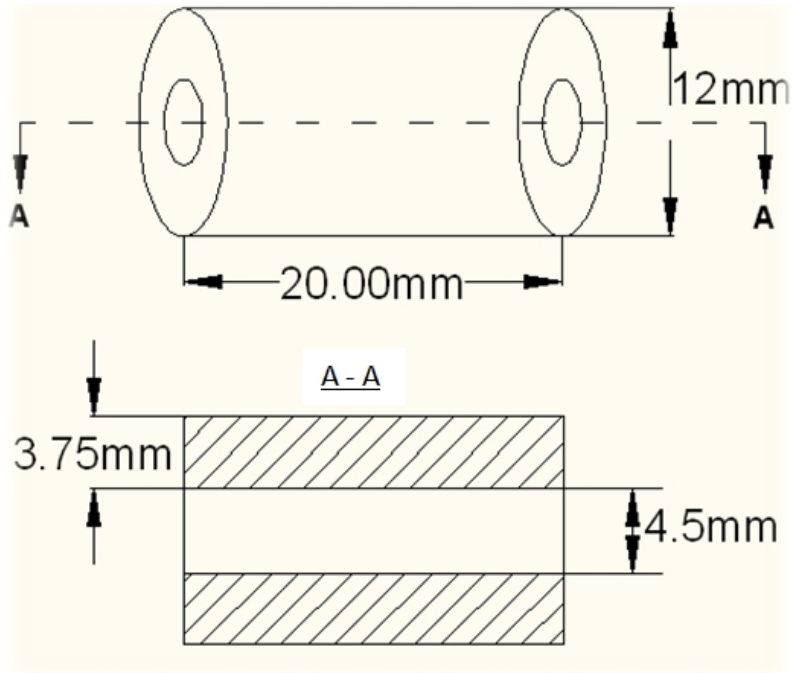


Fig. 6. Nozzle and its cross section

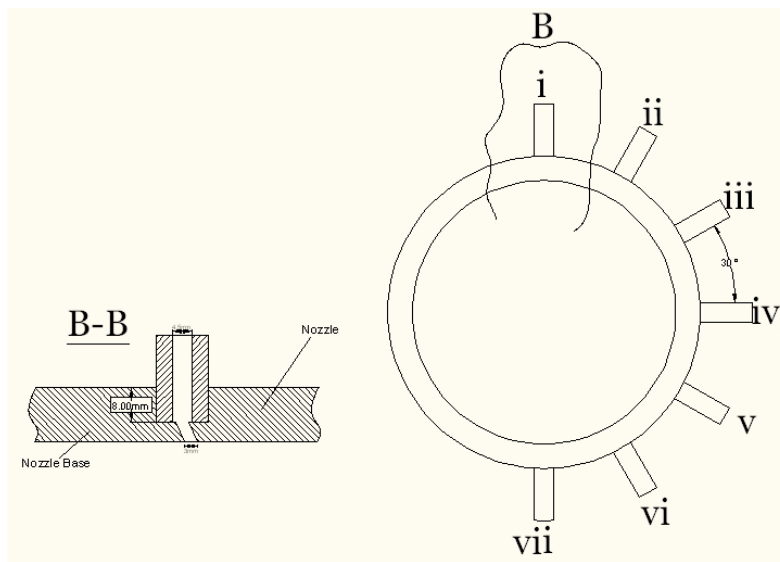


Fig. 7. Cross section of the nozzle and its holder

*i to vii – Nozzles; Nozzle i is the standard one-way CF application; combination of nozzles i & ii, i & iii, i & iv etc forms the two-way CF application*

The experiment was conducted on lathe machine model XL400. The quantity of the cutting fluid (soluble oil) fed through the standard one-way device to the cutting zone was the same with the quantity that was passed through the two-way device.

The experimental test was carried out under the following process variables (conditions): depth of cut = 1.5mm, speed of cutting = 180 rpm and the feed rate = 0.75mm. The time for the experiment was within the range of 20 – 120minutes. The parameters determined were the surface roughness, tool wear and the temperature at the cutting zone.

The temperature was measured with the help of a German non contact temperature measuring instrument (Therma Twin) model TN408LC. The temperature was measured at three different points on the work piece at three different positions of the cutting zones and the average recorded. The temperature was measured in degree Celsius.

The surface roughness was taken at three different points on the machined work piece with an Insize surface roughness tester model ISR-16 type and the average values were recorded.

The tool wear was measured with an Insize digital vernier caliper model SR44 every 20 minutes of machining and the values recorded. The results are presented in Tables 1 - 3 below. The measuring instruments are presented in Fig. 8 a-c.



**Fig. 8A. Germany non contact temperature measuring device**



**Fig. 8B. Insize digital vernier caliper**



Fig. 8C. Insize surface roughness tester ISR 16

### 3. RESULTS AND DISCUSSION

#### 3.1 Results

The results were as presented in Tables 1 – 3

Table 1. Effect of two-way application of CF on temperature

Serial	Time, min	Temperature, °C		Dry turning
		Standard	Two-way	
1	20	28.30	26.70	36.40
2	40	30.60	28.10	39.86
3	60	33.20	27.10	42.93
4	80	32.10	26.70	61.10
5	100	26.40	27.00	62.25
6	120	32.30	27.10	62.50
Average		30.48	27.12	50.84

Table 2. The influence of two-way application of CF on surface roughness

Serial	Time, min	Surface roughness (Ra), $\mu\text{m}$		Dry turning
		Standard	Two-way	
1	20	8.73	7.37	10.65
2	40	8.75	8.01	11.55
3	60	12.37	8.54	28.94
4	80	10.51	8.56	39.05
5	100	7.63	9.60	41.53
6	120	10.03	9.64	43.80
Average		9.67	8.62	29.25



**Table 3. The Influence of two-way application of CF on tool wear**

Serial	Time, min	Tool Wear ( $\lambda$ ), mm		Dry Turning
		Standard	Two-way	
1	20	0.08	0.06	0.44
2	40	0.10	0.08	0.77
3	60	0.12	0.11	1.15
4	80	0.16	0.13	1.63
5	100	0.19	0.15	1.70
6	120	0.23	0.18	1.75
Average		0.15	0.12	1.24

### 3.2 Discussion

The results of the experiment are presented in the Tables 1 to 3. The results of the experiment indicated that the two-way application of CF is more effective in terms of the reduction in the tool wear, surface roughness and temperature as compared with the standard one-way application of CF. This was due to better lubricating and cooling properties of the CF during the two-way feeding leading to a reduction in the frictional force and temperature at cutting zone [6].

#### **3.2.1 The effect of two-way application of CF on the temperature at the cutting zone**

The temperature at the cutting zone for the two-way CF application device was relatively lower than that of standard one-way throughout the whole period of experiment. i.e. from 20 – 120 minutes. However, the temperature was rising and falling during the experiment for the both types. The soluble oil used has duo properties (lubricating & Cooling). The mineral oil lubricates while the water cools [7]. This may be due to the different rates of penetration of the lubricating and cooling effects of the soluble oil used at different cutting zones. Where the temperature falls, it means that the cooling effect was high.

Nonetheless, the average temperature during the experiment was reduced by 11% and 57% respectively by the two-way application as compared to the one-way application and dry turning respectively.

#### **3.2.2 The effect of two-way application of CF on the surface roughness at the cutting zone**

The two-way CF application Device was more effective at reducing the surface roughness throughout the experiment in comparison with the standard way and dry turning (Table 2). The average reduction was approximately 11% and 71% (i.e. from 9.67 $\mu$ m to 8.62 $\mu$ m; 29.25 $\mu$ m to 8.62 $\mu$ m) as compared to one-way and dry turning respectively. In other words the surface quality of the machined workpiece was improved by the two-way application of CF.

#### **3.2.3 The effect of two-way application of CF on the tool wear at the cutting zone**

The effect of using two-way CF application device was presented in Table 3. The results indicated that the two-way application of CF reduced the tool wear in all the experiments. The average reduction was 20% and 90% in comparison with the standard one-way

application of CF and Dry turning. i.e. from 0.15mm to 0.12mm and 1.24mm to 0.12mm respectively.

## **4. CONCLUSION AND RECOMMENDATION**

### **4.1 Conclusion**

The two-way CF application has:

- improved the machined surface quality by reducing the its surface roughness from 9.67 $\mu$ m to 8.62 $\mu$ m for the standard one-way and from 29.25 $\mu$ m to 8.62 $\mu$ m for dry turning;
- reduced the tool wear (prolong tool life) by 20% and 90% for one-way and dry turning respectively;
- reduced the temperature at the cutting zone by 11% and 57% for one-way and dry turning respectively.

Consequently, there is no doubt that the two-way application of cutting fluids device is more efficient than the standard one-way application of CF device. In other words, the cooling as well as the lubricating effects of the two-way application of CF is higher than the one-way application.

### **4.2 Recommendation**

- ❖ Further research should be carried out on use of more than two nozzles simultaneously for application of CF to the cutting area.
- ❖ Modification of the present multiple/ two-way CF feed mechanism may be necessary
- ❖ Other angles of CF feed should be looked into.

## **COMPETING INTERESTS**

Authors have declared that no competing interests exist.

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