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Comparative Study of Surface Roughness in Turning of C45 Steel under Dry, Flood, and Coconut Oil-Based MQL Conditions

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Abstract
This study investigates the influence of cooling–lubrication conditions on surface roughness in turning of C45 steel. Experiments were conducted on an EMCO Maxxturn 45 CNC lathe using carbide cutting tools. The cutting parameters were fixed at a cutting speed of 160 m/min, a feed rate of 0.15 mm/rev, and a depth of cut of 1.0 mm. Three machining conditions, namely dry cutting, flood cooling, and coconut oil-based minimum quantity lubrication (MQL), were compared. The results showed that dry cutting produced the highest surface roughness (2.25 µm), while flood cooling and MQL reduced the roughness to 1.26 µm and 1.31 µm, respectively. Compared with dry cutting, flood cooling and MQL decreased surface roughness by 44.0% and 41.8%, respectively. The findings indicate that coconut oil-based MQL can provide surface quality comparable to conventional flood cooling while offering a more sustainable machining approach.

Keywords: C45 Steel, Surface Roughness, Turning, MQL, Coconut Oil, Flood Cooling

1. Introduction

Surface roughness is one of the most important indicators of machined surface quality because it directly affects the functional performance, wear resistance, and fatigue life of engineering components. In turning operations, surface roughness is influenced by several factors, including cutting parameters, tool geometry, workpiece material, and cooling–lubrication conditions. Among these factors, the cooling–lubrication method plays a significant role in controlling friction and heat generation in the cutting zone, thereby affecting the integrity of the machined surface [1, 2, 3].

Conventional flood cooling has been widely employed in machining processes due to its ability to dissipate heat and improve tool life. However, the excessive use of cutting fluids may cause environmental pollution, health problems for machine operators, and high costs associated with fluid maintenance and disposal [4, 5]. Dry machining has therefore attracted considerable attention as an environmentally friendly alternative. Nevertheless, the absence of lubrication often results in increased cutting temperature, severe tool wear, and deterioration of surface quality, especially under high-speed cutting conditions [6, 7, 8].

Minimum quantity lubrication (MQL) has emerged as a sustainable machining technique capable of reducing cutting fluid consumption while maintaining adequate lubrication at the tool–chip interface. Vegetable oils are considered suitable lubricants for MQL applications because of their biodegradability, renewability, and excellent lubricating properties. Among them, coconut oil possesses high oxidative stability and good viscosity characteristics, making it a promising candidate for machining applications [9, 10, 11]. Several studies have reported that vegetable oil-based MQL systems can effectively improve machining performance and surface finish compared with dry cutting [5, 12, 13, 14, 15].

Although numerous investigations have been conducted on vegetable oil-based MQL, limited information is available regarding the application of coconut oil in turning C45 steel. Therefore, the present study aims to compare the surface roughness obtained under three cooling–lubrication conditions, namely dry cutting, conventional flood cooling, and coconut oil-based MQL. Experiments were performed under identical cutting parameters to evaluate the effectiveness of coconut oil-based MQL as a sustainable alternative to conventional flood cooling.

2. Experimental Procedure

The experiments were carried out on an EMCO Maxxturn 45 CNC lathe under controlled laboratory conditions. The

workpiece material used in this study was C45 steel with a diameter of 40 mm and an average hardness of approximately 200 HB. Carbide cutting tools were employed for all turning operations to ensure stable cutting performance. Three cooling–lubrication conditions, namely dry cutting, conventional flood cooling, and coconut oil-based minimum quantity lubrication (MQL), were investigated. In the MQL condition, coconut oil was supplied to the cutting zone in the form of an oil mist.

The cutting parameters were kept constant throughout the experiments at a cutting speed of 160 m/min, a feed rate of 0.15 mm/rev, and a depth of cut of 1.0 mm. Surface roughness (Ra) was measured using a surface roughness tester, and the average value was recorded for each machining condition.

Table 1: Cutting parameters used in the experiments

Parameter	Value
Cutting speed, Vc (m/min)	160
Feed rate, f (mm/rev)	0.15
Depth of cut, ap (mm)	1
Workpiece material	C45 steel (200 HB)
Tool material	Carbide
Cooling-lubrication conditions	Dry, Flood, MQL

3. Results and Discussion

The surface roughness values obtained under different cooling–lubrication conditions are presented in Table 2.

Table 2: Surface roughness under different cooling-lubrication conditions

Condition	Ra (µm)
Dry cutting	2.25
Flood cooling	1.26
Coconut oil-based MQL	1.31

Dry cutting resulted in the highest surface roughness value of 2.25 µm. The application of flood cooling and coconut oil-based MQL significantly improved the surface finish, reducing the roughness to 1.26 µm and 1.31 µm, respectively. Compared with dry cutting, flood cooling and MQL decreased surface roughness by approximately 44.0% and 41.8%, respectively.

The superior performance of flood cooling can be attributed to its better cooling capability, which effectively dissipates heat generated during machining. Although coconut oil-based MQL produced a slightly higher roughness than flood cooling, its performance was comparable while consuming a much smaller amount of lubricant. Therefore, coconut oil-based MQL can be considered a promising and environmentally friendly alternative to conventional flood cooling in turning operations.

4. Conclusions

This study compared the effect of dry cutting, flood cooling, and coconut oil-based MQL on the surface roughness in turning of C45 steel. The results showed that dry cutting produced the highest surface roughness, whereas flood cooling achieved the lowest value of 1.26 µm. Coconut oil-based MQL yielded a comparable roughness value of 1.31 µm and reduced surface roughness by approximately 41.8% compared with dry cutting. These findings suggest that coconut oil-based MQL has the potential to replace conventional flood cooling in sustainable machining applications.

5. Acknowledgment

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