Effect of Near-Dry Machining (NDM) on surface roughness through sustainable turning of mild carbon steel using coated carbide

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Abstract. Sustainable production as a global word, content important elements on all the fields as well as machining processes. Turning is one of the most fundamental and indispensable processes of metal removal in the industry. Increasing pollution preventing initiatives globally and consumer focus on environmentally conscious products has put increased pressure on industries to minimize or eliminate the use of cutting fluids. The use of Near-Dry Machining (NDM) in machining operation is one of the most effective strategies in this direction to achieve sustainable machining system. This study was purposed to determine the influence of NDM coolant system on surface roughness when turning of mild carbon steel, include power demand. A detailed comparison has been made with dry cutting to assess the process performance on the basis of surface roughness and power demand. The results indicate that providing a reduction on surface roughness and power demand more effectively than dry cutting at high-speed conditions, thereby to achieve sustainable machining system.

1. Introduction

Sustainability is an increasingly important requirement for human activities. This has led to making sustainable development a view that social, economic and environmental problems must be dealt with simultaneously and holistically in the development process. Sustainability has been applied in various fields, including engineering, manufacturing, and design. Manufacturers are increasingly becoming concerned about sustainability issues. For example, recognizing the relationship between manufacturing operations and the natural environment has become an important factor in decision making among industrial society [1].

Sustainability has become an important issue in the manufacturing sector. In the literature, it is generally agreed that sustainable development must include three pillars, namely economic, social and environmental considerations [2]. Therefore, to achieve sustainable development, the industry must produce sustainable production. One of the ways to achieve environmentally friendly production is to reduce the use of lubrication systems in the machining process.

Sustainable production is a solution to overcoming the problem of using a lubrication system that can cause environmental pollution. This applies in engineering, including machining processes [3].

Machinery is an integrated part of the production. Thus, reducing the use of lubricants during machinery will contribute to the reduction of environmental pollution in producing parts.

The paper was proposed to determine the effect of NDM conditions on surface roughness and power demand when turning of mild carbon steel.

2. Experimental methodology
In this paper, the turning process was performed using the PINDAD 2-axis lathe machine (25 - 1500 rpm of spindle speed ranges and 5.62 kW of horsepower) under dry and NDM cooling conditions using coated carbide tool (Mitsubishi’s MC7025) with featured 0.8 mm nose radius and designated as TCLNR 2020K12.

The workpiece material used in the turning process was mild carbon steel, with a diameter of 65 mm and length of 150 mm. The composition of mild carbon steel was detailed in Tables 1.

| Composition | Value |
|-------------|-------|
| C           | 0.04  |
| Mn          | 0.15  |
| Si          | 0.02  |
| P           | 0.012 |
| S           | 0.009 |
| Ti          | 0.020 |
| Nb          | 0.004 |
| B           | 0.0003|
| Al          | 0.04  |
| N           | 0.10  |

The experimental design was developed using nine experiments as shown in Table 2. It was conducted to repetition for each parameter.

| Cutting condition |
|-------------------|
| Levels            | Low  | Centre | High  |
| Cutting speed (rpm)| 590  | 840    | 1500  |
| Feed rate (mm/rev)| 0.052| 0.105  | 0.157 |
| Depth of cut (mm)  | 1.0  |
| Coolant           | Dry and NDM |

3. Results and discussion

3.1. Surface roughness
The experimental result of surface roughness is shown in figures 1 and 2 for both dry cutting and NDM.
Figures 1 and 2 show that the surface roughness was affected by all cutting conditions i.e. cutting speed, and feed rate for both dry and NDM system (except for 840 rpm). Turning results using a lubrication system with NDM show lower surface roughness compared to dry cutting. The results of this experiment have also been carried out by several researchers. Dhar et al. were investigated the effect of NDM on tool wear and surface roughness in AISI-4340 steel turning. Exciting results include a significant reduction in tool wear and surface roughness by NDM especially through reduction of cutting zone temperatures [4]. Sreejith reports the different environmental impacts of lubricants (dry machining, minimum lubricant quantity (MQL), and flood coolant conditions) when 6061 aluminum alloys are worked with diamond-coated carbide tools [5]. It was found that NDM conditions would be a very good alternative for the condition of coolant/lubricant. Therefore, it appears that if NDM is used correctly it can replace the coolant/lubricant environment which is currently used in most machining applications,
so not only will machining be environmentally friendly but it will also improve engine capability characteristics.

3.2. **Power demand**

The experimental result of power demand is shown in figures 3 and 4 for both dry cutting and NDM.

![Figure 3](image1.png)

**Figure 3.** Plotting surface roughness for dry cutting in different cutting speeds.

![Figure 4](image2.png)

**Figure 4.** Plotting surface roughness for NDM in different cutting speeds.

Figures 3 and 4 indicate that the power demand was dominantly affected by cutting conditions i.e. cutting speed, and feed rate for both dry and NDM system. The cutting speed was most significantly
affected by the power demand than feed rate. It found that increasing cutting speed will increase the power demand.

These results were confirmed by Velchev et al [6], their study presented that the increasing cutting speed decreases the power demand when turning of steel 17G2SAF using insert grade GC4235. Nur et al. [7-9] also investigate the turning of AISI 316L stainless steel using coated carbide, they concluded that the equations prediction developed for machining output can be useful in determining the optimum cutting parameters. Another study was conducted by Nur et al. for turning of aluminum alloys [10, 11] and carbon steel [12]. The research result stated that the power demand was influenced by cutting speed. Increasing the cutting speed will decrease power demand because the cutting process was faster.

4. Conclusion

In this paper, the turning of mil carbon steel using a coated carbide was studied and concluded as the following results:

- Surface roughness is affected by variable rotation and feed rate, where if high rotation (1500 rpm) and large feed rate (0.152 mm/rev) will be produce smooth surface. Conversely, if the rotation is low (590 rpm) and the feed rate is large (0.152 mm/rev), it will produce high surface roughness (rough).
- The power demand in the turning process is only influenced by the rotation variable. The greater the rotation used; the value of power demand will increase. Conversely, the smaller the rotation used, the lower the power demand. The feed rate does not affect power consumption.
- The NDM cooling system has a significant influence on the surface roughness of the workpiece, where when using an NDM cooling system it will make the workpiece smoother.

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