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Study On Temperature, Force and Specific Energy of AISI 1020 under MQL Grinding Process

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Abstract. Grinding is one of the most difficult processes in machining operations. Normally, the flood coolant method was used as a cooling agent in the grinding process. The most common defects using flood coolant are higher grinding friction, higher heat generation, and thermal damage. Therefore, the minimum quality lubricant (MQL) was introduced to minimize the defects. The main objective of this project is to compare the performance of MQL and flood coolant techniques in terms of grinding temperature, grinding force and specific energy. Three levels of cutting speeds, three levels of feed rate and depth of cut are adopted in the evaluation. The experiments were conducted on a thin plate of mild steel AISI 1020. The result shows that the MQL technique was effectively supplied to the grinding contact zone. This research revealed that the MQL technique exhibited an advantages on the surface temperature compared to the flood coolant.

Introduction

Grinding is one of the manufacturing process and widely use in the industries for surface finishing. The proper application of grinding fluid has been found to be effective in reducing the thermal effect and surface roughness [1]. Grinding process uses a wheel made from an abrasive or synthetic minerals in a loose or bonded form. It comes with a variety of size, shape and types of abrasive. The grinding wheel composed of abrasive grains held together in a binder. The abrasive grains act as cutting tools by removing the unwanted material. As these abrasive grains wear, the added resistance leads to fracture of the grains or weakening of their bond. Using cutting fluids is a common strategy to reduce the temperature and lubricating effect. As a result, surface integrity, tool life, and also size accuracy can be improved [2]. On the other hand, cutting fluid will produces smoke, airborne mist and other particles in the shop floor air. These drawbacks will cause as environmental, safety concerns and health issues.

MQL has been established as an alternative for conventional flood coolant. Different with flood coolant, MQL uses only a few drops of lubricant. There are many advantages when using MQL. Effective lubrication reduces the cutting force and temperature, improves wheel life, good surface finish at high cutting speed, reduce or eliminate breathing and skin related problem and at the same time saving the lubricant cost [3,4]. The objective of this study is to investigate the grinding performance of MQL which compared with flood grinding in terms of temperature, grinding force, and specific energy.

Experimental Setup

Up grinding tests were performed on AISI 1020 steel with a thickness of 3 mm for temperature measurement as shown in Fig. 1 using a thermal imager camera. The measurements were conducted on a Mazak vertical machining center (Model 410-A) and the temperature value is taken at the rear side of the workpiece. White alumina oxide which has a vitrified bond chosen as a grinding wheel material with dimensions of 100 mm, 20 mm and 25.4 mm for the outer diameter, thickness and hollow diameter, respectively. Summary of grinding conditions is given in Table 1. In addition, the surface roughness was measured using the Mitutoyo SJ-400 Surftest tester.

Cutting forces during the tests were measured using Kistler type 9254 piezoelectric dynamometer. The dynamometer was connected to a change amplifier using a high resistance cable. The amplified signals were recorded on a PC with the data acquisition software. The experimental setup for this task is shown in Fig. 2. Meanwhile, the nozzle setup for MQL supply is shown in Fig. 3.

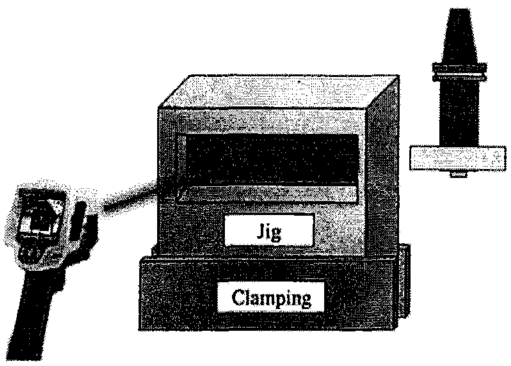


Fig. 1: Experimental setup

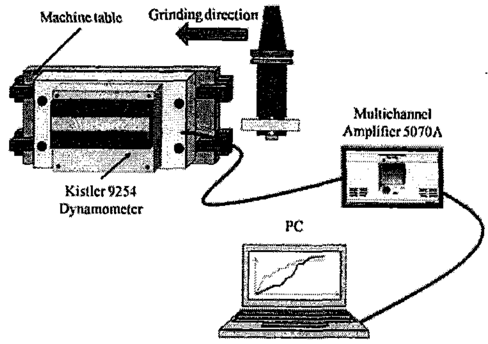


Fig. 2: Grinding force measurement l setup

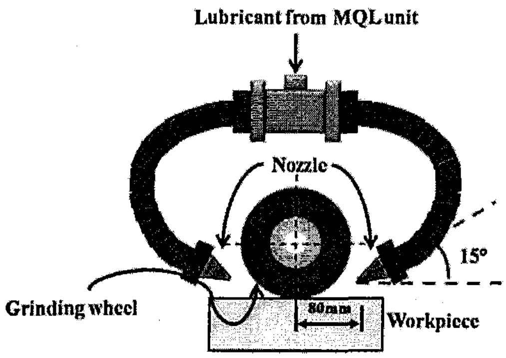


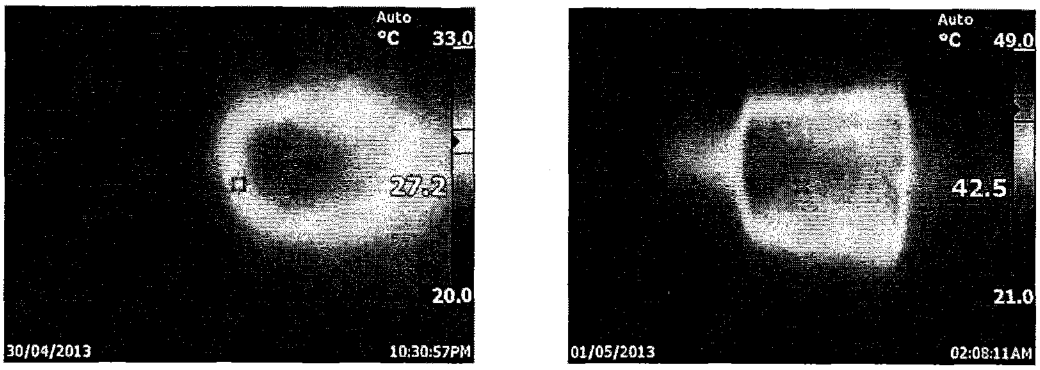
Fig. 3: Nozzle setup

Table 1: Parameter of grinding process

Cutting speed, V_c (m/min)	900,1200,1500
Feed rate, f_r (mm/min)	400, 500, 600
Depth of cut, a_e (mm)	0.2
Cutting type	AISI 1020
Coolant type	MQL (synthetic ester) Water soluble Coolant
Coolant flow rate (l/min)	80 l/hour (MQL) 30 l/min (Flood)

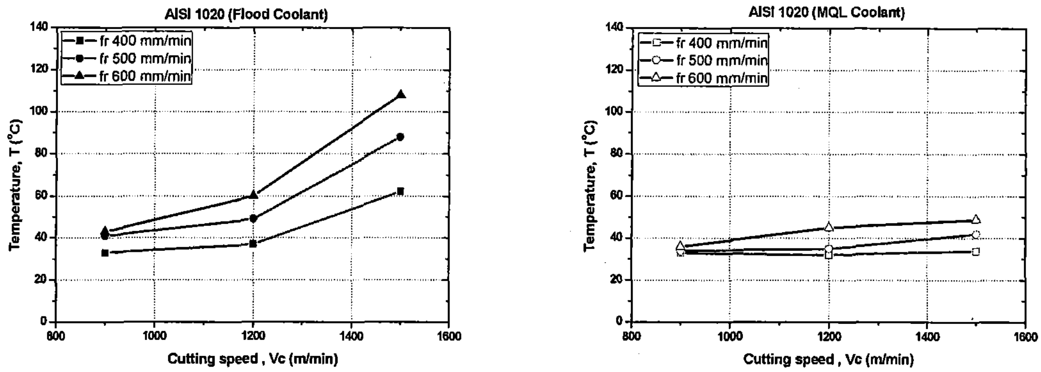
Results and Discussion

Figs. 4 and 5 showed the temperature measurement given by the thermal imaging camera during the surface grinding with both MQL and flood coolant conditions. It can be seen that both cooling techniques follow the basic machining theory, as the cutting speed and feed rate were increased, grinding temperature increases. These are due to the rise of the energy which is used for removing a unit volume of material. The energy is converted to heat within the grinding zone, which may lead to high grinding temperature [5]. The maximum workpiece temperature was at the cutting speed of 1500 m/min and feed rate of 600 mm/min. For instance, the workpiece temperature recorded by MQL and flood coolant conditions were 49 °C and 108 °C respectively. Besides that, the minimum temperature value for MQL and the flood coolant conditions are 33 °C and 34 °C at the cutting speed and feed rate of 900 m/min and 400 mm/min respectively. MQL coolant supply shows an ability to minimize the temperature than the flood coolant condition. The reduction of temperature using MQL technique can be attributed to the capability of the tiny mist particles of MQL penetrates into the grinding zone, subsequently reduces the grinding friction.



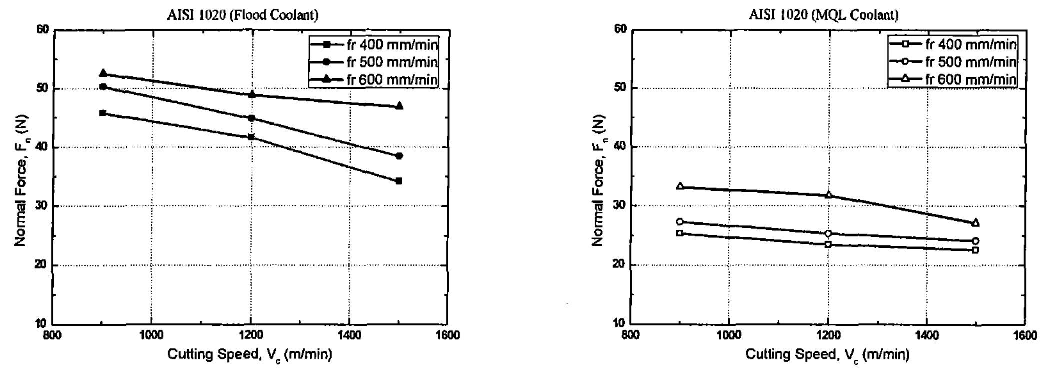
(a) (b)

Fig. 4: Thermal image on the rear of the workpiece at (a) V_c = 900 m/min, f_r = 400 mm/min and (b) V_c = 1500 m/min, f_r = 600 mm/min



(a) (b)

Fig. 5: Temperature for (a) MQL and (b) flood coolant condition of AISI 1020

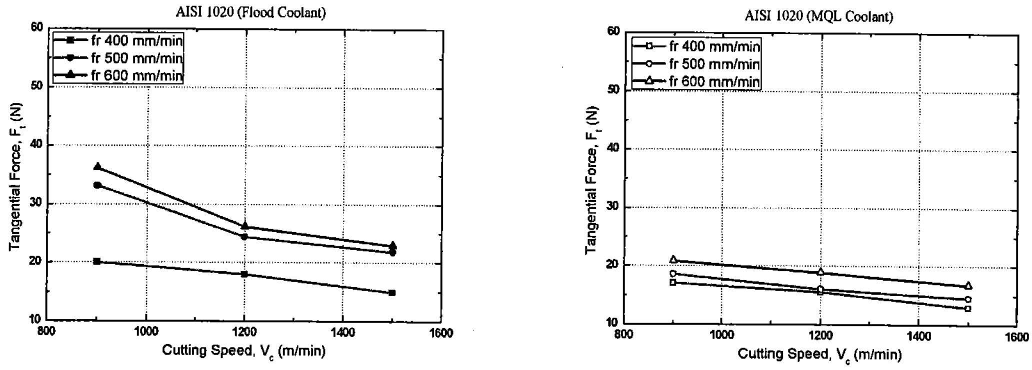


(a) (b)

Fig. 6: Normal force for (a) MQL and (b) flood coolant condition of AISI 1020

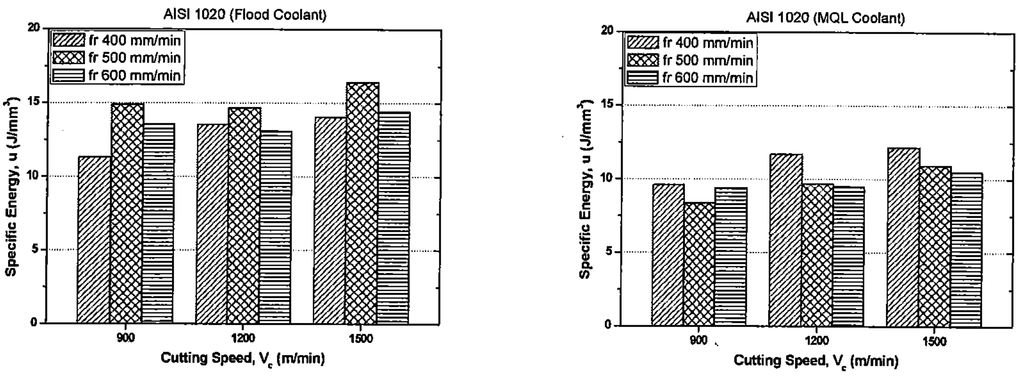
Fig. 6 shows the results of normal force for both MQL and flood coolant conditions. The results show that the normal force magnitude varied when cutting speed and feed rate changed. Besides, it appears that MQL condition significantly reduced the grinding force. The highest value of the normal force under MQL and coolant conditions taken at the cutting speed of 900 m/min and feed rate of 600 mm/min were 33.18 N and 52.53 N respectively. Meanwhile, the lowest normal force values obtained at the cutting speed of 1500 m/min and feed rate of 400 mm/min were 22.61 N and 34.11 N, respectively.

It was noticed that the value of tangential force was much lower than the normal force value as shown in Fig. 7. The higher value of normal force can be attributed to the grinding spindle power and its directly proportional to tangential force. Any increase in tangential force will be accompanied by larger forces acting the individual grits.



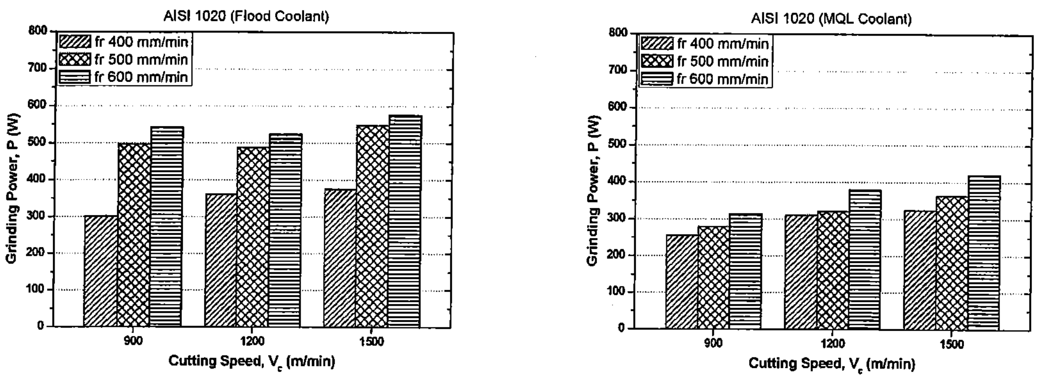
(a) (b)

Fig. 7: Tangential force for (a) MQL and (b) flood coolant of AISI 1020



(a) (b)

Fig. 8: Specific energy for (a) MQL and (b) flood coolant condition of AISI 1020



(a) (b)

Fig. 9: Power for (a) MQL and (b) flood coolant condition of AISI 1020

As illustrated in Fig. 8, MQL condition recorded lower value of specific energy compared to flood coolant condition. Furthermore, the feed rate shows a significant effect of grinding power. As shown in Fig. 9, the grinding power for both conditions shows the growth due to the increasing of feed rate. These are obviously due to the increase of the volume removed per unit time. It can be expressed that flood coolant condition requires more power and energy. This occurs due to the relation between tangential force and heat where high tangential force will lead to higher heat generation and thermal damage. In addition, the increment value of specific energy may lead to the high grinding temperature. This is due to the conversion of energy into heat which is concentrated within the grinding zone.

Summary

This paper presents the result performance of flood coolant and compare the result with MQL at different cutting condition. The main result obtained in this study can be summarized as follows:

i. MQL condition gives an advantages on the surface temperature during the grinding process. It is due to the reduction of the temperature compared to the flood coolant supply.
ii. The grinding forces both for normal and tangential components decrease with the increasing of cutting speed while on the other hand it is increased with the increment of feed rates.
iii. Increasing of cutting speed results in a specific energy increase while the grinding power shows an increment due to the increasing of feed rates.

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