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Kurtosis Quantification of Different Minimal Quantity Lubrication Effects in Machining Cast Iron with Coated and Uncoated Tool

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ABSTRACT – This paper presents comparative study on dry and MQL effect in coated/ uncoated milling process based on kurtosis and skewness quantification. By combining vibration signals, it is possible to identify with more reliability. The use of different statistical measurement such as RMS, kurtosis and skewness, together with surface roughness measurement allows identifying the tool and workpiece condition under dry/ MQL application. It was found that kurtosis detect different MQL affect the average surface roughness for both coated and uncoated end mill.

1. INTRODUCTION

Manufacturing and other industries today are competing to achieve high volume production. Cutting fluids are typically used to ensure they produce good quality finish. It is critical to reduce the usage and reduce cost of using cutting fluid. Moreover, the stability of the cutting tool and workpiece set-up is required in order to have a good surface quality. Thomas and Beauchamp [1] describes the machined surfaces consist of two superimposed profile: the theoretical profile due to operation kinematics and dynamic profile due to cutting-edge vibrations. Therefore, signal processing is important to reach a better understanding of the MQL, coated and uncoated effect on the milling process.

2. METHODOLOGY

Experimental setup is illustrated in Figure 1. The experimental work was performed on conventional Makino KE55 milling machine. The workpiece material used was cast iron FCD450 in the dimension of 150 mm x 150 mm x 50 mm block, while cutting tools are both coated (TiAlN) and uncoated end mill cutting tool (20 mm diameter, 8-flutes). Axial and radial depth of cut in all test was fixed to 1.25 and 20mm respectively in order to limit the amount of testing time. During experiment, two accelerometers were used to assure the reliability of the signals, whereby accelerometer 1 and accelerometer 2 were located at the workpiece and spindle respectively. Vibration signal were captured and recorded by NI data acquisition (DAQ) under sampling rate of 2000Hz.

The milling process were carried out under dry and MQL (9, 18, 27, 36, 45 ml/h). Also, the location for nozzle spray was positioned at 135°. The cutting condition for both cutting tool was carried out as in Table 1. Surface roughness of the workpiece was measured using Mitutoyo portable surface roughness tester subsequently.

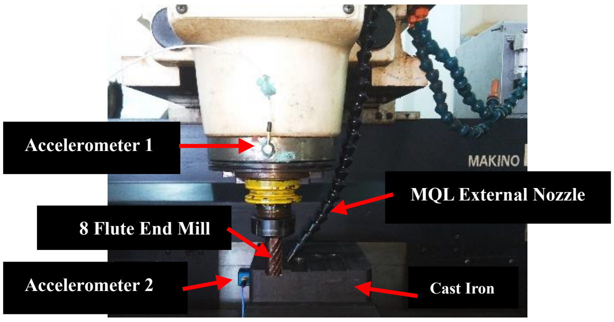


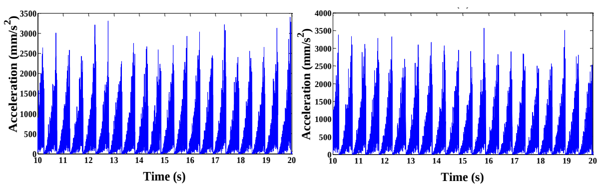
Figure 1 Experimental Setup

Table 1 Machining conditions.

Machining parameters	Values
Spindle speed (rev/min)	3026
Feed rate (mm/min)	165
Axial depth of cut (mm)	1.25
Radial depth of cut (mm)	20
MQL nozzle spraying angle	135°
MQL volume flow rate (ml/h)	9,18,27,36,45

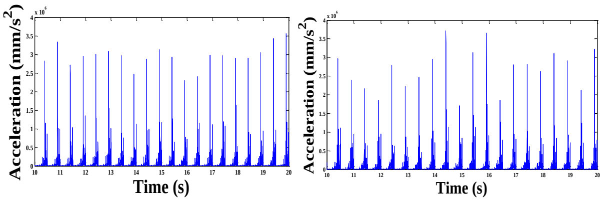
3. RESULT AND DISCUSSION

A spectral comparison of acceleration versus time was performed as illustrated in Figure 2. Each acceleration reading were ten seconds of machining. Comparing the result, Figure 3 shows a higher amplitude of acceleration. When machining ductile material as cast iron, this may due to the friction characteristic of the secondary deformation zone between cutting tool and chip and the third deformation zone between cutting tool and workpiece. Both amplitude for accelerometer 1 and 2 did not shows a significant variation when dry milling and using MQL. Thus, the difference was identified in terms of acceleration amplitude by kurtosis, k (Equation 1) and skewness, s (Equation 2) quantification. These are calculated by the ratio between the centering moment, third and fourth order respectively of a number of elements n in the vector and standard deviation σ [2].



(a) (b)

Figure 2 Time domain of accelerometer 1 using (a) uncoated and (b) coated tool



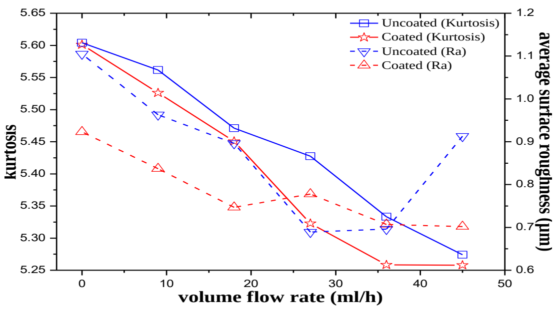
(a) (b)

Figure 3 Time domain of accelerometer 2 using (a)uncoated and (b) coated tool

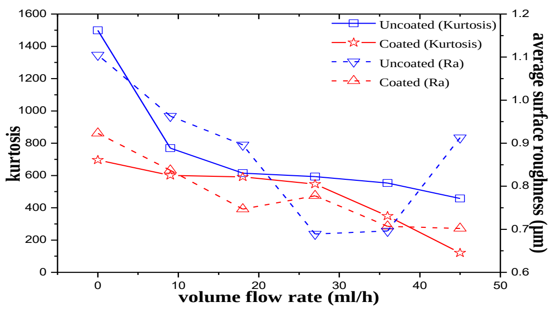
$$k = \frac{\frac{1}{n}\sum_{i=1}^{n}(x-\bar{x})^4}{n\sigma^4} \tag{1}$$

$$s = \frac{\frac{1}{n}\sum_{i=1}^{n}(x_i-\bar{x})^3}{n\sigma^3} \tag{2}$$

The acceleration amplitude and kurtosis calculation together with average surface roughness for accelerometer 1 and 2 were plotted in Figure 4. Considering the volume flow rate used were similar, it demonstrates that the k value using uncoated tool were higher than coated tool. The difference can be seen except during dry cutting and applying 18 ml/h of MQL for accelerometer 1 and 2 respectively. Besides, Figure 5 (a) demonstrate the opposite where by the coated tool obtained higher s value than uncoated tool during dry condition. Meanwhile, the s value from Figure 5 (b) shows the difference cannot be clearly determine at 9, 18, 27 ml/h of MQL flow rate. Based on these, adding surface roughness testing is important to verify the data obtained [3]. The k and s values are often high when using uncoated tool. During machining cast iron, friction and heat is generated due to the rubbing between surfaces. This inducing temperature to increase which substantially influence the cutting force. By applying layer of coating, the chemical compatibility reduces oxidation wear and intense reaction between the coating surface and the cast iron during machining [4].

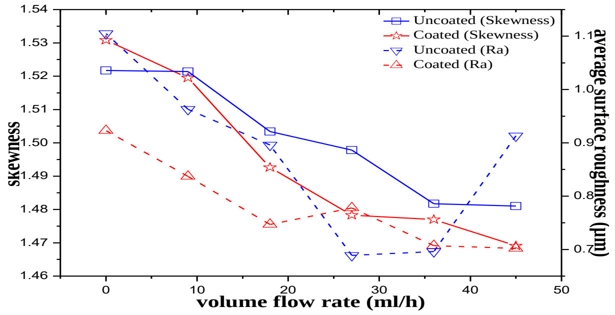


(a)

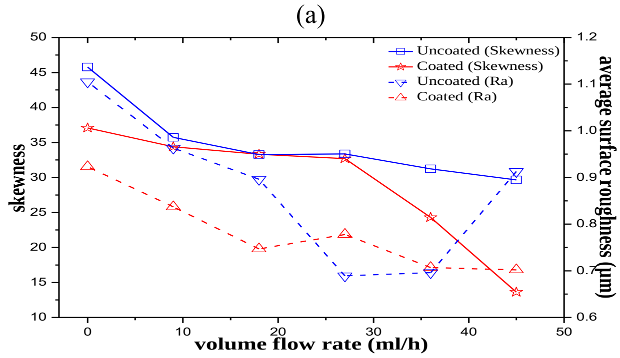


(b)

Figure 4 Kurtosis analysis of (a) accelerometer 1 and (b) accelerometer 2



(a)



(b)

Figure 5 Skewness analysis of (a) accelerometer 1 and (b) accelerometer 2

4. CONCLUSIONS

The following conclusions were obtained:

(a) Kurtosis and skewness quantification seems to be a good indicator of the cutting process and can be applied in a monitoring process of MQL and coating.

(b) Surface roughness verify kurtosis and skewness as suitable statistical tool of monitoring cutting condition.

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