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Characteristic of Vibration Signal from Cutting Tool Against Steel with a Tensile Strength of 60 for CNC Turning Monitoring System

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Abstract

The condition of the insert significantly affects the product quality and manufacturing efficiency of lathe machining. The current study uses the power spectral density distribution of a signal vibration accelerometer machine built for CNC in developing a system to classify various conditions that can occur in a manufacturing environment. For four common lathe machining insert conditions (i.e., built-up edge, flank wear, standard, and fracture), In this case, the insert condition classification system is created with two stages—insert condition modeling and machining model fusion. At the stage of modeling the insert condition, the magnitude feature of the segmented frequency is captured according to the power spectral density distribution of the accelerometer vibration signal. Root mean square (RMS) and Fast Fourier Transform (FFT) was calculated to conduct vibration prediction studies using a turning cutting tool. The results of the raw signal in the experimental new conditions show the RMS value is in the range of 6.24-6.23 mV, and the FFT is 0.0007-0.0009 mV. In good condition, the raw signal condition shows that the RMS value is 54.36-67.08 mV and FFT 0.0068-0.0080 mV. In the middle state of the raw signal, the RMS value is 83.05-112.07mV, and the FFT value is 0.0089-0.0147mV. In poor condition raw signal, the RMS value is 125.14-152.09 mV, and the value FFT is at 0.0137-0.0178. The data clusters are well grouped and directly proportional between the damage to the tool blade and the increased voltage in RMS.

Keywords: CNC turning, cutting tool, vibration

1. Introduction

In recent years, the development of the global manufacturing industry has become more competitive and more important than ever in improving production efficiency, quality products, and cutting costs. The cutting tool cost is one of the most significant manufacturing expenses in the high-speed CNC sector. On the other hand, cutting tool wear is an unavoidable and widespread problem that directly impacts surface quality and dimensional accuracy. To increase productivity and ensure the quality of the workpiece, an effective and reliable working system is needed that can constantly monitor the condition of the tools [1], [2]. CNC machine tools are machine tools that, in the workpiece soldering process by a cutting tool, are assisted by computer numerical control or CNC (Computer Numerical Control). CNC agreed to use a coordinate system to drive the tool on the machine tool. The coordinate system on a CNC lathe is a cartesian coordinate system with two axes: the X-axis and the Z-axis. The zero points present on CNC lathes are the Machine zero point (M) and the zero point of the workpiece (W) [3].

The geometry/shape of the lathe cutting tool mainly depends on the workpiece material and the tool material. Types of lathe-cutting tools It is generally divided into 2; namely, single cut edged lathe cutting tools and inserted lathe-cutting tools. For single-edged lathe-cutting tools are usually used in conventional lathes. This cutting tool material is high-speed steel (HSS), and the cutting tool angle is formed using a sharpening tool grinder machine [4].

In machining technology, one of the most significant criteria considered when assessing the quality of parts is confirmed as better surface roughness. So, to obtain the required level of surface quality of the machine components, the tool's vibration must be minimized to the slightest degree. In the machining process, the most critical parameters affecting surface roughness, tool wear, and vibration are turning factors such as axial feed rate, depth of cut, and rotational speed [5].

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The interaction between the cutting tool and the turning machine will cause wear and even damage to the cutting tool. So, that tool wear affects the quality of surface roughness, dimensional accuracy, and operating costs in the machining proses [6]. Advanced Manufacturing Technology (AMT) development aims to improve product quality. The implementation of Tool condition machining (TCM) is the most crucial part of AMT[7][8]. The procedures carried out in CNC machining and flexible manufacturing systems (FMS) have made TCM even more pertinent [9]. In response to this problem, a study of TCM technology has been carried out. The TCM system mainly uses sensor information collected during the cutting process to monitor the condition of the tool in real time and then predict the time it will take to replace the device while ensuring product quality and extending the tool usage time. With the popularity of flexible manufacturing systems and the emergence of intelligent manufacturing systems and computer-integrated manufacturing systems [10], [11].

In this study, the interaction between the lathe-cutting tool and the workpiece has been identified. The vibration results produced by the lathe-cutting device are expressed in the Root Mean Square (RMS) parameter. Based on the study of tool life, surface finishing, and vibration when rotating nodular cast iron using tool ceramics. They concluded that the surface finish was almost constant with the development of flank wear under different cutting conditions. They also observed that vibration during cutting decreased with increasing speed at low cutting depths, vibrations remaining almost constant with increased flank wear [12]. As the primary cause of tool failure, flank wear is short of wear that is intended to be the criterion in evaluating the tool life [2], [13]–[15].

2. Research Method

2.1. *Material and Parameters*

The workpiece in use is made of medium carbon steel with tensile strength, namely ST60, and a round bar shape with a size of 1 inch. The insert cutting tool uses the MCLN carbide lathe type with the rake angle tool -7° and the Relive Angel Tool 7° Style L - Negative 5° End or Side Cutting Edge Angle for negative 80° diamond.

The turning process is carried out using test parameters: a spindle speed of 1128 rpm, a feed rate of 50 mm/minute, and a depth of cut of 0.5 mm, as shown in Table 1.

2.2. *Scheme of the Experiment*

The turning process stage is categorized into three parts of cutting tool condition: good condition, middle condition, and poor condition. Before carrying out the workpiece sharpening process, first, take the machine vibration data during the condition without the ignition, which is written as the conditions of the news; each has a different vibration value. The projection of the resulting vibration is indicated in the parameters of time (minute) and amplitude (mm). Then the vibration data is processed using the RMS approach to make it easier to identify the vibration analysis results in each cutting tool condition. Figure 1 is the machining scheme used in this research.

Table 1. Test parameters

Parameter	Symbols	Units	Value
Spindel Speed	V	rpm	1128
Feed rate	F	Minute	50
Dept of cut	D	mm	0.5

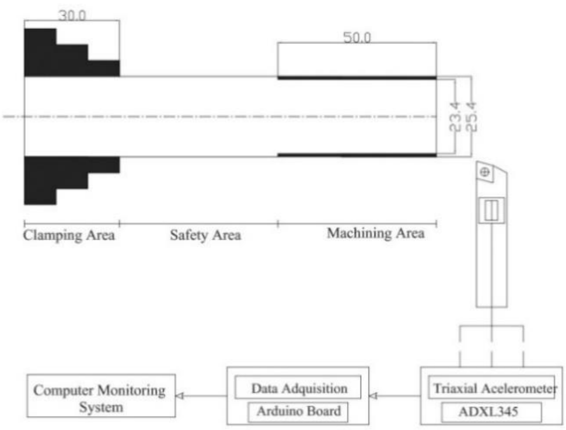


Figure 1. Machining scheme

2.3. *Experimental Setup*

Some of the components used in the experiment test are the accelerometer sensor, which is an essential part of reading the vibration results produced in the turning process. Cutting tools are used to wrench the workpiece; each feeding process is carried out by turning as far as 50 mm. A workpiece is a feeding object using a metal material shaft ST 60.

The cutting tool with the insert cutting tool uses the MCLN carbide lathe type. The shape and coding of the insert cutting tool and its cutting tool holder have been standardized by ISO. The insert cutting tool produced by the maker has a specific color code according to the material of the workpiece to be machined and the cutting conditions. The blue color code is for working steel, the yellow color code is for working stainless steel, and the red color code is for cast ironwork, as shown in Fig. 2. Usually, cutting data is included in the cutting tool insert packaging [16].

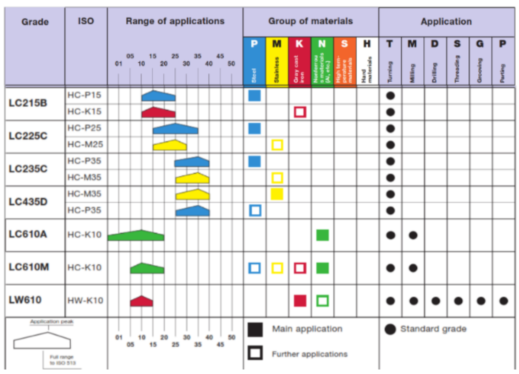


Figure 2. Lathe tool number code

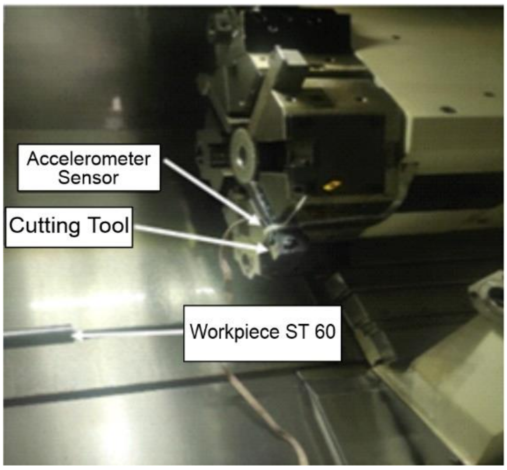
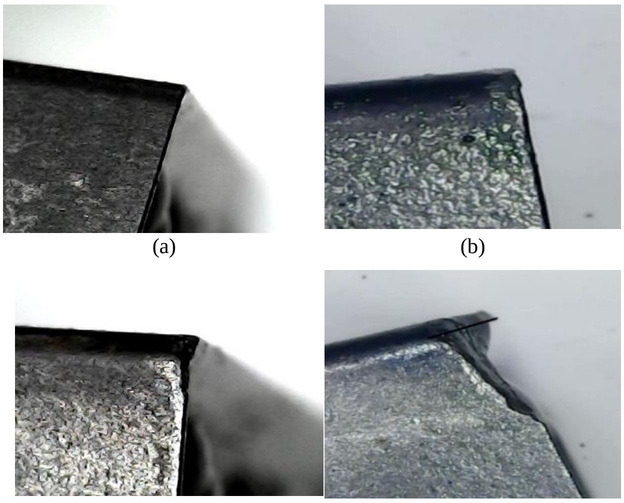


Figure 3. CNC machined parts



(a) (b)

(c) (d)

Figure 4. (a) new condition; (b) good condition; (c) middle condition; (d) poor condition

The processing of cutting on a CNC machine has several parts, as shown in Fig. 3.

3. Results and Discussion

Root mean square (RMS) and Fast Fourier Transform (FFT) was calculated to conduct vibration prediction studies using turning cutting tools. Experimental results show that predictions using Raw Signal values have high accuracy and accuracy compared to fast Fourier Transform (FFT) signal results.

3.1. *Characteristic*

The characteristics of a lathe cutting tool with a worn condition have a flank wear structure with a rough surface.

3.2. *Raw Signal Condition*

Based on trials that have been carried out by classifying cutting tool conditions. Then obtained, the results of each RMS are as follows in Eq. 1.

$$V_{rms} = \sqrt{\frac{1}{b-a}\int_a^b f^2(t)dt} \qquad (1)$$

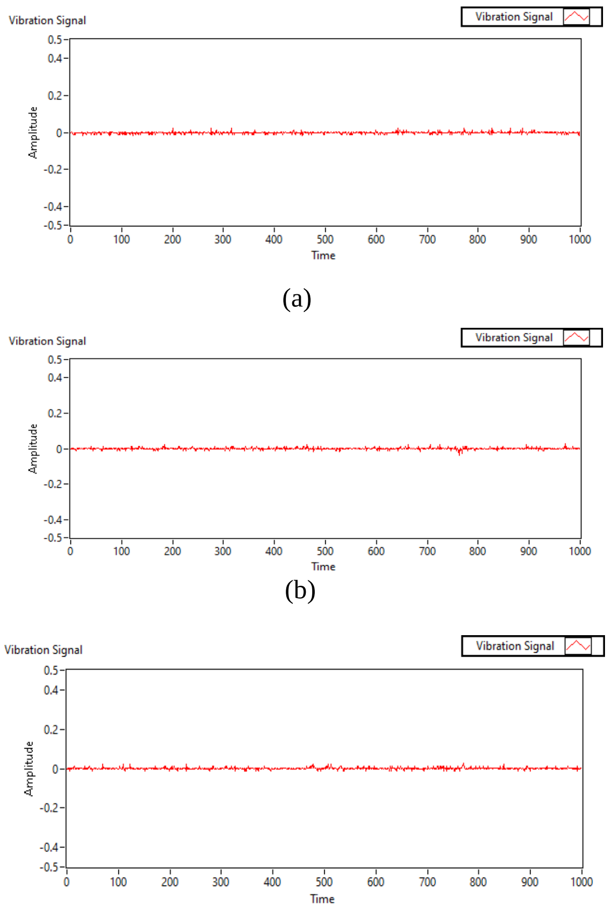
The experimental results are stated in Table 2.

Table 2. RMS data on tool condition

Condition	Experiment	Flank wear (mm)	V_{rms} (mV)	Range (mV)
New Conditions	1	-	6.24	6.24 -6.23
	2	-	6.26	
	3	-	6.23	
Good condition	4	0	54.36	54.36 - 67.08
	5	0.055	59.36	
	6	0.09	67.08	
Middle condition	7	0.103	83.05	83.05 - 112.07
	8	0.179	88.74	
	9	0.243	112.07	
Poor condition	10	0.307	125.14	125.14 – 152.09
	11	0.324	127.14	
	12	0.304	152.09	

Table 2 shows that to see the RMS value, four tool conditions are given: new condition, good condition, middle condition, and poor condition. The state of the tool is seen from the degree of wear on the tool's flank wear structure. Experiments were carried out three times in data collection to see the repetitive comparison of RMS values. From the table, it can be seen that each tool has almost the same value in each experiment. However, in poor condition, the 12 data has a value of 152.09 mV, which is very different from the 10 and 11 data, namely 125.14 mV and 127.14 mV.

Figure 5 shows the results of vibration in raw signal on the new condition, divided into three experiments.

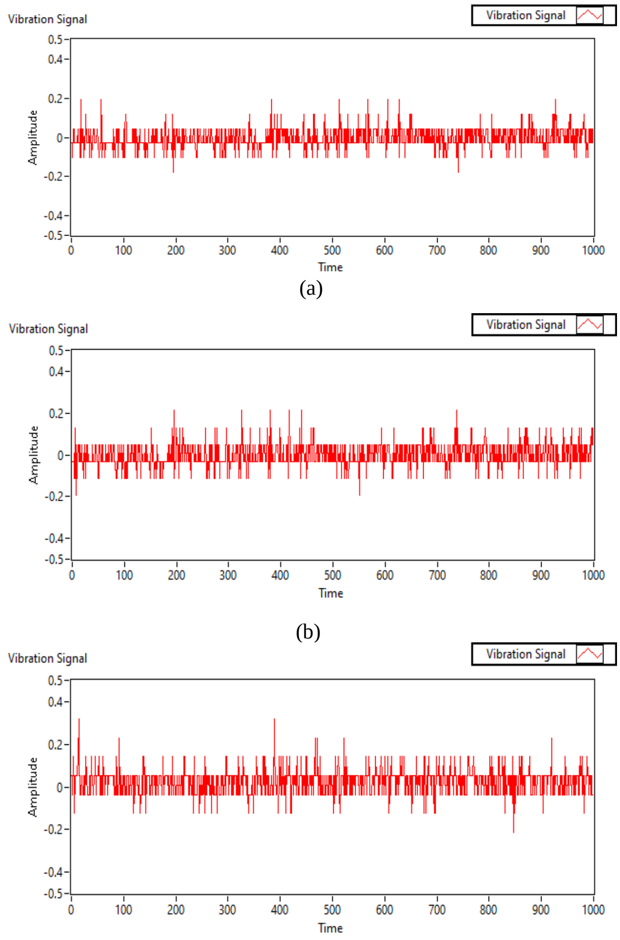


(a)

(b)

(c)

Figure 5. Results of vibration measurement on the new condition (a) Experiment 1; (b) Experiment 2; (c) Experiment 3



(a)

(b)

(c)

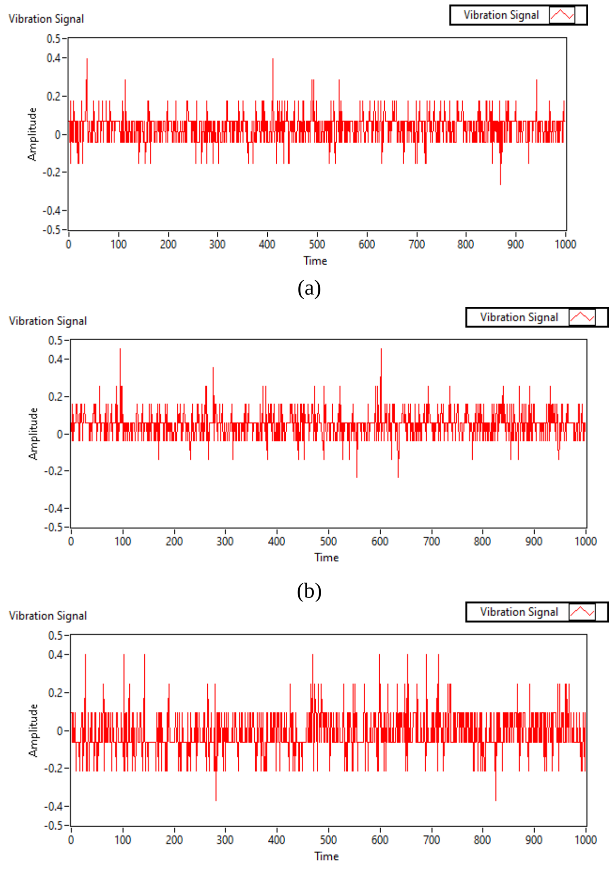
Figure 6. Results of vibration measurement of the tool in good condition (a) experiment 4; (b) experiment 5; (c) experiment 6

Figure 5 shows the results of direct vibration measurements or a namely raw signal using new condition cutting tools by repeating the experiment three times. The first experiment showed the results of the RMS value of 6.24mV, the second with 6.26mV results, and the third with 6.23mV.

Figure 6 shows the results of the vibration measurement of the tool in good condition, divided into three experiments. In this experiment, the amplitude value increased and showed RMS values in the range of 54.36mV to 67.08mV.

Figure 7 shows the results of direct vibration measurements using cutting tools in the middle condition divided into three experiments. In this experiment, the amplitude value increased from RMS 83.05mV to 112.07mV. Directly proportional to the increase in value Flank wear (VB) 0.103mm to 0.243mm.

Figure 8 shows the vibration measurement results on the cutting tool in poor condition, divided into three experiments. In this condition, the wave height reaches 0.5 amplitude, so if you enter the RMS equation, you will get a value of 125.14mV to 152.09mV. This increase is quite severe compared to using a good condition chisel with an amplitude value of 0.1 with an RMS range of 54.36mV to 67.08mV.

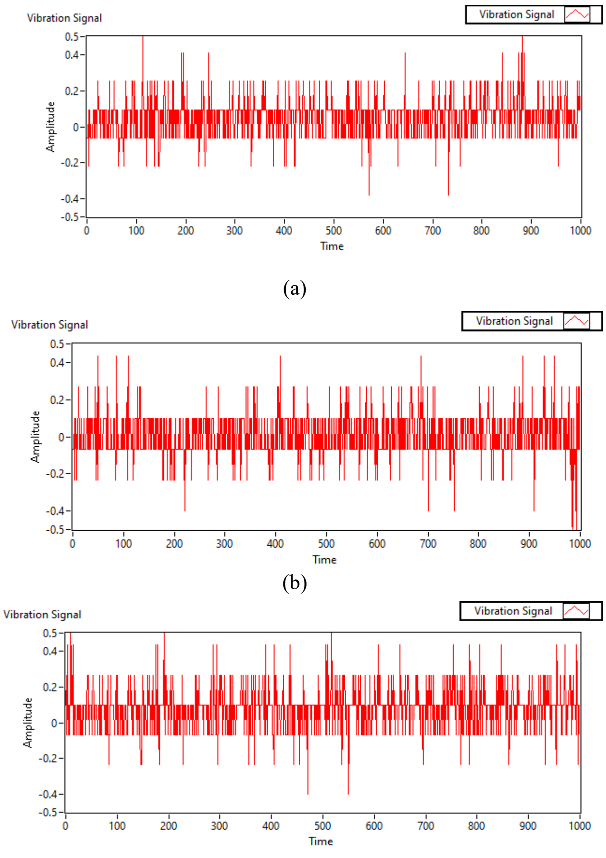


(a)

(b)

(c)

Figure 7. Results of vibration measurement on the cutting tool with middle conditions (a) experiment 7; (b) experiment 8; (c) experiment 9.



(a)

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Figure 8. Results of vibration measurement on the cutting tool with poor conditions (a) experiment 10; (b) experiment 11; (c) experiment 12

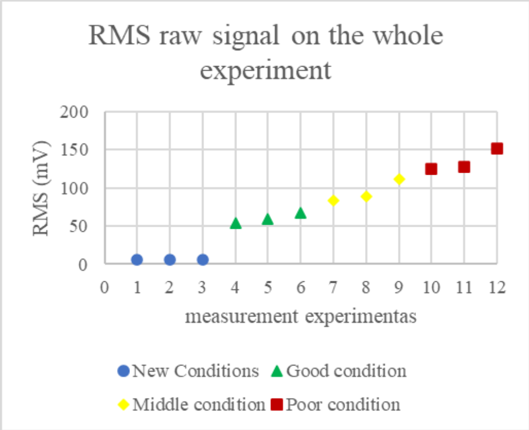


Figure 9. RMS raw signal value on the whole experiment

When considered, the form of data obtained shows that increased damage to the cutting tool eye will be directly proportional to the increase in the voltage of the RMS obtained. And when observed, each condition forms the voltage range of RMS that does not intersect between each cutting tool condition (clusterization). Figure 9 shows the RMS raw signal value.

3.3. *Fast Fourier Transform (FFT) Signal*

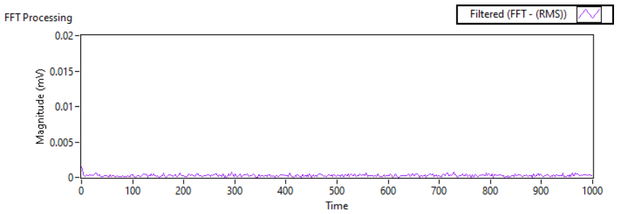
This research study conducted the Fast Fourier Transform signal analysis method to compare the results of Raw and Fast Fourier Transform vibration signals. The FFT signal plot in Table 3 shows the FFT data in the four conditions.

Figure 10 shows the results of the raw signal change to a fast Fourier transform (FFT) using a cutting tool with a new condition, and the RMS value is in the range of 0.0007mV to 0.0009mV.

Figure 11 shows the results of raw signal changes to a fast Fourier transform (FFT) using a good condition chisel, and the flank wear level increases to 0.09mm in direct proportion to the increase in the RMS value in the range 0.0068mV to 0.0080mV.

Table 3. FFT data

Condition	Experiment	Flank wear (mm)	Magnitude (mV)	Range (mV)
	1	-	0.0007	
New Conditions	2	-	0.0009	0.0007 - 0.0009
	3	-	0.0009	
	4	0	0.0068	
Good condition	5	0.055	0.008	0.0068 - 0.0080
	6	0.09	0.007	
	7	0.103	0.0089	
Middle condition	8	0.179	0.0105	0.0089 - 0.0147
	9	0.243	0.0147	
	10	0.307	0.0137	
Poor condition	11	0.324	0.0149	0.0137 – 0.0178
	12	0.304	0.0178	



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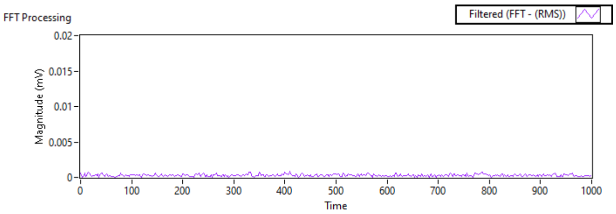

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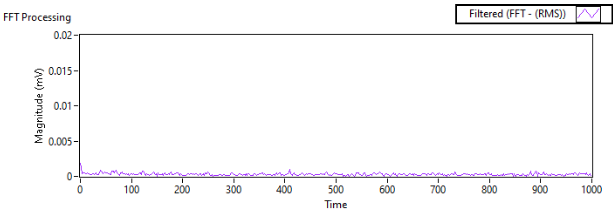
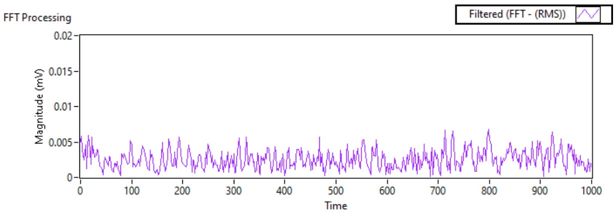


(c)

Figure 10. Signals of FFT process results under new conditions (a) experiment 1; (b) experiment 2; (c) experiment 3



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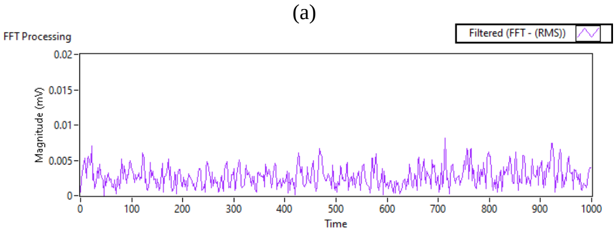

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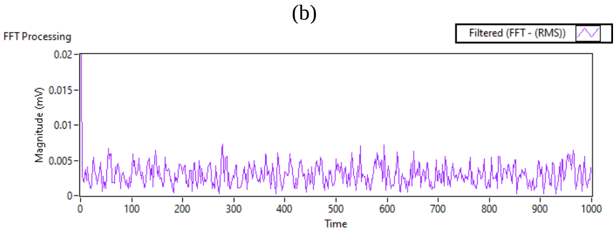
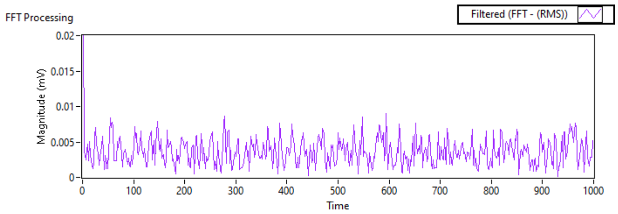


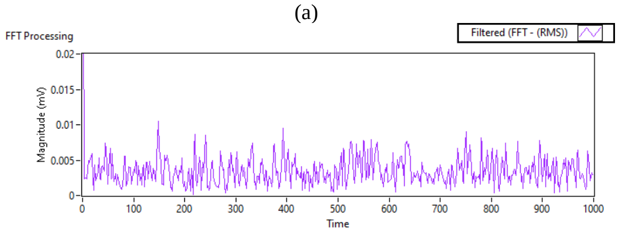
(c)

Figure 11. Signals of FFT process results under suitable conditions (a) experiment 4; (b) experiment 5; (c) experiment 6

Figure 12 shows the results of raw signal changes to the fast Fourier transform (FFT) using the cutting tool of the middle condition. The increase in flank wear of experiment 7 at 0.103mm is directly proportional to the increase in the RMS value of 0.0068mV, and experiment 9 with the Flank wear value of 0.243mm shows an increase in the RMS value of 0.0147mV.



(a)



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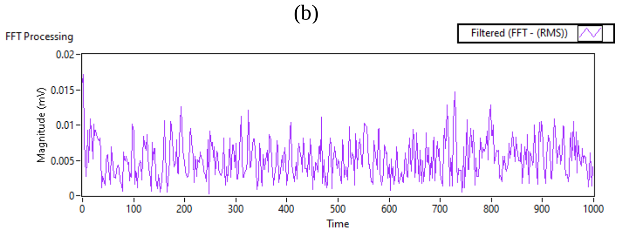

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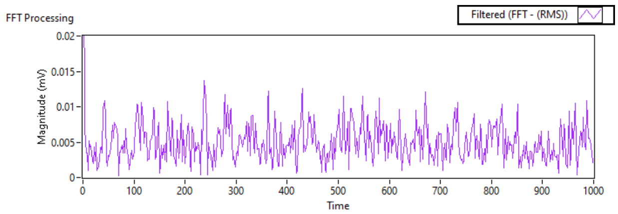
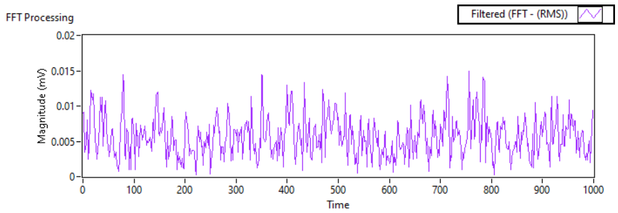
Figure 12. Signals of FFT process results under middle conditions (a) experiment 7; (b) experiment 8; (c) experiment 9



(a)



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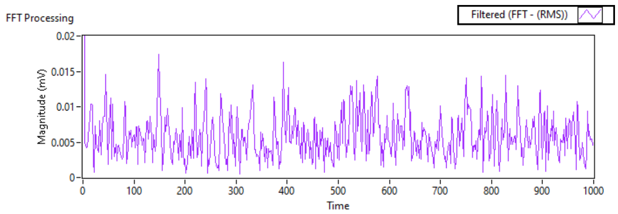

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Figure 13. Signals of FFT process results under poor conditions (a) experiment 10; (b) experiment 11; (c) experiment 12

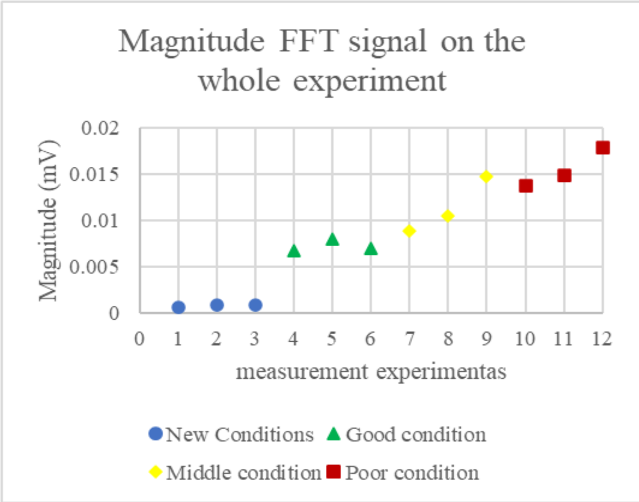

Figure 14. FFT signal condition

Figure 13 shows the results of raw signal changes to a Fast Fourier Transform (FFT) using a cutting tool in poor condition in experiment 10 with a flank wear value of 0.307mm while the RMS value decreased by 0.0137mV from 0.0147 in experiment 9. And it increased again in experiment 11 with flank wear of 0.324mm and an RMS value of 0.0149 mV.

Figure 14 is the overall FFT signal condition. The chart shows that each experiment's range of FFT values shows an increase in the range of damaged tool conditions and a decrease from 0.0089 mV until 0.0147 to a range of damaged tools from 0.0137 mV until 0.0178. the experiment is an imbalance in the data condition poor ten, whose value is in the middle condition range, and condition nine, which is in the damaged condition range. The data obtained show that the increase in magnitude is not always directly proportional to the damage to the tool.

Compared to previous studies using a prediction approach with FFT results[3], the prediction method with RMS values can provide more accurate and linear prediction results because the increase in tool damage will be linear with the increase in the RMS value obtained.

4. Conclusion

Based on the raw signal chart above, it is a combined result of raw signal testing from three cutting tool eye conditions by taking samples from as many as three experiments. The graph explains the increase in RMS values that occurs, depending on the degree of damage to the cutting tool. The greater the degree of damage will affect the degree of magnitude of the RMS value. When considered, the rated voltage value on the raw signal gives a greater value when compared to the measured magnitude value in the FFT process. This improves the reading of the value on the raw signal due to the wide range of reading values obtained.

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