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Analysis of material incision in milling machine against workpiece by vibration method

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Abstract: The Frais Machine is a piece of equipment used in manufacturing. To reach the specified production capacity, the machining process' time requirements must be more effectively managed. The goal of this study is to use the Fast Fourier Transform (FFT) technique to ascertain how changes in workpiece and spindle speed affect vibration. The milling machine utilized in this investigation is the Lushan Model ZX32, and the measuring device is a vibration analyzer coupled to an accelerometer sensor. Sengon Wood, PVC, and Aluminum 5052 are the workpiece varieties used. At spindle speeds of 95 and 150 rpm, the study's findings on aluminum material produced Y axis personal frequencies of 118 Hz with an amplitude of 15.12 mm/s^2 and 144 Hz with an amplitude of 9.657 mm/s^2. While PVC produced personal frequencies on the Y axis of 71 Hz with amplitudes of 12.11 mm/s^2 and 40 Hz with amplitudes of 7.025 mm/s^2 at spindle speeds of 95 and 150 rpm. Personal frequencies at 118 Hz with an amplitude of 10.9 mm/s^2 and 74 Hz with an amplitude of 7.97 mm/s^2 in the X axis are seen in wood materials with spindle speeds of 95 and 150 rpm. The findings demonstrate that differences in spindle rotation and workpiece have an impact on vibration; smaller vibrations are produced at higher rotation rates. Additionally, differences in the workpiece can impact tool life.

Keywords: Milling machine; workpiece variation; rotation speed; vibration; frequency

1. INTRODUCTION

The milling process is one of the machining techniques that is frequently used to create a component. A milling machine's operating principle is that a source of electrical energy is converted into energy of motion and then transmitted through a transmission to obtain rotational motion of the machine spindle. Milling machines can produce flat surfaces and a variety of other forms. The knife is held by and rotated on this machine's spindle to cut the workpiece [1][2]. There are several fundamental components to the machining process, including cutting speed, feeding speed, depth of cut, cutting time, and rate of metal removal. Based on the machine tool's variables and the workpiece's dimensions, it is possible to calculate certain aspects of the machining process [3][4].

The dependent variable, where vibration always happens during the machining process, is vibration on the workpiece and tool. Results like surface roughness are significantly impacted by the influence of machining vibrations that take place in milling machines. The effects of excessive vibration also impact tool and machine life (wear and tear) [5][6][7][8].

A cutting force is produced during the metal-machining process at a particular speed, feed, and depth of cut, with a particular lubrication, material, and geometry [9]. Any of these variables can change and have an impact on forces. Forces are significant because they influence how the tool, workpiece, and worker deflect, which in turn determines how big the finished result will be. Chatter and vibration phenomena, which are ubiquitous in machining, are also influenced by forces [10]. To ascertain the impact of vibration on the workpiece and the end mill during the machining process, vibration testing on the milling machine has been done, among other things, on the workpiece and the milling machine's end mill chisel [5][11][12][13][14][15][16][17][18][19][20][21]. The variable spindle rotation, infeed speed, and infeed depth are shown to have a substantial impact on workpiece vibration, according to statistical study on S45C steel [11].

The analysis' findings for st 42 and st 60 steels demonstrate that the vibration amplitude and surface roughness of the workpiece are correlated [22]. Additionally, surface roughness and vibration amplitude have a rotational association. Additionally, there is a relationship between inset motion and vibration amplitude. Surface roughness, depth of cut, and vibration amplitude are further factors. as well as the surface roughness's vibration amplitude [7].

This study aims to determine the effect of spindle rotation on milling machine vibration, as well as determine the effect of the workpiece on the resulting vibration value. So as to safely determine the equipment for machining operations, including the machine, end mill cutters, and work environment.

2. METHOD

The accelerometer sensor was used in this study to collect vibration data. Using MATLAB software, time domain data from the accelerometer sensor is transformed into frequency domain data. Analysis of vibration signals using an FFT graph.

2.1 Flow chart

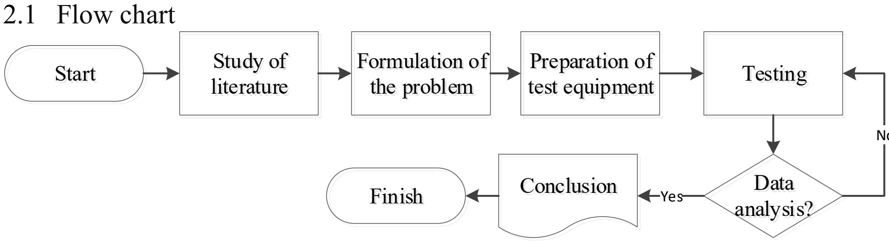


Figure 1. Flow chart

Figure 1 illustrates the steps taken by the author during the research process to gather the data required for the study. The foundation of this research will be a literature review, which at this point involves learning about theories connected to milling machine vibration research through books, journals, or the internet. Formulation of the Problem: The Background of the Research is Used to Formulate the Problem. Getting ready the test equipment, including the FFT analyzer and the accelerometer sensor. Testing, using the FFT Analyzer tool to measure the magnitude of vibrations that occur, is done on milling machines using various materials and rotating speeds. The results of vibration testing between the X, Y, and Z axes using various materials and rotating at various speeds were compared during data processing. utilizing the program FFT Analyzer. Results & Conclusions, which include findings from an analysis of the FFT Analyzer tool's analysis of field test data.

2.2 Data collection and processing stages

Figure 2 shows the phases of the data gathering and processing procedure used by researchers to get the data required for the study. Installing accelerometer sensors on the X, Y, and Z axes, which were controlled by two variations of spindle speed, namely 95 rpm and 150 rpm, was done in order to collect data. **Figure 3** shows more specifics. Figures 3a, 3b, and 3c show the locations of the measurement points on the X, Y, and Z axes, respectively.

Figure 2. Stages of data collection and processing

(a). Axis X (b). Axis Y (c). Axis Z

Figure 3. X, Y, and Z

The steps for gathering data are as follows:

a) Install the Khoctek 107b Accelerometer on the X, Y, and Z axes as shown in step one.
b) Switch the spindle motor on.
c) Perform the feeding face milling procedure.
d) Capture X, Y, and Z axis engine vibration signal data.
e) After that, save the vibration analyzer's data on vibrations to a flash disk.
f) Apply the same procedures to various materials and spindle speeds.

The information gathered from testing with the Khoctek 107b Accelerometer sensor is then saved in a text file (.txt), which will subsequently be loaded into the Matlab program to provide graphical results from the vibration test. The following is the data processing stage:

a) Open Matlab R2020a, first.
b) Then, after selecting new M-file until a new screen displays, manually enter the test data obtained from the vibration analyzer into Matlab using the pre-existing symbols.
c) After entering the data, select the "Run" option from the editor menu area to display a graph of the vibration test results along with the results of the data test.
d) The analysis of the vibration graph comes next after the graphic data has been collected.

3. RESULTS AND DISCUSSION

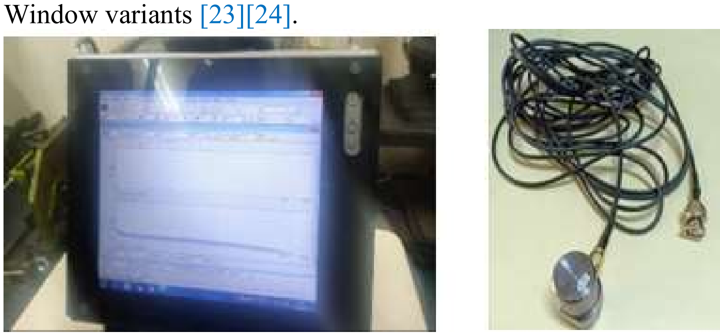
3.1 Model ZX32 milling machine from lushan

The ZX32 type, manufactured in China for the Lushan milling machine used in this investigation, is capable of face milling operations. This machine is typically utilized in the mechanical engineering lab at Mercu Buana University's manufacturing process practicum. Figure 4 depicts the Lushan ZX32 milling machine.

Figure 4. Lushan ZX32 milling machine

3.2 Khoctek 107b vibration analyzer and accelerometer sensor

Ono Sokki Japan's portable FFT Analyzer type CF-3600A (4-ch) was employed as the measuring device in this work. Students at Mercu Buana University frequently utilize this instrument for their vibration practica. As shown in Figure 5a, the measurement data can typically be viewed in both the time domain and the frequency domain. Table 1 lists the features of the FFT Analyzer CF-3600A (4-ch). According to Table 1, the FFT Analyzer can analyze frequencies up to 40 kHz. With available Window variants [23][24].



(a). FFT Analyzer (b). Accelerometer sensor with BNC cable

Figure 5. Vibration measuring instrument

Table 1. Vibration *analyzer specifications*

Type	Analyzer
Number of Channels	4
Touch screen	Yes
Maximum frequency range	40.000 Hz
USB Port	2
VGA Port	1
LAN Port	1

The Khoteck 107b Accelerometer Sensor is the sensor utilized in this investigation. It is linked to a BNC cable as indicated in **Figure 5**b. This Russian-made accelerometer sensor by Khoteck weighs 50 grams and has a frequency range of 2 Hz to 10 kHz. See **Table 2** for further information on the Khoteck 107b Accelerometer sensor's specifications**.**

Table 2. Khoctek 107b *accelerometer sensor specifications*

Type	Piezoelectric
Conversion sensitivity rate	pcs^2 m 5.0 – 7.0
Frequency range	2 Hz – 10.000 Hz
Frequency resonance	> 28 kHz
Transverse sensitivity	< 5 %
Cable length	1.5 m
Dimension (mm)	ϕ 25 x 24
Weight	50g, 8oz

3.3 End Mill 1AL6

The end mill utilized in this study is a High Speed Steel (HSS) end mill with a MOLDINO chisel brand and a 6mm chisel diameter. **Figure 6** contains more information. depicts an end mill with a blade that has the incision on one side [25]. This type of knife has a sharp bottom made of High Speed Steel (HSS).

Figure 6. End Mill 1AL6

3.4 Aluminium 5052

Aluminum 5052 was the type of aluminum employed in this study (**Figure 7**). In order to create this aluminum alloy, magnesium is added to the base metal. With an Al composition of 95.7-97.7%, the 5xxx series aluminum has a 2-4% alloying element content [26].

Figure 7. Aluminum 5052

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3.4 PVC

Figure 8 depicts the PVC material utilized in this study. The most adaptable type of plastic is PVC. PVC is made up of just two basic components, namely:

- Chlorine (salt-forming element)
- Ethylene (from crude oil)

In terms of global use, PVC comes in third place among thermoplastic polymers. Over 50% of PVC produced globally is utilized in building. PVC is a sturdy, reasonably priced building material that is simple to assemble [27].

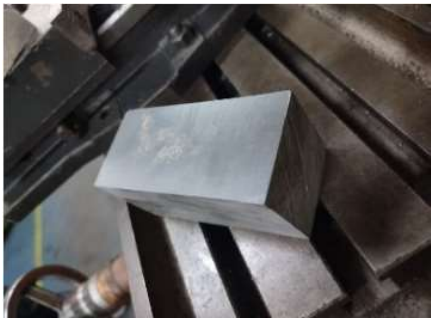

Figure 8. PVCs

3.5 Sengon wood

Sengon tree wood was the type of wood employed in this investigation (Figure 9). Crates, boats, home components, wooden bridges, planking, and the match business are all made from this wood. considering that sengon wood is often light and soft. Sengon wood is fairly solid, straight-grained, and slightly rough, yet it's also simple to work with. The heartwood ranges in color from glossy yellow to red-ivory brown, and is divided into strong class III-IV and durable class III-IV according on its strength and durability [28].

Figure 9. Sengon wood

3.6 Matlab

MATLAB R2020a was the program utilized in this study (**Figure 10**). Matrix Laboratory is the abbreviation for the word. This language combines programming, visualization, and processing abilities in a user-friendly setting. Unlike other languages that need array declarations, Matlab offers an interactive approach that exploits the idea of arrays/matrices as ordinary variable items. The transfuser records vibration data, which is processed using Matlab software utilizing the Fast Fourier Transform (FFT) algorithm.

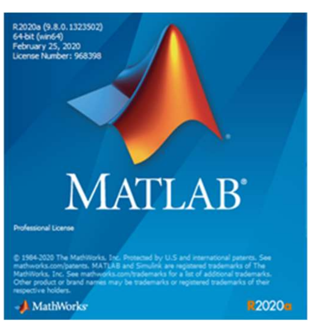

Figure 10. MATLAB R2020a

Results of the Fast Fourier Transform were obtained by processing data from FFT Analyzer experiments using the MATLAB program. Accelerometer sensors were installed on the X, Y, and Z axes, and spindle speeds of 95 rpm and 150 rpm were used to set them for the measurements. If the rotational variation in frequency is converted, 1.6 Hz and 2.5 Hz will result. Researchers put PVC, Sengon Wood, and Aluminum 5052 to the test. A graph of the FFT results on Aluminum 5052 with a rotation speed of 95 rpm is shown in **Figure 11**. The first personal frequency is seen in the image with a frequency of 118 Hz and an amplitude of 2.019 mm/s^2 on the X axis. A personal frequency of 118 Hz and an amplitude of 15.12 mm/s^2 are obtained on the Y axis. And on the Z axis, an amplitude of 14.07 mm/s^2 and a personal frequency of 118 Hz are found. Vibration measurements on aluminum (95 rpm) compared using FFT

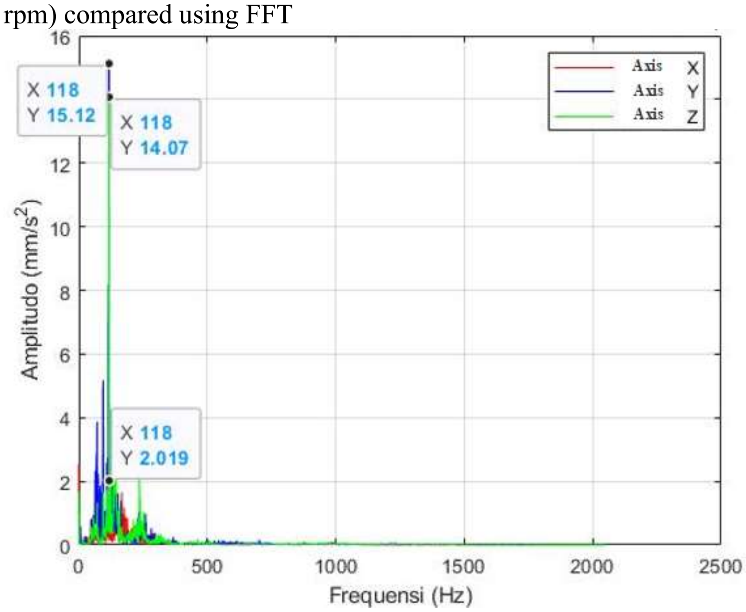

Figure 11. Shows the FFT outcomes on aluminum at 95 rpm.

A graph of the FFT results on Aluminum 5052 with a 150 rpm rotation speed is shown in **Figure 12**. The first personal frequency is seen in the image with a frequency of 71 Hz and an amplitude of 2.218 mm/s^2 on the X axis. A personal frequency of 144 Hz and an amplitude of 9.657 mm/s^2 are obtained on the Y axis. And with an amplitude of 5.283 mm/s^2, a personal frequency of 71 Hz is obtained on the Z axis. The statistical analysis's findings demonstrate that the milling machine's vibration is definitely influenced by the spindle. Vibration measurements on aluminum (150 rpm) compared using FFT.

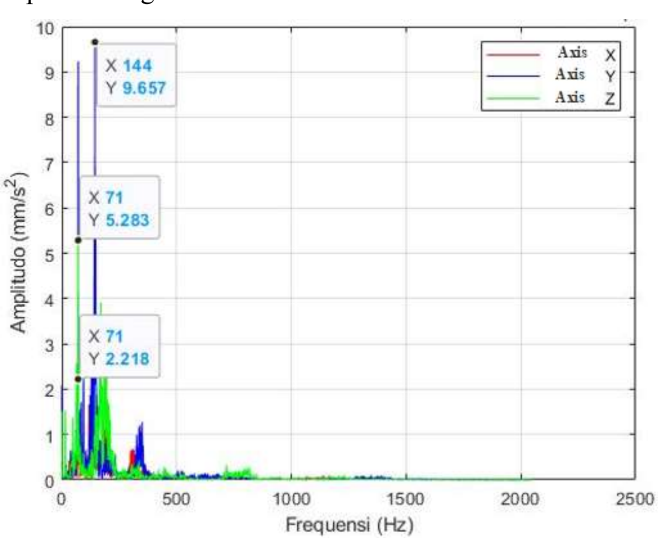

Figure 12. Shows the FFT outcomes on aluminum at 150 rpm.

A graph of the FFT results on PVC with a rotation speed of 95 rpm is shown in **Figure 13**. The first personal frequency is seen in the image with a frequency of 47 Hz and an amplitude of 1.377 mm/s^2 on the X axis. A personal frequency of 71 Hz and an amplitude of 12.11 mm/s^2 are obtained on the Y axis. And with an amplitude of 2.241 mm/s^2, a personal frequency of 165 Hz is obtained on the Z axis. FFT comparison of vibration readings on PVC (95 rpm)

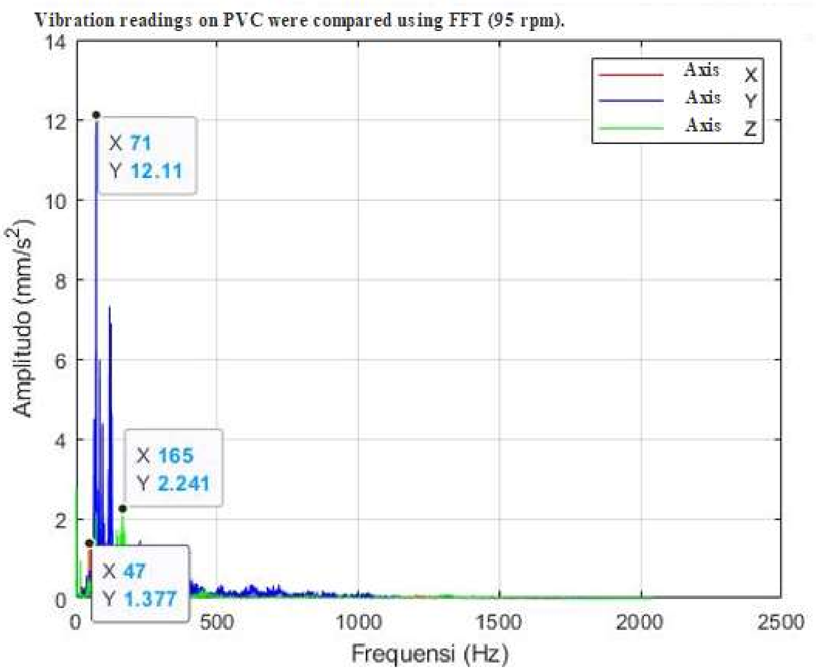

Figure 13. Shows the FFT outcomes on PVC at 95 rpm.

Figure 14. shows a graph of the results of the FFT on PVC with a rotation speed of 150 rpm. In the figure it is detected that the first personal frequency appears at a frequency of 92 Hz with an amplitude of 2.169 mm/s^2 on the X axis. On the Y axis a personal frequency of 40 Hz is obtained with an amplitude of 7.025 mm/s^2. And on the Z axis, a personal frequency of 71 Hz is obtained with an amplitude of 4.227 mm/s^2.

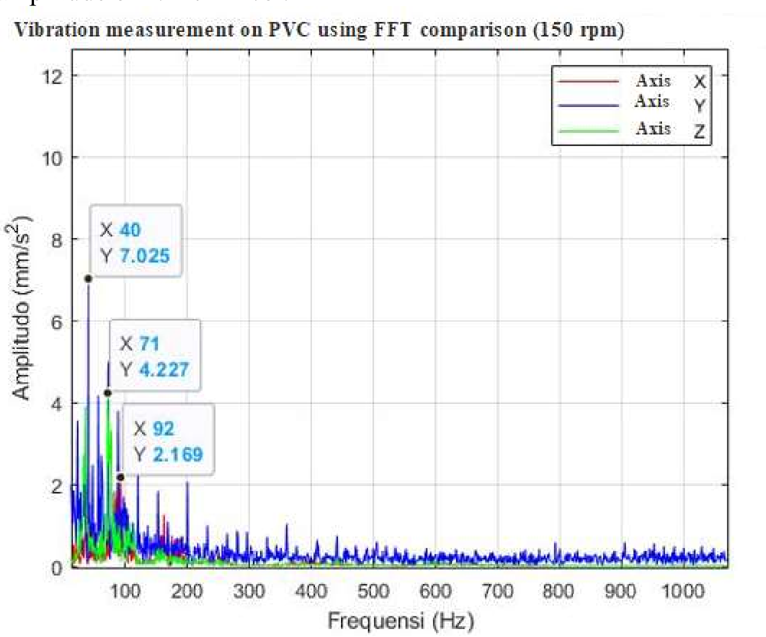

Figure 14. FFT outcomes on PVC at 150 rpm rotating speed

A graph of the FFT results on Sengon Wood with a rotation speed of 95 rpm is shown in **Figure 15**. The first personal frequency is seen in the image with a frequency of 118 Hz and an amplitude of 10.9 mm/s^2 on the X axis. A personal frequency of 118 Hz and an amplitude of 5.022 mm/s^2 are obtained on the Y axis. And with an amplitude of 3.138 mm/s^2, a personal frequency of 143 Hz is obtained on the Z axis. Due to the fibrous nature of sengon wood, the amplitude on the X-axis is fairly considerable. so that a larger amplitude is experienced at the same frequency.

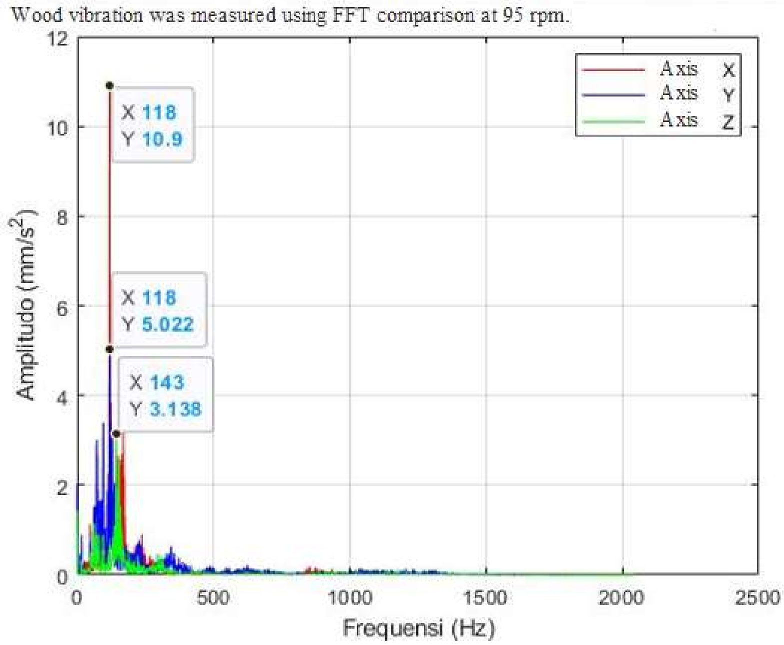

Figure 15. FFT outcomes on wood at a 95 rpm rotational speed

Figure 16 displays a graph of the FFT results on Sengon Wood with a 150 rpm rotation speed. The first personal frequency is seen in the image with a frequency of 74 Hz and an amplitude of 7.97 mm/s^2 on the X axis. A personal frequency of 35 Hz and an amplitude of 5.729 mm/s^2 are obtained on the Y axis. And with an amplitude of 4.239 mm/s^2, a personal frequency of 118 Hz is obtained on the Z axis.

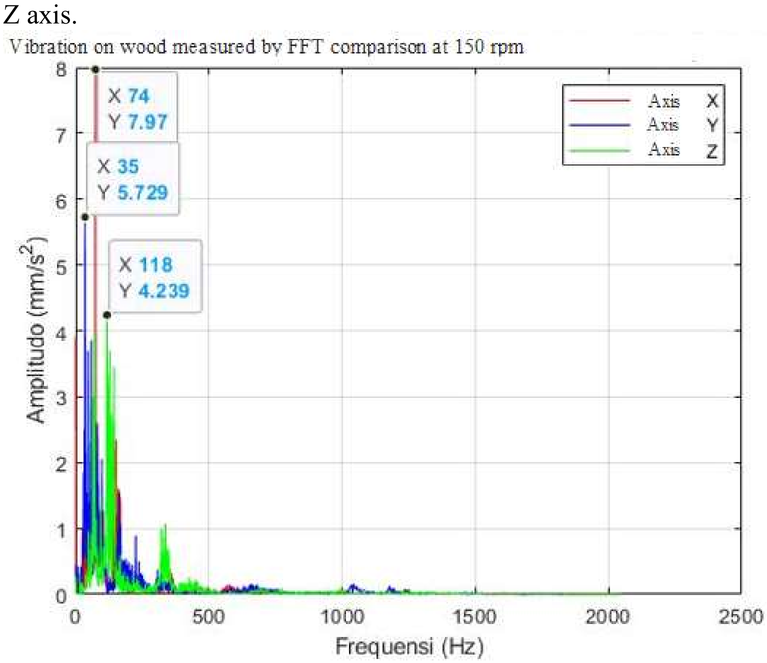

Figure 16. Shows the FFT outcomes on wood at 150 rpm.

Table 3. **S**hows the findings of vibration tests performed on a milling machine.

	Aluminum 95 rpm	**Aluminium 150 rpm**	**PVC 95 rpm**	**PVC 150 rpm**	**Wood 95 rpm**	**Wood 150 rpm**
Axis X	2.019 mm/s^2	2.218 mm/s^2	1.377 mm/s^2	2.169 mm/s^2	10.9 mm/s^2	7.97 mm/s^2
Axis Y	15.12 mm/s^2	9.657 mm/s^2	12.11 mm/s^2	7.025 mm/s^2	5.022 mm/s^2	5.729 mm/s^2
Axis Z	14.07 mm/s^2	5.283 mm/s^2	2.241 mm/s^2	4.227 mm/s^2	3.138 mm/s^2	4.239 mm/s^2

The findings of vibration measurements with variations in spindle rotation speed of 95 rpm and 150 rpm are presented in **Table 3**. The largest vibration amplitude for aluminum and PVC materials occurs on the Y axis, according to **Table 3**. Meanwhile, in Sengon Wood, the X axis has the maximum vibration amplitude.

4. CONCLUSION

It is possible to draw conclusions from this research after gathering information on machine vibration values caused by variations in the spindle's rotation and variations in the workpieces during the milling machining process. The results of the statistical investigation, specifically: The higher the engine speed, the lower the resulting vibration will be, demonstrate that spindle rotation is proved to effect engine vibration. This occurs as a result of the spindle rotating steadily at high spindle speed. Additionally, because the workpiece's fluctuation has a significant impact on the high vibration amplitude, the tool's life will be shortened and it will get blunt more quickly.

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