Vol. 5, No. 1, April 2024, page 83-89
JTTM: Jurnal Terapan Teknik Mesin
p ISSN 2721-5377| e ISSN 2721-7825
http://jurnal.sttmcileungsi.ac.id/index.php/jttm

Investigation of harvesting energy vibrations due to the feed process on milling machines

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Submitted: 30/10/2023 Revised: 19/11/2023 Accepted: 26/11/2023

Abstract: Milling machines are machines used in the production process. The time required during the machining process must be more efficient in order to obtain the desired production capacity. The aim of this paper is to utilize vibrations originating from milling machines in industry as a source of Harvesting Energy Vibration. The research was carried out by varying the feeding depth of the milling machine so that it could be seen how much stress was produced. The Lushan Model ZX32 milling machine was used in this research, where vibrations from the vibration source were measured using an FFT Analyzer connected to an Accelerometer Sensor and Harvesting energy vibration connected to an Oscilloscope. Meanwhile, the workpieces used in this research were Aluminum 5052 and PVC. The results of the research were that on PVC material with an ingestion depth of 1 mm, the vibration frequency at 210 rpm was 71 Hz, the amplitude was 1.38 mm/s^2, resulting in a harvesting energy of 6.449 mV. And the results of research using aluminum at 210 rpm rotation with a feeding depth of 3 mm obtained a vibration frequency of 90 Hz with an amplitude of 1.508 mm/s^2 producing a harvesting energy of 5.856 mV. The research results show that the PVC material produces higher harvesting energy vibration at a depth of 1 mm, and the aluminum material produces higher harvesting energy vibration at a depth of 3 mm.

Keywords: Milling machine; vibration; frequency; FFT; Harvesting

1. INTRODUCTION

In our current age, we are clearly moving towards an all-tech way of life. More people are carrying portable electronic devices than ever before. These devices enable incredible power and versatility in communication and problem solving. However, as portable device technology has advanced rapidly, battery and energy storage technology has not kept pace. New technology allows these portable devices to become smaller, but the battery size remains the same. It may be that sometimes the battery needs to be larger to accommodate the greater power requirements of a portable device. An alternative to batteries is to create energy on the go. Using piezoceramic (PZT) materials is one way to achieve this. Piezoelectrics are the most popular smart materials. Piezoelectric materials have been widely used as transducers capable of converting electrical energy into mechanical movement or force or vice versa, making it possible to harvest energy from vibrating structures [1].

An energy harvester is a tool for collecting energy from mechanical energy and converting it into electrical energy. The electrical energy produced in energy harvesters is relatively small so it cannot be used directly. Generally, the energy produced is stored first in an electrical energy storage (battery or conductor). One of the energy harvesting tools is piezoelectric which is capable of converting mechanical energy from vibrations into electrical energy. When a piezoelectric material experiences pressure, the particles that make up the piezoelectric will become polarized, causing a concentration of electric charge [2].

The milling process is one of the most widely used machining processes for manufacturing components. The time required for conventional and non-conventional machining processes to make components must be as fast as possible in order to achieve high production capacity or be on target. Vibration in the workpiece and tool is a dependent variable where vibration always occurs during the machining process. The influence of machining vibrations that occur on milling machines greatly influences results such as surface roughness. Machine life and tool life (wear) are also affected by the effects of excessive vibration [3]. In research, a vibration drive system was developed with the aim of generating and inducing vibrations. The acceleration of the vibration motion is measured via an accelometer, and oscilloscope settings [4].

Research has been carried out on vibration testing at Mercubuana University, such as vibration analysis using motorbike sources [5], [6]. Identification of tapper bearing damage is carried out by FRF testing, excitation force using harmonic signals via cellphone [6], cracks in gears [7]. Compare the engine and bearing characteristics of two cylinder blocks to determine how sensitive the system is and changes [8]. Tapered bearings provide higher amplitude vibrations than ball bearings [9]. FRF testing is used to determine the dynamic characteristics of a single cylinder diesel engine [10] and Sigra disc brakes [11] that global and local vibration modes are obtained. Apart from that, the bump test method can be used to determine damage to Sigra disc brakes [12]. The vibration method is used in the production process to predict end mill damage on CNC machines [13]. In industrial equipment, damage analysis was carried out on the screw compressor using vibration testing, showing damage to the screw shaft due to unbalance [14]. Meanwhile, electronics is carried out by testing the vehicle actuator to predict the extent of damage by vibration testing using the Hilbert transform method [15]. The FRF method has been widely used to predict a structure, such as detecting damage [16], keretakan [17] and dynamic characteristics of the structure [18].

However, research on feeding workpieces on milling machines to harvest energy from vibrations is still rarely carried out, and tools are also needed to capture these vibrations which are then converted into electrical energy. Therefore, it is necessary to carry out further research regarding workpiece feed on milling machines as a vibration source to harvest energy.

2. METHOD

When conducting research, it is important to make a research plan to get good results. In this research, an experimental study was carried out. There are two data collections, namely vibration data using the FFT Analyzer and energy vibration data harvesting using an oscilloscope. Data from this test will be processed in Matlab, and analyze the current voltage from the influence of the eccentric mass on rotor dynamics, as shown in Figure 1.

Figure 1, it is shown showing the stages of collecting vibration data and harvesting vibration energy, where the accelerator sensor is installed on the milling machine frame. The accelerometer sensor is connected to an FFT analyzer to determine the magnitude of the vibration produced and then analyzed using Matlab. This same treatment is carried out on a havesting energy vibration device, then the resulting voltage is measured using a portable oscilloscope and analyzed using Matlab. The rotation speed of the milling machine is given as 210 rpm. In this study, the depth of feeding was varied at 1 mm, 2 mm, and 3 mm. The test results are then processed and analyzed by comparing the results obtained.

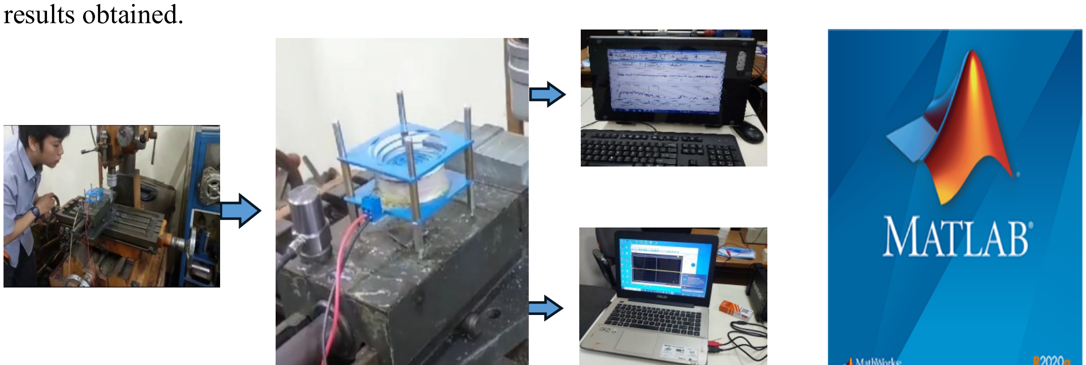

Figure 1. Data collection process (a) experimental measurement of vibration sources, (b) data collection harvesting vibration energy

The tool used to harvest vibration energy uses an electromagnetic type, as shown in Figure 2. The way the energy harvester works is that if vibrations occur in the milling machine due to the

p ISSN 2721-5377 | e ISSN 2721-7825
DOI 10.37373/jttm.v5i1.882

feeding process, it will cause the magnet in this tool to move up and down due to the vibration that occurs. This up and down movement of the magnet passes through the copper coil at the bottom of the magnet, causing variations in the magnetic flux in the coil, which then produces a current output.

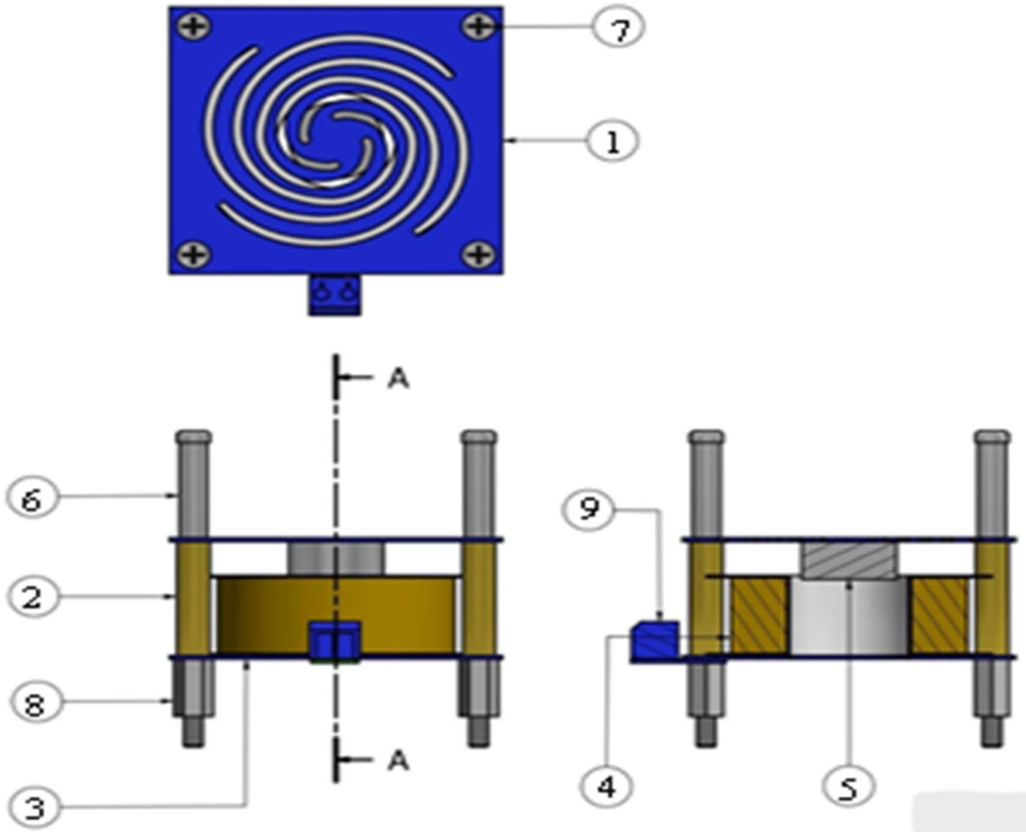

Figure 2. Vibration energy harvesting tool

The spring plate material used to harvest energy is brass plate. The size of the spring plate used is 70 mm x 70 mm with a thickness of 0.02 mm with a circular spiral pattern. For the names of the parts in the vibration energy harvesting tool used in the research, see Table 1.

Table 1. List of components for vibration energy harvesting equipment

Parts List			
Item	Qty	Part Number	Description
1	1	Spring plate	
2	4	Spacer 1	
3	1	Plate	
4	1	Coil	
5	1	Magnet N55	
6	4	Spacer 2	
7	4	Bolt	
8	4	Nut	
9	1	Circuit board	

3. RESULTS AND DISCUSSION

In the research, testing was carried out by setting the FFT Analyzer and Protable Oscilloscope. Milling Machine Number of data taken on the FFT Analyzer frequency range 0–120 Hz. The rotational speed of the milling machine is given at 210 rpm, providing variations in the workpiece and feed depth of 1mm, 2mm, 3mm. Figure 3 shows the FFT results of a PVC workpiece at a depth of

1mm. The amplitude (RMS) is 5.899 mm/s^2, with 59 Hz, 7.185 mm/s^2 with 64 Hz, and 1.38 mm/s^2 with 71 Hz.

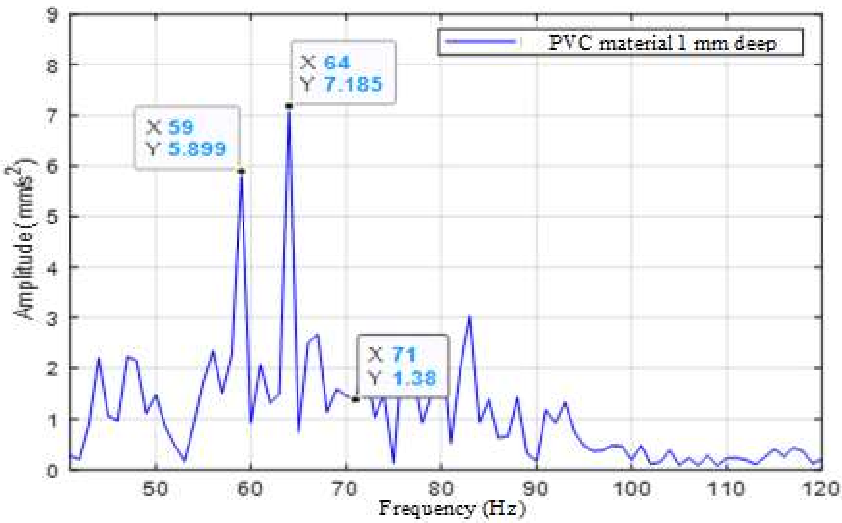

Figure 3. FFT results of a milling machine on a PVC workpiece

Next, the results of the energy harvesting data analysis are carried out by an FFT analysis process using the MATLAB program. FFT results from the oscilloscope, with a PVC workpiece at a depth of 1mm at a rotational speed of 210 rpm can be seen in Figure 4.

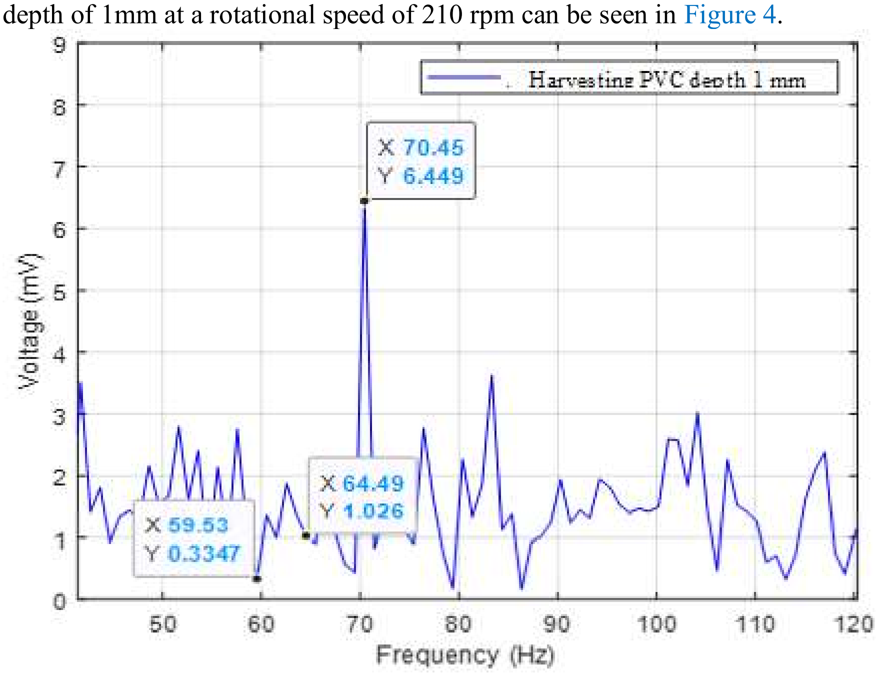

Figure 4. Energy harvesting results with PVC workpiece at a depth of 1 mm

Figure 4 it is shown that the magnitude of the voltage produced by the energy harvester produces a magnitude of vibration frequency voltage at 59 Hz with an amplitude of 5.899 mm/s^2 producing a harvesting energy of 0.3347 mV, while at 64 Hz an amplitude of 7.185 mm/s^2 produces a harvesting energy of 1.026 mV. mV, and at 71 Hz an amplitude of 1.38 mm/s^2 produces a harvesting energy of 6.449 mV.

Tests with aluminum workpieces were also carried out using the same method to determine the effect of workpiece ingestion depth in harvesting vibration energy. Figure 5 shows the results of testing with an aluminum workpiece at a depth of 3mm.

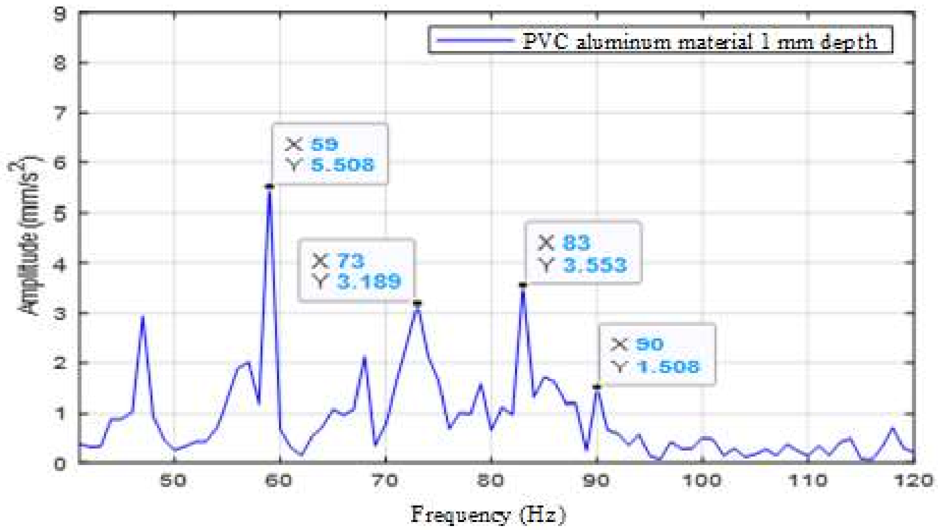

Figure 5. FFT result aluminum workpiece depth 3 mm

Figure 5, the amplitude produced using 3mm depth aluminum. There are 4 points where the highest voltage current is obtained, including at frequencies of 59 Hz, 73 Hz, and 83 Hz, and the smallest is 90 Hz, where the highest voltage current is obtained at a frequency of 59 Hz.

The results of the energy harvesting data analysis are carried out by an FFT analysis process using the MATLAB program. FFT results from the oscilloscope, with an aluminum workpiece at a depth of 3mm at a rotational speed of 210 rpm can be seen in Figure 6.

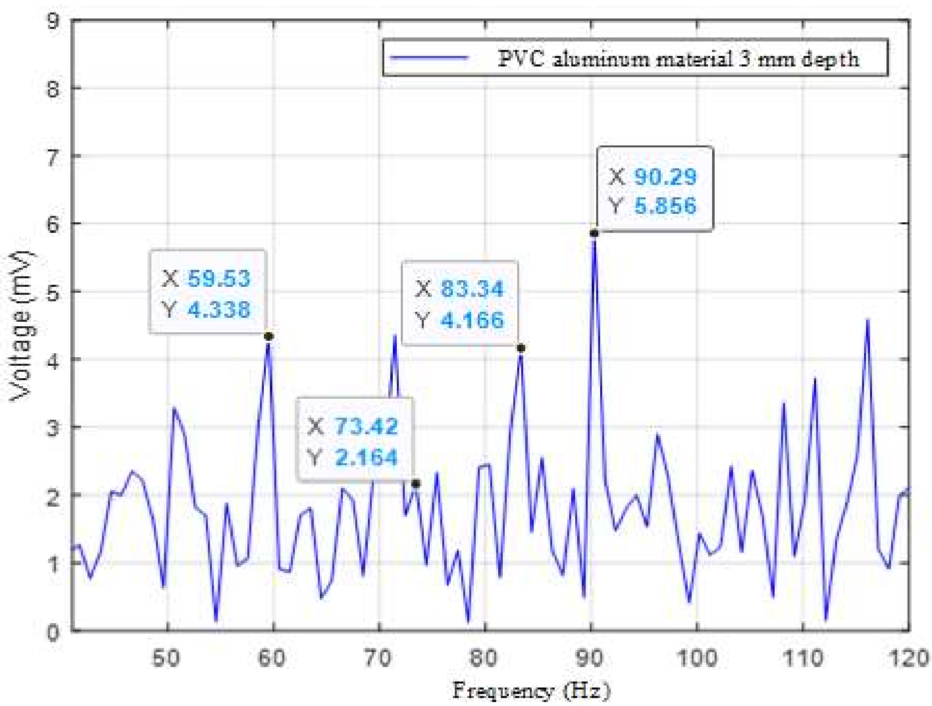

Figure 6. The result of harvesting energy with an aluminum workpiece with a feeding depth of 3mm

Figure 6 it is shown that the voltage generated from the energy harvester produces a voltage of 59 Hz with an amplitude of 5.508 mm/s^2 producing a harvesting energy of 4.338 mV while at 73 Hz with an amplitude of 3.189 mm/s^2 it produces a harvesting energy of 2.164 mV, at 83 Hz with an amplitude of 3.553 mm/s^2 produces a harvesting energy of 4.166 mV, and at 90 Hz with an amplitude of 1.508 mm/s^2 produces a harvesting energy of 5.856 mV.

3 CONCLUSION

Based on this research, vibrations originating from milling machines in industry are used as a source of Harvesting Energy Vibration. The depth of ingestion of the workpiece appears to greatly influence the magnitude of the resulting amplitude but does not affect the magnitude of the stress produced. In this research, the two workpieces show that the aluminum material produces higher harvesting energy vibration at a depth of 3 mm, and the PVC material produces higher harvesting energy vibration at a depth of 1 mm. Further research on harvesting energy from vibrations can be integrated with other renewable energies such as solar, wind and wave power.

ACKNOWLEDGEMENT

We would like to thank Mr. Dikki, and Mr. Firman, as staff of the Mechanical Engineering Laboratory at Mercu Buana University, and colleagues who helped complete this journal.

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