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A comparison of hilbert and fast fourier transform techniques for reciprocating motors

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Abstract: The development of information and technology has had a profound effect on human existence, especially in light of the need for efficient mobility. However, as a car ages, symptoms that impact its safety and performance begin to appear. These signs are cause for concern. Interference with automotive components, like coils, is one problem that can significantly impact driving performance and safety. This issue has been successfully resolved by vibration analysis techniques, which identify damage to various automotive components. In order to understand the vibration characteristics of a piston motor at various rotational speeds. Vibration data was gathered using the piston motor at three different speeds: 900 rpm, 1500 rpm, and 3500 rpm. The analysis made use of both the FFT analyzer, which provides a clear understanding of frequency spectrum information, and the Hilbert approach, which provides a deep understanding of frequency energy. The results showed that changes in reciprocating motor speed caused changes in vibration characteristics. Conversely, the average frequency energy tends to stay constant over a range of speeds, indicating that reciprocating motor characteristics could be intricate and relatively unaffected by changes in speed. This study suggests that using vibration analysis techniques such as FFT and Hilbert can provide different insights into the vibration characteristics of piston motors operating at different speeds. A deeper understanding of this phenomenon may have a big impact on vehicle performance analysis and maintenance programs. Further investigation will be necessary to completely comprehend the intricacy of vibration characteristics in reciprocating motors at different speed conditions.

Keywords: Vibration; Fast Fourier Transform (FFT); Hilbert; piston motor

1. INTRODUCTION

The advancement of information and technology has significantly improved human life by bringing about a number of innovations that make living more comfortable and productive. As technology progresses, so does the necessity for effective mobility, particularly given the rise in urbanization and complexity of lifestyle dynamics. In addition to being a means of transportation, cars have evolved to become an extension of daily life, overcoming the difficulties posed by congested areas and offering a new degree of comfort when driving [1]. In this regard, internal combustion engines—like reciprocating motors—are essential to the support of contemporary mobility.

However, as a car ages, symptoms may show up that affect its safety and performance. Problems with rough engine noises, decreased power, increased engine temperature, and issues with non-optimal fuel combustion are common in vehicles, including minibuses and other types of vehicles [2]. Vehicle malfunctions, like coil problems, can seriously affect performance and driver safety [3].

Vibration analysis techniques have overcome this difficulty by successfully detecting damage to a variety of vehicle components, including coil components. Vibration analysis measures the vibration characteristics of a vehicle while it is in motion by using sensors that are installed on various vehicle components. The Fast Fourier Transform (FFT) tool is then used to examine this vibration data in order to find any odd patterns or indications of damage. The vibration data offers important hints regarding the state of the car's parts. But since the vibrations in the coil of a 4-stroke piston motor are non-linear, a non-linear vibration analysis technique, like the Hilbert method, is required [4]. Numerous studies on the dynamics of motorized vehicles and their components, as well as vibrations in them, have been conducted. The results indicate that vibration analysis is a useful tool for

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determining when damage is likely to occur [5]–[18]. Fault detection uses frequency and instantaneous amplitude as input variables. To find nonlinear features, combined time-frequency analysis based on wavelet analysis is also used [19]–[21].

Thus, the purpose of this study is to compare the Hilbert and Fast Fourier Transform (FFT) approaches in relation to piston motors. It is intended that by comparing the efficacy and benefits of each FFT and Hilbert method in analyzing piston motor vibrations, readers will be able to make an informed decision.

2. METHOD

Making a research plan before beginning any investigation is essential to ensuring that the findings align with the goals of the study. An experimental investigation was conducted in this work. Two sets of data are collected: vibration data obtained with the FFT Analyzer. The Hilbert approach is used by the researcher to obtain time-frequency energy data, and the author will evaluate the two ways' efficacy on piston motors. The test data will be analyzed using Matlab R2022a software.

An accelerometer sensor that is mounted on the piston motor frame is used to gather vibration data. To measure the amount of vibration generated, the accelerometer sensor is connected to an FFT analyzer. Matlab R2022a software is then used to analyze the data. Next, the Hilbert implementation was used to generate an analytical signal for the time-frequency energy data of the piston motor, and Matlab R2022a software was used for analysis. The piston motor speed used in this investigation was 900 rpm. As illustrated in Figure 1, the test findings are then processed and assessed by contrasting the efficacy of the two techniques, namely FFT and Hilbert, in assessing piston motors.

Figure 1. Data collection process

The accelerometer sensor and ceramic isolator are the instruments utilized to measure this vibration current. This tool measures the vibrations generated by the piston motor by measuring the variations in speed that take place on the Daihatsu Sigra. The accelerometer sensor is mounted on the piston motor. The accelerometer sensor does this by translating mechanical vibrations into frequency signals that depict the piston motor's vibration characteristics. Researchers employed a Ceramic Isolator and made sure the Acceleometer sensor worked in a safe and stable manner during data collection in an effort to preserve the Acceleometer sensor's functioning and avoid any excessive heat that might be generated by a piston motor engine. Following these measurements, the data will be subjected to additional analysis, which will involve the vibration frequency spectrum analysis using the FFT and Hilbert methods.

3. RESULTS AND DISCUSSION

In the study, the FFT Analyzer was set up for testing. The FFT Analyzer has 4096 data harvests with a frequency range of 1 to 120 Hz. The piston motor's rotational speed is specified between 900 and 3500 rpm.

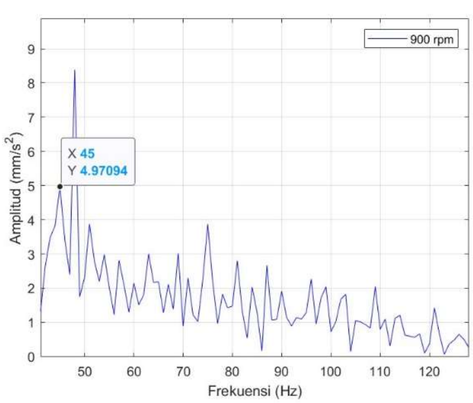

Figure 2. FFT results of a piston motor with a speed of 900 rpm

The FFT findings of a piston motor operating at 900 rpm are displayed in Figure 2. Since the average amplitude (RMS) is less than 5 mm/s^2, the vibrations generated at the vibration source are still quite little.

The Hilbert method was used to analyze the FFT results using the Matlab R2022a software. Figure 3 displays the findings of an analysis performed at 900 rpm using the Hilbert method. According to Figure 3, 0.5 radians/sample is the average frequency energy produced.

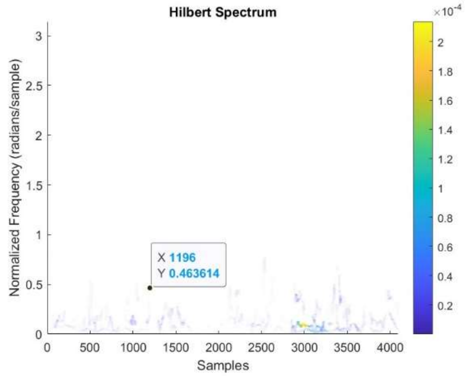

Figure 3. Results of the Hilbert method with a speed of 900 rpm

Using the same procedure, a piston motor operating at 1500 rpm was tested. The purpose of this speed increase is to better understand how the piston motor responds to different speeds. It also aids in identifying different performance aspects and potential issues that could occur in different operational scenarios. The test results with a speed of 1500 rpm are shown in Figure 4 and Figure 5. The average amplitude (RMS) of Figure 4 is 10 mm/s^2, indicating an increase in the vibrations generated at the vibration source.

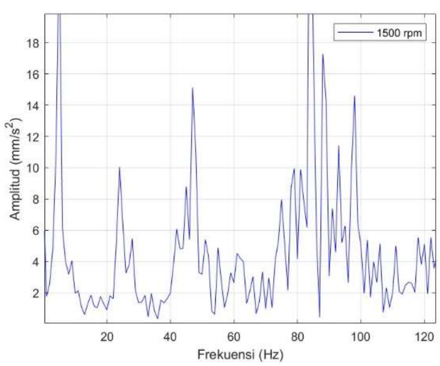

Figure 4. FFT results of a piston motor with a speed of 1500 rpm

The Hilbert method was used to analyze the FFT results in Figure 4 using the same software, Matlab R2022a. Figure 5 displays the findings from the 1500 rpm Hilbert method analysis.

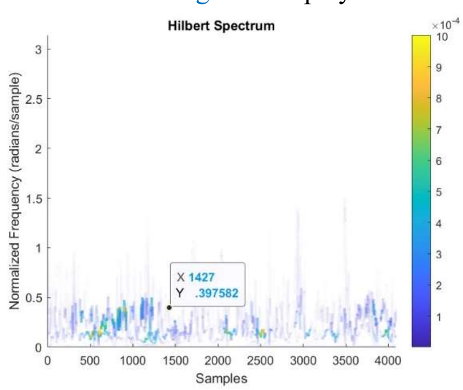

Figure 5. Results of the Hilbert method with a speed of 1500 rpm

The results indicate that the average frequency energy is 0.5 radians/sample, as shown in Figure 5. This indicates that, when compared to earlier data at 900 rpm power, no progress has been made.

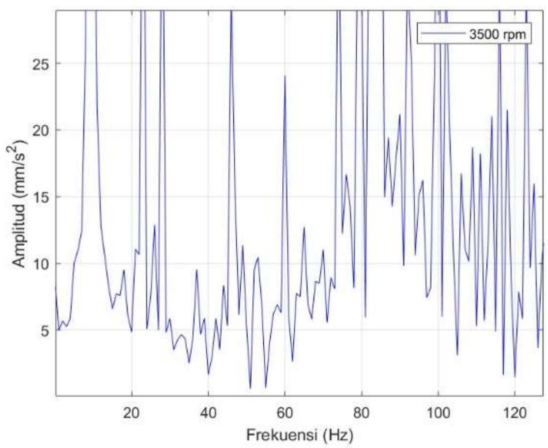

Figure 6. FFT results of a piston motor with a speed of 3500 rpm

Test results at 3500 rpm are shown in Figure 6 and Figure 7. The amplitude value in Figure 6 is increasing; two highest points are found at frequencies of 9 Hz and 83 Hz, with amplitudes of 128 mm/s^2 and 195 mm/s^2, respectively.

The Hilbert method of data processing yields an average energy frequency of 0.5 radians/sample, as seen in Figure 7. This affects the indications that show whether a sensor is malfunctioning or functioning normally.

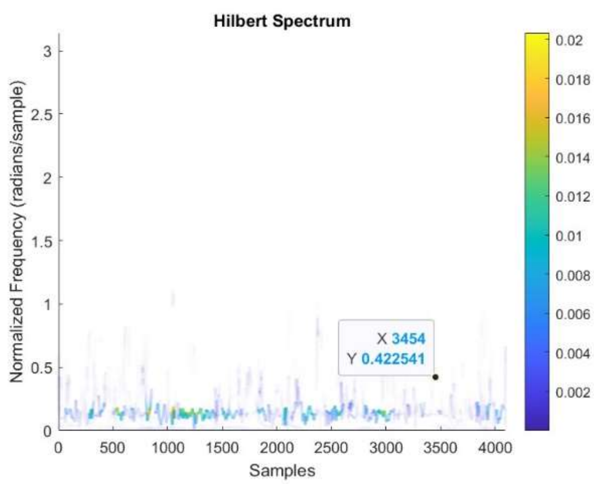

Figure 7. Results of the Hilbert method with a speed of 3500 rpm

3 CONCLUSION

According to this research, industry uses vibrations from milling machines as a source of Harvesting Energy Vibration. While it has no effect on the amount of stress generated, the depth at which the workpiece is ingested seems to have a significant impact on the amplitude that results. The two workpieces in this study demonstrate that, at a depth of 3 mm, the aluminum material produces higher harvesting energy vibration, and, at a depth of 1 mm, the PVC material produces higher harvesting energy vibration. Additional investigation into vibration energy harvesting can be combined with other renewable energy sources, like solar, wind, and wave power.

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