Vol. 4, No. 2, October 2023, page 156-162
JTTM: Jurnal Terapan Teknik Mesin
p ISSN 2721-5377| e ISSN 2721-7825
http://jurnal.sttmcileungsi.ac.id/index.php/jttm

Identification of ignition system coil damage on MPV 1000 CC vehicle using fast fourier transform

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Submitted: 19/04/2023 Revised:04/05/2023 Accepted: 05/05/2023

Abstract: The coil is the main component of the vehicle in the ignition system. So that the coil can continue to function correctly, it is vital to plan ahead and maintain its performance. One method that can be done is the vibration method. Vibration testing was carried out on a 1000 cc MPV vehicle with rotational variations of 800 rpm, 1500 rpm, 2500 rpm and 3500 rpm. Vibration testing is carried out using an accelerometer sensor connected to the FFT Analyzer to measure the vibration response, then an analysis is carried out using Matlab. From the research results obtained at the Y-axis point with a rotating speed of 1500 rpm the first shape mode appears at a frequency of 45 Hz with an amplitude of 1.357 mm/s^2 under normal conditions. Whereas in abnormal conditions the first shape mode appears at a frequency of 41 Hz with an amplitude of 1,944 mm/s^2. In abnormal conditions, damage due to bearing defects is obtained, this is due to the discovery of a frequency of 4x rpm at 1500 rpm rotation. Furthermore, at a rotational speed of 2500 rpm the measurement results on the engine show that the first shape mode appears at a frequency of 48 Hz with an amplitude of 2256 mm/s^2 in normal coil conditions. Whereas in abnormal conditions the first shape mode appears with a frequency of 41 Hz with an amplitude of 4.176 mm/s^2. The frequency at 82 Hz under abnormal conditions shown under normal conditions does not appear. This shows the occurrence of losses, because it occurs at 2x rpm at 2500 rpm rotation.

Keywords: Ignition coil; MPV; FFT; mode shape; matlab

1. INTRODUCTION

Damage to the ignition coil prevents the piston motor from operating at its best. The combustion system of the engine will be impacted by damage to or issues with the ignition coil, which will result in the piston motor vibrating irregularly [1] [2]. This occurs as a result of the coil's connection to the combustion system [3], as a result, vibrations are created that affect the driver's comfort while driving [4].

One of the best methods for tracking and determining engine conditions is the vibration method [5]. Vibration generally has a significant impact on machine performance and lowers maintenance costs [6]. Students and instructors in mechanical engineering at Mercu Buana University have conducted research on piston motor damage [7] [8] [9] [10] [11] [12].

The ignition system using the vibration approach will be the main topic of this study. The engine components are made up of different parts that move in a rotary fashion, so based on research experience to date, it is not predictable how much the frequency is caused by damage to the ignition system when the engine experiences excessive vibration. It is envisaged that this research would enable anticipation to be used to preserve coil performance and ensure its continued proper operation. The Fast Fourier Transform (FFT) is one method of vibration that is frequently used. FFT analysis was performed because the FFT Analyzer tool had already been utilized by numerous studies [13][14]. Matlab was used to process the FFT Analyzer's measurement results.

2. METHOD

Mercu Buana University vibrations, laboratory research. In this study, a literature review is conducted before the application of quantitative research methodologies, which is necessary to

DOI 10.37373/jttm.v4i2.554

identify any innovative aspects of earlier studies. Then comes prepping the tools and supplies to be used, and finally testing preparation. **Figure 1** shows how the research was conducted.

A test plan was executed in advance of the test employing a different rotational speed for the 1000 cc MPV engine. Place the accelerometer sensor, which has three points: axis (X), axis (Y), and axis (Z), on the engine of the car before testing. A BNC cable is used to connect the accelerometer sensor to the FFT Analyzer. There are four different engine speed ranges that are used: 800, 1500, 2500, and 3500 rpm. Matlab was used to evaluate the FFT Analyzer's measurement results. The MPV 1000 cc piston motor is depicted in **Figure 2**. **Table 1** lists the specs for 1000 cc MPV automobiles.

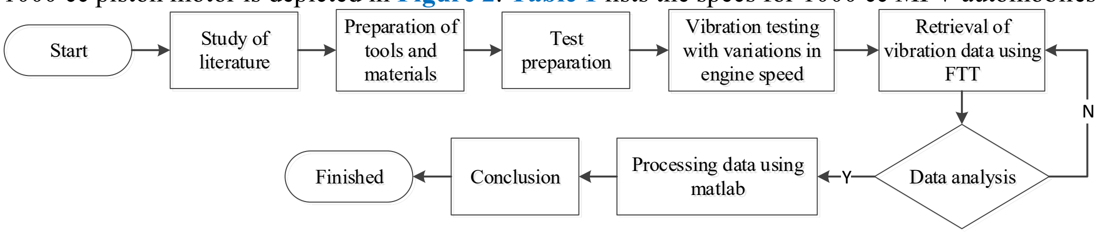

Figure 1. The flow of research methods

A study was done to find out the characteristics of the vibrations that happen at these three sites under both normal and damaged coil situations by positioning the sensors at the (X), (Y), and (Z) axes. The investigation was conducted with the equipment in a static state.

Figure 2. A 1000 cc piston-powered MPV

The measurement sites on a 1000 cc Mpv piston engine are shown in **Figure 3**. Additionally, the FFT Analyzer is used to measure the resulting vibration response. Matlab was used to evaluate the data, as shown in **Figure 4**.

Table 1. Lists the specifications for 1000 cc MPVs

Item	Spesifikasi
Machine Type	EJ-VE 1.0 VVT-I DOHC
Capacity Cylinder	989 CC
Power Max	6/5600 ps/rpm
Torsi Max	9.2/3600 kg-Nm/rpm
Tank Capacity	45 Liter
Transmission Type	Manual, 5 speed Forward
Steering System	Rack Pinions

Table 2 lists the specifications for the portable FFT analyzer type CF-3600A (4-ch) with a touch panel computer that uses simultaneous analysis and recording.

Figure 3. Placement of Axis Points (X), (Y) and (Z)

Table 2. Specifications for the FFT Analyzer CF-3600A

Dimension	410w x 314 (H) 150 D mm
Power Voltage	19 VDC
Power Consumption	70 VA
Operating Temperature	5 − 40°c
Storage Temperature	−10 to 60°c
Weight	10kg
Cooling Fan	Not-Provided
Instantaneous	Battery Charging Circuit

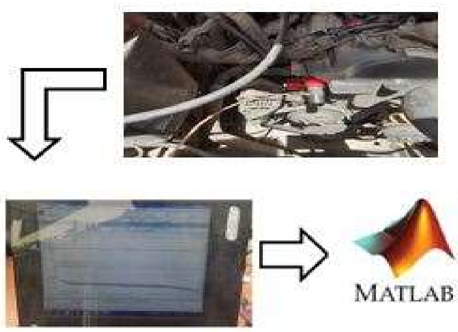

Figure 4. Data measurement and analysis

3. RESULTS AND DISCUSSION

Damage to the ignition coil prevents the piston motor from operating at its best. The combustion system of the engine will be impacted by damage to or issues with the ignition coil of the car, which will result in abnormal vibration of the piston motor. This occurs as a result of the coil's direct connection to the combustion system, as depicted in **Figure 5**. The discomfort of the driver while driving will be compromised by the vibrations caused by damaged coils [4].

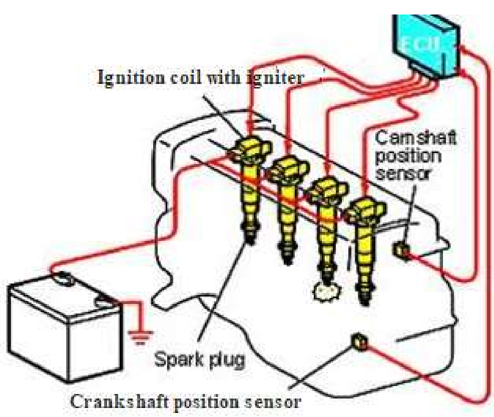

Figure 5. DIS ignition system [15]

The accelerometer sensor was attached to the vehicle's engine, which is placed at three positions, namely the X, Y, and Z axes, and rotational speeds of 800 rpm, 1500 rpm, 2500 rpm, and 3500 rpm were used during the investigation. It will produce the frequencies of 13, 25, 42, and 58 Hz when converted to frequency form. A graph of the FFT findings on the axis (Y) with a 1500 rpm rotating speed is shown in **Figure 6**. According to the engine's measurement data, under typical circumstances, the first shape mode has an amplitude of 1,223 mm/s^2 and a frequency of 45 Hz. Under anomalous circumstances, a form mode with an amplitude of 1,944 mm/s^2 and a frequency of 41 Hz develops. Under normal circumstances, the frequency at 100 Hz that is visible does not occur. Because it occurs at 4x rpm, this is a sign that a bearing issue has occurred.

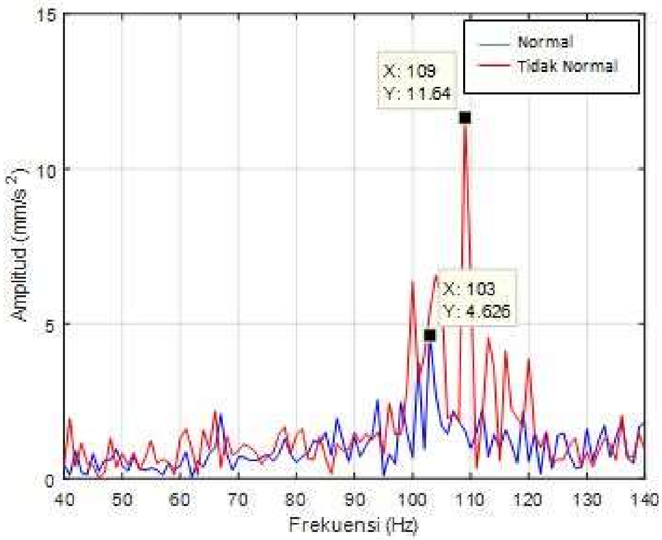

Figure 6. FFT results for normal and abnormal coil conditions with a rotation speed of 1500 rpm

Figure 6's normal and abnormal frequency circumstances are given in **Table 3**. Local and global frequencies are shown in **Table 3**; global frequencies are displayed at a frequency of 61 Hz. While local frequencies of 45 Hz, 75 Hz, 94 Hz, 103 Hz, 112 Hz, 119 Hz, 126 Hz, and 133 Hz are present under normal circumstances.

Table 3. Frequency data for normal and abnormal conditions at 1500 rpm

Mode Shape	Normal Frequency (Hz)	Amplitude (mm/s$^{2)}$	Abnormal Frequency (Hz)	Amplitude (mm/s$^{2)}$
1	-	-	41 Hz	1.944 mm/s^2
2	45 Hz	1.223 mm/s^2	-	-
3	-	-	48 Hz	1.313 mm/s^2
4	-	-	55 Hz	1.219 mm/s^2
5	61 Hz	0.9523 mm/s^2	61 Hz	1.608 mm/s^2
6	-	-	67 Hz	2.194 mm/s^2
7	75 Hz	1.175 mm/s^2	-	-
8	-	-	84 Hz	1.362 mm/s^2
9	-	-	42 Hz	0.7157 mm/s^2
10	94 Hz	3.826 mm/s^2	-	-
11	-	-	100 Hz	6.364 mm/s^2
12	103 Hz	4.625 mm/s^2	-	-
13	-	-	105 Hz	1.321 mm/s^2
14	-	-	109 Hz	11.64 mm/s^2
15	112 Hz	3.37 mm/s^2	-	-
16	-	-	116 Hz	4.124 mm/s^2
17	119 Hz	3.325mm/s^2	-	-
18	-	-	121 Hz	3.359 mm/s^2
19	126 Hz	2.203 mm/s^2	-	-
20	-	-	129 Hz	1.315 mm/s^2

Mode Shape	Normal Frequency (Hz)	Amplitude (mm/s²)	Abnormal Frequency (Hz)	Amplitude (mm/s²)
21	133 Hz	2.592 mm/s^2	-	-
22	-	-	136 Hz	2.045 mm/s^2
23	-	-	140 Hz	1.447 /s^2

Figure 7 displays a graph of the FFT findings on the axis (Y) at a 2500 rpm rotating speed. According to the engine's test data, under typical coil settings, the first form mode manifests at a frequency of 48 Hz and an amplitude of 2,256 mm/s^2. In the meantime, a form mode with a frequency of 41 Hz and an amplitude of 4,176 mm/s^2 manifests under abnormal circumstances. Under normal circumstances, the frequency of 82 Hz that is visible does not exist. Because it happens at a 2x rpm, this illustrates the presence of losses.

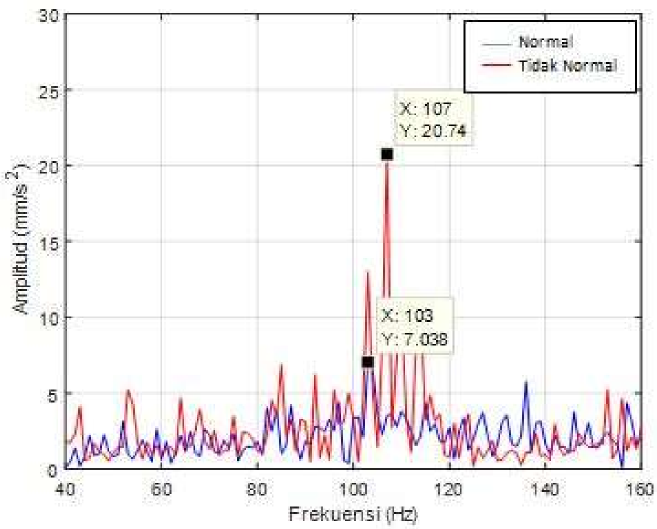

Figure 7. FFT results for normal and abnormal coil conditions with a rotation speed of 2500 rpm

As indicated in **Table 4**, global frequencies occur at frequencies of 75 Hz and 103 Hz while local frequencies in abnormal conditions occur at frequencies of 41 Hz, 54 Hz, 64 Hz, 68 Hz, 85 Hz, 107 Hz, 114 Hz, 124 Hz, 142 Hz, and 156 Hz. **Figure 6**'s amplitude peaks are used to create **Table 4**.

Table 4. Frequency data for normal and abnormal conditions at 2500 rpm

Mode Shape	Normal Frequency (Hz)	Amplitude (mm/s²)	Abnormal Frequency (Hz)	Amplitude (mm/s²)
1			41 Hz	4.176 mm/s^2
2	48 Hz	2.256 mm/s^2	-	-
3	-	-	54 Hz	4.322 mm/s^2
4	59 Hz	2.653 mm/s^2	-	-
5	-	-	64 Hz	6.612 mm/s^2
6	-	-	68 Hz	3.921 mm/s^2
7	75 Hz	1.844 mm/s^2	75 Hz	2.412 mm/s^2
8	-	-	82 Hz	4.062 mm/s^2
9	-	-	85 Hz	1.767 mm/s^2
10	87 Hz	4.182 mm/s^2	-	-
11	92 Hz	4.423 mm/s^2	-	-
12	103 Hz	7.038 mm/s^2	103 Hz	13.708 mm/s^2
13	-	-	107 Hz	20.74 mm/s^2
14	-	-	114 Hz	1.071 mm/s^2
15	120 Hz	2.727 mm/s^2	-	-
16	-	-	124 Hz	3.634 mm/s^2
17	136 Hz	5.727 mm/s^2	-	-
18	-	-	142 Hz	2.984 mm/s^2

Mode Shape	Normal Frequency (Hz)	Amplitude (mm/s$^{2)}$	Abnormal Frequency (Hz)	Amplitude (mm/s$^{2)}$
19	149 Hz	3.058 mm/s^2	-	-
20	-	-	156 Hz	4.624 /s^2

Table 4 demonstrates that there are losses caused by damage to the ignition system coil at a rotational speed of 2500 rpm. This is demonstrated by the emergence of 2x rpm, which is equal to 82 Hz. Additionally, the measurement yields a global frequency that oscillates between 75 Hz and 103 Hz. In contrast, **Table 3** shows that under abnormal circumstances, at a rotational speed of 1500 rpm, there is a frequency of 4x rpm that denotes the onset of a bearing defect. The frequency at which the global frequency manifests is 61 Hz.

3 CONCLUSION

Under typical circumstances, the engine exhibits the first form mode at a frequency of 45 Hz and an amplitude of 1,223 mm/s^2 at a rotating speed of 1500 rpm. Under anomalous circumstances, a form mode with an amplitude of 1,944 mm/s^2 and a frequency of 41 Hz develops. Under normal circumstances, the frequency at 100 Hz that is visible does not occur. This suggests that a bearing defect has occurred, as a result of the 4x rpm. Additionally, the engine measurement findings show that, under normal coil settings, the first shape mode manifests at a frequency of 48 Hz and an amplitude of 2256 mm/s^2 at a rotational speed of 2500 rpm. Meanwhile, under abnormal circumstances, a 41 Hz frequency shape mode with an amplitude of 4,176 mm/s^2 manifests. Under normal circumstances, the frequency at 82 Hz that is visible does not exist. Because it happens at a 2x rpm, this illustrates the presence of losses.

ACKNOWLEDGEMENT

We would like to thank the head of the Mercu Buana University mechanical engineering lab and friends who have helped a lot in completing this research.

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