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Analysis of the impact of misfiring on the throttle body in Ayla vehicles using the fast fourier transform method

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Abstract: An essential component of an automobile's air intake system, the throttle body controls airflow during combustion by acting as an idle speed control mechanism. Making ensuring the throttle body is operating properly is crucial to keeping the engine running at its best. The Fast Fourier Transform vibration analysis is one technique used for this (FFT). A an LCGC Ayla 1000 cc vehicle's throttle body and engine underwent vibration testing with rotational rates set to 750 rpm, 1000 rpm, 1500 rpm, and 2000 rpm. Vibration responses were measured using an accelerometer sensor coupled to an FFT analyzer, and Matlab was used for analysis. The throttle body had anomalous frequency readings at 1977 Hz with an amplitude of 0.03171 m/s2, according to the test results. On the other hand, the frequency value at 1410 Hz with an amplitude of 0.03435 m/s2 was observed under normal circumstances. Similar to this, abnormal frequency values with an amplitude of 0.02378 m/s2 were found on the engine at 1493 Hz, whereas normal frequency values with the same amplitude were found at 1712 Hz. These results point to incomplete combustion as the cause of the increased vibration.

Keywords: Throttle body; idle speed control; LCGC; ayla; Matlab

1. INTRODUCTION

A vehicle's throttle body is an essential part that guarantees exact control over the air-to-fuel ratio (A/F) flow, resulting in the best possible driving experience and the intended level of engine economy [1]. Damage to the throttle body may cause partial or malfunctioning combustion, which would lower engine performance and increase fuel consumption [2]. Using a vibration technique, this study will concentrate on the airflow system in the combustion process [3]. The reciprocating mechanism that transforms energy into rotational motion is what causes engine vibrations [4]. Vibration analysis is the approach used to track and determine engine status. Vibration measurements are frequently carried out to support predictive maintenance [5][6]. Both frequency domain and temporal domain analysis can be used for vibration signal processing [7]. Temporal domain analysis retrieves properties like phase, amplitude values, and temporal features from real-time signal data [8]. Amplitude, phase, power spectrum, fast fourier transform (FFT), active window, and filtering are all included in frequency domain analysis [9][10].

Previous studies have shown that when the engine encounters severe vibrations, it is difficult to forecast the level of frequency created by the airflow system breakdown [11]. The dynamics of single-cylinder diesel engines, disc brake damage characteristics, alternator bearing failure prediction, and misfire characteristics in 1000cc MPV vehicles have all been studied previously using predictive maintenance methodologies [12][13][6]. The airflow system in car engines has a big impact on total engine performance and efficiency, hence this research is important [14][13]. Although the Fast Fourier Transform (FFT) is a widely used technique for vibration research, this paper investigates additional methods for vibration frequency analysis [15][16]. More research in this area can improve knowledge of the vibration properties linked to damage to the throttle body, especially in idle speed control. The findings of the FFT analyzer measurement are processed using Matlab.

Thus, the primary goal of this study is to ascertain the relationship between engine rotational speed and idle speed control damage using the Fast Fourier Transform (FFT) approach. This study uses the FFT approach for idle speed control to examine damage to idle speed control.

2. METHOD

This investigation was carried out at Mercu Buana University's laboratory. To start, a study of the literature was done to collect pertinent data from earlier studies on the subject. Next, the supplies and tools were ready, and then, as Figure 1 illustrates, the testing was ready.

A 1000 cc LCGC Ayla vehicle was used for the testing, and it was run at several rotational speeds. The engine and the faulty part both have accelerometer sensors installed. The FFT analyzer was then attached to cables. The following rotational rates were tested: 750, 1000, 1600, and 2000 rpm. The FFT analyzer's measurement findings were subsequently examined using Matlab Figure 2 shows the engine of the LCGC Ayla 1000 cc. The LCGC Ayla 1000cc vehicle's specs are listed in Table 1.

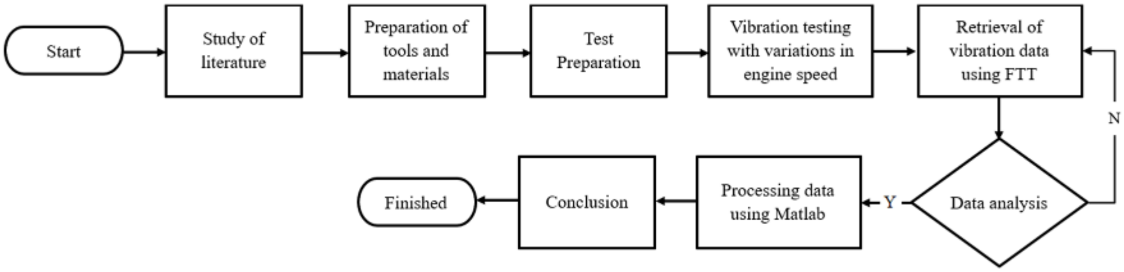

Figure 1. Illustrates the research process.

Installing accelerometer sensors on the throttle body and engine in both normal and damaged states, the study sought to investigate the vibration characteristics. Equipment was used to research while the engine was stationary.

Figure 2. Ayla 1000cc engine.

Figure 3. shows the measurement spots on the LCGC Ayla 1000cc engine and the throttle body. The vibration values are measured using the FFT Analyzer. As seen in Figure 4 data evaluation is done using Matlab R2020a.

Table 1. Specifications of the LCGC Ayla 1000cc engine.

Item	Specifications
Machine Type	1KR-DE 1.0 DOHC 3 Silinder
Capacity Cylinder	989 CC
Power Max	64,1 hp @ 6.000 rpm
Torsi Max	86 Nm @ 3.600 rpm
Transmission Type	Manual, 5-Speed Forward
Steering System	Rack Pinions

Vibration values are measured using the portable FFT analyzer type CF-3600A (4-ch), which has a touch panel computer and enables simultaneous analysis and recording. The tool's parameters are listed in Table 2.

Figure 3. Placement of vibration accelerometer sensors.

Table 2. Specifications of the FFT analyzer CF-3600A.

Item	Specifications
Power Voltage	19 VDC
Dimension	410w x 314 (H) 150 D mm
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

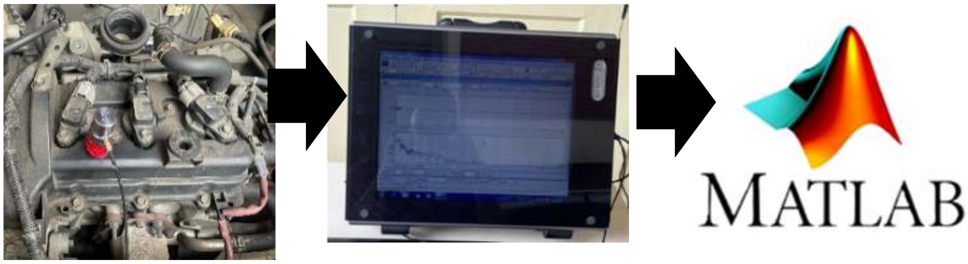

Figure 4. Measurement and data analysis.

3. RESULTS AND DISCUSSION

When the throttle body is damaged, there is insufficient mixing of air and fuel in the engine cylinder, which causes vibration and malfunction and makes starting the car engine difficult [17]. Driving comfort is impacted by the direct interaction between the combustion system and the airflow system, as seen in Figure 5.

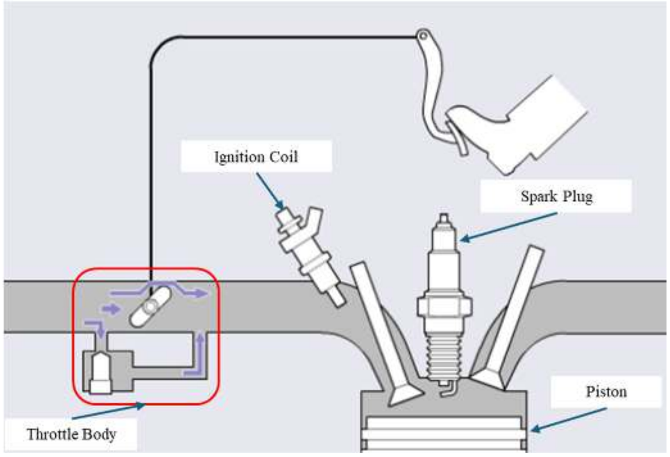

Figure 5. Airflow system in the combustion process.

An accelerometer sensor and FFT analyzer were mounted on the engine and throttle body, and the engine was rotated at four different speeds: 750, 1000, 1600, and 2000 rpm [16]. Under typical circumstances, the throttle body test results revealed a frequency value of 1410 Hz and an amplitude of 0.03435 m/s^2. On the other hand, 1977 Hz with an amplitude of 0.03171 m/s2 was the frequency value achieved under abnormal conditions. While the drop in amplitude indicates a loss in power or disturbances in the throttle body mechanism, particularly in idle speed control, the rise in frequency could be caused by several factors such as wear, leakage, or dirt buildup within the throttle body [18]. This is depicted in Figure 6.

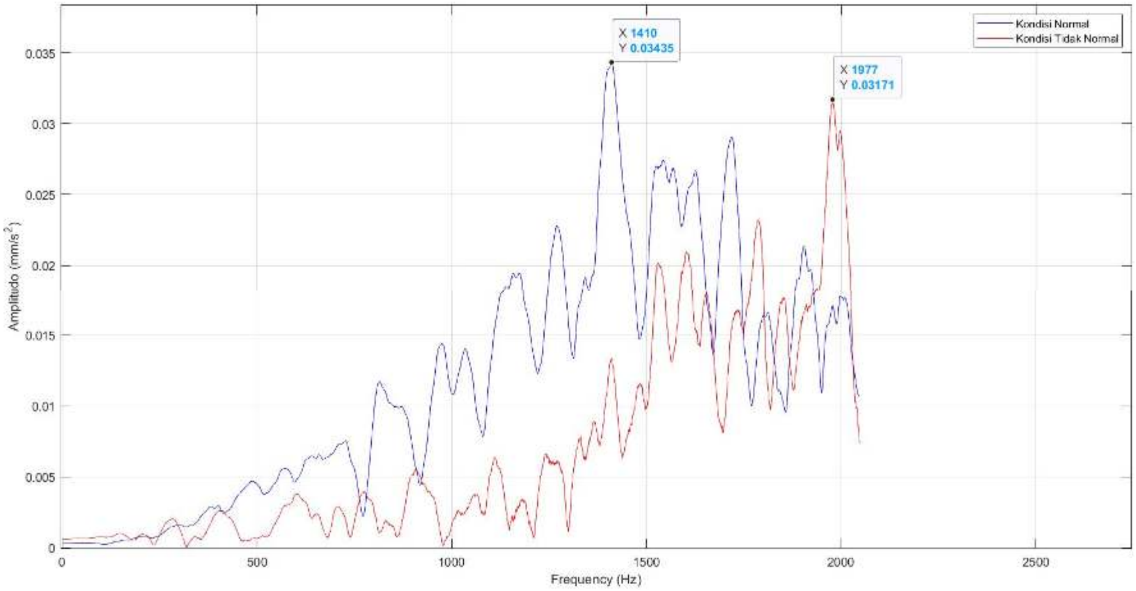

Figure 6. FFT results of the throttle body in normal and abnormal conditions at 1000 rpm rotation speed.

Combining frequency normal and abnormal circumstances shown in FFT form, the analysis of throttle body damage was carried out, producing 35 mode shapes. Local and global frequencies that are visible on the throttle body can be seen on the graph. The graph clearly shows that the abnormal state, which is brought on by the idle speed control shaft mechanism, is lower than the usual frequency, as Table 3 makes clear.

Table 3. Throttle body frequency data under normal and exceptional circumstances at 1000 rpm rotational speed.

Mode	Normal		Abnormal	
Shape	Frequency (Hz)	Amplitude (mm/s^2)	Frequency (Hz)	Amplitude (mm/s^2)
1	-	-	150 Hz	0,001001 mm/s^2
2	-	-	285 Hz	0,002018 mm/s^2
3	379 Hz	0,00289 mm/s^2	-	-
4	-	-	412 Hz	0,002609 mm/s^2
5	487 Hz	0,004691 mm/s^2	-	-
6	573 Hz	0,005594 mm/s^2	-	-
7	-	-	600 Hz	0,003852 mm/s^2
8	-	-	705 Hz	0,002906 mm/s^2
9	727 Hz	0,007564 mm/s^2	-	-
10	-	-	776 Hz	0,003943 mm/s^2
11	813 Hz	0,01171 mm/s^2	-	-
12	-	-	910 Hz	0,005546 mm/s^2
13	973 Hz	0,01437 mm/s^2	-	-
14	1034 Hz	0,01401 mm/s^2	-	-

Mode	Normal		Abnormal	
Shape	Frequency (Hz)	Amplitude (mm/s^2)	Frequency (Hz)	Amplitude (mm/s^2)
15	-	-	1063 Hz	0,00379 mm/s^2
16	-	-	1111 Hz	0,006376 mm/s^2
17	1173 Hz	0,01941 mm/s^2	-	-
18	-	-	1242 Hz	0,006555 mm/s^2
19	1270 Hz	0,02278 mm/s^2	-	-
20	-	-	1331 Hz	0,007822 mm/s^2
21	-	-	1366 Hz	0,008917 mm/s^2
22	1410 Hz	0,03435 mm/s^2	-	-
23	-	-	1483 Hz	0,01157 mm/s^2
24	-	-	1530 Hz	0,02021 mm/s^2
25	1544 Hz	0,02741 mm/s^2	-	-
26	-	-	1602 Hz	0,02097 mm/s^2
27	1625 Hz	0,02673 mm/s^2	-	-
28	-	-	1654 Hz	0,018 mm/s^2
29	1718 Hz	0,02907 mm/s^2	-	-
30	-	-	1787 Hz	0,02325 mm/s^2
31	1812 Hz	0,01659 mm/s^2	-	-
32	-	-	1851 Hz	0,02325 mm/s^2
33	1903 Hz	0,02135 mm/s^2	-	-
34	-	-	1977 Hz	0,03171 mm/s^2
35	1998 Hz	0,01775 mm/s^2	-	-

The engine's test results at a rotational speed of 1000 rpm are displayed in Figure 7 These results resulted in a total of 43 mode forms, which combine both normal and pathological situations. According to the engine testing results, in typical operating conditions, the frequency value was 1712 Hz, and the amplitude was 0.02378 m/s^2. On the other hand, the frequency value recorded under abnormal conditions was 1493 Hz with an amplitude of 0.02479 m/s^2. This shift in frequency from typical to atypical indicates a significant modification of the engine's dynamic characteristics under anomalous conditions, most likely as a result of combustion process defects.

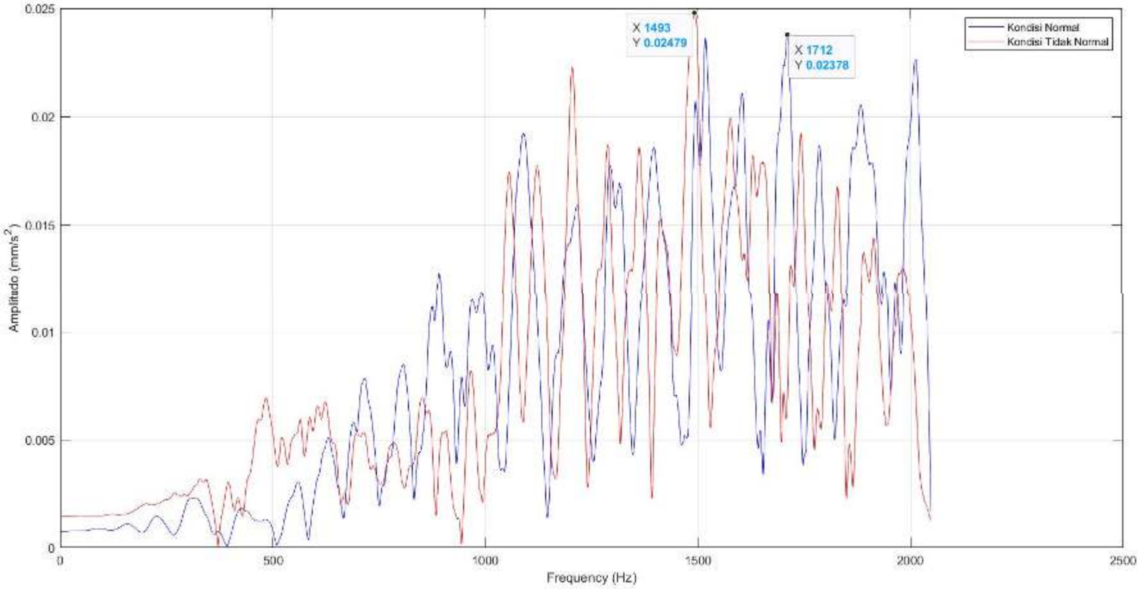

Figure 7. FFT results of the engine in normal and abnormal conditions at 1000 rpm rotation speed.

The engine damage analysis involved combining frequencies under normal and abnormal conditions displayed in FFT form, similar to the testing method used for disc brakes in the Sigra vehicle as depicted in

Figure 7. The graph shows local and global frequencies present on the engine under both normal and abnormal conditions, as detailed in Table 4. Two global frequencies are identified 714 Hz and 1292 Hz.

Table 4. Frequency data of engine in normal and abnormal conditions at 1000 rpm rotation speed.

Mode	**Normal**		**Abnormal**	
Shape	**Frequency (Hz)**	**Amplitude (mm/s²)**	**Frequency (Hz)**	**Amplitude (mm/s²)**
1	160 Hz	0,001103 mm/s²	-	-
2	227 Hz	0,001445 mm/s²	-	-
3	313 Hz	0,002297 mm/s²	-	-
4	-	-	331 Hz	0,003171 mm/s²
5	-	-	395 Hz	0,003019 mm/s²
6	426 Hz	0,001809 mm/s²	-	-
7	-	-	485 Hz	0,006896 mm/s²
8	-	-	523 Hz	0,005057 mm/s²
9	558 Hz	0,003027 mm/s²	-	-
10	-	-	564 Hz	0,005934 mm/s²
11	-	-	624 Hz	0,006743 mm/s²
12	631 Hz	0,005081 mm/s²	-	-
13	714 Hz	0,007807 mm/s²	714 Hz	0,005355 mm/s²
14	-	-	783 Hz	0,004844 mm/s²
15	806 Hz	0,00849 mm/s²	-	-
16	-	-	851 Hz	0,006916 mm/s²
17	893 Hz	0,01273 mm/s²	-	-
18	-	-	906 Hz	0,005396 mm/s²
19	-	-	966 Hz	0,008181 mm/s²
20	993 Hz	0,01182 mm/s²	-	-
21	-	-	1057 Hz	0,01746 mm/s²
22	1090 Hz	0,01923 mm/s²	-	-
23	-	-	1122 Hz	0,01769 mm/s²
24	-	-	1205 Hz	0,0226 mm/s²
25	1216 Hz	0,01594 mm/s²	-	-
26	1292 Hz	0,01753 mm/s²	1292 Hz	0,01804 mm/s²
27	-	-	1363 Hz	0,01858 mm/s²
28	1396 Hz	0,01848 mm/s²	-	-
29	-	-	1412 Hz	0,01525 mm/s²
30	-	-	1493 Hz	0,02479 mm/s²
31	1519 Hz	0,02364 mm/s²	-	-
32	-	-	1578 Hz	0,01994 mm/s²
33	1605 Hz	0,02107 mm/s²	-	-
34	-	-	1631 Hz	0,01819 mm/s²
35	-	-	1685 Hz	0,01188 mm/s²
36	1712 Hz	0,02378 mm/s²	-	-
37	-	-	1745 Hz	0,0191 mm/s²
38	1787 Hz	0,01866 mm/s²	-	-
39	-	-	1830 Hz	0,0168 mm/s²
40	1886 Hz	0,0205 mm/s²	-	-
41	-	-	1916 Hz	0,01433 mm/s²

Mode Shape	Normal		Abnormal	
	Frequency (Hz)	Amplitude (mm/s^2)	Frequency (Hz)	Amplitude (mm/s^2)
42	-	-	1985 Hz	0,01301 mm/s^2
43	2015 Hz	0,02264 mm/s^2	-	-

At 1976 Hz Table 3 shows an abnormality in the throttle body caused by the idle speed control shaft mechanism. Table 4 demonstrates that there is an irregularity in the engine's frequency at 1493 Hz. Additionally, two global frequencies oscillate between 714 Hz and 1292 Hz. These findings indicate a connection between engine vibration patterns and the throttle body, indicating that insufficient air results in an inefficient combustion process in the engine.

4. CONCLUSION

Vibration measurements were used to demonstrate how the engine and throttle body performed in both normal and abnormal circumstances with different engine speed fluctuations. Under abnormal conditions, the throttle body's frequency reading in this study was 1977 Hz with an amplitude of 0.03171 m/s^2. On the other hand, the throttle body's frequency reading under normal conditions was 1410 Hz with an amplitude of 0.03435 m/s^2. This implies that there might be unusual operating circumstances. Moreover, anomalous circumstances were detected at a frequency of 1493 Hz and an amplitude of 0.02378 m/s^2 at an engine rotation speed of 1000 rpm. In contrast, normal frequency values were recorded at 1712 Hz with an amplitude of 0.02378 m/s^2. Variations in the engine and throttle body vibration characteristics suggest a connection between engine misfiring or poor combustion with the throttle body damaged due to insufficient airflow and fuel mixing in the combustion chamber.

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