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Identification of misfiring in engine 1000cc using fast fourier transform analysis

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Abstract: Motorized vehicles are the primary mode of transportation in the neighborhood. An automobile is one of the motorized vehicles. Because of the mixing of air and gasoline, cars may move. The spark plug plays a crucial function in combustion because it ignites the mixture of fuel and air to generate combustion. Incomplete combustion will consequently result in misfiring. Damage to the spark plug, injector, and ignition coil are just a few of the things that might lead to misfiring. Therefore, due to misfiring, research on preventive maintenance for cars is required. Utilizing the vibration approach is one option. The combustion process in this study is stimulated by changing the 1000cc engine's speed. The engine speed ranges from 900 to 3500 revolutions per minute. The accelerometer sensor is then positioned vertically and horizontally on the machine's surface. According to this study, the first form mode's frequency at 900 rpm has an amplitude of 3,433 mm/s2 and occurs at a frequency of 69 Hz. In contrast, the first mode form occurs under typical circumstances at a frequency of 99 Hz and an amplitude of 1,254 mm/s^2. Furthermore, at a rotational speed of 2500 rpm, the frequency in the first shape mode is abnormal at 69 Hz with an amplitude of $8{,}957\ mm/s^2$. In contrast, under typical circumstances, the first form mode has a frequency of 249 Hz and an amplitude of 6,721 mm/s2. A frequency of 4x rpm was discovered for the rotational speed parameters of 900 rpm and 2500 rpm. This demonstrates that a misfiring-related bearing issue exists in the piston motor system.

Keywords: Misfiring; motorcycle pistons; FFT; accelerometer

1. INTRODUCTION

The car is a form of transportation that the people of Indonesia use frequently. An automobile is one of the motorized vehicles. The car moves because of the combination of fuel and air, which raises the combustion temperature. A spark plug then ignites the mixture of fuel and air in the combustion chamber, causing the car to move [1]. Misfiring will occur as a result of incomplete combustion. Spark plug damage is one of the reasons for misfiring. Spark plug flaws lead to misfiring during the combustion process. Therefore, spark plugs require upkeep or replacement in order to prevent misfiring [2]. The failure of the piston motor's combustion process due to misfiring would damage engine performance, resulting in increased fuel consumption and unsteady output [3]. Mistakes will also be brought on by harm to the engine, ignition system, engine power system, etc. Various things can lead to misfiring [4] damage to the spark plug, the injector, and the coil among others. The electrodes on the spark plug have gone out, which results in ignition in an incomplete combustion chamber, which prevents the power plant from producing its maximum amount of electricity.

A spark plug injury [5] particularly, the electrodes and the spark plug insulator's tip flaws brought on by incomplete combustion. Second, a moist yellow coating on the spark plug brought on by the mixing of gasoline or oil with water, as well as from applying the incorrect additive, resulting in a yellow insulator tip [6][7][8]. This results in abnormal vibrations in the piston motor.

The vibration method hasn't done anything to mitigate the damage spark plugs in the combustion system are now causing. In order to better understand misfiring caused by spark plug damage utilizing the vibration approach, research is required. Despite the fact that the intensity may be quite low, all moving machinery vibrates [6]. Engine vibration can be caused by imbalanced rotary or torque forces, which don't have a set value, as well as fluctuations in the piston's gas pressure [9][10][11], and variations in the bending moment or inertial force with each movement of the object. By modifying the effect on the frequency and amplitude, vibration can be lessened. It can be noisy to operate a machine if the vibration frequency is physically out of control, and the machine will shake irregularly if the vibration amplitude is out of control. investigation into piston motor damage [12][13][14][15][16] dynamic features have been extensively investigated by mechanical engineering at Mercu Buana University [17][18][19] if the gun malfunctions. Additionally, a lot of research on vibration in machine tools has been done [20]

As a result, investigation into piston motor spark plug damage is required in order to develop a vibration-based preventative maintenance strategy. FFT analysis is one of the popular methods for vibration analysis. On a 1000cc piston motor, this research was done by adjusting the speed to 900 rpm, 1500 rpm, 2500 rpm, and 3500 rpm. This study is anticipated to be useful in forecasting spark plug damage that results in misfiring utilizing the vibration method [21]

2. METHOD

It is essential to create a research plan for this study in order to get good outcomes. In this study, quantitative research techniques are used as a guide. **Figure 1** shows the research flowchart. Prior to doing research, it is essential to undertake a literature review to learn about previous studies that have been done as a result of misfiring, particularly on spark plug damage. According to the findings of literature reviews, vibration method study on misfiring-related harm is rarely done. Therefore, by getting the necessary instruments and materials ready, this research can continue. Once this condition has been met, continue with the engine rotation variations that will be used. The FFT Analyzer was then used to capture data after that. The data must be retrieved once more if the data gathering produces a lot of noise. But Matlab will be used to assess the noise if it is little.

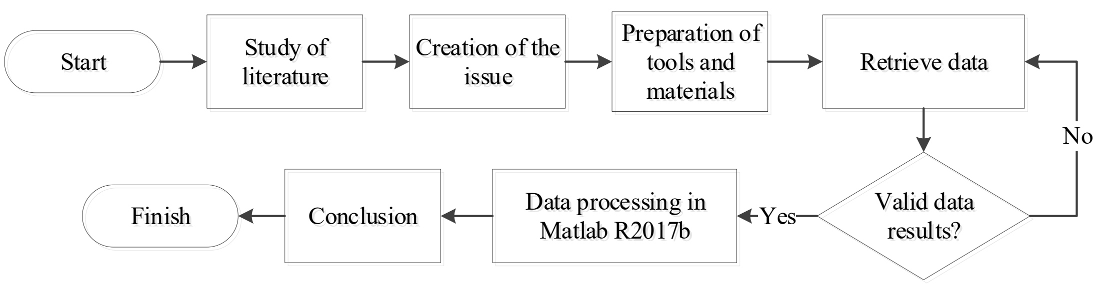

Figure 1. Research flow

The combustion process in this study generates the excitation force by altering engine speed. The engine speed ranges from 900 rpm to 3500 rpm in the example. The accelerometer sensor is then positioned vertically and horizontally on the machine's surface. As indicated in **Figure 2**, the piston engine's pistons (A), (B), and (C) are the locations where the vibration response is monitored.

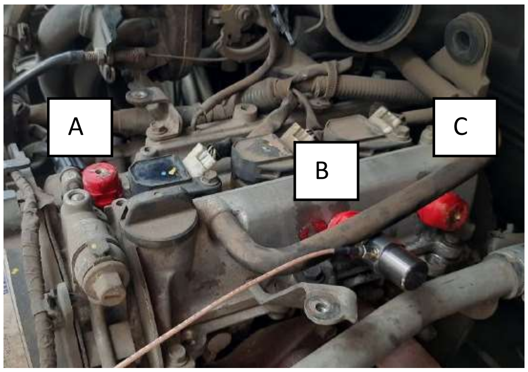

Figure 2. The points of the measured vibration response

The vibration characteristics that occur at points (A), (B), and (C) during the combustion process of a piston engine are static when the sensors are positioned at these three locations. **Table 1** displays the vibration response produced by the accelerometer sensor and then linked via a BNC cable to a portable CF-3600A (4-ch)

FFT analyzer with touch panel computer for simultaneous analysis and recording. Furthermore, Matlab R2017b was used to evaluate the data derived from the results measurements. **Table 2** in this study provides more information on the 1000 piston motor's specifications

Table 1. Specifications for the FFT Analyzer CF-3600A

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

Table 2. 1000cc piston motor specifications

Item	Spesifikasi
Machine Type	EJ-VE 1.0 VVT-i DOHC
Cylinder	989 cc
Maximum Power	63/5600 ps/rpm
Maximum Torque	9.2/3600 kg - Nm/rpm
Tank Capacity	45 liter
Fuel type	Unleaded raw materials

Figure 3 the accelerometer sensor is the kind of device used. This feature measures a machine's vibration.

Figure 3. Shows how data is gathered.

3. RESULTS AND DISCUSSION

The combustion quality is still intimately correlated with the pressure value in the combustion chamber. The widespread application of incursion pressure sensors up to this point has been hampered by their mysterious nature, major limitations like low resistance, and high cost. Although there have been notable technological advancements in this field, leading to cheaper prices and smaller sensor sizes, further advancement in this field is expected to be impeded by significant limits brought on by excessively laborious labour.

- There is no need for direct access to the combustion chamber.
- The installation temperature of the spark plug ignition system is relatively low (up to 140°C) because of the cooling system.

- Due to the fact that it is situated outside of the combustion chamber, the measurement is not impacted by the numerous potential sources of inaccuracy brought on by the high pressure and great heat in the combustion chamber (such as during engine phase transitions).

The sensor's outer thread is an asymmetrical trapezoid with patented construction, ensuring that the axial load will not affect the sensor's ability to maintain linear characteristics. The sensor housing is built of an aluminum alloy with an expansion coefficient identical to that of the material used for the machine head, minimizing thermal interference errors. Nickel plating on the surface guards against corrosion and thread abrasion.

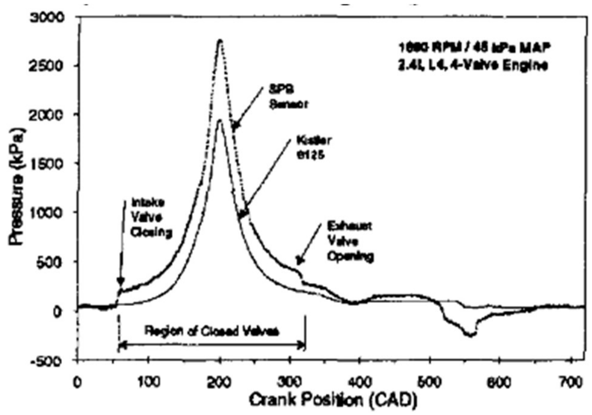

Figure 4. The data from a single combustion event at part throttle for the SPB sensor and Kistler 6125 as a function of crank position [I2][22]

Results of the Fast Fourier Transform are obtained by processing data from FFT Analyzer measurements using the software Matlab. The piston engine's accelerometer sensor was used to measure four different engine speeds: 900 rpm, 1500 rpm, 2500 rpm, and 3500 rpm. These measurements were translated to frequencies of 15 Hz, 25 Hz, 42 Hz, and 58 Hz. **Figure 4** depicts the FFT graph for a piston engine running at 900 revolutions per minute. According to the tests made on the piston motor engine and depicted in the figure, under typical operating conditions, the frequency emerges at a frequency of 309 Hz with an amplitude of 2.311 mm/s^2. In contrast, under abnormal circumstances, the frequency is 69 Hz and the amplitude is 3.433 mm/s2. The local and global frequencies used to test the 1000cc piston motor are shown in **Table 3**.

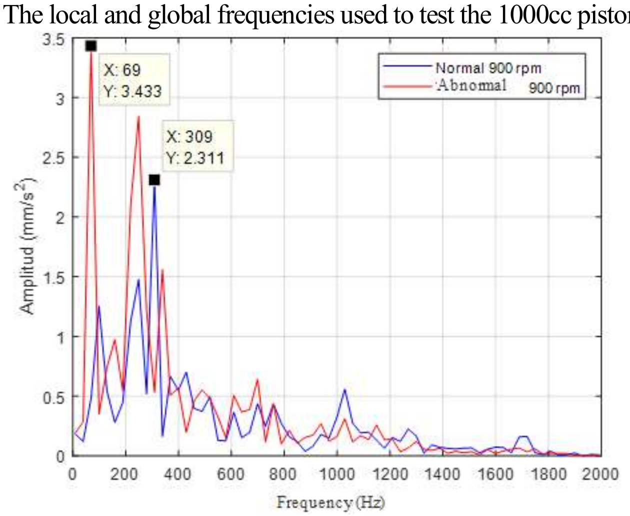

Figure 5. FFT results for an engine with a 900 rpm rotational speed.

There are 23 form modes, or combinations of normal and pathological situations, as shown in **Figure 5**. There are two frequencies that are used worldwide, 349 Hz and 749 Hz. Unlike normal frequencies, abnormal frequencies first occur. This demonstrates that the system's spring stiffness has decreased. **Table 3** provides more information regarding the frequency that occurs.

Table 3. Test results for variations of 900 rpm spinning on a 1000cc piston motor that are normal and abnormal.

No	Normal		Abnormal	
	Frequency (Hz)	Amplitude (mm/s^{2})	Frequency (Hz)	Amplitude (mm/s^{2})
1	-	-	69 Hz	3.433 mm/s^2
2	99 Hz	1.254 mm/s^2	-	-
3			159 Hz	0.9754 mm/s^2
4	249 Hz	1.477 mm/s^2	249 Hz	2.844 mm/s^2
5	309 Hz	2.311 mm/s^2	-	-
6			339 Hz	0.569 mm/s^2
7	369 Hz	0.664 mm/s^2	-	-
8	-	-	399 Hz	0.942 mm/s^2
9	429 Hz	0.7014 mm/s^2	-	-
10	-	-	489 Hz	0.5048 mm/s^2
11	519 Hz	0.4799 mm/s^2	-	-
12	-	-	609 Hz	0.8961 mm/s^2
13	699 Hz	0.436 mm/s^2	-	-
14	749 Hz	0.2759 mm/s^2	749 Hz	1.321 mm/s^2
15	-	-	819 Hz	0.2132 mm/s^2
16	939 Hz	0.1789 mm/s^2	-	-
17	1029 Hz	0.5583 mm/s^2	-	-
18	-	-	1149 Hz	0.2573 mm/s^2
19	1269 Hz	0.2251 mm/s^2	-	-
20	-	-	1299 Hz	0.1196 mm/s^2
21	-	-	1509 Hz	0.03501 mm/s^2
22	-	-	1689 Hz	0.0644 mm/s^2
23	1809 Hz	0.03807 mm/s^2	-	-

The frequency at 900 rpm rotation is demonstrated to be 4x rpm under abnormal circumstances, indicating a bearing problem occurs in the first shape mode, as indicated in table 3. Additionally, a global frequency occurring at 249 Hz and 749 Hz was discovered.

Figure 6 displays the results of measurements made on a piston motor operating at 2500 rpm, revealing that the first form mode's frequency is 249 Hz and that its normal-condition amplitude is 6.721 mm/s^2. This contrasts with the abnormal condition, which has a third shape mode frequency of 249 Hz and a maximum amplitude of 15.66 mm/s^2. **Table 4** displays the form modes that emerge under normal and abnormal circumstances from the results of a misfiring test on a 1000cc piston motor. **Table 4** also demonstrates the existence of both local and global frequencies.

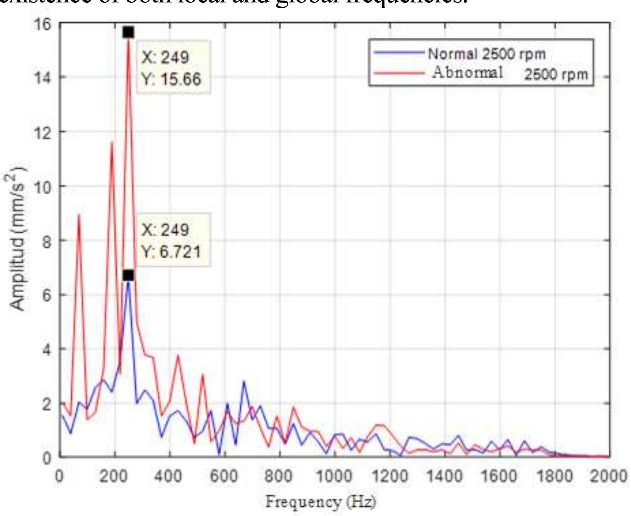

Figure 6. FFT results on an engine with a rotational speed of 2500 rpm

There are 24 form modes, or combinations of normal and pathological situations, as shown in **Figure 5**. Three frequencies are used globally: 249 Hz, 849 Hz, and 1499 Hz. Unlike normal frequencies, abnormal frequencies first occur. This demonstrates that the system's spring stiffness has decreased.

Table 4. Test results for variations of a 1000cc piston motor rotating at 2500 rpm that are normal and anomalous

No	Normal Frequency (Hz)	Amplitude (mm/s$^{2)}$	Abnormal Frequency (Hz)	Amplitude (mm/s$^{2)}$
1	-	-	69 Hz	8.957 mm/s^2
2	-	-	168 Hz	11.62 mm/s^2
3	249 Hz	6.721 mm/s^2	249 Hz	15.66 mm/s^2
4	309 Hz	2.493 mm/s^2		
5	-	-	429 Hz	3.738 mm/s^2
6	-	-	519 Hz	3.071 mm/s^2
7	549 Hz	1.733 mm/s^2	-	-
8	609 Hz	2.009 mm/s^2	-	-
9	-	-	789 Hz	1.537 mm/s^2
10	669 Hz	2.825 mm/s^2	-	-
11	729 Hz	1.916 mm/s^2	-	-
12	-	-	789 Hz	1.537 mm/s^2
13	849 Hz	1.87 mm/s^2	849 Hz	1.242 mm/s^2
14	-	-	-	-
15	90 Hz	0.9131 mm/s^2	-	-
16	-	-	999 Hz	0.7522 mm/s^2
17	-	-	1059 Hz	0.7155 mm/s^2
18	1149 Hz	0.8637 mm/s^2	-	-
19	1269 Hz	0.7373 mm/s^2	-	-
20	1499 Hz	0.8021 mm/s^2	1499 Hz	0.5236 mm/s^2
21	-	-	1509 Hz	0.4557 mm/s^2
22	1569 Hz	0.5802 mm/s^2	-	-
23	1629 Hz	0.6455 mm/s^2	-	-
24	1689 Hz	0.6029 mm/s^2	-	-

Figure 4. It is demonstrated that misfiring leads to a bearing problem at 2500 rpm. This is demonstrated by the appearance of 4x rpm, or 168 Hz. Additionally, the global frequency that results from tests at 2500 rpm is shown. The global frequency occurs at 249 Hz, 849 Hz, and 1499 Hz in both normal and abnormal spark plug circumstances.

4. CONCLUSION

The vibration approach can be used to anticipate if a piston motor's performance is normal or abnormal. The variation in frequency that takes place demonstrates this. In this study, it is demonstrated that the initial form mode, which has an amplitude of 3.433 mm/s^2, appears at 900 rpm, the frequency, under abnormal circumstances. In contrast, the first shape mode occurs under typical circumstances at a frequency of 99 Hz and an amplitude of 1.254 mm/s^2. In atypical circumstances where bearing problems are known to arise. This is because it happens at 4x rpm. Additionally, at a rotational speed of 2500 rpm, anomalous circumstances in the first shape mode occurred at a frequency of 69 Hz and an amplitude of 8.957 mm/s2. In contrast, the first form mode occurs under normal circumstances at a frequency of 249 Hz and an amplitude of 6.721 mm/s2.

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REFERENCE

[1] B. D. Cahyo and M. R. Al Fauzi, “Analisa Pengaruh Ignition Timing Terhadap Daya dan Torsi

Piston Engine SOHC Four Stroke," *J. Penelit. Politek. Penerbangan Surabaya*, vol. 5, no. 2, pp. 29–37, 2020.
[2] S. E. Siegel, Joshua E; Kumar, Sumeet; Ehrenberg, Isaac Mayer; Sarma, "Engine Misfire Detection with Pervasive Mobile Audio," vol. 9853, no. 03 September 2016, pp. 41-226., 2016, doi: https://doi.org/10.1007/978-3-319-46131-1_26.
[3] D. Kurniawan, "Desain dan Analisa Sistem Kontrol Bahan Bakar pada Semi-Free Piston Diesel Engine Tipe Dua Langkah Ber-piston Ganda Berlawanan Arah," 2016.
[4] A. K. Babu, V. Antony Aroul Raj, and G. Kumaresan, "Misfire detection in a multi-cylinder diesel engine: A machine learning approach," *J. Eng. Sci. Technol.*, vol. 11, no. 2, pp. 278–295, 2016.
[5] T. Ginting, "Pengaruh Jarak Celah Busi Terhadap Daya Mesin Kijang Innova Bensin," *J. Tek. Inform. Kaputama*, vol. 3, no. 1, pp. 42–50, 2019.
[6] R. Sadiana, "Analisis respon sistem getaran pada mesin torak 1)," vol. 4, no. 2, 2016.
[7] R. G. Holik Hasan, Mujianto Haris, "Rancang Bangun Sistem Pengapian Semi Elektronik Double Trigger Sebagai Pengembangan Sistem Pengapian Konvensional," *X-Max*, vol. 1, no. November 2016, pp. 14–21, 2016.
[8] I. Wiratmaja, "Analisa Unjuk Kerja Motor Bensin Akibat Pemakaian Biogasoline," *J. Energi Dan Manufaktur*, vol. 4, no. 1, p. 10, 2010.
[9] J. A. Czarnigowski, P. Jaklinski, K. Ścisłowski, D. Rkas, and K. Skiba, "The Use of a Low Frequency Vibration Signal in Detecting the Misfire of a Cylinder of an Aircraft Piston Engine," *SAE Tech. Pap.*, no. 2020, 2020, doi: 10.4271/2020-01-2023.
[10] T. Mikalsen, Rikard and Roskilly, "A review of free-piston engine history and applications," *Appl. Therm. Eng.*, vol. 27, no. october 2017, pp. 2339–2352, 2007, doi: 10.1016/j.applthermaleng.2007.03.015.
[11] Aprian Fadhlu Rahman, Armila, and Rudi Kurniawan Arief, "Analisis Pengaruh Jumlah Lubang Nozzle Injektor terhadap Torsi pada Pembesaran Piston Motor Matic Injection," *TEKNOSAINS J. Sains, Teknol. dan Inform.*, vol. 9, no. 1, pp. 29–39, 2022, doi: 10.37373/tekno.v9i1.139.
[12] A. P. W. Subekti Muhammad Nurul Hidayat, Abdul Hamid ,Basuki Dwi Efendi, Jeffri Silaen, "IDENTIFIKASI KERUSAKAN ALTENATOR DAIHATSU LUXIO DENGAN METODA FUNGSI RESPON FREKUENSI," no. November 2020, pp. 315–323, 2021.
[13] S. Subekti, "Studying the Dynamic Characteristics To Lengthen the Operating Life for a Diesel Engine Using Frequency Response Function (Frf) Measurement," *Sinergi*, vol. 22, no. 3, p. 161, 2018, doi: 10.22441/sinergi.2018.3.004.
[14] S. Bekti, "Karakteristik Dinamik Disc Brake Daihatsu Sigra 1200 cc dengan Metode Bump Test," *FLYWHEEL J. Tek. Mesin Untirta*, vol. V, no. 1, p. 14, 2019, doi: 10.36055/fwl.v0i0.3947.
[15] A. Subekti, S., Hidayat, M. N., Efendi, B. D., Hamid, A., & Murwanto, "Hilbert Transform Analyzer for Mechanical Fault Detection of Vehicle Alternators," *Automot. Exp.*, vol. 3, no. 3, pp. 89–95, 2020.
[16] E. Saputra, S. Subekti, and T. Supriyanto, "Analisis getaran pengendara kawasaki ninja 2 tak 150 cc akibat porting pada saluran intake dan exhaust," *J. Ter. Mesin*, vol. 4, no. April, pp. 1–11, 2023.
[17] M. Saidiman, M. Satya Nugroho, Subekti, and A. Hamid, "Karakteristik Dinamik Computer Numerical Control Milling Router 4 Axis," *Sist. J. Ilm. Nas. Bid. Ilmu Tek.*, vol. 9, no. 2, pp. 33–43, 2021, doi: 10.53580/sistemik.v9i02.62.
[18] M. F. Gulang, Z. D. Haq, H. Alpiyanto, and S. Subekti, "Karakteristik dinamik needle bearing pada camshaft dohc suzuki satria fu150 yang telah di modifikasi, dengan metode bump test," *Tek. J. Sains dan Teknol.*, vol. 16, no. 2, p. 237, 2020, doi: 10.36055/tjst.v16i2.8461.
[19] M. A. Pratiwi, M. Ikhsan, R. D. Octavianto, A. Hamid, and S. Subekti, "Dynamic Characterization of Ball Bearing in Turbine Propeller Using Bump Test Method," *Sinergi*, vol. 25, no. 2, p. 135, 2021, doi: 10.22441/sinergi.2021.2.004.
[20] A. W. Biantoro, H. Maryanto, A. K. Hidayanto, and A. Hamid, "the Investigation of End Mill Feeds on Cnc Router Machine Using Vibration Method," *Sinergi*, vol. 24, no. 2, p. 117, 2020,

doi: 10.22441/sinergi.2020.2.005.
[21] F. A. Wicaksono, S. Subekti, and K. Indriyanto, “Analisis pengaruh penyumbatan aliran fluida pada pipa dengan,” vol. 6, no. April, pp. 77–83, 2021.
[22] I. Silnikow, “OVERVIEW OF ENGINE MISFIRE DETECTION METHODS USED,” vol. 8, no. 1, 2001.