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Harvesting energy vibration derived from the rotational speed of a A 4-stroke engine

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Abstract: The possibility of producing electricity by harnessing the vibration energy of a four-stroke engine. There is a dearth of research on using vibration energy as a source of electrical energy, with most previous studies concentrating on examining the vibration characteristics and frequency response functions of the 4-stroke engine. As a result, the main objective of this research is to close this gap by creating a mechanism to capture the vibration energy from the 4-stroke engine. The methodology used is an experimental investigation in which Matlab and an FFT analyzer are used to collect data. The study's findings show that the 4-stroke piston motor has multiple mode shapes. The energy harvesting apparatus that is being used is electromagnetic in nature. Research indicates that more work needs to be done to improve the efficiency of using the vibrations from a 4-stroke piston motor as a source of electrical energy. The 4-stroke piston motor has different mode shapes at different rotational speeds, but it is not able to produce a substantial amount of electrical energy with the electromagnetic energy harvesting device. Consequently, this study lays the groundwork for future investigations into using a 4-stroke piston motor's vibrations as a more effective source of electrical energy.

Keywords: Vibration; energy; electrical; motor; efficiency

1. INTRODUCTION

Every person now considers electricity to be a basic need, so the availability of electricity is essential to all human activity [1]. In order to prevent a possible energy shortage, the demand for electrical energy must be satisfied, which is still growing [2]. Fossil fuels are currently the primary source used to meet the needs for electrical energy. On the other hand, because of their limited nature, fossil fuels are non-renewable natural resources with a finite supply [3]. Indonesia's petroleum reserves are estimated to be sufficient only for the next nine years, according to data from the Minister of Energy and Mineral Resources (ESDM). The remaining petroleum is estimated to be 4.17 billion barrels, consisting of 2.44 billion barrels of proven oil availability and an additional 2.44 billion barrels of unknown oil availability.

The environment contains a variety of energy sources that can be used to generate energy, including the sun, wind, tides, geothermal heat, and mechanical vibrations [4],[5]. Among these energy sources, widely dispersed vibrational energy in the environment is gaining attention as a potential small-scale, low-power power generation source. It has been acknowledged that converting waste vibration energy into useful electrical energy presents a very promising alternative to conventional batteries for use in wireless communication devices or monitoring sensors. These devices' energy-harvesting features not only save battery and maintenance costs but also help save energy and lessen their negative environmental effects. The vibration that a piston engine or motor produces is one type of vibration that we frequently experience.

A motor with four working strokes in a single cycle is called a 4-stroke piston motor. One possible application for piston motor vibrations is as a renewable energy source. Numerous factors contribute to this vibration, such as piston movement, rotational speed, the process of mixing fuel and air in the cylinder chamber, pressure from the fuel spray from the plunger pump nozzle, gas pressure on the exhaust suction valve, and expansion-related vibrations from the exhaust. combustion of fuel

[6]. Mercu Buana University has conducted a great deal of research on vibration testing, including frequency response testing [6],[7] and analysis of vibrations that occur on motorcycles [8],[9],[10],[11],[12],[13],[14]. It has been demonstrated that, in comparison to ball bearings, tempered bearings offer larger vibration amplitudes [15].

Because of this, it is crucial to develop this system in order to use the vibrations of a 4-stroke piston motor as a source of energy. This research will primarily address this topic

2. METHOD

Getting good results is important in a research plan. Prior to starting any research, it is essential to read through the literature to learn about earlier studies on vibration energy harvesting and four-stroke piston motors [16].

There hasn't been much research on using vibration energy as a source of electrical energy, according to the results of the literature review. Thus, this research can be continued by setting up the required tools and supplies. Proceed with the engine speed variations that will be used at 700, 1000, and 1100 RPM once these requirements are satisfied. The data is then captured using the FFT Analyzer. If there are numerous disruptions during the data collection process, the data must be recollected. The vibration graph of a four-stroke piston motor will be determined using Matlab.

This research was guided by an experimental study. There are two methods for gathering data: harvesting energy vibration data with an oscilloscope and collecting vibration data with an FFT Analyzer. Matlab will be used to process the test data and analyze the current voltage resulting from the rotational speed of a 4-stroke piston motor, as illustrated in

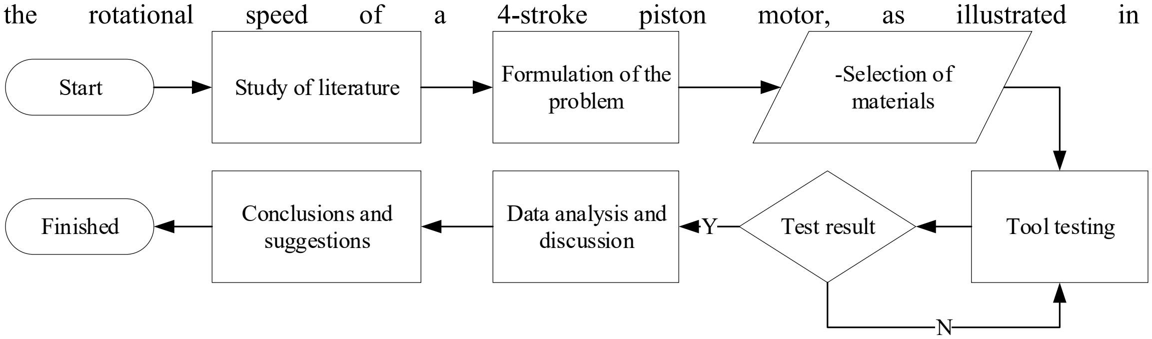

Figure 1.

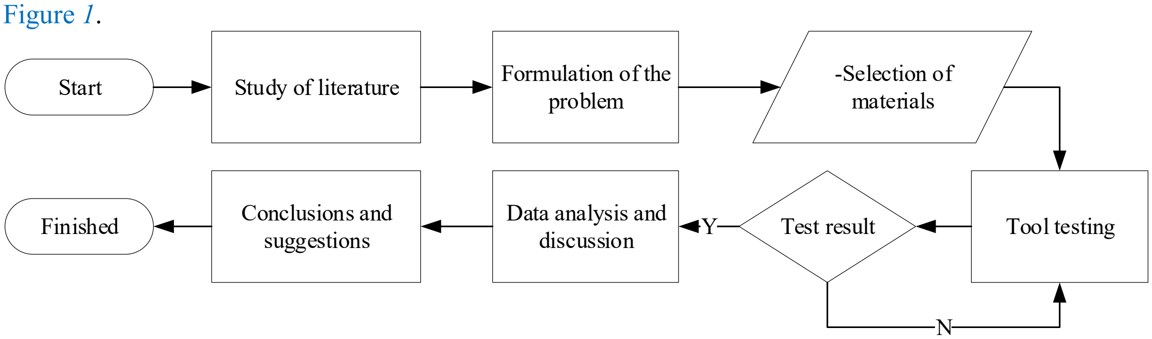

Figure 1. Research stages

The rotational speeds used for this test were 700, 1000, and 1100 RPM. The 4-stroke piston engine's top is then where the accelerometer sensor is mounted. The harvesting tool and accelerometer sensor are positioned as depicted in Figure 2 to identify vibrations in the 4-stroke piston motorbike.

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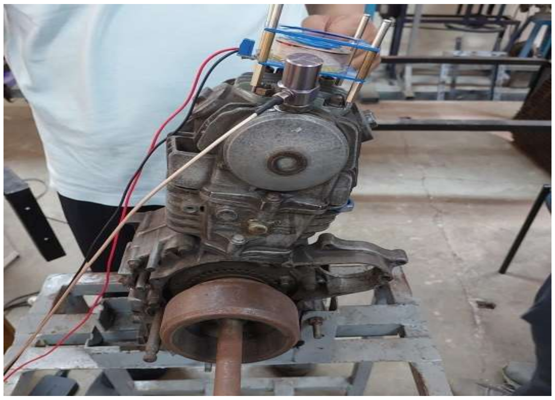

Figure 2. Vibration testing on a 4-stroke piston motor

Vibration characteristics on a 4-stroke motorcycle are dynamic when measured with a vibration sensor at rotational speeds of 700, 1000, and 1100 RPM. After measuring the vibrations caused by the 4-stroke piston motor, an accelerometer sensor is attached to the CF-3600A portable via a BNC cable. An FFT analysis is then performed on a touch screen computer to obtain the frequency domain and time domain data. The data from the measurement results are evaluated in the following step using Matlab R2021a. In order to measure electrical signals graphically on a screen, an oscilloscope is utilized to determine the energy generated by vibrations. After that, analysis was done using Matlab R2021a to assess the visual data, as Figure 3 illustrates.

There are two steps involved in the data collection process. In the first section, vibration sources—more especially, vibrations generated by a 4-stroke piston motor—are experimentally measured. In the meantime, the second section entails gathering vibration data and performing frequency domain analysis using the FFT Analyzer tool. In order to comprehend the vibration characteristics of 4-stroke piston motors and turn them into a potential source of electrical energy, this data collection process is essential.

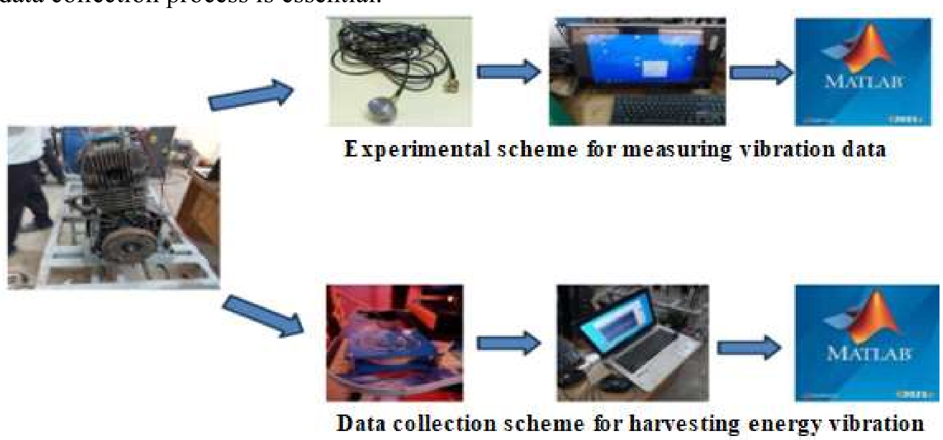

Figure 3. Data collection process (a) experimental measurement of vibration sources, (b) data collection harvesting vibration energy.

An electromagnetic tool is used to collect vibration energy. This tool operates by causing the spring plate and magnet to move up and down in response to vibrations that happen when the vibrations from the 4-piston motor are not picked up by the vibration energy harvesting device. The copper coil at the bottom of the magnet experiences variations in magnetic flux as a result of the magnet's up and down movement, which ultimately results in a current output from the coil. A device that can harvest energy from vibrations is shown in Figure 4 and Table 1. The spring plate, spacer, plate, coil, N55 magnet, bolts, nuts, and circuit board are some of the parts that make up this tool.

A spring plate, also known as a spring plate, is a flexible element that can move elastically in response to specific pressure or movement. Its job is to take in mechanical movement's kinetic energy and transform it into electrical energy. In order to avoid the two electrodes coming into direct contact, spacers are also employed. This is crucial to preserving generator performance and guarding against damage from short circuits. A plate serves as a surface for gathering and absorbing energy from the source. There are several materials for plates, such as glass, plastic, or metal.

The coil is therefore a crucial part of the generator that produces energy. It is made up of a wire coil that is tightly wound. A magnetic field that is created around the coil by an electric current flowing through it can be utilized to produce electrical energy. The N55 magnet is the one that generates electric current. A neodymium magnet with exceptionally high magnetic strength is the N55 magnet. Its composition consists of neodymium, iron, and boron. Its magnetic strength is approximately 1.5 times that of N42 magnets Because N55 magnets have a high magnetic strength, they are frequently used in energy-producing generators. Usually, this magnet is installed on the generator rotor in a vibration energy producing device. The rotor's magnetic field interacts with the N55 magnet as it rotates as a result of energy from an energy source, producing an electric current.

The generator's various parts are connected by bolts, and the bolts themselves are held in place by nuts. Finally, an electronic component that connects different other electronic components is the circuit board, also known as a circuit board. The insulating material used to make circuit boards, such as fiberglass or FR4, is covered in metal strips. The purpose of these metal pathways is to transport electricity.

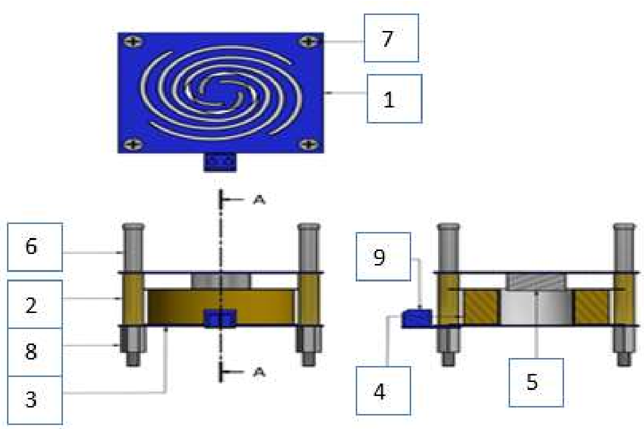

Figure 4. Vibration energy harvesting device

Table 1. Components of vibration energy harvesting equipment

Part List		
Item	**Qty**	**Part Number**
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

Stainless steel is the material of the spring plate that is used to collect energy. The spring plate that is used has dimensions of 70 mm by 70 mm and a thickness of 0.02 mm. It is shaped like a circular spiral.

3. RESULTS AND DISCUSSION

The FFT Analyzer and Protable Oscilloscope settings were tested during the research. A 4-stroke piston motor operating at different rotational speeds of 700, 1000, and 1100 RPM was used to collect data. The FFT results of a 4-stroke piston motor operating at 700 RPM are displayed in Figure 5. Less than 3 mm/s^2 is the average amplitude magnitude (RMS).

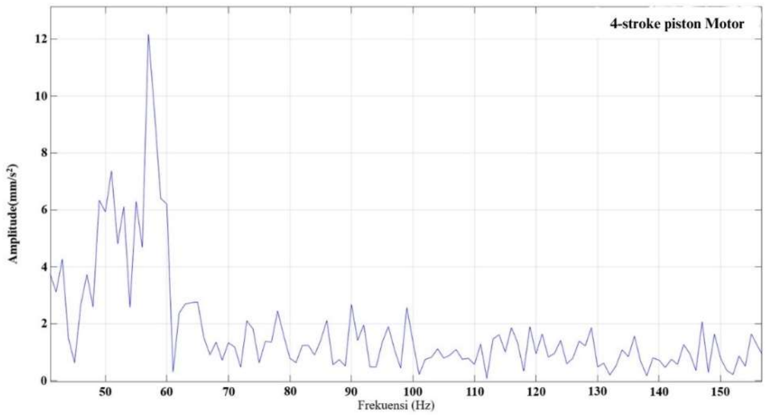

Figure 5. FFT results for a 4-stroke piston motor with a rotational speed of 700 RPM

The MATLAB software is used to do an FFT analysis on the energy harvesting data analysis results. Figure 5 displays the oscilloscope's FFT results at a rotational speed of 700 RPM. Figure 6 illustrates how the energy harvester's voltage produces the highest voltage of 19.78 mV at a frequency of 13 Hz.

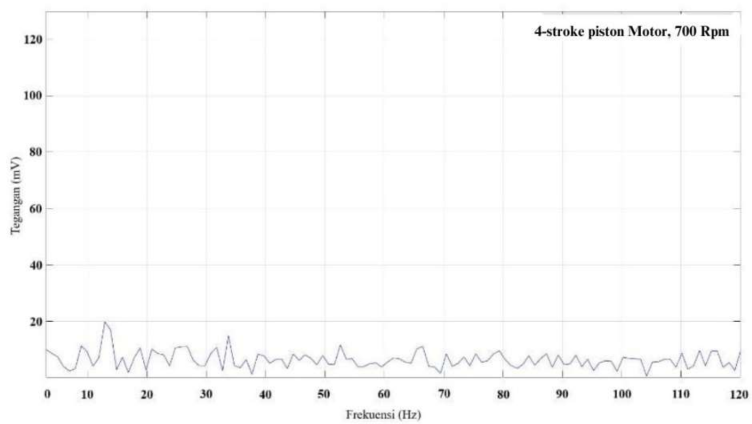

Figure 6. The result of harvesting energy from a 4-stroke piston engine at a rotational speed of 700 RPM.

The same procedure was used to test piston motors with rotational speeds of 1000 and 1100 Rpm. The purpose of adding rotational speed is to ascertain how it affects vibration energy collecting. The test results at a rotating speed of 1000 Rpm are shown in Figure 7 and Figure 8. Additionally, the test results at a rotational speed of 1100 Rpm are shown in Figure 9 and Figure 10.

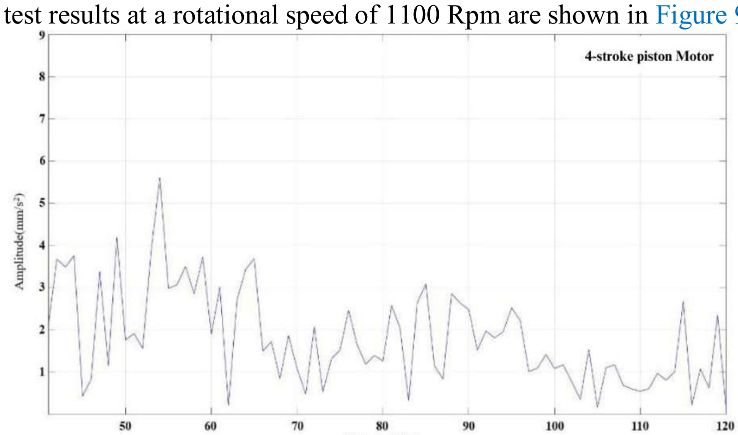

Figure 7. FFT results for a 4-stroke piston motor with a rotational speed of 1000 RPM

Figure 8, the maximum voltage current is obtained at a frequency of 4 Hertz, 177.59 mV, and there are 5 points of the highest voltage current obtained, including at a frequency of 9 Hz, 13 Hertz, 19 Hertz, and 26 Hertz.

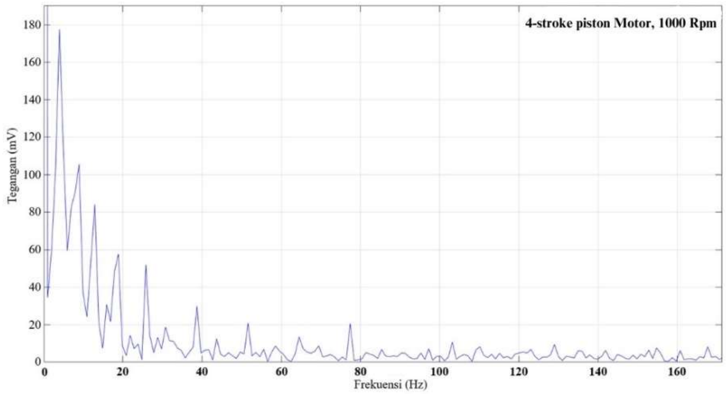

Figure 8. The result of harvesting energy from a 4-stroke piston engine at a rotational speed of 1000 RPM

The greater the rotation speed, the higher the amplitude value of the first mode shape, as shown in the image below. In the image it is shown that there are four visible shape modes, namely at 60 Hz, 62Hz, 92 Hz and 114 Hz.

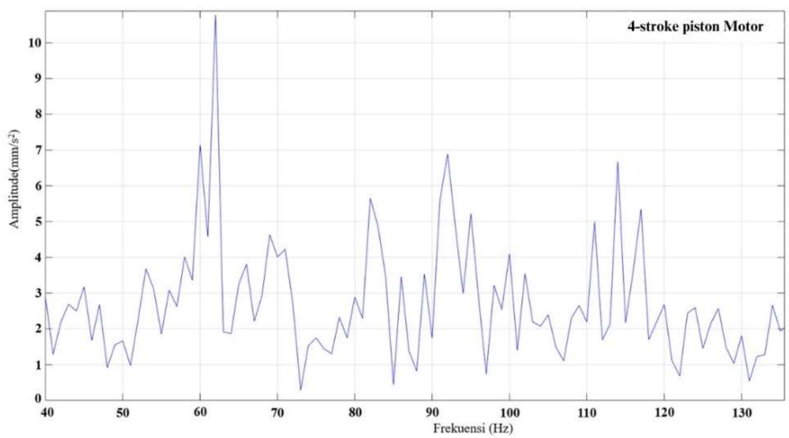

Figure 9. FFT results for a 4-stroke piston motor with a rotational speed of 1100 RPM

Figure 10, the oscilloscope's data processing results indicate that five highest voltage current points were obtained, with the frequencies of 2 Hz, 5 Hz, 10 Hz, 12 Hz, and 19 Hz among them. where 167.20 mV, the highest voltage produced, happens at a frequency of 12 Hz.

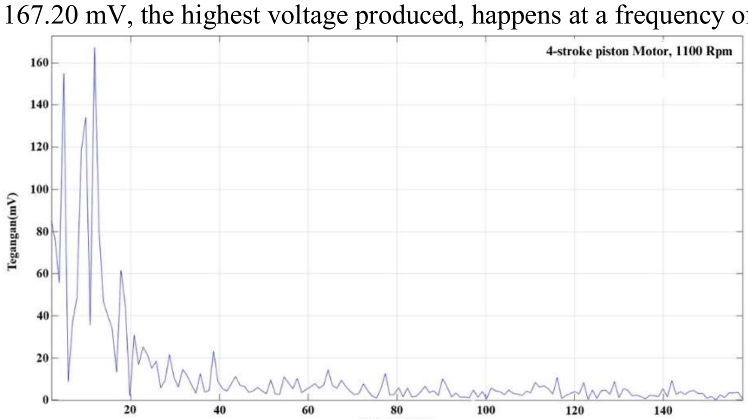

Figure 10. The result of harvesting energy from A 4-stroke piston engine at a rotational speed of 1100 RPM.

Four-stroke piston motors vibrate for a variety of reasons, including rotational speed, piston up-and-down movement, explosive reactions in the cylinder chamber, distribution system, fuel pressure from the plunger pump nozzle, and exhaust suction valve pressure. Numerous studies have been conducted on vibration testing, including vibration analysis and frequency response function testing, for 4-stroke piston motors. On the other hand, the use of vibration energy as a source of electrical energy has not been extensively studied. The purpose of this study is to use a four-stroke piston motor vibrations as a source of energy

This study employs an experimental design. Prior to starting this study, a review of the literature was done to learn about earlier studies that looked into vibration energy harvesting and 4-stroke piston motors. Following that, data was gathered using engine speed variations of 700, 1000, and 1100 Rpm. After that, the data is processed through Matlab and FFT Analyzer to create a graph showing the vibrations that a 4-stroke piston motor experiences.

Utilizing an electromagnetic energy harvester, vibration energy is collected. This device generates an output of current by converting the vibrations from a 4-stroke piston motor into an up-and-down movement of a magnet that travels through a copper winding coil. The vibration energy harvester's parts include circuit boards, bolts, nuts, N55 magnets, spring plates, spacers, plates, coils, and circuit boards.

The study's findings indicate that 4-stroke piston motors with rotational speeds of 700, 1000, and 1100 Rpm have multiple shape modes. Shape modes at frequencies of 2 Hertz, 5 Hertz, 10 Hertz, 12 Hertz, and 19 Hertz are present at a rotational speed of 700 Rpm. Shape modes are present at frequencies of 4 Hertz, 9 Hertz, 13 Hertz, 19 Hertz, and 26 Hertz at a rotational speed of 1000 Rpm. In the meantime, shape modes at frequencies of 60, 62, 92, and 114 Hz exist at a rotational speed of 1100 Rpm.

3 CONCLUSION

A four-stroke piston motor's vibration can be converted into electrical energy. Four-stroke piston motors have multiple shape modes at different rotational speeds, and an electromagnetic energy harvesting device is employed. A four-stroke piston motor's vibration cannot be efficiently used as a source of electrical energy. Four-stroke piston motors have multiple shape modes at different rotational speeds, but the energy harvesting device that is used—an electromagnetic type—is not able to generate a substantial amount of electrical energy. Therefore, this study demonstrates that further development is required to improve the efficiency of using 4-stroke piston motor vibrations as a source of electrical energy.

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