DEVELOPMENT OF RS-WZ3 SENSOR IN IOT BASED VIBRATION MONITORING SYSTEM

Widyaningrum Indrasari[1*], Catur Anthony Hermanta[1], Heri Firmansyah[2]

[1]*Department of Physics, Faculty of Mathematics and Natural Sciences, Universitas Negeri Jakarta, Jakarta 13220, Indonesia*

[2]*Department of Automation Engineering Technology, Faculty of Engineering, Universitas Negeri Jakarta, Jakarta 13220, Indonesia*

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ABSTRACT

This article develops a vibration monitoring system on the machine using the RS-WZ3 sensor, which is based on MEMS (Micro-Electro-Mechanical Systems) technology. The RS-WZ3 sensor can measure vibrations on three axes (X, Y, and Z), as well as the surface temperature of the motor. The MAX485 module and the ESP32 microcontroller transform the vibration data from the sensor into a digital signal, subsequently displaying it on a web interface accessible remotely in real time. Sensor calibration is carried out by comparing the measurement results of the RS-WZ3 sensor with those of the GM63A vibration meter, which shows good accuracy with an average error of 2.01%. Testing of this system shows that the RS-WZ3 sensor is effective in measuring and monitoring machine vibrations in real time, enabling more efficient predictive maintenance and reducing maintenance costs.

Keywords: Vibration monitoring; RS-WZ3 sensor; Predictive maintenance

Introduction

Industry plays a crucial role in the economy, with machines being a core element in the production process. A machine is a device that converts electrical energy into mechanical energy. An ideal machine is one that converts all electrical energy into mechanical energy or kinetic energy. Various aspects of physics[1] allow for the monitoring of a machine's health condition, including machine vibration. Machine vibration refers to the oscillation or back-and-forth movement that occurs in machine components when they are operating. Vibration occurs in all cases of rotational machine operation, both steady and unsteady.[2] Each machine has a specified normal vibration limit. Vibration that exceeds the normal limit (overvibration) will damage and interfere with the components inside,[3] thereby reducing machine performance. If left for a long time, it can cause serious damage to the machine,[4] which will result in production losses and increased maintenance costs. Therefore, it is necessary to monitor the machine's vibration conditions.[5]

Machine vibration monitoring is an important process in predictive maintenance to detect and analyze machine conditions,[6] as well as determine damage to machine components.[7] To build a good monitoring system, it is necessary to select the right sensor and integrate it into the data acquisition and data transmission systems. Machine monitoring systems use various types of vibration sensors, such as piezoelectric,[8,9] accelerometer,[10] displacement sensor[11,12], or capacitive sensor.[13] A MEMS accelerometer is DC coupled and can respond to frequencies as low as 0Hz. MEMS DC response accelerometers can measure static or very low frequency (<1Hz) acceleration or if velocity and displacement information are to be extracted from the acceleration data. Capacitive-type accelerometers are based on the capacitance changes in the seismic mass under acceleration and are the most common technology used for accelerometers today.

*Corresponding author.
E-Mail: Widyaningrum-indrasari@unj.ac.id

These accelerometers employ Micro Electro Mechanical Systems (MEMS) fabrication technology which can bring economy of scale to high volume applications, hence lower manufacturing cost. One inherent characteristic with all capacitive devices is its internal clock. The clock frequency (~500kHz) is an integral part of the current detection circuit, which is invariably present in the output signal due to internal leakage. The high frequency noise may well be outside of the acceleration measurement range of interest, but it is always there with the signal. Piezoresistive is the other commonly used sensing technology for DC-response accelerometers. Instead of sensing the capacitance changes in the seismic mass, a piezoresistive accelerometer produces resistance changes in the strain gauges that are part of the accelerometer's seismic system. The output of most piezoresistive designs is generally sensitive to temperature variation. It is necessary to apply temperature compensation to its output internally or externally. Modern piezoresistive accelerometers incorporate ASIC for all forms of on-board signal conditioning, as well as in-situ temperature compensation. The bandwidth of piezoresistive accelerometers can reach upwards of 7,000 Hz. The emergence of IoT technology has enabled the advancement of website-based monitoring, enabling the transmission of sensor measurement results and the execution of data analysis through cloud computing.[14] Website-based systems allow real-time access from various locations via an internet connection, making them ideal for monitoring the condition of machines spread across multiple locations.

This article describes the development of a vibration measurement system on a machine using the RS-WZ3 sensor. MEMS (Micro-Electro-Mechanical Systems) fabricates the RS-WZ3 sensor, an accelerometer sensor. The RS-WZ3 sensor has high accuracy for measuring vibrations on rotating equipment, and it is flexible in installation, making it more practical.[15] A website integrates the sensor readings, enabling quick remote access to data.[16] This technology collects, analyzes, and displays vibration data from the RS-WZ3 sensor directly through a web interface, simplifying predictive maintenance for technicians. By hosting all functionality on a central server accessible via a web browser, this system eliminates the need for special software installations on individual user devices.[17]

Methods

In this study, vibration measurements were carried out using an RS-WZ3 sensor. This sensor requires a power supply of 10 V and can measure frequencies in the range of 10–1600 Hz and speeds in the range of 0–50 mm/s.[18] This sensor operates using the M8 single-axis triaxial vibration method, which employs three primary axes: X, Y, and Z, enabling it to detect vibrations along these axes and arrange or position it precisely. The MEMS chip processes the output signal from the sensor element to determine the voltage.[15] The ESP WiFi microcontroller is used as a control system that allows the data retrieval process to be processed faster. The max485 module transforms the vibration signal from the sensor measurement into a digital signal that the microcontroller will receive.[19] Figure 1 displays the research flow diagram.

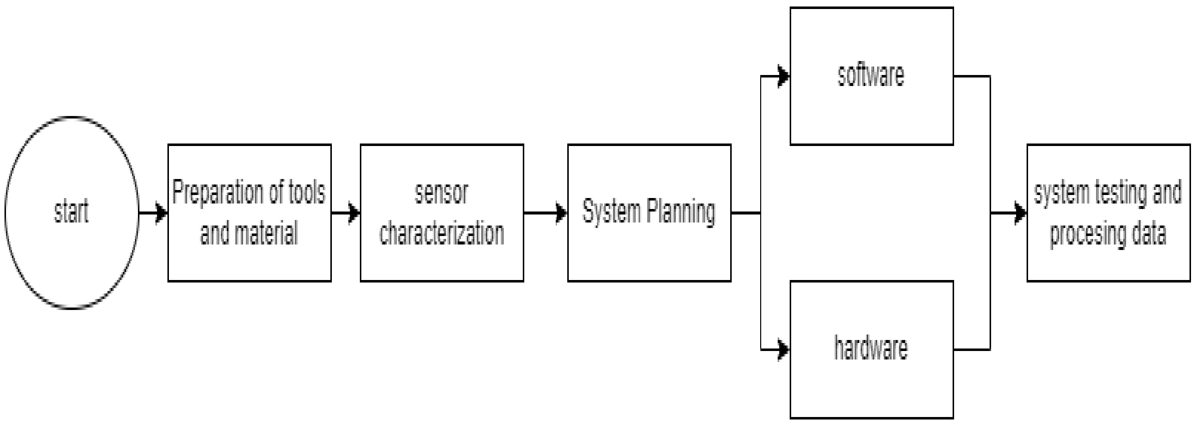

Figure 1. Research flow diagram

According to Figure 1, the first stage of the research involves characterizing the sensor by calibrating it using standard tools and conducting sensor testing. Then, the system design, which consists of software design and hardware design, is carried out. The hardware design requires a communication protocol to enable the ESP32 microcontroller to read sensor output data. Therefore, Max485 is installed, which functions to convert voltage signals into digital signals. The device also displays the sensor's data results on the LCD.

The IoT-integrated monitoring system is built using ThingSpeak as a communication protocol. Data from sensors will be sent to ThingSpeak and then visualized using the available dashboard. Figures 1 and 2 represent the research flowchart and system block diagram, respectively.

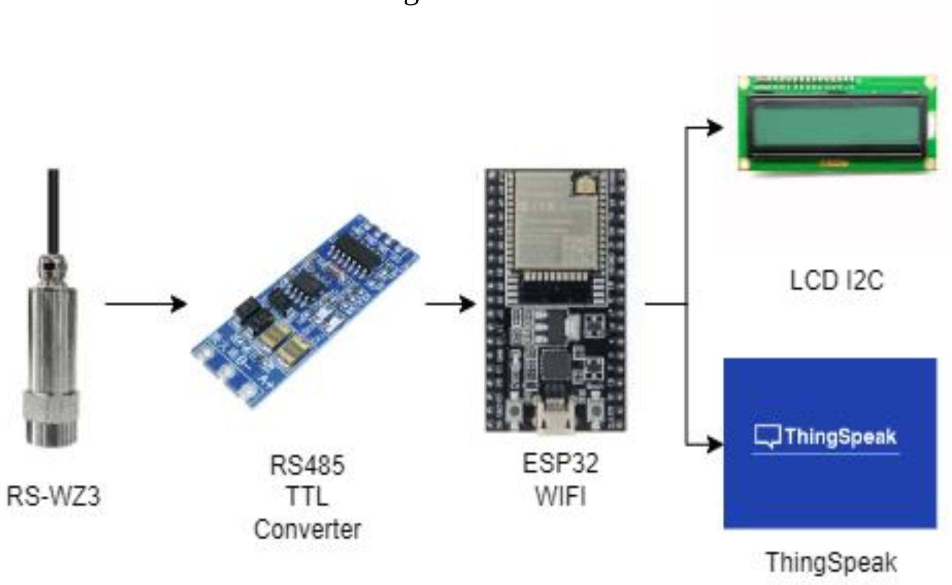

Figure 2. Overall Block Diagram.

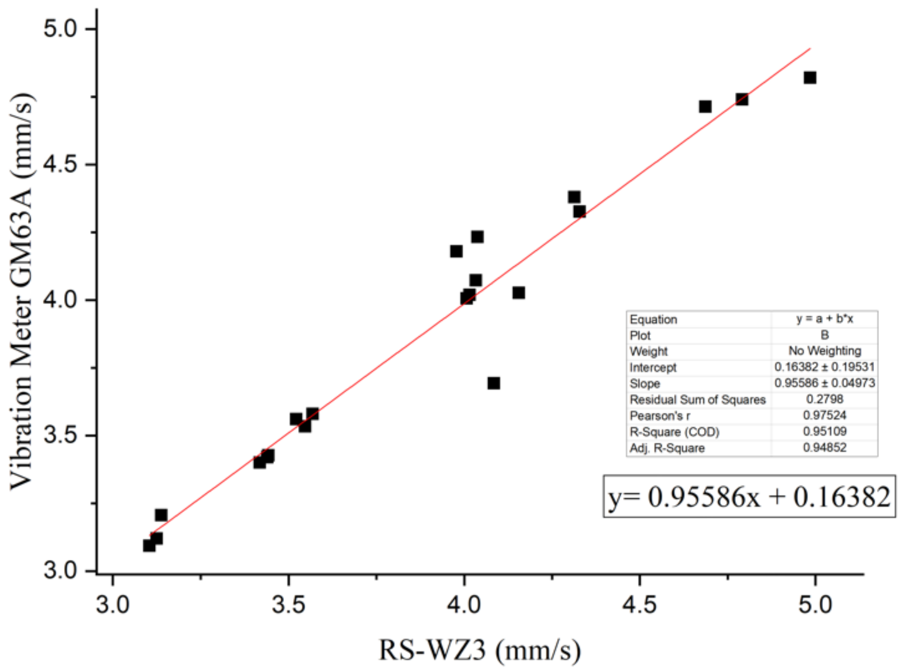

Figure 3. Calibration results a graph of the RS-WZ3 vibration sensor

Result and Discussion

This section showcases the outcomes of the RS-WZ3 sensor calibration, sensor test results, website development monitoring, and sensor testing procedures.

a. Calibration of the RS-WZ3 Vibration Sensor

Vibration sensor calibration is done by directly comparing the values read on the RS-WZ3 vibration sensor with the values read on the GM63A vibration meter as a reference measuring tool. The measurement process is carried out using a vibration source from a drill machine with a frequency that has been differentiated according to its respective gears. Measurements are carried out three times for five different gear variations, and the difference in start time on each gear is varied by 30s, 45s, and 60s. This process will cause vibrations on the RS-WZ3 sensor, and the sensor will convert the difference in vibration speed into output voltages. At this stage, measurements are also carried out with a vibration source from a fan whose rotation speed is varied. The graph in Figure 3 displays the measurement results.

Based on the graph (Figure 3), a linear regression plot was then carried out to obtain the calibration equation for the RS-WZ3 vibration sensor, namely:

$$y=0.99586x+0.16382 \quad (1)$$

where x represents the sensor measurement result, and y denotes the vibration meter result.

b. Sensor System Testing

The Arduino programming code implements the regression function equation to assess the accuracy of the sensor calibration equation approach and verify the system's functionality. When the calibration equation is entered into the code, the sensor can display the frequency of the calibrated vibration source. This aims to improve the accuracy of the sensor measurement results, making them more reliable and accurate. The process of sensor testing involves re-measuring the vibration. At this stage, the RS-WZ3 sensor will be tested by comparing the frequency value measured by the sensor with the frequency value measured by the vibration meter. The testing process was carried out at three different speed levels. Table 1 displays the test results.

Table 1. RS-WZ3 Sensor Test Results

Vibration (mm/s)		Error (%)
Vibration Meter	**RS-WZ3**	
3,35	3,38	1,26
3,35	3,38	2,08
3,29	3,29	2,03
3,17	3,14	1,60
3,09	3,08	2,14
3,13	3,14	1,79
2,94	2,99	2,67
2,95	2,97	2,37
2,98	2,98	2,17
Average		2,01

The table presents a comparison of vibration measurements (in mm/s) between the Vibration Meter and the RS-WZ3 sensor, along with the percentage error between the two devices. The table reveals a close relationship between the measurement values produced by the vibration meter and RS-WZ3. For example, if the vibration meter measures

3.35 mm/s, the RS-WZ3 measures 3.38 mm/s with an error of 1.26%. Overall, the average error of all measurements is 2.01%. The available data indicates that the RS-WZ3 sensor outperforms the standard vibration meter in terms of vibration measurement accuracy. Although there is a slight variation in the error value for each measurement, the error range is still within acceptable limits for machine vibration monitoring applications. Use the chart below combined with additional factors to judge the overall vibration severity: ISO 2372 (10816) Standards provide guidance for evaluating vibration severity in machines operating in the 10 to 200Hz (600 to 12,000 RPM) frequency range. Examples of these types of machines are small, direct-coupled electric motors and pumps, production motors, medium motors, generators, steam and gas turbines, turbo-compressors, turbo-pumps and fans. Some of these machines can be coupled rigidly or flexibly, or connected through gears. The axis of the rotating shaft may be horizontal, vertical or inclined at any angle.

c. IoT-Based Monitoring

This monitoring uses ThingSpeak to send sensors to the database and a dashboard. The IoT system flow in this study starts with setting the coding and entering the API key. Next, ThingSpeak will receive the vibration data from the sensor and visualize it as a dashboard.

Table 2. The ISO 10816 Vibration Severity Standards

VIBRATION SEVERITY PER ISO 10816						
Machine			Class I Small Machines	Class II Medium Machines	Class III Large Rigid Foundation	Class IV Large Soft Foundation
	in/s	mm/s				
Vibration Velocity V rms	0.01	0.28	Good	Good	Good	Good
	0.02	0.45	Good	Good	Good	Good
	0.03	0.71	Good	Good	Good	Good
	0.04	1.12	satisfactory	Good	Good	Good
	0.07	1.80	satisfactory	satisfactory	Good	Good
	0.11	2.80	unsatisfactory	satisfactory	satisfactory	Good
	0.18	4.50	unsatisfactory	unsatisfactory	satisfactory	satisfactory
	0.28	7.10	unacceptable	unsatisfactory	unsatisfactory	satisfactory
	0.44	11.2	unacceptable	unacceptable	unsatisfactory	unsatisfactory
	0.70	18.0	unacceptable	unacceptable	unacceptable	unsatisfactory
	0.71	28.0	unacceptable	unacceptable	unacceptable	unacceptable
	1.10	45.0	unacceptable	unacceptable	unacceptable	unacceptable

Figure 4. Monitoring Dashboard

d. System Testing

System testing was conducted to validate the functionality of the developed system. Testing was conducted using a car engine when it was turned on for 6 minutes. The data collection time was set at 15 seconds. In this test, the RS-WZ3 vibration sensor was placed on the surface of the car's engine plate. The graph in Figure 4 displays the results of the system measurements

A car engine produces natural vibrations when operating due to the combustion process and the internal movement of engine components, according to the graph shown. Even in neutral, these vibrations can intensify when the engine operates at higher speeds.

The test results demonstrate a positive correlation between the car's speed and the level of vibration produced. This means that the higher the car's speed, the greater the vibration measured by the sensor on the engine. The engine produces an increasing amount of energy to propel the internal components at higher speeds. Vibration sensors measure these mechanical vibrations, which propagate through various parts of the car. This fundamental principle demonstrates that the engine's operating mechanical energy can trigger vibrations in the structures and systems linked to it. Tests using the same method were also carried out on motorcycle engines, drilling machines, and fans; the results can be seen in Figure 6:

Conclusion

A real-time vibration measuring device on the machine has been developed using the RS-WZ3 sensor with the MAX485 module and the ESP32 as a controller. The results of the study showed that the RS-WZ3 sensor has good accuracy, with an average error of 2.13%. The development of a website-based monitoring system enables the display of vibration measurement results from real-time sensors, enabling remote data analysis and enhancing the efficiency of predictive maintenance. Further optimization of the system with the MING stack environment will make this IoT application more industrial-grade.

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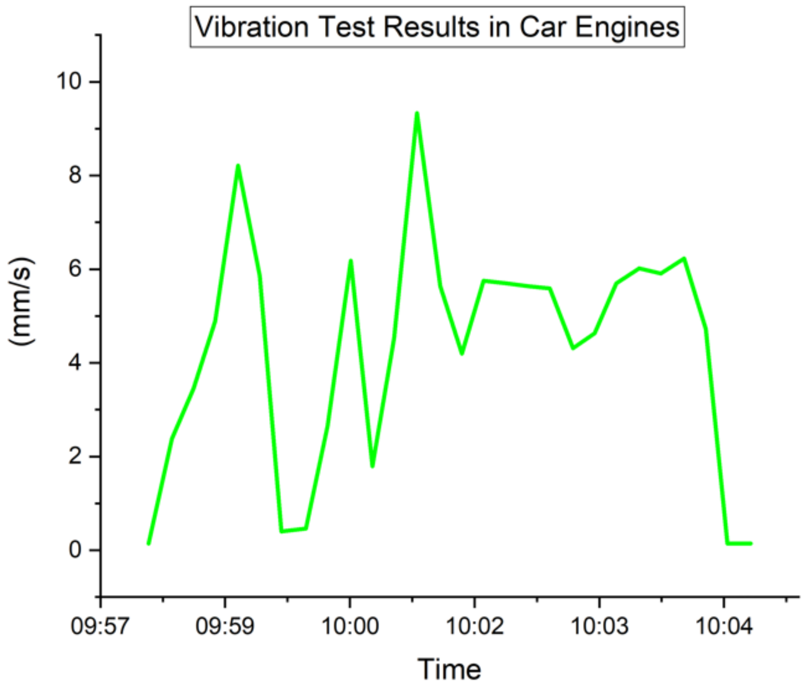
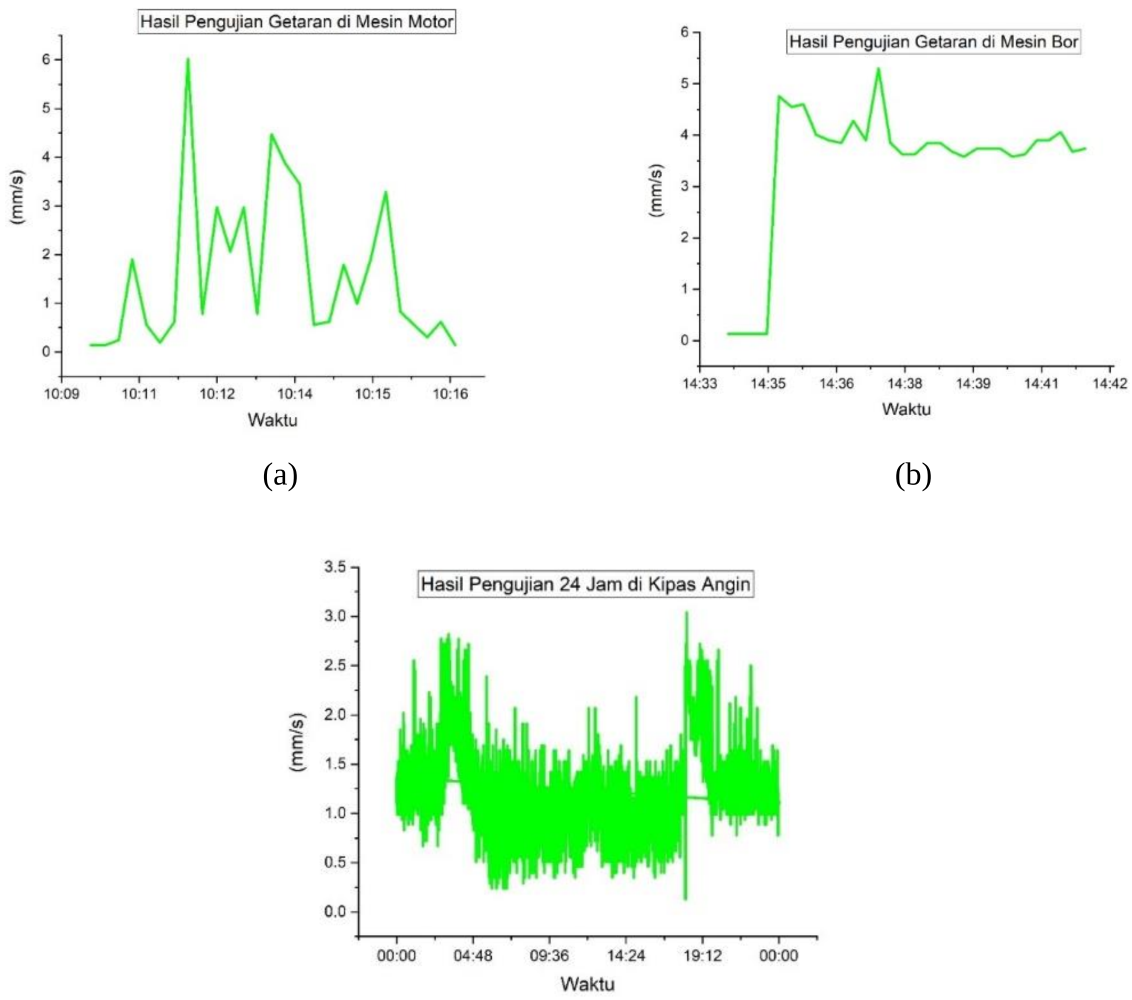


Figure 5. Results of vibration monitoring on a car engine



(a) (b)

(c)

Figure 6. Results of vibration monitoring on (a) motorcycle engines, (b) drilling machines, and (c) fans

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