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THREE AXIS VIBRATION MEASURING INSTRUMENT USING A SMARTPHONE DISPLAY-BASED ACCELEROMETER SENSOR

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ABSTRACT

Applications for vibration measurement include machine analysis, measuring vehicle stress, and monitoring building structures. Modern vibration measurement instruments are typically expensive, intricate, and not necessarily readily available to everyone. This research creates and develops a vibration measuring tool that makes use of an accelerometer sensor and a smartphone as a display because of this. Vibration data from the sensor can be transmitted via the Internet of Things, passed through a microcontroller, and then received on a smartphone. This measurement device has the benefits of being simple to use, widely available, and inexpensive. The Four-D (4-D) model is utilized in the Research and Development (R&D) technique. Define, design, develop, and desiminate make up the 4-D approach. A tool that can detect in three dimensions from the x, y, and z axes is the outcome of this research. This tool's design incorporates a smartphone as the display, an ADXL345 accelerometer as a sensor, and a NodeMCU ESP32 microcontroller as a microcontroller. The average accuracy and precision of this tool are 100% and 92%, respectively. It is anticipated that the creation of this measuring tool would expand the accessibility of more effective vibration measurement tools that can be applied in a variety of contexts.

Keywords : Vibration, ADXL 345, Smartphone, Internet of Things

I. INTRODUCTION

In today's rapidly advancing technology age, smartphones have become an integral part of our daily lives. These devices offer a variety of functions beyond just communication, including the ability to act as versatile sensors. One such sensor is the accelerometer, which measures the acceleration acting on your smartphone. Using this technology, researchers and engineers have developed innovative applications in various fields, including vibration measurement. Vibration measurement is important in a variety of applications, including building structure monitoring, machine analysis, and vehicle shock measurement. Conventional vibration measuring devices available today are generally expensive, complicated, and not always easily accessible to everyone. The development of sensor technology has opened new opportunities to develop tools for measuring vibration. in general, vibration can be measured with accelerometer sensors that are sensitive and capable of measuring acceleration on three different axes (X, Y, and Z) [1].

Accelerometers have the potential to be practical and inexpensive vibration measurement tools, but there are some challenges that need to be overcome. One is to processes accelerometer data accurately and efficiently to provide useful information about vibration in three dimensions. In addition, a user-friendly interface and clear visual representation are required so that users can easily understand the measurement results. In this context, his 3D vibrometer design using smartphone display-based accelerometers are relevant. This tool aims to provide a practical, portable, cost-effective solution for measuring and analyzing 3D vibration by leveraging the potential of smartphones. During development, we need to research and develop data processing methods and an intuitive interface to ensure the accuracy and ease of use of this meter[2][3].

The instrument can provide benefits to professionals, engineers, and other users who require a practical and easy-to-use vibration measurement tool without requiring additional investment in specialized devices. In

Rolando's research, ADXL345 accelerometers were used as part of a vibration-based system to monitor the structural health of bridges. The ADXL345 accelerometer is his MEMS (Micro-Electro-Mechanical Systems) based 3-axis sensor that can measure his 3-axis acceleration X, Y and Z simultaneously. Due to its high sensitivity and small size, it is suitable for vibration monitoring of structures such as bridges. In this study, ADXL345 accelerometers are placed at strategic points on the bridge to measure the vibrations produced. This sensor produces an analog signal, which is then converted into a digital signal for further processing[4].

In Amra's research, the main purpose of creating a vibrometer using an ATmega16 microcontroller-based accelerometer and a PC display is to measure and monitor the vibration level of an object or system. The accelerometer produces an analog signal, which is passed to his ATmega16 microcontroller. Using his ATmega16 microcontroller-based accelerometer with a PC display to manufacture a vibration meter combines sensor and microcontroller technology to create a tool that can accurately measure and monitor vibrations. Integration with computers and his PC displays allows the use, analysis and monitoring of data in a wider range of applications[5]. The microcontroller acts as the "brain" of the fall detection system, collecting data from the accelerometer and sending it to the IoT platform. With the accelerometer, data from the accelerometer is sent to his NodeMCU microcontroller for further processing[6]. IoT (Internet of Things) is a concept that aims to expand the benefits of continuously connected internet connectivity. Using IoT allows earthquake vibrations to be monitored remotely[7]. The Internet of Things is also a concept where certain objects have the ability to transfer data over a network[8]. IoT (Internet of Things) is used because it is more effective and more flexible[9]. NodeMCU is a development of the ESP8266 with e-Lua-based firmware. The NodeMCU is equipped with a microUSB port that functions for programming and as a power supply to power the NodeMCU[10]. The ESP32 is an inexpensive microcontroller to use[11]. The ADXL345 accelerometer is a sensor used to measure the acceleration of an object. An accelerometer can measure dynamic acceleration and static acceleration. Measurement of dynamic acceleration is a measurement of the acceleration of a moving object, while the acceleration of a static measurement is a measurement of the earth's gravity[12]. Firebase is a back-end cloud service provider based in San Francisco, California. Firebase makes a number of products for mobile or web application development. One of the features of Firebase is that Real time database is used as an implementation related to instruments that are made so that all devices can be viewed remotely[13], [14].

As described above, researches on acceleration sensors as vibration measuring devices have been actively conducted in various fields. However, there are still not many implementations that display data measured by sensors on smartphones. The implementation of the standard remains conventional in its measurement. Legacy measurements are only available for certain circles, not others.

This tool is designed to use NodeMCU ESP 32 and smartphone as a data display. This tool uses internet technology to take digital measurements. By using the Internet for measurement, all groups can carry out the measurement results. As a result of the design, the price of the gauge, which is more expensive than traditional gauges, can be minimized. The Sensor accelerometer ADXL345 allows you to perform measurements in three dimensions (x, y, z)[15]. This tool is designed with the aim of detecting vibrations, utilizing the Internet of Things and can be implemented in various fields.

II. METHOD

The research model carried out belongs to research and development research (R&D), uses a 4-D methodology (4-D model) and consists of four phases. According to Thiagajaran, he has four stages of definition, design, development and dissemination. It is necessary to test the effectiveness of the resulting product. Research and development (R&D) methods can be interpreted as the scientific method of researching, designing, manufacturing, and confirming the effectiveness of manufactured products[16].

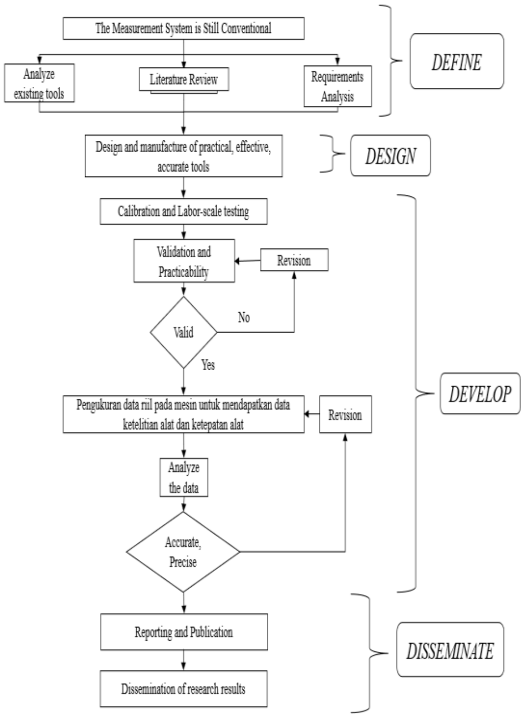

Fig 1. Flowchart research

The defining stage is the stage for establishing and defining the requirements that must be met by the tool, namely by analyzing conventional tools, one of the current conventional tools is the measuring instrument used by the Meteorological, Climatological, and Geophysical Agency. The following points should be considered when determining the need for these tools. However, these devices are expensive, and the unknown factory construction of the components of the system makes them difficult to repair in the event of failure.

Fig 2. Accelerograph

The design stage is carried out to design the instrument following the results of the goal spesifications at the defined stage. This stage consists of system design, hardware, and software design. An overview of the hardware and its parts can be seen in Figure 2. This system is designed to read data from sensors that will be processed by the microcontrolller to be displayed using a smartphone. The microcontroller used in this tool is NodeMCU ESP32 which is programmed using the Arduino IDE programming language and will be displayed on a smartphone using app inventor application.

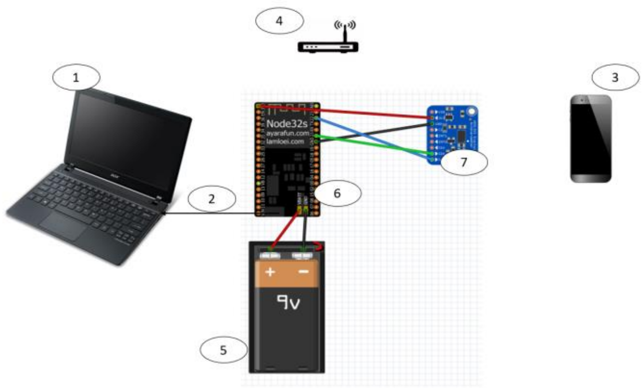

Fig 3. Hardware design

Figure 3. describe the parts of the system hardware consisting of (1) Personal computer as output display for vibration (2) Micro USB as a connector for microcontroller (3) Smartphone as a output display for the value from the sensor (4) Wifi portable as a media for sending data from app inventor from the microcontroller (5) battery as a power supply for the instrument if needed (6) NodeMCU ESP32 as a microcontroller (7) Accelerometer ADXL345 as a vibration sensor. Then, the development stage aims to produce a product for developing the instrument based on the design and performance following the specification objectives.

III. RESULTS AND DISCUSSION

The research and development results using a Four-D development model are obtained after completing the definition and design stages. The data generated in this study include the results of making instrument to determine design specifications based on the design stage and testing tools to see the device's performance specifications. Measurement result data is displayed in the form and graphs. The results of the system design can be seen in Figure 3.

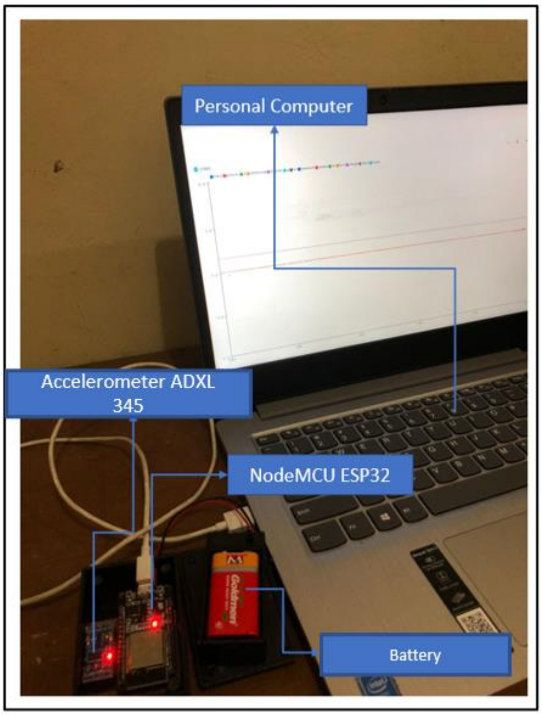

Fig 4. Physical form of the tool

The series of making measuring instruments are equipped with a battery and a Micro USB as a series of power supplies for the tool. Batteries are used because the microcontroller is very sensitive, so if the current flowing to the microcontroller is unstable, the microcontroller will not function properly. This measuring tool has advantages and disadvantages. The advantage of this measuring instrument is that it can be used as a vibration measurement tool other than earthquakes. With the use of batteries as a power supply, this tool can work portable. When this tool is used as a portable, readings can be seen on Android smartphones. The disadvantage of this tool is that when reading vibration data using a Personal Computer, the input voltage only uses a Personal Computer (PC) using a Micro USB cable, so that vibration data in the form of graphics can be viewed via the Serial Plotter in the Arduino IDE software.

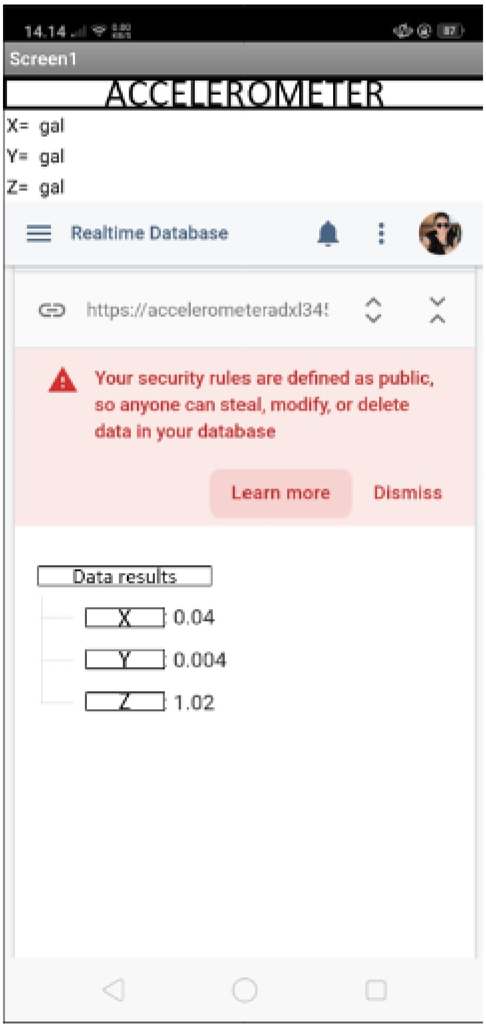

Fig 5. Interface data

The interface data display is shown in Figure 5. The display shows the axis x, axis y, and axis z. The data always change every 0.2 second. In shown that the data in realtime position. The interface data is built named app inventor that connect to firebase realtime database. Other result were obtained from the testing process. The test was conducted to determine the instrument's performance is detecting vibration. Instrument testing is carried out to determine the accuracy, precision, and measurement error of the sensor.

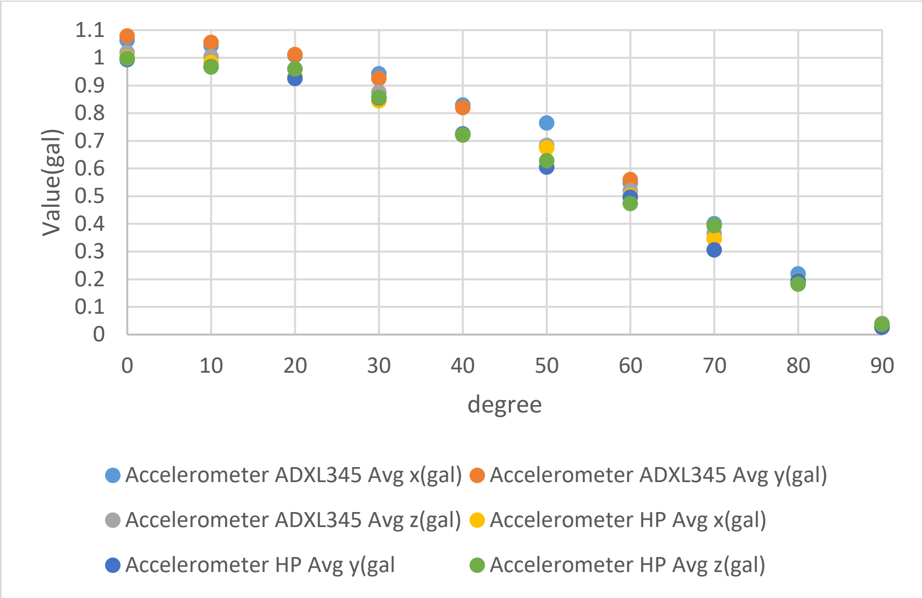

Fig 6. The graphic of sensor accuracy testing

It can be seen in Figure 6. The greater the value of the angle, the value of the acceleration to the slope of the curve will be smaller, that the comparison of the measurement results of the two instrumenst shows the same value. From the test, the average accuracy is 92%, with a measurement error of 8%. An error occure without on purpose, due to an error in the readings of the tool, aligning the positions of the two instruments.

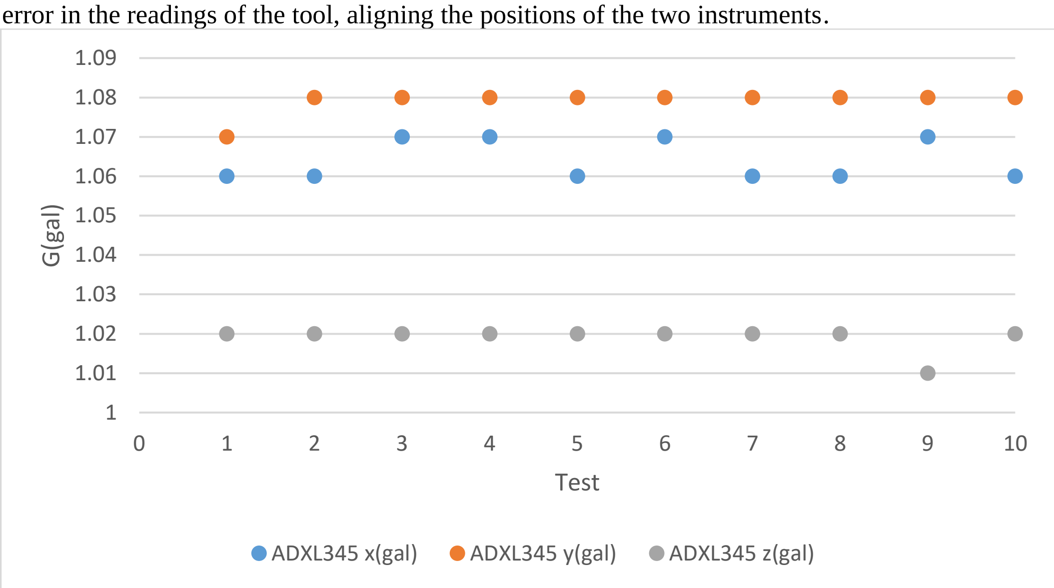

Fig 7. The precision ADXL345 at 0 degree

It can be seen in Figure7 that the precision accelerometer ADXL345 at 0 degree are very closely every point that had been record. The results of repeated measurement on ADXL345 so that precision data is obtained. From these measurements, it was found that the results of repeated measurements of the ADXL345 obtained almost same value. The precision value of the ADXL345 sensor is relatively high, as seen from the average precision percentage of 100% every each of axis. These data indicate that the ADXL345 sensor is quite apporiate to use. In this study, a motor is used to obtain a vibration value that will be detected by a vibration device by taking indirect measurements [17]. The purpose of the vibration of the motor is that the value has a value that varies according to the voltage changes that occur in the motor, and also the value of the resulting vibration can be seen clearly on the graph. Vibration display results can be seen in Figure 7.

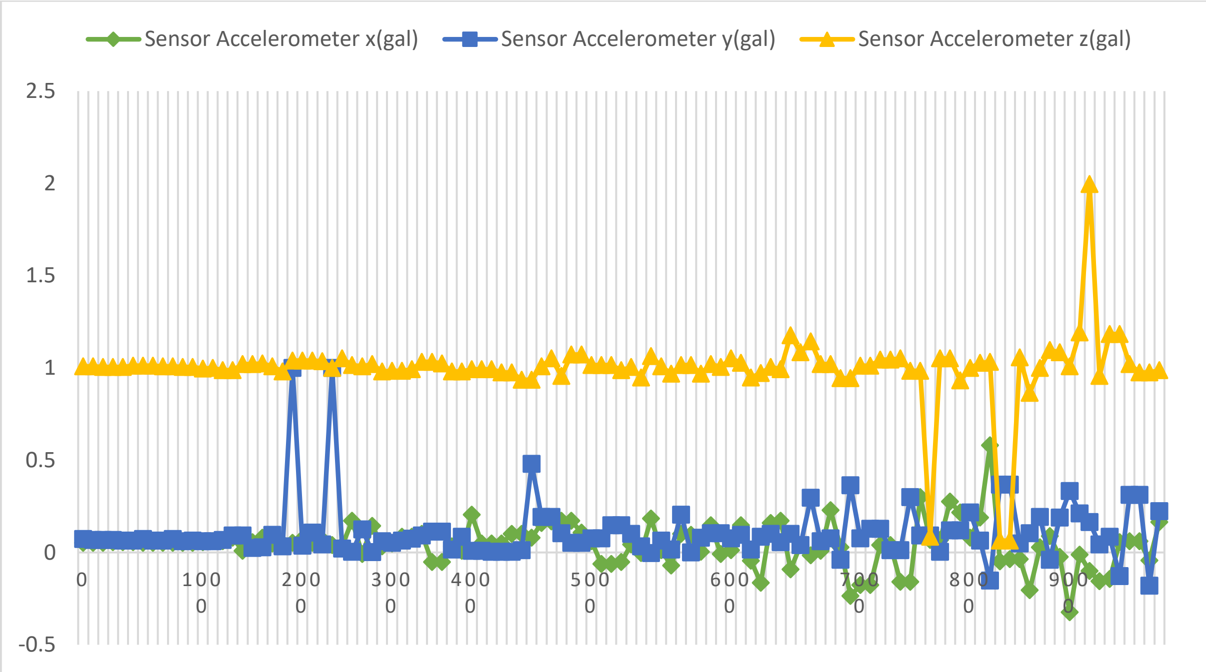

Fig 8. Measurements graph

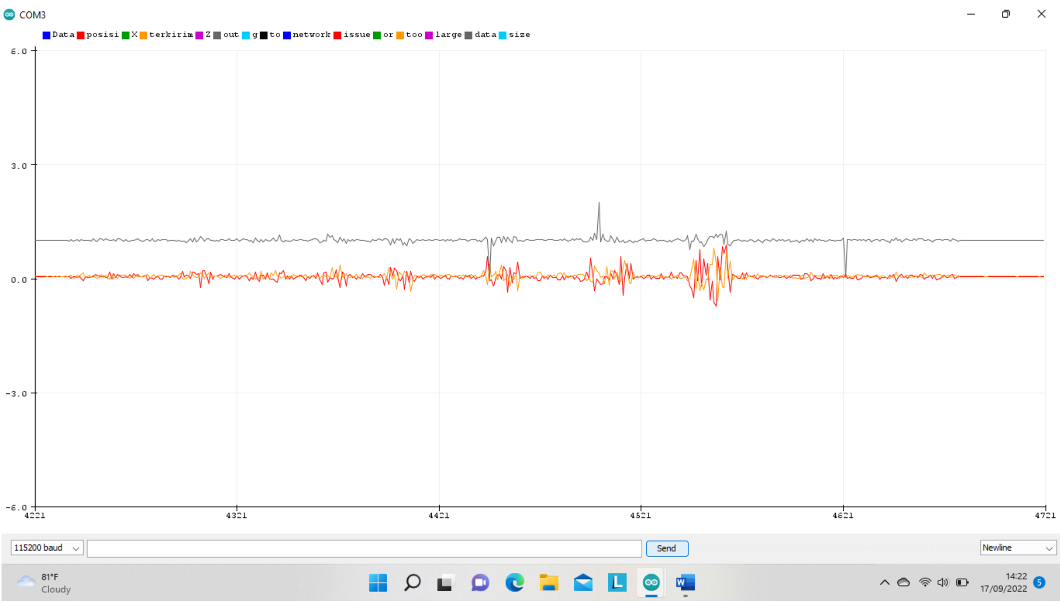

Fig 9. Serial Plotter graph

In this research, the data collection includes direct and indirect research. Measuring the slope between angles is a direct study, and indirect research is conducting a simulation of engine vibration. In interpretation, in order to realize the vibration results according to earthquake vibrations, in Figure 8 and 9, it can be seen the value of motor vibration variations by varying the motor rpm starting from 1000rpm, 2000rpm, 3000rpm, 4000rpm, 5000rpm, 6000rpm, 7000rpm, 8000rpm, 9000rpm so that the tool that has been designed can detect vibration and generate graph data. The slope measurement aims to find the value of precision and accuracy on the vibration-measuring instrument. The test scheme for engine vibration is aimed at getting the acceleration value.

To support some of the measurement data above, the author adds several sources regarding existing theories, measuring the slope aims to find the value of precision and accuracy in vibration measuring instruments[18]. The testing scheme for engine vibration is intended to obtain acceleration values. From testing the ADXL345 accelerometer sensor can detect vibrations in three dimensions, the vibration is in the form of acceleration[19]. Accelerometer sensors can be applied to accelerate vehicles, monitor structures and buildings, and can be used to detect earthquake vibrations[20].

From testing, the ADXL345 accelerometer sensor can detect vibrations in three dimensions. The vibration is in the form of acceleration. Mechanically, the ADXL345 sensor can detect vibrations generated by the motor. The resulting vibration is in the form of acceleration units, where acceleration is G (gal). The acceleration obtained refers to a vibration. Based on Figure 8, the vibration data obtained is comparable to Figure 7. Figure 8 shows that the greater the rpm value on the motor, the greater the vibration value obtained by the ADXL345 sensor.

IV. CONCLUSION

Based on development Three Axis Vibration Measuring Instrument Using A Smartphone Display-Based Accelerometer Sensor, it can be concluded that the Accelerometer ADXL345 sensor design specifications work at voltage of 3.3V-5V. the power supply is used an battery and also output micro USB from the PC. The accelerometer is connected to NodeMCU ESP32, which can connect to the internet via WiFi and then send the data to the firebase server. The server displays the data, which can be accessed in real-time. The results of the performance specifications of the Vibration Instrument include accuracy and precision data from sensors. The results if testing accuracy and precision of the Accelerometer ADXL345, the average accuracy percentage is 92%, and the average percentage of precision is 100%. Based on the data obtained from the test that have been carried out, it can be said that ADXL345 is accurate and precise to use. ADXL345 accelerometer sensor experiment to measure vibration in three dimensions is theoretically appropriate, this can be seen from the vibration movement pattern data and the tool developed in terms of performance and design and can measure vibration in three dimensions.

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