The characterization of giant magnetoresistance sensor for prototype of bridge deflection measurement

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Abstract. The Shift is the displacement of the object's position from its initial state to its final state. Shifting phenomena can be found in landslides, cracks in building construction, or bridges. One of the sensors used to detect deflection is the GMR sensor. The GMR sensor is a sensor that can detect changes in magnetic fields. The configuration of permanent magnets and GMR sensors can be used to detect micro-order shifts. This research was conducted in several stages, namely making a bridge model, making a sensor circuit, signal conditioning circuit and testing characteristics. The research method is to place a permanent magnet on the static and GMR sensors on the part that is easily shifted on the bridge. The test results show that the GMR sensor can detect shifts in the 10micro order and the sensitivity of the GMR sensor can be obtained at 0.0131 Volt / mm. The voltage response of the GMR sensor to shift distance is exponential. The maximum shift test is obtained at half the bridge span. This research can be used for monitoring bridge shifts.

1. Introduction

The bridge is an important part of infrastructure facilities. Bridges can increase economic distribution activities between regions. Archipelagic countries desperately need bridges to improve transportation. Indonesia is an archipelagic country so that inter-island transportation must be within the reach of using the best technology so that transportation security and safety are controlled. The bridge is one means of transportation between islands. The construction of bridge must suitable the standards set by the Bridge Management System [1]. One standardization requirement for bridge construction is bridge resistance in holding vehicle loads across or human loads and strain conditions experienced by bridges.

Some cases of damage that often occur on the bridge is the shifting of the pile, the occurrence of cracks in the bridge floor, even the worst condition is the collapse of the bridge. The case of damage occurs because the monitoring of bridge service conditions cannot know the initial damage arising on a small scale or micro. Bridge security in resisting vehicle loads passes or human load is experienced directly by the bridge floor, so monitoring on the bridge floor is needed specifically for maintenance of bridge service.

The use of technology in monitoring bridge service conditions has been carried out using the concept of weight In Motion with the principle that it detects a vehicle's weight moving at a certain speed on the road by measuring the vehicle's wheel load while running. sensor technology that has been used in the WIM method is piezoelectric, capacitive mats, and hydraulic and system load cells. However, these
sensors have weaknesses such as being easily exposed to corrosion, easily exposed to electromagnetic interference, and have low accuracy.

Technologies such as fiber optic sensors that have high sensitivity have been carried out to monitor the bridge service conditions. In the process of monitoring bridge service or being able to support load weight measurement systems running but still showing errors in the range 28.3%.

The monitoring process can be carried out using the concept of shift. The result of displacement detection which is in the smallest order can be assumed as a disturbance that occurs in bridge construction so that monitoring can be carried out. Some sensors used to detect shifts are Hall effect sensors, LVDT, capacitive sensors, GMR sensors. In this study using GMR sensors to detect very small shifts. The GMR sensor is a type of magnetic sensor made of magnetoresistive material. The Giant effect of magnetoresistance itself was first reported by Baibich et al. in 1988 in measurement using Fe/Cr magnetic superlattice [2]. Giant magnetoresistance has advantages over other magnetic sensors. Some GMR sensor applications include porphyrin detection [3], measuring electrical power [4], measuring hemoglobin [5], real time monitoring of cell phagocytosis during the separation process [6], tumor detection with GMR biosensor microarray [7], measures the number of biomarkers through the magnetic nanoparticles bound to the sensor GMR-SV [8], measures the pulse of blood flow [9]. The GMR sensor can detect changes in magnetic fields that are very small because they have high sensitivity. Based on this information, the GMR sensor and permanent magnet are used to detect bridge deflection.

2. Methods
This research was made in several stages, namely making a bridge model, making a sensor circuit, signal conditioning circuit and testing characteristics. Construction The bridge model is shown as Figure 1. This bridge model consists of supports located at both ends of the bridge. When the bridge supports the load, the bridge is deflected. Based on a reference from Bridge Management System 1992, (Pratama, et al. 2013) bridge deflection tolerance can be calculated using equation (1):

$$\Delta x = \frac{L}{400} \geq \Delta'$$

With the span length L used, $\Delta x$ is the allowable deflection limit and $\Delta'$ is the deflection.

Furthermore, the bridge deflection using the GMR sensor contained in the measuring system. This measuring system consists of transducer, GMR sensor, wheat stone circuit and voltmeter. Moving loads cause bridge deflation. Deflection of the bridge is connected with a transducer consisting of a permanent magnet and station for the sensor.
Deflection of the bridge causes the movement of permanent magnets and changes in the position of the permanent magnet causing changes in the magnetic field. Furthermore, changes in the magnetic field are sensed by the GMR sensor. The GMR sensor is integrated with the Wheatstone circuit as a signal conditioner as shown in Figure 3. Voltmeter measures the output signal of Wheatstone circuit.

![Diagram](image)

**Figure 3.** Block GMR Sensor with Wheatstone Bridge Circuit Diagram [9].

Figure 3 shows the GM00 type AA002 sensor integrated in a wheat stone bridge circuit. Pin 1 and pin 5 as the output of the bridge connected to the voltmeter. Pin 4 is connected to ground and pin 8 is connected to a voltage source + 5 Volt.

### 3. Results and Discussion

Testing the characteristics of the GMR sensor versus deflection due to running load is carried out in three ways. The three tests are measuring the voltage of the GMR sensor against the load running when the GMR sensor is placed in a quarter, a half and three-quarters of the length of the bridge. The distance and direction of the running load are determined from the reference point of pivot A.

#### 3.1. GMR Sensor Test Results in quarter-bridge position (8cm from Pivot A)

Figure 4 shows the test results with the load running 9.8N at the time of the GMR sensor position at a quarter of the bridge length (8 cm from the point of Pivot A). The results show when the load position is at 0 cm there is a deflection of 2.24 mm. Then the biggest deflection occurs when the load is in the position of 5 - 11 cm by 4.1 mm. The condition starts to change again when the load is 12 cm with the deflection size reduced to 3.73 mm. The sensor responds to deflection changes in all positions; even in the 36 cm position the change in deflection is still detected at 0.38 mm. The maximum GMR sensor response is 2.66 Volt when the distance is at 8 cm. At the load position in the 0 cm the GMR sensor voltage response is 2.638 Volt.

![Graph](image)

**Figure 4.** Graph of Output Voltage of GMR Sensors versus Distance (Position of GMR sensor at a quarter of the length of the bridge).
3.2. **GMR Sensor Test Results in half-bridge position (18cm from Pivot A)**
The result shown in Figure 5 is the relationship of the output voltage response of the GMR sensor to the load running when the sensor is placed in the middle of the bridge length (18cm from the pivot A). At the fulcrum A shows that direct deflection occurs when the 0cm position is 2.24mm. Then the biggest deflection occurs when the load is at position 11-17cm by 7.09mm and the GMR sensor voltage response is 2.705V. The sensor responds to deflection changes in all positions, even in the 36cm position the change in deflection is still detected at 0.38mm. Walking load causes the load arm to change from A pivot to B pivot, so the moment of force also changes relative to point A and Pivot B.

![Figure 5](image)

**Figure 5.** Graph of Output Voltage of GMR Sensors versus Distance (Sensor position at half the bridge).

3.3. **GMR Sensor Test Results in the position of three bridge lengths (28cm from Pivot A)**
The results shown in the graph of the response of the GMR sensor output voltage response to the load position which has an outer diameter of 10cm and a value of 9.800N when the sensor conditions are placed 28cm from the fulcrum A shows direct deflection when the load position is 0cm by 0.38mm. Then the most deflection occurs when the load is in the position of 13-25cm at 2.24mm. The condition begins to change again when the load is in the 26cm position with the deflection size reduced to 1.87mm. Then when the load is at 33cm, the sensor no longer receives a deflection response. This shows that the position of 0 – 32cm is the span of the bridge that can be detected by the sensor at position 28cm from the fulcrum A when the bridge is passed a load of 9,800 N.

![Figure 6](image)

**Figure 6.** GMR Sensor Output Voltage Chart versus Distance (Sensor position in three quarters of a bridge).

Then this deflection also occurs as a result of working the force moment at the fulcrum A. If the value of the load arm approaches the sensor position, the deflection will be even greater. The added value of the load arm results in an increase in the force moment and results in greater deflection, but
when the load arm has exceeded the sensor position, the statement of the value of the arm increases the
greater the deflection does not apply. This is because the sensor response when the load passes through
its position will decrease because deflection occurs in areas that are no longer the range of the sensor
response range.

Of the three variations in the position of the sensor used, the most suitable variation used must have
the broadest characteristic sensor response range as small as any given load and must have a coefficient
determination Adj. R² is best approached 1. determination of LCD measurements of 49, 32%. The
position of the 18cm sensor location has a response range of 85.39%. Whereas the position of the 28cm
sensor has a wide range of sensor response from 8 - 30cm with a coefficient of determination of LCD
measurement of 75.47%. So that it can be concluded that the suitable variation is used to find out the
deflection in the bridge using the GMR sensor is the variation of the position of the sensor located at
18cm because it has the closest coefficient of determination of 1 at 85.39% rather than the result of the
coefficient position determination coefficient.

3.4. Result of Sensitivity Test of GMR Sensor versus Deflection

Testing the sensitivity of the GMR sensor to deflection is carried out using the position of the GMR
sensor in the middle. Figure 7 shows the relationship of the GMR sensor output voltage to deflection.

Based on Figure 7, the equation \( y = 0.0131x + 2.5732 \) is obtained so that the sensitivity of the GMR
sensor can be obtained at 0.0131 Volt/mm.

![Figure 7. Output Voltage of GMR Sensor versus Deflection.](image)

4. Conclusion

The characterization of GMR Sensor for Bridge deflection measurement show that the GMR sensor can
detect shifts in the 10micro order and the sensitivity of the GMR sensor can be obtained at 0.0131
Volt/mm. The voltage response of the GMR sensor to shift distance is exponential. The maximum shift
test is obtained at half the bridge span.

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