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Early Detection of Overheating in Motorcycle Disc Brakes Based on Arduino

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Abstract— The braking system is very important on a motorcycle. The primary function of the braking system is to slow down and even stop the motorcycle. The braking system using disc brakes on motorcycles is commonly used today, especially on automatic transmission motorcycles. One of the disadvantages of disc brakes is the heat caused by the disc's friction with the brake pads if you apply continuous braking. This continuous braking is often done by a motor rider when crossing downhill roads in mountainous areas. Excessive heat in the disc brakes causes the brake fluid to boil, resulting in air bubbles resulting in braking failure. The failure of the braking system on a motorcycle is hazardous for the rider and others. The experimental method detects braking system failure by catching the disc brake's temperature with a touchless temperature sensor, MLX90614. Temperature detection is processed with Arduino as a control, and the temperature is displayed on the LCD. If the disc brake temperature is above 200ºC, a buzzer is activated as a warning to the driver. The test results show that the system can display a temperature reading on the LCD lower than the thermometer gun, with the most inferior reading difference of 0.2ºC and the highest 0.4ºC. The system can also display notifications to users on disc brake temperatures above 200ºC, namely at temperatures of 211.1ºC, 224.3ºC, and 237.5ºC, which were achieved at 200, 225, and 250 seconds.

Keywords: Early Detection, Disc Brake, MLX90614, Temperature Sensor, Arduino.

I. INTRODUCTION

The rapid development of the automotive industry and intense competition among automotive manufacturers have made automotive manufacturers competing to produce faster than before. Therefore, we need a better braking system too. The braking system is a virtual device in a vehicle, especially a motorcycle. The primary function of the braking system is to slow down the vehicle and even stop it. The speed of the vehicle can be appropriately controlled. The principle of the braking system is to convert kinetic energy into heat energy [1]. Heat energy in disc brakes is generated by the friction between the metal disc and the brake pads when it comes into contact during braking.

The brake system with disc brakes is widely used on motorcycles that use automatic transmissions. This type of motorcycle relies entirely on disc brakes to control the speed of the motorcycle. Automatic motorbikes are motorbikes that are in great demand by most people in Indonesia because of their practicality. Automatic motorbikes have been chosen because many riders find them easier and more comfortable to operate.

One of the causes of the many accidents on this automatic transmission motorcycle is the braking system's malfunction. Braking failure often occurs in mountainous locations where there are many downhill roads. When braking is done, friction between the iron disc and the brake pads, causing heat. Also, the lack of knowledge of motorcyclists in continuously braking disc brakes may result in brake failure. Because in automatic transmission motorbikes, there is no engine brake plus the burden on the vehicle and the rider that must be borne by the disc brakes, over a long period, there will be overheating of the disc brakes. Overheating the disc brakes will result in 1) The caliper's seal expands, and the caliper piston jams. 2) The disc brake disc that is too hot will expand and make the surface slippery so that the brake pads cannot grip the disc surface [2]. The disc brake condition that is too hot and constantly rubbing against the brake lining will transfer heat to the brake fluid through the piston, causing the brake fluid to boil and air bubbles form, causing false air and causing the disc brake to malfunction [3]. This braking system's failure is hazardous and can have fatal consequences for the rider and others. Peneliti melakukan kajian berdasarkan

Arduino is known as a micro controlling device that is well known by many hardware developers. Arduino's open-source nature that can be modified easily, supported by a large library of programs, integrated modules, and a relatively low price, has now become a favorite in making various electronics and robotics projects. At this time Arduino is widely used as a control device in various fields including robotics [4]-[9], agriculture [10]-[13], and the automotive sector [14]-[17]. The researcher also conducted a study to support the results of the discussion of this paper [18]19].

Based on the foregoing is necessary to make modifications to the motorcycle disc brake braking system by adding an overheat detection device using Arduino. The function to provide early warning in the form of a buzzer sound to motorcyclists before the braking system failure occurs, which can be fatal to the rider and other people.

II. RESEARCH METHODOLOGY

This study was designed using an experimental research model through the following stages:

- Problem Identification is carried out by conducting a literature study to determine the core of this research.

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- Model design is critical in realizing the real system. The purpose of designing the model is to plan the design of hardware and software.
- Model testing of the model that has been designed will be carried out. The purpose of this test is to ascertain whether the model that has been designed is following what is desired and to anticipate any errors that may occur in its implementation.
- Conclusions are drawn based on the analysis or interpretation of the data from the model testing that has been done.

Software design is the definition of functional requirements and preparation for the design of a system. System design can be defined as depicting, planning, and sketching or arranging several separate elements into a complete and functional unit, including system block diagrams, system flowcharts, user interface design, and database design.

A microcontroller-based system cannot operate based only on the design of hardware components but also requires a sequence of instructions known as a program. Designing software based on a microcontroller system must be following the working principles of the system being built. Flowcharts are generally used to describe the sequence of detailed instructions and the relationship between one instruction and another. The overheating detection workflow diagram for motorcycle disc brakes shown in Figure 1.

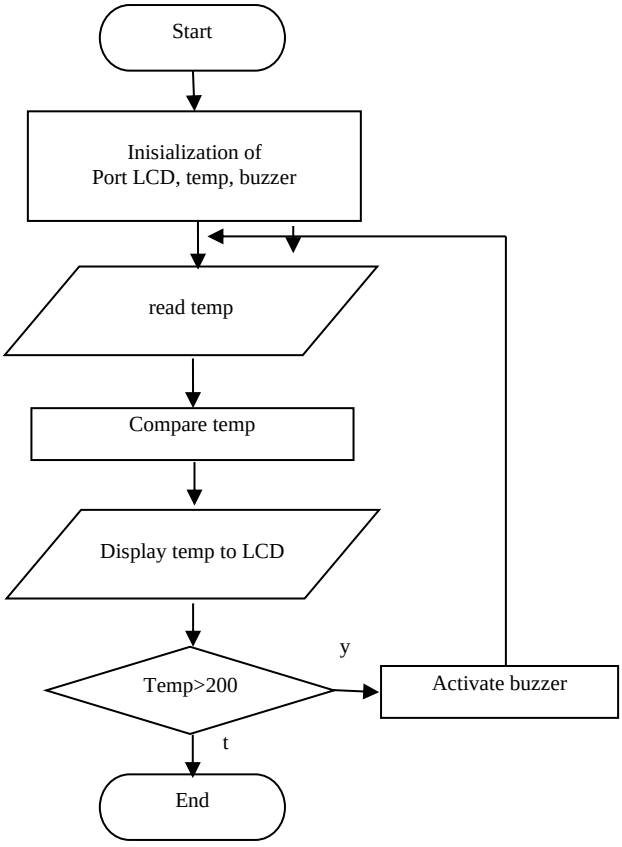

Figure 1. Workflow diagram

After the hardware and software design stages are complete, it is continued with the implementation stage. This implementation stage is the stage of translating the results of designing hardware and software. Next, the testing phase is carried out, which aims to determine the performance of the system being built.

A. Disk Brake Components

Disc brake systems are more widely used than drum brakes. This is because disc brakes have many advantages compared to drum brakes. Disc brakes are used on the front wheels only or both wheels. The disc brake components are slightly different from the drum brake components, but they still have the same function: to slow down or stop the motorbike. The disc brake braking system consists of several components: reservoir tank, brake lever, brake pump, brake hose, brake caliper, piston, piston seal, brake pads, and discs, as shown in Figure. 2.

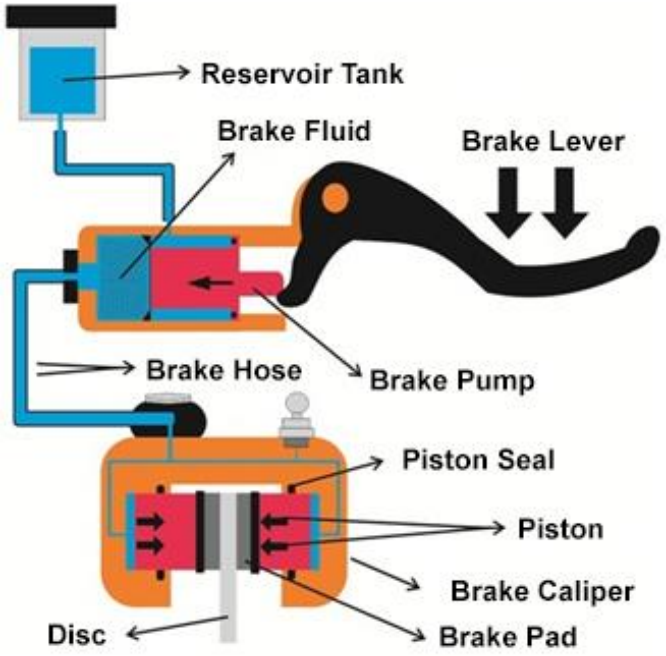

Figure 2. The components of a disc brake on a motorcycle.

The working principle of disc brakes is that when the brake lever is pressed, the pump will press the brake fluid in the reservoir tank so that pressure is passed through the brake hose to the brake caliper. Inside the brake caliper, there is a piston where there is caliper pressure. This piston will move outwards, pushing the brake pads and friction between the brake pads and the disc, thereby reducing the vehicle speed.

This research measures the heat temperature at the source of the heat, namely the disc. Kinetic energy is converted into heat energy when the disc rubs against the brake lining. If you apply continuous braking, the disc will become very hot even until the disc burns, as shown in Figure 3. This overheating condition can cause several problems,

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which are considered the cause of the disc brake malfunction described above.

Some automatic transmission motorcycles adopt disc brakes only on the front wheels, while the rear wheels adopt drum brakes. The disc brake at the front wheel position can be seen as in Figure 4. In comparison, other brands adopt disc brakes on both wheels. The position of the rear disc brake can be seen in Figure 5.

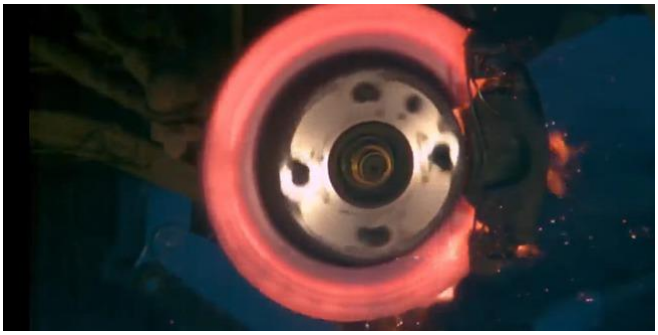

Figure 3. The disc's burning condition.

Figure 4. Disc brake in front-wheel position.

Figure 5. Disc brake in rear wheel position.

In operation, disc brakes require brake fluid to provide hydraulic pressure to the brake calipers so that they can push the piston. When the piston is pushed out, the brake pads are automatically pushed towards the disc, causing friction. The brake fluid used in this study is the DOT-3 type, as shown in Figure 6.

This type of brake fluid was chosen because it is the type of brake fluid most commonly used by motorcyclists. This brake fluid has a dry boiling point of 205^{o} Celsius, the lowest among other brake fluid types such as DOT-4 and DOT-5 [20].

Figure 6. DOT-3 brake fluid.

B. Sensor Module MLX90614

Overheating detection of disc brakes requires a heat-sensing sensor. Due to the disc condition that is always rotating or in a situation that is still in motion, a heat sensor is needed, requiring direct contact with the heat source. The sensor used must be a sensor that can read the heat range below or above the DOT-3 brake fluid's boiling point. Based on this, a sensor that suits the conditions mentioned above is selected, namely the MLX90614 sensor.

The MLX90614 sensor is a non-contact infrared temperature sensor with high accuracy. This sensor operates in a voltage range of 3.6 - 5 Volts DC. The measured object's temperature ranges from -70^{o} C to 382.2^{o} C with an accuracy level of 0.02^{o}C. Measuring distance from the object 2 - 5 cm according to the page [21]. This sensor is often used in the industrial world to measure moving objects such as rotating shafts in electric motors. Due to its high accuracy and precision, this sensor can also be used in various commercial applications.

Figure 7. MLX90614 temperature sensor.

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Several studies that measure the accuracy of the MLX90614 sensor based on a distance from 1 - 5 cm have reported that the measured value on the sensor is smaller than the mercury thermometer with a range of 4.4^{o} C at 1 cm and 8.64^{o} C at a distance of 5 cm when the object temperature indicates 50^{o}C according to the mercury thermometer [22]. As an illustration of the MLX90614 non-contact temperature sensor, as in Figure 7.

C. Arduino Uno

The Arduino Uno, which is used as a controller in this study, operates at a voltage of 5 volts DC, the recommended input voltage is 7-12 volts DC, but the input voltage limit that can be tolerated is between 6-20 volts DC, the Atmega328P microcontroller, 14 digital I/O pins available, six pins PWM, 6 pins Analog input, with each pin having a current of 20mA. The Arduino Uno has a clock speed of 16MHz and has 32 KB of flash memory, 2 KB of SRAM, and 1 KB of EEPROM. This Arduino Uno was chosen because the motorbike has a working voltage of 12 - 13.6 volts DC, so it is still compatible when used as an Arduino Uno input voltage. As an illustration of the Arduino Uno controller board, it can be seen in Figure 8.

Figure 8. Arduino Uno controller board.

D. LCD 16x2 Module

A data display module is needed to display research data from the Arduino controller board independently, namely a 16x2 LCD (Liquid Crystal Display). This module uses liquid crystal material to display data in the form of numbers, letters, and images. This module is easy to find in everyday life, for example, on game bots, calculators, and even television. This 16x2 LCD consists of 16 columns and two rows, is equipped with backlight lamps, has 192 characters, can be addressed with 4 bits or 8 bits, and a programmed character generator. An illustration of this 16x2 LCD can be seen in Figure 9.

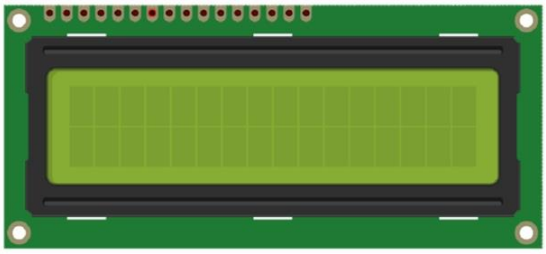

Figure 9. LCD 16x2 module.

The 16x2 LCD module is the most comfortable medium for observing the display of control results from the Arduino board because it produces many good character displays. The 16x2 LCD can output 32 characters at a time consisting of 16 characters in the first and second lines.

E. I2C (Inter-Integrated Circuit) Module

In general, this 16x2 LCD has 16 control pins for operation. This is, of course, very wasteful using Arduino pins. Therefore it is necessary to add a special module to control this 16x2 LCD so that it can be controlled via the I2C (Inter-Integrated Circuit) line using this I2C module. The 16x2 LCD can be controlled via just two pins, namely SDA (Serial Data) and SCL (Serial Clock), to save Arduino pins' use. This I2C module is a two-way serial communication standard specifically designed to use two separate channels to send and receive data. The I2C system carries information from the I2C to the controller via SDA and SCL channels. The device connected to this I2C module can be operated as a master or slave. It is called the master because it initiates a data transfer on the I2C bus by forming a start signal and ending data transfer by forming a stop signal and generating a clock signal. Meanwhile, it is called a slave because the device is the device the master is pointing at. An illustration of the I2C module can be seen in Figure 10.

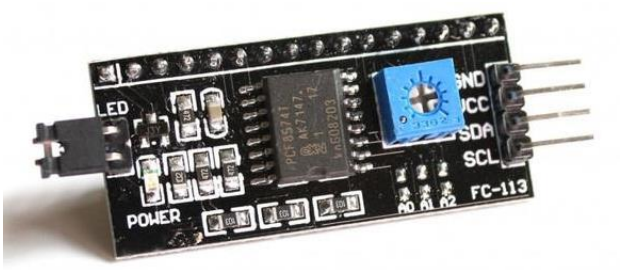

Figure 10. I2C LCD *interface.*

F. Buzzer

The buzzer is a component that can emit sound vibrations in the form of sound waves that can be heard by humans. The basic principle of the buzzer is to convert electrical signals into sound vibrations. In the direction, it resembles a loudspeaker but has a more straightforward function. Buzzer used in everyday life is generally used as an alarm. There are two types of the buzzer, namely an active buzzer -- a buzzer with its sound, and a passive buzzer that does not have its sound, so an oscillator circuit is needed to generate the buzzer sound waves.

Figure 11. Active buzzer.

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In this research, the buzzer used is an active-buzzer. This active buzzer is sufficient to be fed with a voltage of 5 volts DC to emit sound waves. An illustration of this active buzzer can be seen in Figure 11.

III. Result and Discussion

This research starts with hardware design followed by software design. The hardware design of overheating detection of motorbike disc brakes can be seen in Figure 12.

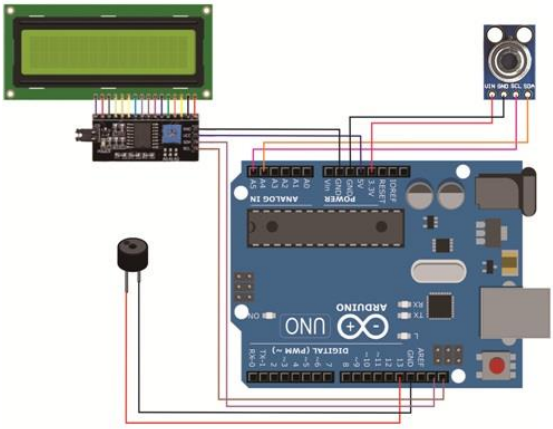

Figure 12. Hardware design.

The system detects heat from the disc via the MLX90614 non-contact temperature sensor. Data from the temperature sensor is sent to Arduino via an analog pin. The sensor's data is then processed by Arduino and displayed on the LCD via the SDA and SCL serial pins to the I2C module. When the temperature exceeds the maximum allowable limit, Arduino will activate digital pin 13 to sound the buzzer.

Figure 13. System hardware implementation.

Hardware implementation is the stage of implementing hardware by the plans that have been made so that the system works according to its needs and functions. The hardware consists of several modules and basic electronic components. Hardware is arranged according to the function of the software so that it can be connected to others.

The hardware implementation stage consists of an Arduino UNO, an MLX90614 temperature sensor, an active buzzer, an LCD module, and an I2C module. This hardware's parts are interconnected and integrated according to the disc brake heat detection requirements and functions.

The software implementation consists of instructions on the Arduino IDE that aim to read data from the temperature sensor, process sensor data, display sensor data on the LCD, and sound the buzzer as shown in the program listing below.

```
#include <LiquidCrystal_I2C.h>
#include <Wire.h>
#include <Adafruit_MLX90614.h>
Adafruit_MLX90614 mlx = Adafruit_MLX90614();
LiquidCrystal_I2C lcd = LiquidCrystal_I2C(0x27,16,2);
int buzzer=13; //pin untuk buzzer
void setup() {
Serial.begin(9600);
lcd.init();
lcd.backlight();
pinMode(buzzer, OUTPUT);
lcd.setCursor(0,0);
lcd.print("Deteksi");
lcd.setCursor(0,1);
lcd.print("Suhu Piringan");
delay(5000);
lcd.clear();
mlx.begin();
}
void loop() {
float objek = mlx.readObjectTempC();
  if (objek >=200){
    buzzer_on();
lcd.setCursor(0,1);
    lcd.print("Suhu Tinggi");
    buzzer_off();
  }
  else if (objek <200){
    buzzer_off();
lcd.clear();
lcd.setCursor(0,1);
    lcd.print("Suhu Rendah");
  }
lcd.setCursor(0,0);
  lcd.print("Suhu =" );
lcd.setCursor(7,0);
  lcd.print(objek);
  lcd.print(char(0xdf));
  lcd.print("C");
}
void buzzer_on (){
digitalWrite(buzzer, HIGH);
delay(1000);
}
void buzzer_off (){
digitalWrite(buzzer, LOW);
delay(1000);
}
```


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Testing of the system aims to test the capabilities of the system based on predetermined specifications. Testing of this system is carried out on the capabilities of the system, namely:

- System accuracy in detecting disc brake heat.
- System ability to display temperature to LCD.
- The system's ability to display notifications by sounding the buzzer according to the specified temperature.

Figure 14. Testing with an electric motor.

System testing is done using an electric motor 1 HP 2800 rpm as a substitute for the wheels' rotation. Testing of this system is carried out by being given a fixed braking load, and then the electric motor is rotated regularly at a speed of 2800 rpm. The distance between the sensor and the disc is 5 cm. As a comparison of measurement accuracy, another tool is used in the form of a thermometer gun to determine the difference in the system's measurement results on the LCD screen with a thermometer gun. Then the disc brake heat is detected periodically every 25 seconds. The results of testing with an electric motor can be seen in Table 1.

TABLE 1.
SYSTEM TESTING RESULTS

Time second	Thermo-meter Gun (ºC)	Temperature System (LCD) (ºC)	Difference (ºC)	Buzzer
25	94,7	94,5	0,2	*off*
50	121,3	120,9	0,4	*off*
75	143,4	143,1	0,3	*off*
100	164,8	164,4	0,4	*off*
125	177,2	176,8	0,4	*off*
150	186,7	186,5	0,2	*off*
175	197,3	196,9	0,4	*off*
200	211,5	211,1	0,4	*on*
225	224,6	224,3	0,3	*on*
250	237,9	237,5	0,4	*on*

IV. CONCLUSION

The trials conducted show that the results of designing hardware and software for overheating detection of Arduino-based motorcycle disc brakes can be summarized as follows. The system can display temperature detection into the LCD. The detection of disc heat generated by design differs from the Thermo gun of at least 0.2ºC and a maximum of 0.4ºC, a more excellent value on the thermometer gun. The system can issue notifications in the form of a buzzer sound at system temperatures of 211.1ºC, 221.3ºC, and 237.5ºC, which were achieved at 200, 225, and 250 seconds.

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