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Design of brake failure control on motorcycle disc brakes through an integrated cooling system

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ABSTRACT

The increasing number of traffic accidents is a challenge for driver safety. The biggest factor in traffic accidents in terms of vehicles, one of which is brake failure. The number of cases of failed brakes was 7,083 cases and increased in the following year by 32% or 9,333 cases. The main cause of brake failure is the temperature condition in the brake calipers which overheats, triggering the occurrence of brake vapour lock. So, there is an urgent need for innovative solutions that can overcome the failure of the brakes on motorcycles due to the lack of effectiveness of the cooling system in the callipers. This study aimed to analyze the effectiveness of E-BRACE (electronic brake cooling control system) in preventing brake failure and to describe the design and innovation of E-BRACE as a technology for controlling brake failure through an integrated cooling system. The research was experimentally carried out with functionality tests to describe the effectiveness of E-BRACE. The test revealed that E-BRACE was very effective in stabilizing the temperature in the 9th to 15th-minute range. The highest E-BRACE effectiveness in the 15th minute is 55 %.

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1. Introduction

The increasing number of traffic accidents is a challenge for driver safety [1]-[4]. In Indonesia, the number of traffic accidents has started to increase by 3,617 cases, or 3.6% in 2020-2021 [5]. In addition, the biggest factor in traffic accidents, of which is in terms of vehicles [6][7]. One of the main causes of traffic accidents is brake malfunction [8]-[10], with a total of 7,083 cases of failed brakes and an increase in the following year by 32% or 9,333 cases [11]. If calculated in a year, as many as 25 brake failure accidents occur every day throughout Indonesia.

Brake failure is a condition where the brake system of a vehicle is malfunctioning [12]-[14]. This condition is crucial because it can endanger the driver. The main cause of brake failure is the brake vapour lock [15]. The brake vapour lock event is a temperature condition in the brake callipers that overheats, causing a reduction in brake fluid [16][17]. The gas produced from overheating will result in the brake system failing to work (malfunctioning), because when the brake pedal is pressed the brake fluid pressure cannot be transmitted to the calliper piston [18][19].

Based on these problems, it is urgently needed to have an innovative solution that can overcome the failure of the brakes on motorcycles due to the lack of effectiveness of the cooling system in the callipers. The E-BRACE (electronic brake cooling control system) is present as a brake failure accident control technology that is integrated into motorcycles.

This study aimed to analyze the effectiveness of E-BRACE in preventing brake failure and to describe the design and innovation of E-BRACE as a technology for controlling brake failure through an integrated cooling system. It is hoped that this research become a new reference in reducing the number of accidents that occur due to failed brakes.

2. Method

The research was carried out with the following stages:

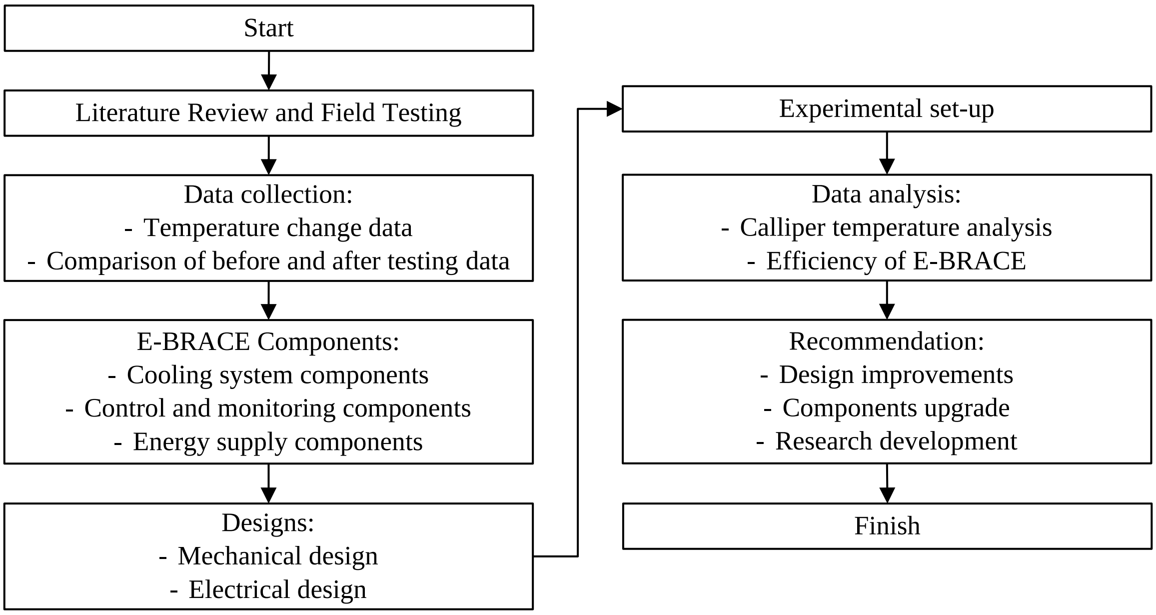


Fig. 1. Flowchart of research stages

This research was carried out experimentally to determine the temperature changes that occur during the braking process which accumulate and cause brake vapour lock. The data collected from this research was temperature changes and comparison before and after the E-BRACE test. To obtain this data, the main components of E-BRACE were determined, including cooling system components, control and monitoring components, and energy supply components used. Then an E-BRACE test plan was created, starting from the mechanical design as information on the mechanical work carried out to the electrical design to create an electrical installation that could connect the control system with the cooling system. So the test results were obtained in the form of calliper temperature data obtained from accumulated braking and the level of efficiency when using E-BRACE compared to without using E-BRACE.

2.1 E-BRACE Components

All E-BRACE components were placed from the middle front (body) to the lower front (brake calliper) of the motorcycle. Because it adapts to the disc brake location at the front of the motorcycle. Installation of E-BRACE components was carried out circularly and integrated with the system.

The cooling system has several components, including a 40 x 80 mm water block, 240 mm radiator, 12V DC fan, 42 cm hose, DOT 3 brake fluid, and a 12V DC water pump. This system is responsible for reducing the heat of brake fluid that occurs when braking in downhill road conditions. The water block and radiator function as absorbing or removing the heat generated by the brake fluid

[20][21]. In addition, the cooling system is assembled in such a way as to be mutually sustainable. The control and monitoring component is the input detection and control component of the E-BRACE work system which consists of a type k thermocouple sensor integrated with Arduino Nano which functions to provide an analog signal from the response to heat temperature then displayed via a 16 x 2 LCD. Arduino is a control system of design for all electronic devices [22]. The electrical energy used in this tool utilizes an existing power source on motorcycles, namely batteries. In addition, the E-BRACE requires a 12V DC power supply.

2.2 Mechanical Design

The mechanical design of the testing tool was made by using Autodesk Fusion 360 software. The detailed dimensions of this tool can be seen in Fig. 2

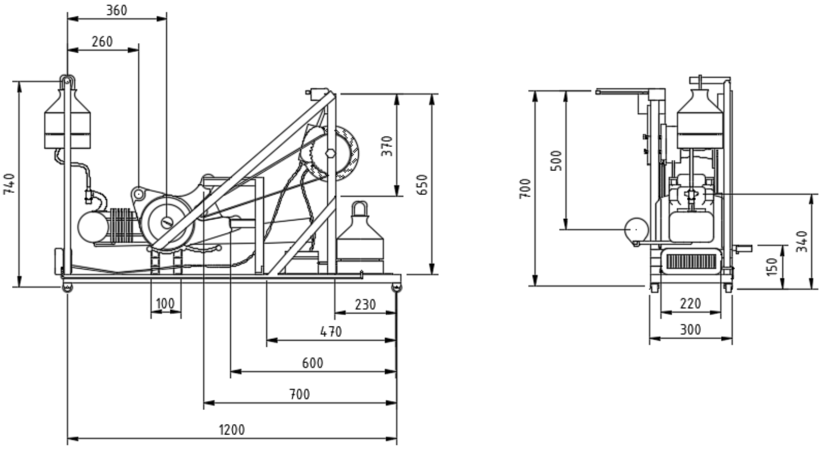


Fig. 2. Setting dimensions of prototype design

Fig. 2 shows the prototype design with its dimensions for E-BRACE testing. Motorcycle disc brake testing was carried out by creating a model or simulation flow of brake failure events through this prototype. Because the test to obtain brake failure (brake vapour lock) is not possible in downhill road conditions, a simulation of this test was conducted in safe conditions. The main materials used to make the frame of the braking system include 4 x 4 cm ST37-hollow steel and 5 x 5 cm cast iron with a thickness of 3 mm each. This material was chosen because it is ductile and strong against vibration and high temperatures. The main components of this test model consist of a 125 cc 4-stroke engine, drum, axle, brake master, disc brakes, brake calliper, brake lever, hydraulic brake hose, acceleration gas handle, gear, and chain. Then the other components of the E-BRACE prototype were added which included a radiator, water block, thermal paste, 12 VDC fan, 12 VDC water pump, reservoir tank, and water hose.

The prototype model was made to be as similar as possible to motorcycle braking in general. The first height of this prototype is 740 mm from the ground with a hollow steel frame and casters for placement of the reservoir tank so that cooling water can flow perfectly, assisted by a water pump. The second height of this prototype is 650 mm from the base surface of the prototype for the placement of drums, disc brakes, brake callipers, and axles. On the right side, there is another reservoir tank space with a size of 230 mm as a place for the cooling water to exit from the water block. The 4-stroke engine was positioned slightly mid-range of the length of the prototype.

2.3 Electrical Design

The circuit and control system wiring as shown in Fig. 3. At this stage, a control system was made on a PCB with various components, such as Arduino Nano, LCD, Relay, Thermocouple type k Sensor, Battery, and other supporting components.

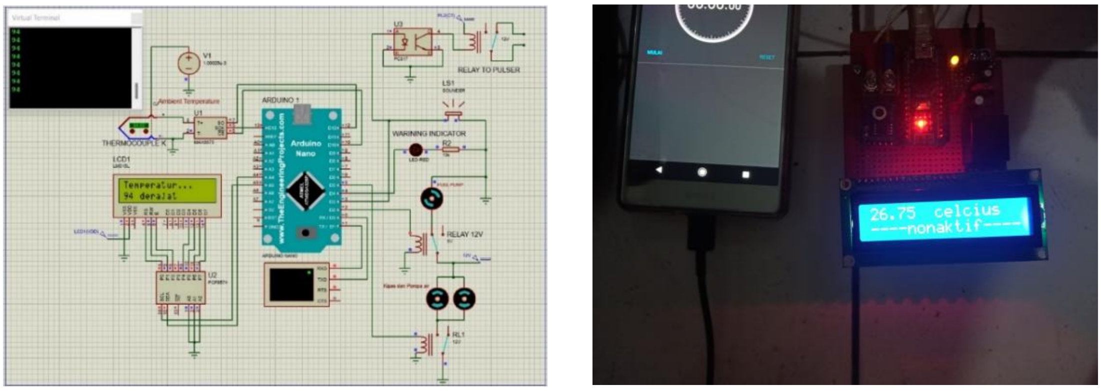
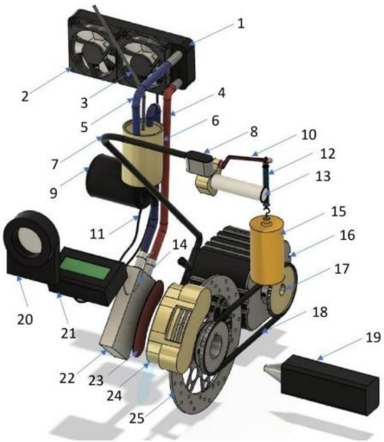


Fig. 3. Circuit design and control system

The process of creating a circuit using Proteus Pro 8 software began by simulating the control system circuit to see whether the circuit can run and connect well or not. This stage was programmed by the C++ language to create a simulation of the circuit. After all the components had been assembled, the next step was to upload the program that had been made.

2.4 Experimental Set-Up



Information:

1. Radiators
2. 12V DC fan
3. Air hose
4. Heat flow hose
5. Cold flow hose
6. Reservoir tanks
7. Hydraulic brake hose
8. Brake master
9. Pump
10. Brake lever
11. Pump cable
12. Spring balance
13. Handle gas acceleration
14. Thermocouple sensor type-k
15. Ballast
16. Engines
17. Gears
18. Chain
19. Tachometers
20. Stopwatch
21. Box controller and LCD
22. Waterblock
23. Thermal paste
24. Brake calliper
25. Disc brakes

Fig. 4. Assembly View

This test was carried out by measuring before and after treatment and is called the One Group Pretest-Posttest Design Method. Starting with turning on the motorcycle with idle conditions. The spring balance was used simultaneously with the accelerator gas handle and the brake handle and the stopwatch was used to measure the time when the engine accelerates. The acceleration gas handle was rotated down slowly and observing the RPM on the tachometer when it reached 500 RPM on the drum, the brake lever pressed by 30N. At the specified RPM, change in the temperature rise of the brake fluid at the specified time variation were observed and recorded. The test was carried out before and after using

E-BRACE. Then, the data was processed and analysed to know the effect of the E-BRACE innovation on callipers.

3. Results and Discussion

The results of the E-BRACE test to obtain the effect of brake failure control on motorcycles can be seen in Fig. 5

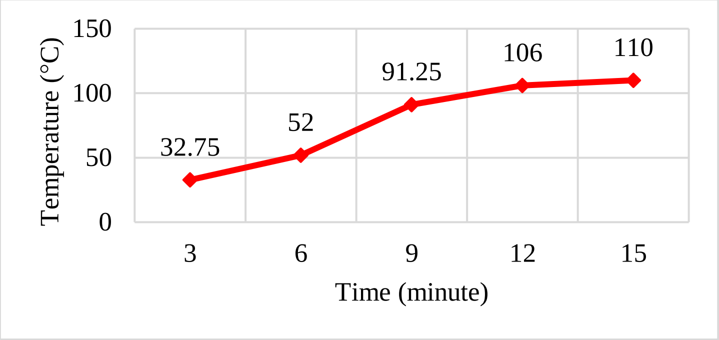


Fig. 5. Before Testing with E-BRACE

The increase in temperature at each time when braking and accelerating the gas simultaneously shows a linear increase as can be seen in Fig. 5. In accordance with the conduction heat transfer, at the beginning of the test the amount of heat transferred to the calliper is directly proportional, and the heat reduction from the calliper is more dominant [23]. This condition can cause brake vapour lock. Continuous braking accompanied by accelerating gas can create air bubbles in the calliper [24][25]. So that during the braking process, the piston in the calliper compresses the air, causing the brakes to fail. Referring to the specifications of the brake fluid used in motorcycles, DOT 3 brake fluid has a boiling point of 140 °C [26]. If the temperature of the brake fluid exceeds this temperature, the bubbles will accumulate due to the change in the liquid phase to vapour. When this moment arrives, the calliper will not be able to compress until the brake failure occurs.

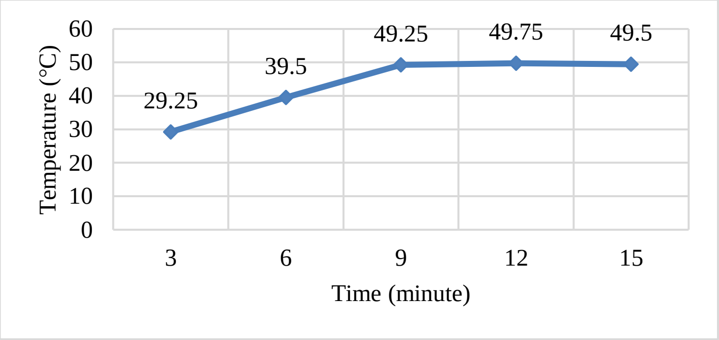


Fig. 6. After Testing with E-BRACE

When using the E-BRACE, the temperature becomes constant from the 9th minute to the 15th minute when the braking and acceleration processes are still in progress together, as shown in Fig. 6. This is because water and air as flowing fluids are very good at releasing heat [27]. When the temperature reaches < 50° C, the system sends a signal to the controller to activate the cooling system. Radiators and water pumps work for the circulation process (heat transfer) [28]. Fig. 7 shows that there is a fairly large gap in the influence of the E-BRACE innovation.

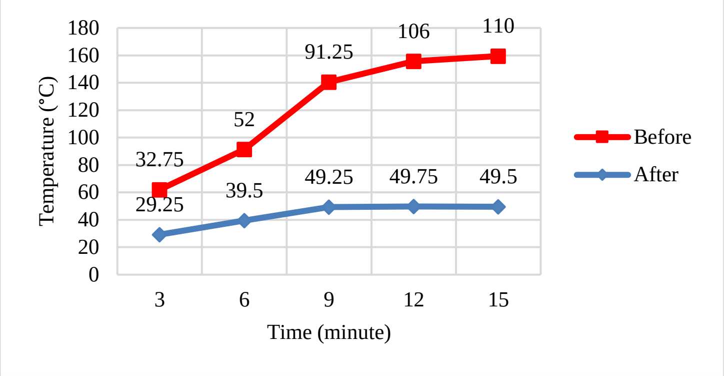


Fig 7. Comparison of Before and After Testing with E-BRACE

In the 3rd minute, there is a change in the temperature of the brake fluid in the calliper until the 6th minute, when the temperature difference starts to occur. On the waterblock layer, there is also thermal paste which can help relieve the caliper temperature. Then from the 9th to 15th minutes, the control system is active when the temperature reaches nearly 50 °C, so the cooling system works and the temperature becomes stable. This test states that if the temperature of the brake fluid does not increase continuously, then the brake fluid can not cause air bubbles to accumulate so that brake failure can be prevented [24][25].

Table 1. The E-BRACE Effectiveness

Time (minute)	Before Testing (°C)	After Testing (°C)	E-BRACE Effectiveness (%)
3	32.75	29.25	11
6	52	39.5	24
9	91.25	49.25	46
12	106	49.75	53
15	110	49.5	55

Table 1 shows that the 15th minute gets the highest percentage of 55 %. By comparing before the test and after the test, it is found that the temperature drop starts in the 3rd minute and the temperature stabilizes from the 9th to 15th minutes.

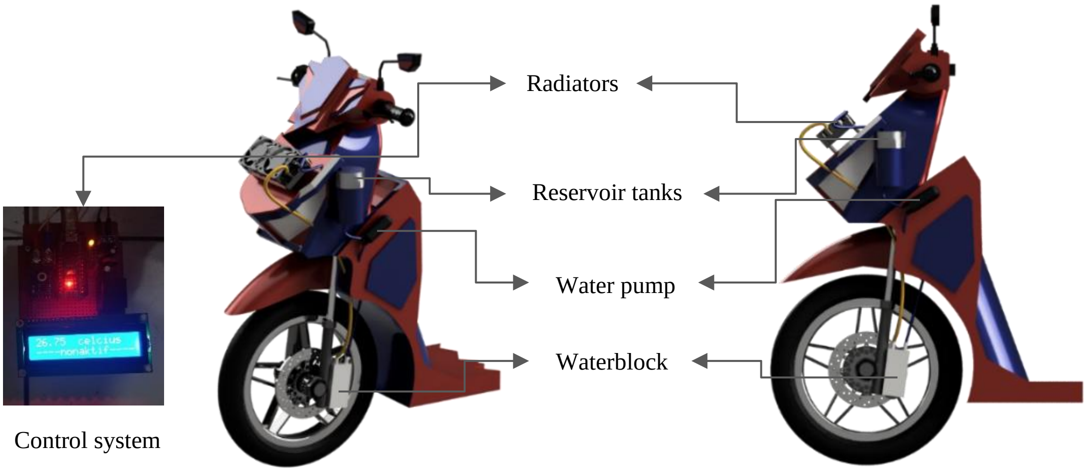


Fig. 8. E-BRACE Design

This happens when the heat absorbed by the water block does not increase its temperature, but the heat opposes the intermolecular forces in the water block [29][30]. These molecules break away from their bonds as long as the water flows inside the water block and the airflow from the radiator continues to flow, so the temperature remains constant.

The E-BRACE design as shown in Fig. 8 has several capable advantages in controlling the temperature of motorcycle brake fluid to prevent brake failure. This prototype is installed on the front body of an automatic motorcycle that uses disc brakes. This visual output is in the form of 2 safety features, such as the first warning when the brake fluid temperature is > 50 °C then the cooling system works, and a second warning when the brake fluid temperature reaches > 110 °C then the buzzer sounds and displays a stop warning in the LCD. Automatically, the electric current in the spark plug is cut off causing the motorcycle engine to stall. Additionally, E-BRACE requires a supply of 5V DC battery power. This makes E-BRACE have great potential for realizing zero accidents on downhill road areas.

4. Conclusion

The analysis concludes that the E-BRACE prototype can prevent brake vapour locks through the application of an integrated cooling system on a motorcycle brake system. The test results show that E-BRACE is very effective in stabilizing the temperature in the 9th to 15th-minute range, with the highest effectiveness occurring at the 15th minute, namely 55 %. It is hoped that this research will be further developed by knowing the speed of the coolant flow rate, brake fluid pressure, and the replacement of the initial design using a water block into a water jacket so that the effect of the cooling system in the maximum disc brake system can be inspected.

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