ANALYSIS OF THE BRAKE CALIPER POSITIONING IN VEHICLES

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ABSTRACT

This paper aims to analyze the positioning of the brake caliper on vehicles, considering the most common situations, namely in front of or behind the brake disc. The positioning of the brake caliper on cars depends on the design and configuration of the brake system specific to each vehicle model. This positioning is determined by the engineers and designers responsible for the vehicle's safety, considering factors such as chassis geometry, weight distribution, desired braking performance, and other relevant technical factors. Generally, the brake caliper is located near the brake disc so that it can apply the necessary pressure to efficiently stop the wheels. Typically, in the case of disc brake systems, the brake caliper is positioned in front of the wheel, near the brake disc. There are cases where the positioning is behind the disc. Starting from this controversy, we considered it opportune to analyze the two cases on a stand that replicates the brake system. Thus, the two situations were analyzed using pressures of 2, 4, and 6 bars in the brake pipe. The variations in brake disc temperatures and braking distances were determined for each case to draw a conclusion regarding the positioning of the caliper. The decision regarding the placement of the brake caliper in front of or behind the wheel is made by the vehicle manufacturer based on technical specifications and the desired performance of the brake system.

KEYWORDS: brake system, brake caliper, temperature, braking distance

1. INTRODUCTION

There are several types of braking systems used in vehicles, and the selection depends on various factors, including performance, costs, and design requirements. The most common types of braking systems in vehicles include:

- *Disc brake systems* where braking force is generated through friction between brake pads and the disc when the caliper is applied.
- *Drum brake systems* where braking force is generated when brake shoes press against the drum during braking.
- *ABS (Anti-Lock Braking System)* brake systems, where the brake pressure is electronically controlled to prevent wheel lock-up during intense braking.
- *Regenerative braking systems*, where the kinetic energy generated during braking is converted into electrical energy to charge the batteries of an electric or hybrid vehicle.
- *Hydraulic brake systems* that use brake fluid to transmit the pressure applied on the brake pedal to the braking mechanism. Hydraulic systems are common in both disc and drum brakes, [1], [2].

These systems can be used in different combinations and can be adapted to the specific requirements of vehicles. The continuous development of technology brings constant innovations in the field of braking systems, with a focus on safety, efficiency, and durability.

Currently, the most widely used braking system in vehicles is the disc brake system, especially for front wheels. This system has become predominant due to its advantages in performance and efficiency:

- Disc brakes provide superior performance in terms of braking distance and the ability to stop quickly, significantly contributing to vehicle safety.
- Disc brakes are more resistant to overheating than drum brakes, making them suitable for more intense driving conditions or vehicles that require high braking capacity.
- Disc brakes offer better control sensitivity. The driver can more precisely control the braking force, providing a more pleasant and controlled driving experience.
- The exposed disc allows better heat dissipation generated during braking, contributing to

maintaining system efficiency under heavy usage conditions.

- Disc brakes generally have lower wear compared to drum brakes, resulting in lower long-term maintenance costs, [3], [4].

However, it is important to note that for the rear wheels of many vehicles, drum brakes can still be used as they may be more economical and meet certain design and performance requirements. Additionally, regenerative braking systems are becoming increasingly common in electric and hybrid vehicles, contributing to energy efficiency.

The disc brake in vehicles represents a complex and efficient system designed to ensure a quick and controlled stopping of the vehicle under various traffic conditions. This braking system is based on the principle of transforming kinetic energy into heat through a pair of brake discs and calipers.

The basic structure of the disc brake consists of a solid brake disc attached to the vehicle's wheels and a caliper containing the braking mechanism, as shown in Figure 1. Inside the caliper, there are brake pads, usually made of a composite material such as fiberglass and phenolic resin, which generate friction when pressed against the brake disc. When the driver applies the brake, a piston inside the caliper is activated, causing the brake pads to press against the brake disc. This pressure and resulting friction generate a stopping force, converting the kinetic energy of the wheels into heat. This energy transformation process is essential for reducing the vehicle's speed and controlling it during braking, [1], [2], [3], [4], [5].

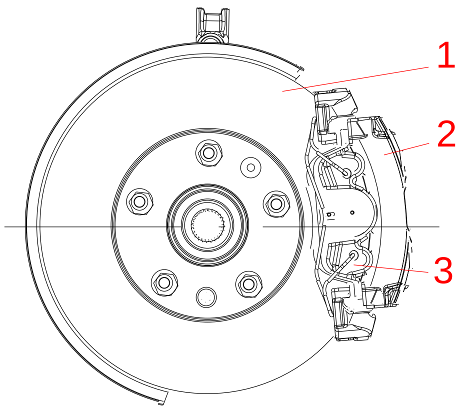

Fig. 1. *Disc Brake System*
1 - Brake disc, 2 - Caliper, 3 - Brake pad

The efficiency of the disc brake is attributed to its ability to dissipate the heat generated during braking, maintaining consistent performance under various usage conditions. Additionally, the disc brake system provides better sensitivity and control over the braking process, enhancing the safety and maneuverability of the vehicle.

Various manufacturers position the caliper on the brake disc based on the model, capacity, and type of the vehicle. Thus, caliper positions can be found at the top of the disc, as well as in front of or behind it. This positioning leads to a modification of the brake efficiency, impacting both braking distance and the temperature of the brake disc.

2. METHOD OF ANALYZING THE BRAKE CALIPER POSITION

To efficiently analyze the positioning of the brake caliper in front of or behind the disc, a rigorous method is required. A systematic approach involves:

- Determining the influence of caliper positioning on braking distance and disc temperature.
- Selecting a specific vehicle and identifying the brake system under analysis, ensuring the availability of necessary data for measurements and analysis.
- Identifying critical variables, such as caliper position (in front of or behind the disc), pressure applied in the brake pipe, chassis geometry, weight distribution, and other relevant factors.
- Simulating real braking conditions by choosing different pressures in the brake pipe and reproducing variations in caliper positioning to obtain comparative data.
- Conducting experiments and collecting precise and reliable data regarding braking distance and disc temperature under various testing conditions.
- Analyzing data using specialized software or statistical tools for the collected data.
- Performance evaluation based on comparisons between caliper positioning and its effects on braking distance and disc temperature.
- Drawing conclusions based on the results of the analysis for caliper positioning, considering the study's findings, [3], [4], [5], [6].

Due to the impossibility of mounting sensors on the vehicle's brake discs and the collection of inaccurate data, it was necessary to design and create a brake stand that faithfully reproduces the braking system, [1]. The design of the stand was carried out using computer-aided graphics software, Catia V5 R21. All components of the brake system were modeled, incorporating them into a metal frame. The main modeled components of the hydraulic brake system included the brake pedal, brake servo, brake pump, liquid reservoir, rigid and flexible pipes, connecting elements, disc brake calipers, and an electric motor, as shown in Figure 2.

Starting from the controversy surrounding the positioning of the brake caliper in front of or behind the brake disc, we utilized a stand composed of an electric motor, an inertial mass, and a braking system consisting of a caliper and disc. The motor used is a three-phase motor with a rotation speed of 750 rpm, and the inertial mass is 60 kg. The stand did not allow for the modification of the caliper's position, and to conduct the determinations, it was necessary to reverse the rotation direction of the electric motor.

The determinations were carried out according to calculations for a speed of 92 km/h in three stages for brake pipe pressures of 2, 4, and 6 bars, and data were collected using an Arduino Uno R3 module. Figure 2 illustrates the brake stand diagram. The braking distance was calculated based on counting the number of complete rotations until the stop, considering that the circumference of the rubber-equipped wheel is 2150 mm. This counting was performed automatically using a Hall sensor that received impulses from three magnets arranged at 120° on the inertial mass. The temperature in the brake disc, whose diameter is 230 mm, was determined using a non-contact infrared sensor model MLX 90614.

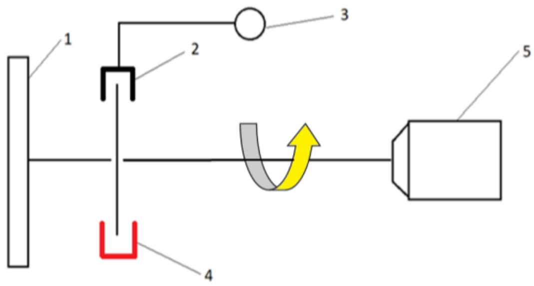

Fig. 2. *Brake Stand Diagram*
1 - Inertial mass, 2 - Caliper positioned in front, 3 – Pressure gauge, 4 - Caliper positioned behind, 5 - Electric motor

3. RESULTS OBTAINED FOR THE CALIPER POSITION IN FRONT OR BEHIND THE BRAKE DISC

The first determination was carried out for a constant pressure in the brake pipe of 2 bars. The stand is equipped with a pedal stroke limiter to limit the brake fluid pressure. For this experiment, the pedal stroke was limited until the pressure gauge indicated 2 bars. For braking with the caliper positioned in front, the following results were obtained according to the presented graphs.

It is observed that with the caliper positioned in front of the brake disc, we have a braking distance of 35.117 meters in approximately 2.6 seconds, a temperature of 47°C, and a temperature variation of 5.6°C, as shown in Figure 3.

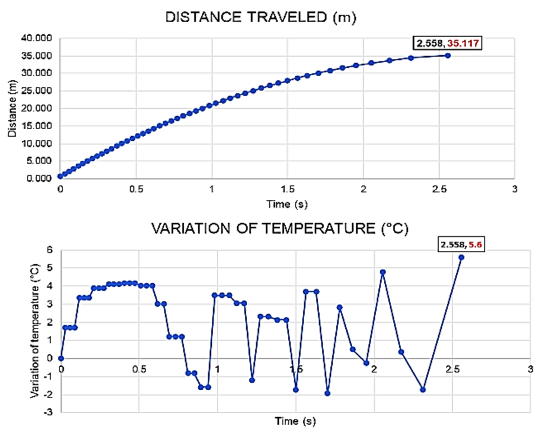

Fig. 3. *The distance traveled and the temperature variation in the disc until complete stop with the caliper positioned in front for a pressure of 2 bars*

For the pressure of 2 bars and with the caliper positioned behind the brake disc, the graphs in Figure 4 were obtained. Thus, it is observed that with the caliper positioned behind the brake disc, we have a braking distance of 43 meters in approximately 3 seconds, a temperature of 44°C, and a temperature variation of 1.7°C.

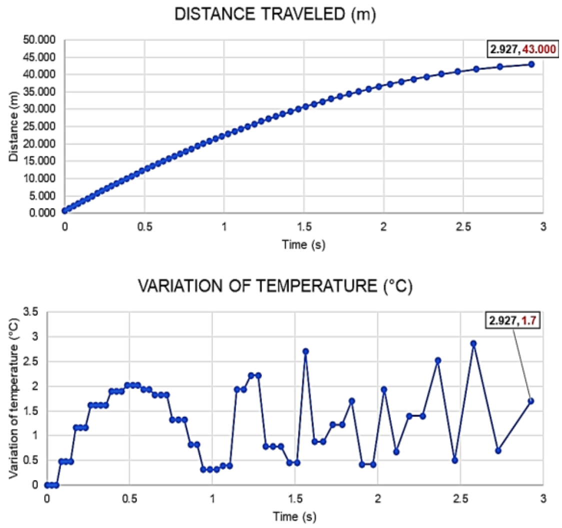

Fig. 4. *Braking distance and temperature variation in the disc until stop with the caliper positioned behind the brake disc for a pressure of 2 bars*

For the second determination at a constant pressure in the brake pipe of 4 bars, the graphs presented in Figures 5 and 6 were obtained. Thus, it is observed that with the caliper positioned in front of the brake disc, we have a braking distance of 18.633 meters in approximately 1.3 seconds, a temperature of 40°C, and a temperature variation of 1.88°C, as shown in Figure 5.

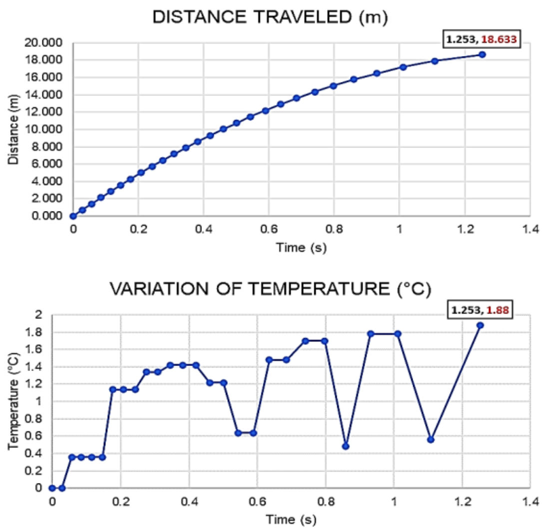

Fig. 5. *Braking distance and temperature variation in the disc until stop with the caliper positioned in*

front of the brake disc for a pressure of 4 bars

For the pressure of 4 bars and with the caliper positioned behind, it is noted that a braking distance of 20.783 meters is achieved in approximately 1.4 seconds, with a temperature of 55°C and a temperature variation of 1.7°C, as shown in Figure 6.

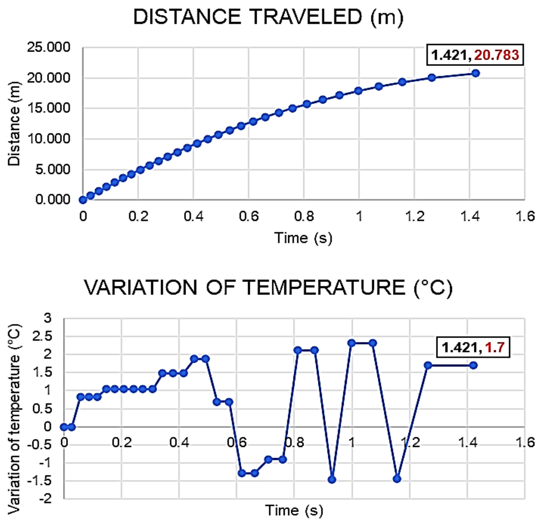

Fig. 6. *Braking distance and temperature variation in the disc until stop with the caliper positioned behind the brake disc for a pressure of 4 bars*

For the third determination at a constant pressure in the brake pipe of 6 bars, the graphs in Figures 7 and 8 were obtained. Thus, it is observed that with the caliper positioned in front of the brake disc, we have a braking distance of 14.333 meters in approximately 0.9 seconds, a temperature of 49°C, and a temperature variation of 1.7°C, as shown in Figure 7.

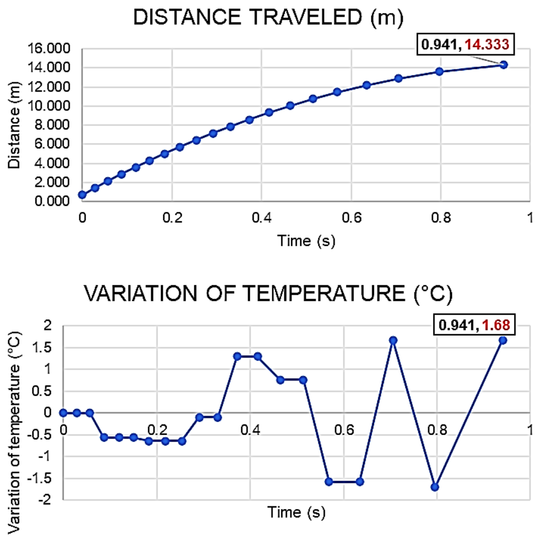

Fig. 7. *Braking distance and temperature variation in the disc until stop with the caliper positioned in front of the brake disc for a pressure of 6 bars*

For the pressure of 6 bars and with the caliper positioned behind the brake disc, it is noted that a braking distance of 15.767 meters is achieved in approximately 0.99 seconds, with a temperature of 57°C and a temperature variation of 1.2°C, as shown in Figure 8.

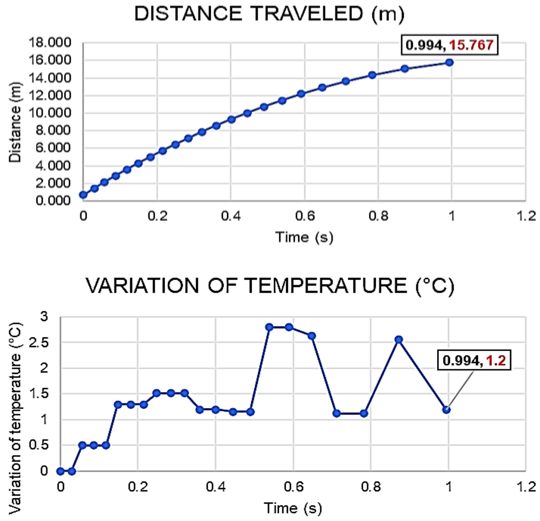

Fig. 8. *Braking distance and temperature variation in the disc until stop with the caliper positioned behind the brake disc for a pressure of 6 bars*

Braking distance and the temperature in the brake disc are two essential aspects that can vary depending on the positioning of the caliper in front of or behind the disc. These differences can influence the performance of the braking system and can be analyzed in detail to understand the advantages and disadvantages of each configuration, [7], [8], [9], [10], [11], [12].

These critical variables were investigated in our study, where we analyzed the braking distance and temperature variation in the brake disc for different brake pipe pressures and caliper positions. The results obtained highlighted that the positioning of the caliper in front of or behind the disc can significantly impact the performance of the braking system, [2].

In the case of positioning the caliper in front of the disc, we observed a shorter braking distance and a more pronounced thermal variation in the disc. This configuration tended to provide a quicker stop but also generated a more significant increase in disc temperature. On the other hand, positioning the caliper behind the disc led to a longer braking distance but a more moderate thermal variation in the disc.

These findings underscore the importance of choosing the correct caliper position in designing the braking system, and automotive manufacturers can make informed decisions regarding this configuration based on the specific requirements of the vehicle, as well as priorities related to performance, safety, and durability.

The findings we will have regarding the importance of choosing the correct caliper position in designing the braking system can influence automotive manufacturers in making decisions regarding this configuration based on the specific requirements of the vehicle, as well as priorities related to performance, safety, and durability.

4. CONCLUSIONS ON THE POSITIONING OF THE BRAKE CALIPER IN FRONT OR BEHIND THE BRAKE DISC

When applying a constant pressure of 2 bars in the brake pipe, a shorter braking distance is observed when positioning the caliper in front of the disc compared to positioning it behind the disc. Therefore, a conclusion can be drawn that positioning the caliper in front is more efficient.

In the case of a pressure of 4 bars in the brake pipe, it is observed that positioning the caliper in front of the brake disc is more efficient by reducing the braking distance and providing better cooling for the brake disc in this scenario.

For a pressure of 6 bars in the brake pipe, it can be concluded that positioning the caliper in front of the brake disc is much more efficient than positioning it behind the brake disc, as evidenced by better braking distances and lower temperatures at the brake disc.

Following the analysis of the caliper's positioning relative to the brake disc, we can make several general observations:

- The optimal position of the caliper is in front of the brake disc according to the results obtained on the test stand, which practically demonstrated that the braking distance increases when the caliper is positioned behind the disc.
- From the obtained results, it was observed that positioning the caliper in front of the brake disc is more efficient in terms of the temperature generated in the brake disc, and the time until complete stop is also reduced.
- The results obtained from the simulated braking tests on the stand in this study lead to the conclusion that temperature is an important factor influencing the performance of the brake disc.
- Research indicates that an increase in disc temperature leads to a decrease in braking performance.
- The analysis of positioning the caliper in front of or behind the brake disc highlights some significant conclusions:
- In general, positioning the caliper in front of the brake disc seems to offer advantages in terms of a shorter braking distance. This is due to the ability to apply the braking force directly at the point of contact between the brake pads and the disc, generating a more efficient pressure.
- In the case of positioning the caliper behind the disc, the efficiency of the braking distance may depend on the complexity of the system and how the braking force is distributed on the disc.
- Placing the caliper in front of the disc can lead to a higher concentration of heat in that area, due to the direct application of the braking force in front of the disc's rotational movement.
- In the case of positioning the caliper behind the disc, the temperature in the disc may be more uniformly distributed, but this aspect also depends on the efficiency of the brake cooling system.
- Vehicle manufacturers make decisions regarding the caliper's positioning based on the technical specifications and desired performance of the braking system for each model. The analysis needs to be tailored to the characteristics of the braking system for each vehicle, considering the chassis geometry, weight distribution, and other specific factors.

The choice between positioning the caliper in front of or behind the brake disc is a complex decision influenced by multiple variables. The efficiency of the braking system, braking distance, and disc temperature depend on how these variables are managed within the specific vehicle system.

In conclusion, the decision between positioning the caliper in front of or behind the brake disc is a complex one, influenced by multiple variables. The efficiency of the braking system, braking distance, and disc temperature depend on how these variables are managed within the specific vehicle system.

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