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CAR BRAKING SYSTEM – GENERAL ASPECTS IN A REVIEW

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Abstract: One of the roles of the braking systems, which it has to fulfil, is to prevent the wheels from locking and keeping the sliding from falling within certain limits. Also, the primary goal is to ensure the required decelerations and progressive braking, without shocks. The safety of the vehicle, as well as the possibility of full use of speed and acceleration during its operation, is ensured by the braking capacity. Thus, the braking system must meet a number of essential criteria. The advent of automobiles has given rise to the need for the most efficient braking system that can ensure high standards of performance, reliability and safety. The braking system is indispensable for the safety of road users. The need for an efficient and efficient braking system has led to its continuous improvement, becoming more and more complex with the advent of microelectronics. Today, the braking mechanisms are assisted by complex systems such as: the anti–grip system during braking (ABS), which ensures the contact of the wheel with the surface with which it is in contact; electronic stability control system (ESP), which ensures a dynamic stability control, detecting slippage; anti–slip systems, which ensure the stability of the vehicle in different conditions.

Keywords: car breaking system, disk brakes, drum braking systems, brake pads

INTRODUCTION

As early as 5000 BC (Post W., 2019), when the first use of the wheel dates back, mankind was faced with the problem of using a braking system. Over time, it has undergone many improvements, in order to obtain a system as efficient as possible, which corresponds to current needs and technologies.

The first efficient braking system dates back to 1796, representing a wooden shoe–type braking system. It survived for several decades and was later replaced by a system that used damp textiles as a friction material, the latter being in turn replaced by tanned leather.

With the advent of motorized carriages, the need for a much more efficient braking system appeared, so that in 1880, the braking system used ferrule as a friction material. (Cimpeanu & Cimpeanu, 2019)

One of the roles of the braking systems, which it has to fulfil, is to prevent the wheels from locking and keeping the sliding from falling within certain limits. Also, the primary goal is to ensure the required decelerations and progressive braking, without shocks (Tretsiak, Kliauzovich, Augsburg, Sendler, & Ivanov) (Stefan–Ionescu, 2019).

The safety of the vehicle, as well as the possibility of full use of speed and acceleration during its operation, is ensured by the braking capacity. Thus, the braking system must meet a number of essential criteria such as:

- Stopping the car safely
- Immobilizing the car when it is on a slope
- Ensuring required decelerations
- Ensuring progressive braking
- Minimal effort on the part of the driver
- Proportionality between the effort applied to the drive mechanism and the deceleration
- Braking force to act in both braking directions
- Ensuring braking only when the driver intervenes
- Ensuring heat dissipation during braking
- Simple shrinkage, easy maintenance
- Prevent unwanted acceleration while driving downhill
- Immobilizing the vehicle when it is parked (Stefan–Ionescu, 2019, Post W., 2019).

Thus, the braking system is indispensable for the safety of road users. The need for an efficient and efficient braking system has led to its continuous improvement, becoming more and more complex with the advent of microelectronics (Post W., 2019).

MATERIALS AND METHODS

There are 2 types of braking systems to use: disc brake type braking system and clog braking system. The latter are currently used on the rear axle of cars, but their aim is to replace them with disc–type braking systems (Reif, 2019). A breaking system is presented in figure 1.

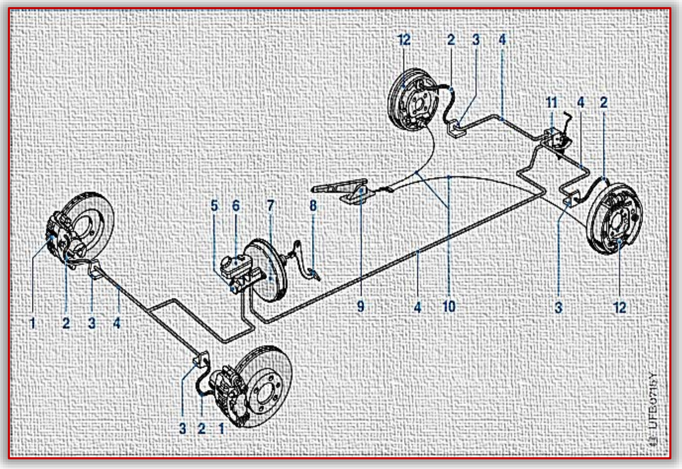

Figure 1 – Conventional braking system on both axles of the car (Reif, 2019)

In order to actuate the braking system, the driver applies force to the brake pedal (8) by moving the rod which connects the brake pedal to the actuator piston (7). The actuator amplifies the pressing force and transmits it to the rod connected to the main cylinder (6). The main cylinder converts the mechanical force into hydraulic force. Inside the main cylinder, there are two pistons that push the hydraulic fluid from the main cylinder pressure chamber into the brake lines (4) and the brake hoses (2), thus transmitting the hydraulic pressure from the disc brakes (1) to the wheels. The front axles, and the drum brakes (12) are presented the rear axle wheels. If one of the brake circuits fails, the other remains fully functional so that braking is provided by a secondary braking system. The brake fluid container (6) is connected to the main cylinder (6), completing the fluid volume fluctuations in the brake circuits (Reif, 2019).

The parking brake system applies the rear axle brakes (12) via the lever (9) and the parking brake cable (10).

During braking, as the deceleration increases, much of the car's load is moved from the rear axle to the front axle (dynamic axle load change). Thus, the pressure regulating valve (11) lowers the brake pressure on the rear wheels to prevent overloading them. This process is called braking force balancing, unlike the ABS system, where this process involves controlling the braking force (Reif, 2019).

In unfavourable conditions, such as wet asphalt, slippery road, sudden reaction from the driver, it is possible for the vehicle's wheels to lock during braking, making the vehicle uncontrollable. To prevent such situations, the anti–lock braking system (ABS) detects if one or more wheels are gripped, ensuring a constant or reduced pressure for them, preventing wheel locking, and also ensuring the stability of the vehicle. Thus, the vehicle can be stopped safely.

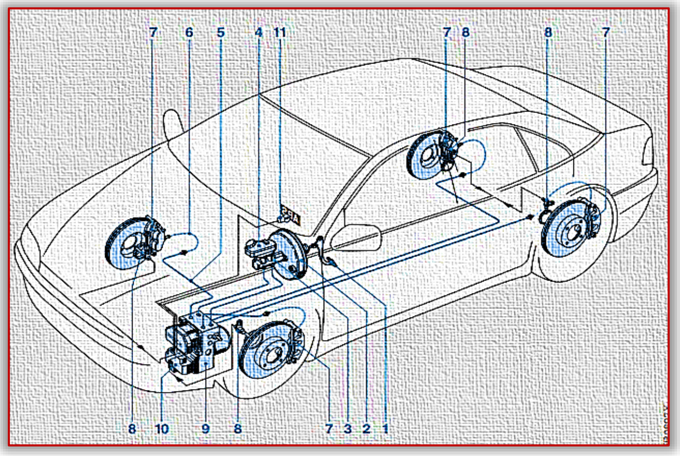

Figure 2 – ABS braking system

The ABS system is based on the components of the conventional braking system, as follows:

- brake pedal (1) (Figure 2)
- brake booster (2)
- main cylinder (3)
- Brake fluid reservoir (4)
- Brake fluid hoses (5)
- Brake fluid hoses (6)
- brake pads and discs (7)

In addition, there are:

- Wheel speed sensors (8)
- hydraulic modulator (9)
- ABS control unit (10)
- warning light (11) which illuminates when the ABS system does not work (Reif, 2019)

The ABS system must meet a number of requirements, characterized by safety standards associated with the braking response dynamics and braking system technology, such as stability and manoeuvrability, efficiency, timing characteristics and reliability (Reif, 2019)

Thus, the braking system of vehicles plays the main role in the safety of the driver and other road users, being composed of a series of complex elements designed for its proper operation, according to the rules.

DISK BREAK COMPONENTS

A vehicle needs a braking system to stop or adjust its speed depending on the change of road and traffic conditions. The basic principle used in braking systems is to convert the kinetic energy of a vehicle into another form of energy. During a braking operation, not all the kinetic energy is converted into the desired shape. Thus, when braking by friction, a certain energy can be dissipated in the form of vibrations.

There are two types of brakes, namely drum brakes and disc brakes. The latter are widely used. Disc and pad brakes, compared to drum brakes, cool faster, due to a larger friction surface and greater exposure to air flow, there is the ability to self–clean due to centrifugal forces (Rashid, 2014)

Studies have shown that disc brakes are the most effective at stopping cars whose mass is significant, with ever–increasing performance, and whose safety standards are becoming more demanding (Stefan–Ionescu, 2019).

The most important advantages of using disc brakes over drum brakes are the following:

- low sensitivity to the variation of the coefficient of friction.
- uniform pressure distribution on the friction surfaces and, as a result, uniform wear of the gaskets
- large cooling surface and good heat dissipation conditions allow them to dissipate high energy in the form of heat.
- stability in operation at low and high temperatures – balancing axial forces and lack of radial forces
- the possibility of operation with small clearances between the friction surfaces which drastically decreases the commissioning time
- independence of braking efficiency from the degree of wear of the friction linings
- ensuring the same braking moment regardless of the direction of travel – the deformations of the parts in the friction torque much more advantageous: the disc deforms in the rough axial direction unlike the radial deformation of the drum which causes change in its shape, thus affecting the play between friction surfaces;
- easy replacement of gaskets (Stefan–Ionescu, 2019)

In the case of the disc brake system, the pads are pressed onto a rotating disc when braking, generating heat due to friction between the pads and the disc. This is transferred to the outside environment, resulting in the cooling of the disk. (Rashid, 2014) Such a braking system consists of a caliper, fixed by screws, on the spindle port, a disc installed between the hub and the wheel. The brake pads are embedded in the caliper, which under the action of hydraulic cylinders, will press on the disc and stop its rotational movement.

DISC BREAK CALIPER

The disc brake caliper can be fixed or floating. In the case of the fixed caliper (Figure 3), it is absolutely necessary to place two pistons on each side of the disc, while in the case of the mobile caliper (Figure 4), only one piston can be arranged (Stefan–Ionescu, 2019).

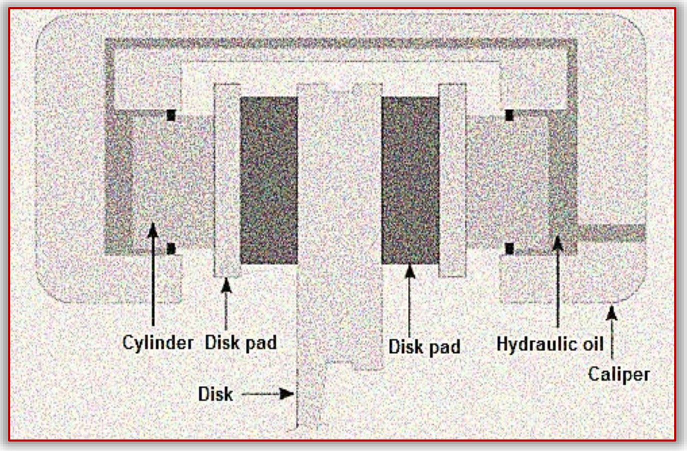

Figure 3 – Fixed caliper (Rashid, 2014)

When pressure is applied, the piston moves and pushes the inner brake pad. When it comes in contact with the surface of the disc, the stirrup moves in the opposite direction so that the outer plate comes into contact with the surface of the disc. Following this process, the rotational motion is stopped (Reif, 2019).

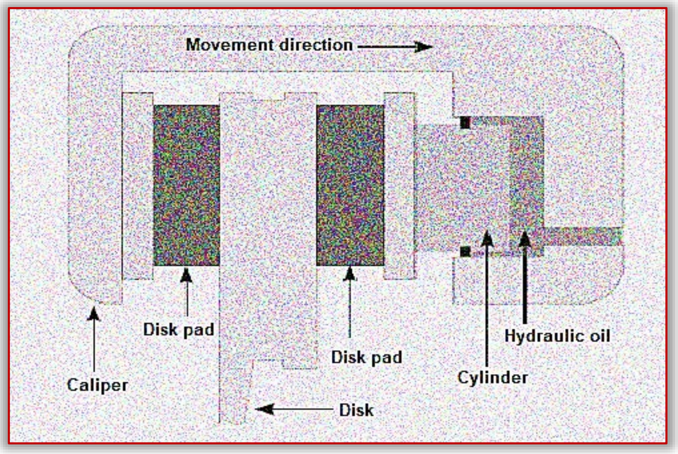

Figure 4 – Mobile disk (Rashid, 2014)

In general, inner and outer plates have different contact pressure distributions and different wear behaviors, due to the different support, drive system and the difference in thermal deformations of the internal and external surfaces of a. (Rashid, 2014)

BRAKE PADS

The brake pads are made of a rigid metal plate and a friction material as an adhesive part. The latter must withstand high temperatures, pressure and friction. The contact surface is relatively small, which means that the friction material is subjected to high pressures and forces, significant thermal loads and dynamic stresses 20 times higher than drum brakes. The friction material is the element subject to wear, which means that the brake pads require frequent replacement compared to the brake disc. They have a small surface area compared to the braking they develop (Stefan–Ionescu, 2019).

A good brake pad must meet certain thermo–mechanical requirements and develop a stable coefficient of friction. The stiffness of the friction material is relatively low, but the metal plate must be rigid to transmit the force provided by the hydraulic piston and to distribute the pressure evenly on the contact surface with the disc. This allows a uniform wear of the gasket, maintaining a constant braking and an optimal distribution of heat flow (Stefan–Ionescu, 2019).

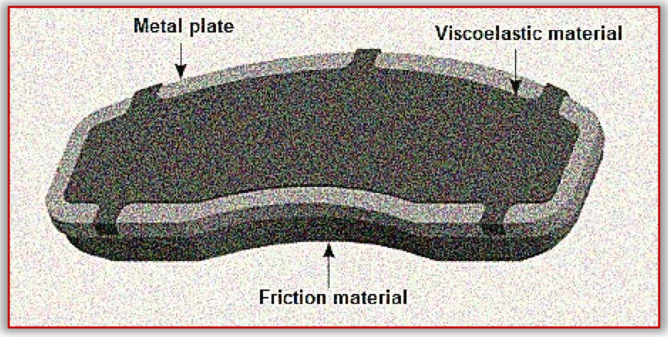

Figure 5 –Disk pad (Rashid, 2014)

In some cases, an additional layer of material, called a substrate, is added between the friction material and the metal plate, in order to absorb the vibrations resulting from the contact of the pad and the brake disc (Rashid, 2014).

The role of the metal plate is to support the friction material. They can be mounted by various methods such as adhesion, welding or clamping (Rashid, 2014).

The viscoelastic material is found between the back of the metal plate and the piston, the case of the fixed stirrup, or the metal plate and the housing of the movable stirrup. Its role is to dampen the vibrations resulting from the contact between the plate and the disc. They can be made of a steel core with a viscous coating or a viscoelastic core with a metal coating (Rashid, 2014).

BRAKE DISC

The brake disc is fixed to the wheel hub and has the same rotating motion as it. It is made mostly of gray cast iron, being very resistant to wear. In the case of high–performance vehicles, the brake disc has an aluminum or steel hub or bowl and a ceramic carbon brake pad (crown), assembled by screws (Stefan–Ionescu, 2019).

The braking power of the disc brake is determined by the speed at which the kinetic energy is converted into heat, due to the frictional forces between the plate and the disc.

The resulting heat must be removed as soon as possible, otherwise the temperature of the disc may increase and affect the braking performance (Rashid, 2014).

Thus, in order to obtain optimum performance, ventilation holes have been designed in the brake discs which increase the cooling speed.

Brake discs can be divided into two categories:

≡ solid brake disc
≡ ventilated brake discs

The solid brake disc is the most rudimentary model, while the ventilated disc has holes on the surface of the disc and / or channels between the two discs, facilitating air circulation and heat exchange with the environment. Ventilated brake discs have a higher cooling rate, so a lower surface temperature. Low temperature reduces the risk of brake fading and disc and pad wear (Rashid, 2014).

Both the solid and the ventilated disc have or do not have a mounting hub (bowl). The bowl increases the distance between the axle friction surface and the disc surface, making it easier to cool the disc and helping to protect the bearings from the high temperature wheel generated during braking operation. A schematic description of these two types of disks is shown in Figure 6. (Rashid, 2014)

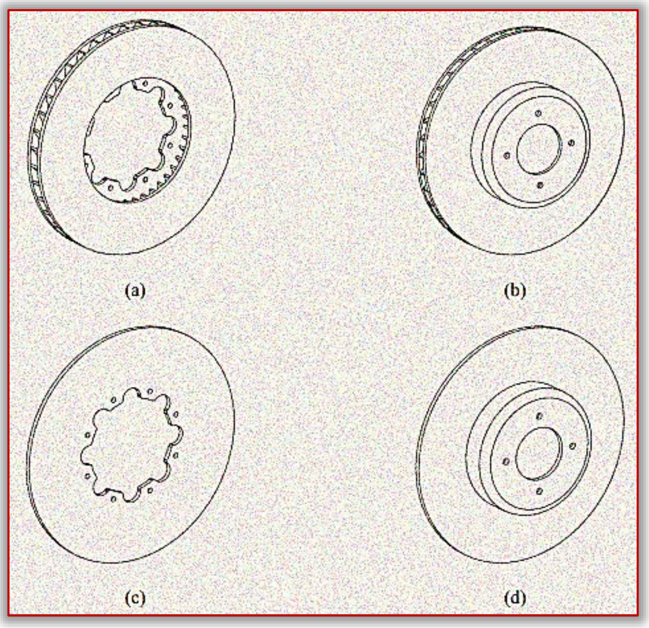

Figure 6 – Representation of different types of brake discs
a) disc with ventilation without hub b) disc with ventilation hub; b) solid disc without hub; d) solid disc with hub (Rashid, 2014)

If the bowl is not part of the brake disc, it is called a hybrid or composite brake disc.

There are different ways to mount the disc on the bowl. Figure 7 shows two methods of mounting the disc on a bowl, with a connecting element, a steel screw or a ceramic bolt. They are mounted in the radial direction of the disc (Rashid, 2014).

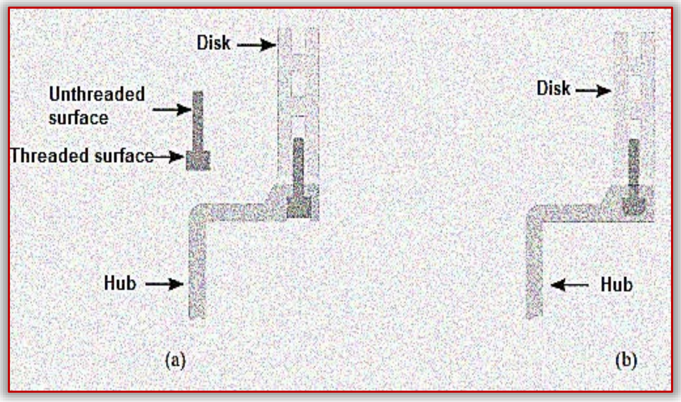

Figure 7 – Representation of the disc fixed on the hub
a) disc with ventilation without hub b) disc with ventilation hub; (Rashid, 2014)

For brake discs with ventilation, different shapes of ducts are used: radial straight, curved, diamond–shaped or teardrop, arched (Figure 8). Each configuration provides a unique airflow, but in all cases, air enters the center of the disk and is released through its outside. Due to the air circulation, high voltages can occur in the center of the brake disc, which is a disadvantage in case of heavy use (Rashid, 2014).

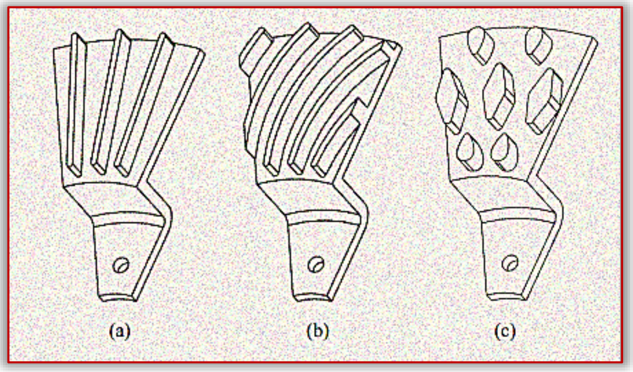

Figure 8 – Representation of brake disc ventilation ducts
a) straight; b) curved; c) diamond and tear (Rashid, 2014)

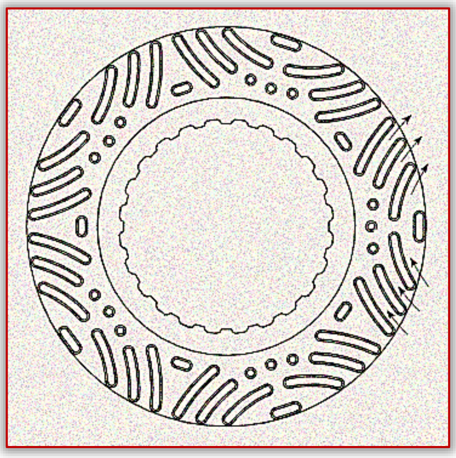

Figure 9 – Representation of airflow circulation in brake discs (Rashid, 2014)

RESULTS

Disc brakes are known to experience severe working conditions in conditions of thermal fatigue, wear and heavy mechanical loads. Among various materials, cast iron is the most widely used material in disc brakes because it has a unique combination of excellent wear resistance and higher heat transfer coefficient.

Different parameters, including alloying elements and their morphology, affect the tribological behavior of cast irons. There are several studies on the effects of alloying elements, on the wear resistance of gray cast iron. Silicone, chromium and manganese are known to have a positive influence on the wear resistance of the brake disc (Abutu, 2018).

It is expected that higher hardness and tensile strength can be achieved, in combination with a lower wear loss, by adding silicon and chromium as an alloy to the gray cast iron.

In addition to the chemistry and microstructure of the alloy, abrasion and wear test variables also have prominent attributions to the wear behavior of gray cast iron. Whether the test is performed under dry or lubricated conditions, the speed of the parts moving continuously during the test and the applied load have an effect on the wear behavior of the alloys.

For example, gray cast iron shows a much better wear resistance under lubrication conditions, obviously due to the lower coefficient of friction. It is known that gray cast iron alloys have a characteristic lubrication in themselves due to the presence of graphite particles in their microstructures. Therefore, cast iron is still by far the most widely used material in disc brakes in trains and cars (Abutu, 2018).

Given that disc brakes are an essential component of passenger safety in the vehicle, it is essential to understand the degradation mechanisms of this component.

Degradation and failure of the disc brake is very complicated due to the simultaneous contributions of mechanical loading, surface conditions and thermal stresses. The fact that the disc brakes face dynamic loading conditions makes the interpretation of the faults even more complicated. It is postulated that surface washing, formed during abrasion, creates spots that can initiate cracks. Subsequent loading causes the disk to crack and malfunction. The reason for the cracks is caused by fatigue caused by cyclic thermomechanical loading (Abutu, 2018).

As a result of the brake disc malfunction, the phenomenon of brake vibration occurs. This term refers to the uneven braking torque, resulting in fluctuations in braking force that occur during a complete rotation of the disc. These phenomena are classified into thermal trepidation and cold trepidation. Thermal shaking occurs during deceleration at high speeds, and cold shaking can occur at any speed (TEXTAR, n.d.). Thermal vibration can be defined as a resonant vibration in a frequency range between 100 and 250 Hz. Sound intensity varies throughout deceleration, but does not affect braking. These fluctuations can be felt as a vibration of the steering wheel, impulses in the brake pedal and the vibration of the chassis components.

Braking speed depends on the force applied to the pedal. Thermal vibration can usually be identified by a circular arrangement of points on the friction surface of the disk. These axles are caused by local overheating during braking, which causes the transfer of materials from the brake pad to the brake disc and / or the permanent change in the structure of the brake disc cast material. Usually, the transferred material is removed during normal braking. To prevent the risks, it would be ideal to replace the disc and not recondition it (Abutu, 2018)..

The performance of the brake depends not only on the thermal and mechanical properties of the disc friction materials, but is also affected by the topography of the contact surfaces and the third body formed as a result of wear processes (Kemmer, 2002, Österle, et al., 2008)

In addition to the causes mentioned above, there are other factors that can cause thermal shock, such as improper wheel balancing, worn wheel suspension bearing parts, steering system and incorrect front axle alignment. The trepidation is caused by multiple factors, making it difficult to identify the exact cause (TEXTAR, n.d.).

CONCLUSIONS

Disc brake is a complex system and understanding the various issues related to its design and operation requires expertise in various disciplines, e.g. tribology, materials science, fluid dynamics, vibrations, etc.

Disc brakes have evolved over the decades due to extensive research and development. There are still many phenomena that are not fully understood. For the complete and realistic analysis of disc braking systems, the further development of nonlinear finite element models, which could simulate the realistic evolution of the contact interface, is crucial.

The problems that have attracted a lot of attention from the research community are represented by the phenomena that appeared in the braking system, such as squeaking, vibrations, tremors. Due to the continuous development of disc brake systems, they have become less and less common, but the problem has not yet completely disappeared. The problem of predicting sensitivity to brake application remains a difficult task for the brake research community. (Rashid, 2014)

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