International Scientific and Professional Conference
Politehnika 2025
Belgrade, Serbia
28th November 2025

ANALYSIS OF BRAKE DRUM DAMAGE IN MOTOR VEHICLE BRAKING SYSTEMS

Dobrivoje Ćatić[1], Faculty of engineering, University of Kragujevac
Vladimir Ćatić[2], HTEC Group

Abstract: *This paper analyzes the causes and consequences of brake drum damage in motor vehicle braking systems. The introduction emphasizes the importance of braking systems for traffic safety. From the standpoint of reliability and operational safety, the brake drum represents one of the most critical components of the braking system. Failure analysis of drum brake elements requires a thorough understanding of their structure, operating principles, and parameters. As a friction pair, the brake drum and brake shoe linings are subjected to intense friction, wear, and high operating temperatures, which in turn cause different forms of damage. The paper examines the causes, mechanisms, and consequences of the most common brake drum damages, as well as possible approaches for their remediation. Improving traffic safety and reducing the operating costs of braking systems necessitate the identification of early indicators of damage. Timely detection of such damage and the implementation of appropriate corrective measures can enhance the reliability and safety of the motor vehicle braking system.*

Keywords: Motor vehicles, Brake drum, Damage analysis

1. INTRODUCTION

Braking systems in motor vehicles represent a typical example of complex vehicle systems whose structure is determined by the complex target function defined by the applicable international and national regulations on vehicle traffic safety [1, 2]. The main subsystems of the braking system are: the service brake, the auxiliary brake, the parking brake, and, in heavier motor vehicles, the supplementary brake or retarder. In motor vehicles, both service and parking (auxiliary) brakes utilize drum (radial) and disc (axial) mechanisms. Drum brakes are primarily applied in heavy-duty vehicles, whereas disc brakes are more common in passenger cars. Given their operating conditions and influence on active vehicle safety, brakes play a particularly significant role in the overall reliability of motor vehicle braking systems. Based on the Failure modes, effects, and criticality analysis (FMECA) of drum brake components in motor vehicles, it has been determined that the brake linings and the brake drum exhibit the highest criticality [3]. Criticality represents a relative measure of the severity of failure mode consequences and the frequency of their occurrence.

For a comprehensive analysis of the causes, mechanisms, and consequences of brake drum damage in motor vehicle braking systems, it is essential to examine the structure and function of the drum brake, operating parameters, component interactions, working conditions, and relevant influencing factors. The most frequent causes of brake drum damage include wear of the friction surface, elevated operating temperatures with uneven thermal cycling of the drum wall, as well as improper installation and maintenance.

[1]caticd@kg.ac.rs
[2]vladimir.catic@htecgroup.com

2. FUNCTIONING AND FAILURE ANALYSIS OF DRUM BRAKES

The brake drum shown in Figure 1 [4] represents a single-acting brake, the so-called simplex brake. The considered drum brake model operates as follows. By pressing the brake pedal, the brake fluid under high pressure from the master cylinder is delivered through metal and flexible pipes to the wheel cylinders. The high oil pressure actuates the pistons of the wheel cylinder, which act on the upper ends of the brake shoes, pressing the friction lining against the surface of the drum. The radial pressure of the shoe linings on the drum surface generates friction, which slows down the rotation of the drum and, consequently, the vehicle wheel. When braking ceases, the drum brake components return to their initial position, allowing the drum to rotate freely.

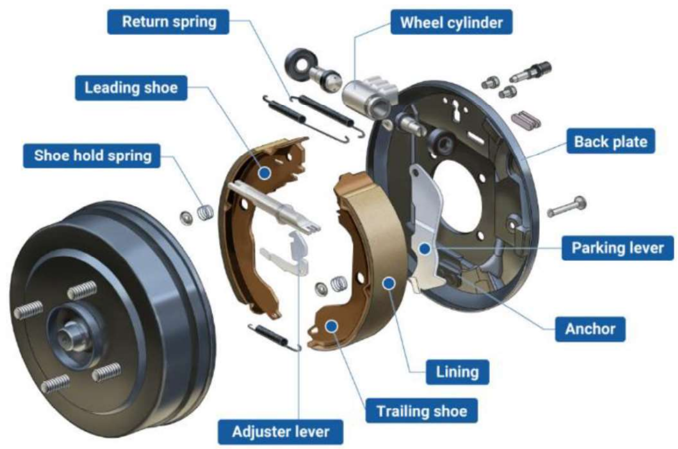


Figure 1. Components of the drum brake mechanism
Source: [4]

In the drum brake system of motor vehicles, both complete and partial failures may occur [3]. Complete failures arise when the brake is unable to generate braking torque. In the case of partial failures, the operating parameters of the drum brake (braking torque, operating temperature, braking uniformity, noise intensity during braking, etc.), are significantly deteriorated. Failures that lead to a reduction in braking torque are generally referred to as friction failures. These can be either permanent or transient. Permanent friction failures of a drum brake may occur, among other causes, due to damage to the drum or to the brake shoe linings. Overheating of the drum brake components occurs when the heat generated by converting the vehicle's kinetic energy into thermal energy exceeds the amount of heat the brake elements can dissipate to the environment. As a result of overheating of drum brake components, the following may occur: deformation of elements (drum ovality, shoe distortion), drum cracking, the appearance of blue spots and martensitic patches on the drum friction surface, brake lining damage, changes in material properties (loss of elasticity of return springs), etc. Uneven braking represents a specific type of permanent friction failure in which, in addition to reduced braking torque, brake judder during braking and pedal vibration are strongly pronounced. Brake noise arises due to the non-uniform friction process between the brake shoe linings and the drum. This generates vibrations of various frequencies, the sound waves of which may be audible.

3. CAUSES AND CONSEQUENCES OF BRAKE DRUM DAMAGE

During service, the brake drum and shoe linings are subjected to friction and wear under high thermal loads. Consequently, various forms of damage may occur, leading to a reduction in the overall performance of the braking system [5, 6, 7]. Cracked drums (Figure 2. a)) [5] are typically detected by visual inspection. The crack in the drum has an axial orientation and extends through the entire drum wall. The most common cause of drum cracking is excessive heating and cooling during operation. In addition, cracks may occur if the drum is not suitable for a particular application or in cases of driver misuse during braking (extreme braking conditions). Reduction of drum wall thickness due to wear, or due to machining aimed at eliminating observed defects, decreases the static strength of the drum and increases the likelihood of crack initiation. In the region of the drum affected by a crack, elastic deformations are more pronounced, leading to uneven pressure distribution along the arc length of the brake lining and a significant reduction in braking torque. As a result, brake vibration becomes highly pronounced. A cracked drum must be replaced, which means that this failure mode results in a complete brake drum failure.

Heat-checking (Thermal cracks) (Figure 2. b)) [6] appears as a series of narrow, short, and shallow cracks on the braking surface of the drum. They occur under normal operating conditions as a result of alternating heating and cooling of the drum's friction surface and represent a typical characteristic of drum brakes. Heat checks do not affect the braking torque of the drum brake. Due to their shallow depth, thermal cracks tend to disappear with wear of the friction surface and reappear as a normal outcome of the braking process. However, there is a possibility that heat checks may gradually develop into more severe cracks, in which case drum replacement will be required. For this reason, during routine inspections of the vehicle braking system, attention should also be paid to the condition of thermal cracks in the drum.

Oiling/greasing of friction surfaces (Figure 2. c)) [5] occurs when the drum and shoe friction surfaces become contaminated with oil or grease, either from the external environment, from brake fluid leakage in the wheel cylinder, or from grease leakage in the wheel hub due to poor sealing. Such contamination leads to a drastic reduction in the coefficient of friction and braking efficiency. If the interior of the drum brake has been exposed to contamination over an extended period, oil or grease may penetrate the drum material, causing discoloration of the braking surface. Restoration of braking performance requires eliminating the source of oil or grease, thoroughly cleaning all drum brake components, and grinding the friction surfaces. If the brake shoe linings are soaked with oil or grease, they must be replaced.

a) b) c)

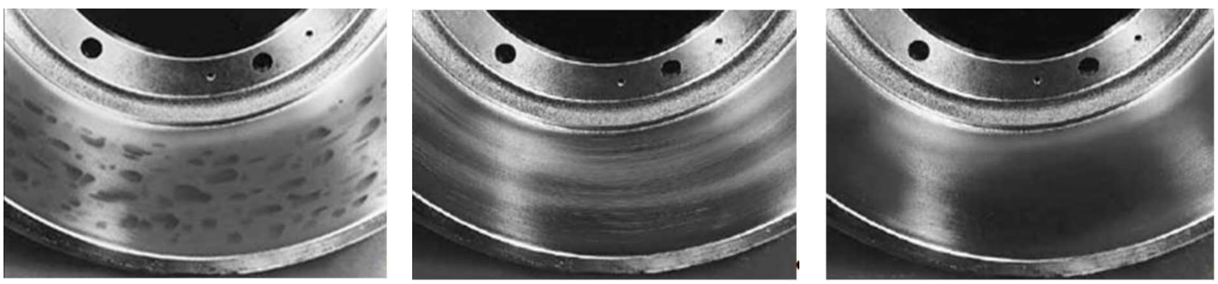
Figure 2. a) Cracked drum, b) Heat-checking, c) Oiling/greasing of friction surfaces

Source: [5,6]

Martensite spots (Figure 3. a)) [5] appear as extremely hard, slightly raised dark spots on the braking surface of the drum. The presence of such spots indicates that the drum has been exposed to operating regimes that caused structural changes in the drum material. During rapid cooling of a heated grey cast iron drum, the austenitic structure of the material transforms into martensite. This transformation is accompanied by a relative volume increase of the material, leading to the formation of raised dark spots on the drum's friction surface. The existence of these hard, elevated spots results in reduced braking torque, severe localized heating that can cause drum deformation and the initiation of surface cracks, uneven wear of brake linings, as well as vibrations and excessive noise during braking. Failure to detect martensite spots in time and to eliminate the causes of drum overheating inevitably requires drum replacement.

Scored brake drums (Figure 3. b)) [5] are characterized by pronounced deep grooves on the braking surface of the drum. Such grooves may occur due to completely worn-out brake linings, which cause direct contact between the drum and the metallic backing plate of the brake shoe, leading to severe wear. Similarly, when a friction lining cracks, fragments of the lining may become trapped between the drum and the shoe, producing grooves. At elevated operating temperatures, the hardness of the drum's sliding surface decreases, making it susceptible to abrasive wear when in contact with hard inclusions from the brake linings. In all these cases, besides the reduction of the friction coefficient between the friction elements, braking efficiency decreases, noise during braking increases, and intense abrasive wear of the drum surface occurs in the form of deep grooves. If the grooves are not excessively deep, they may be removed by machining the drum, provided that the maximum permissible drum diameter is not exceeded. Otherwise, the drum must be replaced.

Blue drums (Figure 3. c)) [5] manifest as localized discoloration of the drum's friction surface. Incomplete contact between the friction surfaces of the drum and the brake linings leads to uneven heat distribution across the surface and the formation of thermal, or so-called blue, spots. The contact areas of the drum surface are subjected to higher heating. As a result, the structure of the drum material changes and its hardness increases significantly. If the causes of blue spot formation are not eliminated, continued operation of the drum may lead to the development of martensite spots, with all the associated consequences. The presence of blue spots in a limited extent does not require machining or drum replacement.



a) b) c)

Figure 3. a) Martensite spots, b) Scored brake drum, c) Blue drum

Source: [5]

Polished drums (Figure 4. a)) [6] can be identified by a smooth, shiny braking surface. It has been observed that the problem of polished drums occurs much more frequently when asbestos-free brake linings are used. The presence of polished surfaces leads to a reduction in the coefficient of friction between the drum and the brake shoes. Once polished drum surfaces are detected, it is necessary to grind the drum and lining friction surfaces with sandpaper of appropriate grit size. In addition, when replacing brake linings, grinding of the drum's braking surface is recommended.

Out-of-round drums are indicated by variations in drum diameter at different points on the braking surface and by uneven wear of the drum and brake linings. Drum deformation occurs due to severe localized heating during braking and subsequent uneven cooling, which leads to the formation of thermal residual stresses that are superimposed on service stresses. Depending on the intensity of the total stress, plastic deformations may occur, manifested as a loss of concentricity of the drum's sliding surface and a transition from a circular to an oval shape. The extent of drum deformation is determined by measuring the diameter at different points on the braking surface (Figure 4. b)) [7]. If the maximum measured diameter of the drum's braking surface remains below the allowable service limit, the drum can be machined to restore concentricity. Otherwise, the drum must be replaced.

Excessive wear (Figure 4. c)) [7] of the drum along the edges of the contact surface between the lining and the drum may be caused by improper contact during braking due to incorrect installation or deformation of the drum or brake shoes. Wear of the drum in areas corresponding to the rivet holes of the lining occurs as a result of abrasive material accumulation in those regions. After detecting excessive wear, the first step is to identify and eliminate the cause. Subsequently, as with the presence of grooves on the drum's sliding surface, if the wear depth is within the allowable service limit, the drum can be machined to remove the damage. Otherwise, the drum must be replaced.

a) b) c)

Figure 4. a) Polished drum, b) Drum deformation, c) Excessive wear
Source: [6,7]

Oversized (worn) drums. Over time, under normal operating conditions, friction causes wear of the drum and brake shoe lining surfaces. As wear progresses, the lining thickness decreases, the drum's inner diameter increases, and the wall thickness is reduced. An increase in the drum's inner diameter up to the service limit is the most common reason for removing a drum from service. In addition, the presence of grooves on the drum's sliding surface, uneven wear around the drum circumference, loss of concentricity due to plastic deformations, and similar issues often require machining to eliminate the observed defects. However, such machining further increases the drum's inner diameter. With reduced wall thickness, the drum's capacity to absorb and dissipate heat generated during braking is diminished. This leads to a significant rise in operating temperature of the drum brake, a reduction in the coefficient of friction, further diameter increase due to thermal expansion, deterioration of the drum material's mechanical properties, and other adverse effects. Each brake drum is stamped by the manufacturer with the nominal diameter of a new drum and the maximum allowable diameter, beyond which the drum must be replaced. Figure 5. a) [5] illustrates the procedure for measuring the inner diameter of a brake drum. Mounting ring cracking (Figure 5. b)) [6] can be identified by the presence of fractures or cracks along the circumference of the drum's mounting surface. This defect occurs when interference exists between the contact surfaces of the hub and the drum. The most common causes of cracks in the mounting ring are improper drum installation on the hub during assembly, hub damage, or the accumulation of dirt and corrosion on the hub surface. In addition, if an inappropriate drum is installed, with a smaller mounting ring diameter than the hub's supporting surface, mounting ring damage may occur. Radial cracking of the bolt holes on the mounting surface (Figure 5. c)) [6] occurs due to the same causes already described for mounting ring cracking. If any cracks are detected along the circumference of the drum's mounting surface or around the bolt holes, the drum must be replaced. Before installing a new, suitable drum, it is necessary to visually inspect the hub's supporting surface and eliminate any defects by cleaning the hub or replacing it if required. In addition, during drum installation, it must be ensured that the mounting surface of the drum fits properly and evenly onto the hub's contact surface. Based on the previous analysis of brake drum damage, it can be concluded that the observed damages affect the operational capability of the component in different ways. Depending on the type and extent of the brake drum damage, a decision is made whether the brake drum needs to be replaced or whether repair is possible through appropriate maintenance measures.

a) b) c)

Figure 5. a) Oversized (worn) drum, b) Mounting ring cracking, c) Radial cracking of the bolt holes
Source: [5,6]

4. CONCLUSION

The results of the analysis of the causes, mechanisms, and consequences of brake drum damage can be utilized in several ways: for product development aimed at eliminating observed deficiencies and continuously improving quality; for preparing sections of user manuals related to the braking system of motor vehicles; for failure diagnostics and for defining criteria to support decisions on whether a damaged drum must be replaced or can be repaired; and for developing maintenance instructions and planning maintenance measures during service. A comparative analysis of the failure modes and consequences of elements from different brake drum designs and different brake lining materials can be applied to the selection of the optimal solution for specific operating conditions. Reliable and safe operation of a brake drum presupposes that: the quality of its components complies with design documentation, the assembly of brake elements is performed properly and the maintenance of the braking system is carried out by qualified personnel using appropriate equipment and original spare parts.

This research was supported by the Faculty of engineering, University of Kragujevac [grant number 451-03-137/2025-03/200107, dated February 4, 2025].

LITERATURE

[1] Edited by Crolla, A. D.: *Automotive Engineering Powertrain, Chassis System and Vehicle Body*, Published by Elsevier Inc., 2009.
[2] Day, A.: *Braking of Road Vehicles*, Published by Elsevier Inc., 2014.
[3] Ćatić D., Glišović J., Miković J., Veličković S.: Analysis of failure causes and the criticality degree of elements of motor vehicle's drum brakes, *Tribology in Industry*, Vol. 36, No. 3, pp. 316-325, ISSN 0354-8996.
[4] Drum Brakes, [Internet] Available on: https://shorturl.at/ZnJno , (Accessed: 10.06.2025.)
[5] Maintenance and Installation Manual, [Internet] Available on: https://shorturl.at/S7Rdz, (Accessed: 25.04.2025.)
[6] Brakes - troubleshooting guide, Brake Drums, [Internet] Available on: https://tinyurl.com/4uh4dymr , (Accessed: 30. 04. 2025.)
[7] Common Drum Problems, [Internet] Available on: https://tinyurl.com/sj7xjdz4 , (Accessed: 30.04.2025.)