ANNALS of Faculty Engineering Hunedoara
– International Journal of Engineering
Tome XIII [2015] – Fascicule 3 [August]
ISSN: 1584-2673 [CD-Rom; online]
a free-access multidisciplinary publication of the Faculty of Engineering Hunedoara

[1.] Andrei CRĂCIUN

# EVOLUTION OF MATERIALS FOR MOTOR VEHICLES BRAKE DISCS

[1.] University Politehnica Timişoara, Faculty ofEngineering Hunedoara, ROMANIA

**Abstract**: At the end of the 19th century appearance of the first automotive assembly required development of different components of their braking systems. Historically, the first material used in the production of automotive brake discs were gray cast iron with the following properties: good diffusivity and thermal conductivity, corrosion resistance, abrasion stability, low weight, low noise, durability, operational and low price. From a technological standpoint, over time, they have been made a large number of experiments, especially with the beginning of the Second World War. Therefore, for more than one hundred years, have seen more materials intended to meet all these features, but until now the most used material in large scale production of brake discs was still the gray iron. The paper presents the evolution of materials used in making brake discs and order research in the composite material and the positive implications of their use in the automotive industry.
**Keywords**: automotive brake discs, materials, evolution of materials, composite material

## 1. INTRODUCTION

The automotive industry is an economic sector that uses products obtained in all other industries ( metallurgy, chemistry, electronics, textiles, etc.) and the main consumer for most of them. On the other hand, during the operation, the vehicle is a major consumer of petroleum products and industrial fluids. Because of this, the automotive industry is the largest consumer of materials in economy.

However, competition in this area and the requirements imposed on motor vehicles requires mastering the properties of materials, development of new materials and technologies processing, in order to increase performance and operational safety, adapted to market requirements.

In order to meet the demands manifested in the quality, cost and performance vehicles, current concerns are directed towards the recovery of the latest research in materials and modern technology in all areas which contribute to achieving vehicle. By using new materials and the application of modern technologies in the design, manufacture and testing of motor vehicles shall ensure:

- improving the efficiency of engines and transmissions;
- reduction of pollutants in the exhaust gas components;
- obtaining parts as small weight, rigidity and high resistance to wear;

## 2. THE STUDY OF THE PROBLEM

The main function of brake systems is to reduce vehicle speed to a desired value or to stop it. This is accomplished by converting kinetic energy into heat by friction process and dissipation him effectively by the braking system components.

Many parts of the composition of vehicle actively or passively contribute to increasing their required performance. Safety is closely linked to the effectiveness of the braking system, which is one of the most important component of a vehicle. The correct operation of braking systems is essential, both for the safe of transports and passengers. During operation the vehicles, brake system components require brake discs that are constantly undergo thermal and mechanical deformations relatively high, which in time can lead to intense wear, formal changes or deterioration of this. Also, the braking torque is influenced by a number of random factors, such as: weather conditions and type of surface which the vehicle runs. The vehicles braking system consists of several components, figure 1,[1].

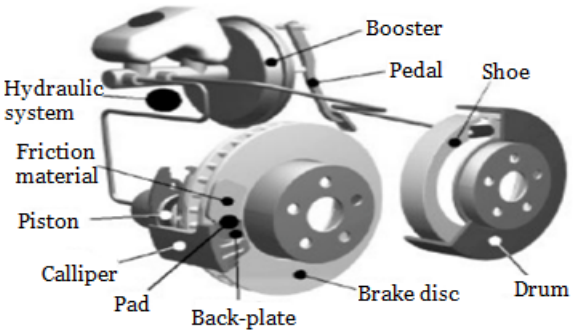
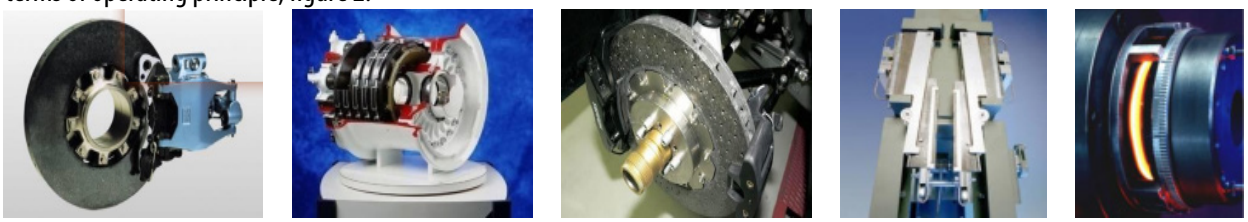



**Figure 1.** Components of the braking system of vehicles.[1]

Braking systems are not only found in all vehicles, but also embedded in other machinery, which serving various technological processes specific to several industries. Regarding construction brake discs, there are several constructive forms, but all are similar in terms of operating principle, figure 2.



train plane vehicle elevator slide bridge

**Figure 2**. Brake discs used in the braking systems, [1]

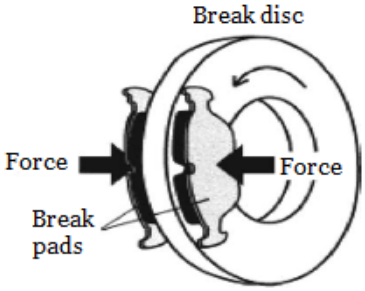



**Figure 3**. The principle of operation of the brake discs, [2]

The most importatnt component in the braking system is the brake disc. The main functions of the brake discs are sending a considerable mechanical force and heat dissipation obtained during the operation, figure 3, [2].

During deceleration the brake disc temperature and brake pad assembly can reach values close to 650$^0$C, it depends on the severity and the number of brakings. Overheating disk-plate assembly can have serious consequences, reducing braking safety systems, [2].

For this reason, the materials used in the making of the brake disc should present a high heat capacity and diffusivity, as well as a low density. They also must provide a good coefficient of friction, stable mechanical characteristics at high temperatures in humity and high wear resistance. In the selection of materials for brake discs the most importatnt is the thermal diffusivity and thermal conductivity because the discs must perform simultaneously transfer and heat dissipation by converting the kinetic energy into thermal energy, [3]. Thus, the brake disc is created in temperature gradients which can lead to the phenomenon of thermal fatigue. In addition, during braking, the brake disk is exposed to a mechanical load cyclically applied by the brake pads, which leads to wear of the two components (disc plate). Therefore in normal conditions disc is exposed to fatigue loads, [4].

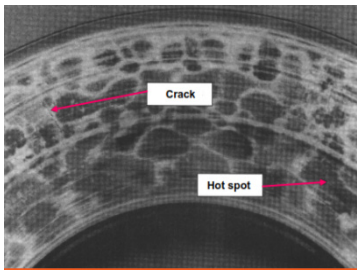



**Figure 4**. Thermal fatigue cracks on the surface of a disc brake made of grey cast iron, [2]

The brake disc can be subjected to three types of fatigue: thermal (where component is subject to abrupt temperature changes only without load), isothermal (where the temperature and load are stable) and thermo (temperature and load are variable) [5] . Most importantly to represent the best condition during braking disc is thermomechanical fatigue where maximum load is applied when the temperature is the lowest possible, and variable. Sudden changes in temperature may cause localized heating or can lead to thermal shock, which causes behavior change brake disk material due to structural changes. They either may cause occurrence of cracks on the surface of the disc, or the occurrence of residual internal stress upon cooling, figure 4, [2].

All of them require analyzes, studies and research on materials and technologies used in the manufacture of brake discs.

## 3. ANALYSIS, DISCUSSION, APPROACHES, INTERPRETATIONS

Automobile history began in 1700 when Nicholas Cugnot convinced the King of France to finance his project, a vehicle of 10 tonnes for towing cannons. The vehicle run with 10 km / h and was powered by a steam boiler. On the first trip, the inventor realized that did not provide a solution to stop it, which is why his vehicle hit a wall, so the first accident took place. However merit inventor could not be ignorant, [6].

Around 1886, Gottlieb Daimler and Carl Benz changed history, inventing, independently of one another, the first prototypes of cars with internal combustion engines, which were produced only effective after ten years, [6].

At the end of the 19th century, thanks to the appearance of many automobiles, components development has imposed them, both in terms of materials used and in terms of their geometrical shape.

The inventor of the first material embedded in the brake lining was Herbert Frood in 1897. The material was made of cotton impregnated with a solution of bitumen was used both to train wheel and the wheels of the first car. This invention led to the establishment of the foundation of Ferodo Company, which produces materials for braking until today, [6].

The first disc brake was created in 1902 by an english engineer, Frederick William Lanchester. It describes the rotor as a metal plate rigidly connected to the rear wheels of the vehicle, having claws pressed against the edges [6]. This period highlights a major

development of new technologies for the production of brake discs. The first companies who introduce these new technologies was Mercedes and Renault, [7]. Table 1 presents chronologically, the evolution of the materials used to build the brake discs, [6].
During the twentieth century-the first brake disc created in 1902 has been continuously improved, both in terms of material and in terms of performance.
The evolution of automotive brake discs was marked by Dunlop Gridlingand Lockhed Corporation, whose products are similar to those records today, [6]. The first material of which were made brake discs was gray iron that meets all requirements in terms of: thermal conductivity, thermal diffusivity, corrosion resistance, durability in operation, low noise, stability friction, low wear, price low cost. Over more than 100 years we have developed numerous materials that were created in order to improve brake performance. However, many of these have proved to be ineffective, the only material which has been preserved to these days was gray cast iron.

**Table 1.** Evolution chronological used to build materials from the brake discs,[6]

| Material description | Application(s) | Approximate year |
|---|---|---|
| Cast iron on steel | used in blocks and other components of railroad car brakes | 1870 |
| Cotton or hair (straps) | cart wheel and the first automobiles | 1897 |
| Asbestos tissue and other wires to increase strength and performance | trucks and automobiles | 1908 |
| Bronze particles with low ash content bituminous coal, produced with internal reinforcement of short fiber | trucks and automobiles | 1926 |
| Material molded from a dry mixture of post-metallic to replace the fragile cast iron brake pad on electric trains | London subway | 1930 |
| Flexible resin developed with agglutinant elements more intricately formulated | drum brake reinforcement | 1930 |
| Metal alloyed with resin | for aeronautic industry use | 1950 |
| Glass, mineral, metallic, carbon, and synthetic fibers to give semi-metals better performance than amianthus (beginning of the discussion aboutamianthus safety) | automobiles and trucks | 1960 |
| Compounds without amianthus | drum brakes and car equipment | 1980 |
| Suggestion of carbon fiber use | automotive brakes | 1991 |

Cast iron is a traditional metal material containing 2 <C <4.5%, shows high resistance to high temperatures, a relatively low manufacturing cost, but because of its large weight increases brake discs, which implies consumption of large quantities of fuel in the operation of vehicles due to large inertia. Discs made of cast iron is obtained in foundries which must be strictly controlled as the chemical composition and cooling process to route the shape, distribution and excess carbon precipitation [6]. They ensure minimizing distortions of processing, good wear characteristics, low vibration and high resistance to cracking, the subsequent use.
Irons provide excellent thermal conductivity, which facilitates dissipation of heat generated by friction brake pads during braking and good vibration damping capacity. One is how to make heat transfer capacity is to increase the thermal diffusivity, which is fundamental to the design parameter brakes. Thermal diffusivity may be used to calculate the thermal conductivity, which is a measure of the transfer of heat is made. Brake discs with improved thermal conductivity have a considerable increase in the resistance to thermal fatigue, which makes it possible to increase their lifespan, [8]. Currently, gray cast remained the most used material in the manufacture of brake discs as it presents the best price / quality ratio.
In general, materials used to build the brake discs must have the following properties: good thermal diffusivity, high thermal conductivity, corrosion resistance, abrasion stability, low weight, low noise operation and sustainability as a low cost price. The chemical composition and geometry of the brake discs influence their sustainability because they have influence over brake on the transmission of heat flow implications on the ability of vibration attenuation, noise and produce sharp wear.
To have these properties was considered appropriate combination of several materials with different properties in different proportions; thus the composite materials [9]. The initial goal of achieving composites was less competitive classic material whose properties of strength and stiffness could not be improved by other means, this being achieved by the introduction in their structure some form of reinforcement fibers, [9].
In recent decades much attention was given to improving performative brake discs on their behavior when friction brake pads. This effort has led to the development of materials such as ferrous copper alloys, aluminum matrix composites, carbon composites, [9].
The composite material is a combination of two or more constituents of the same type, or different, from physical and chemical point of view. The materials retain their separate identity in the final composite. Their combination offering its properties and characteristics different from those of constituents, figure 5, [8].

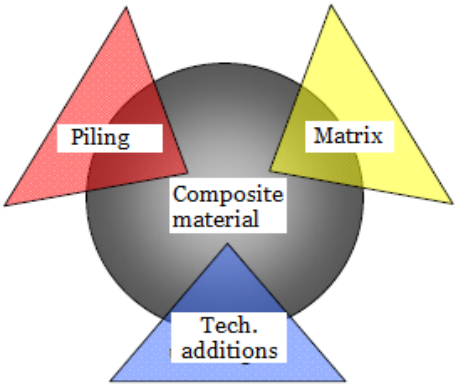



**Figure 5**. The structure of composite materials, [8]

Composite materials are designed to meet the requirements in terms of [9]: resistant to chemical agents, resistance to corrosion, mechanical strength and rigidity, resistance to varying loads, shock resistance and wear resistance, dimensional stability, and not lastly low weight. Their main advantage is the high ratio between strength and weight density [8]. These features not only ensured the widespread use of these materials, but have stimulated research for discovery of new types of materials with improved properties.

Materials that can enter to the structure of composites are plastics, synthetic fibers, glass fibers, carbon, boron, wood fiber, metal, cellulose, etc. metals such as Ni, Co, Al, Cr, Ti, W, Ta, Zr, Mo, [9].

Research conducted to date shows that titanium alloys provides a lower weight brake discs, approximately 37% lower than those of the same size made of cast iron and also good resistance to high temperatures, but the price manufacturing is high, [5].

The literature discloses that aluminum matrix alloys do not dissipate heat as well as gray cast irons, leading to construction of the brake disk with a larger surface, losing the advantage of low weight,[6].

With regard to composites of aluminum-metal matrix reinforced with ceramic particles, which have a low-density, high thermal conductivity, low weight, approximately 50-60% as compared to gray cast iron, due to the low density of aluminum, [9 ].

Nowadays there are over 2 000 types of materials used in the production of brake discs. In the automotive industry, these materials increase the reAl-Cu matrix composites reinforced with SiC have a hardness and superior wear resistance of cast irons. Due to the low density they have a major advantage in producing brake discs, ensuring fuel efficiency during braking due to relatively low inertia, but their price of manufacturing is high, [6].

The literature includes studies about possibility of producing truck discs with a cheaper cast iron alloy with high thermal fatigue strength. They used prototypes of different alloys with variable quantities of elements and some of them had nichel and cerium inoculated. They verified the connection between the material thermal fatigue strength, its physical and mechanical properties, and its corresponding microstructure. They noticed that the higher graphite quantity is distributed on a matrix with refined grains, the lower the crack propagation rate is, and that the number of graphite flakes increases with nickel addition and some cerium inoculation. They also observed that the thermal fatigue limit is not severely affected by the number of cycles before the beginning of the crack, but after it. From this survey, a low cost brake discs alloy was developed, equivalent to the one used nowadays, [2].

The goal of research in composite materials is to achieve the following objectives:

1. Investigation of the basic characteristics of the components and composite materials as a whole;
2. Optimizing materials for specific operating conditions;
3. The development of manufacturing technologies and study their influence on the material properties;
4. Development of analytical procedures for the determination of material properties and behavior prediction parts during operation;
5. Development of experimental assistance of parts and decline in vehicle weight, which translates into lower fuel consumption and increase performance. Figure 6 shows different embodiments of the brake disc of composite.
6. Nondestructive material integrity and operational safety;
7. Findings sustainability, life cycle and how the occurrence of defects.

- disc brake type DRL | -brake disc type Schunk Kohlenstofftechnic | - disc brake type SGL | - disc brake type Brembo

**Figure 6**. Ventilated brake discs made of composite materials,[7]

Overriding concerns and achievements of the high-performance composite materials in all developed countries, due to the desire to continue the process of technological development through the use of higher quality materials and made possible through the efficient and clean processes and technologies, [6].

Figure 7 illustrates composite materials consumption by 2010 worldwide, compared with traditional materials or natural products [2].

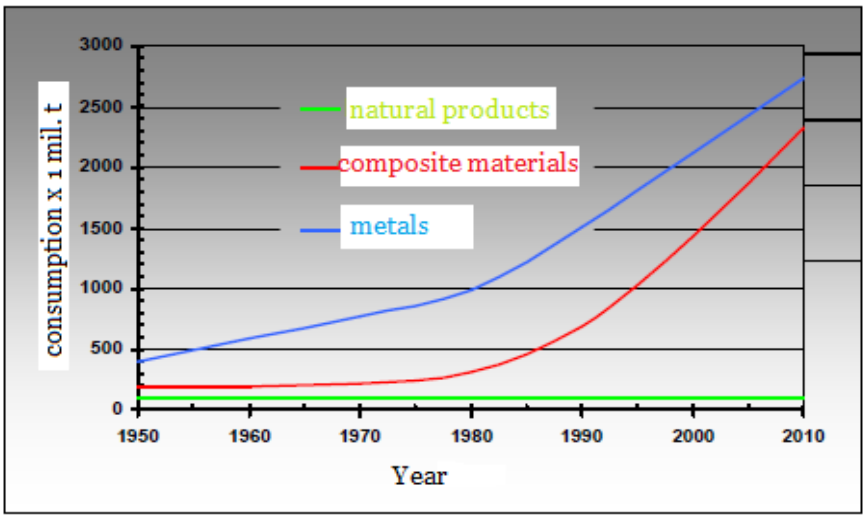



**Figure 7**. Composite materials consumption in worldwide, [2]

Traditional materials used in vehicle design have been studied in time, so today we know their characteristics, advantages and disadvantages. Technological problems that can not be adequately resolved by using these materials as resources issues, how to achieve economic aspects have led researchers in the field of road vehicles to seek special materials to replace those classics. A study by experts at the request of a Japanese car manufacturing companies main conclusion that: "companies that do not take measures to replace traditional materials with new ones will not be able to compete" [8].

The selection process for achieving brake disc material is difficult due to the large number of parameters that must be met simultaneously.

## 4. CONCLUSION

Following the study conducted on the development of materials technologies in the automotive industry following conclusions:

- Competitiveness in the automotive industry, requires obtaining new products that provide high parameters in operation, resulting in achieving a more efficient and reliable vehicle;
- Automotive industry development generates a impulse for other industries;
- In the automotive industry, the use of composite materials leading to increased resistance, while decreasing their weight, this translating to reducing fuel consumption and increasing performance;
- Composite materials do not occur naturally, but are artificially created to respond to well-defined requirements;
- Through an appropriate choice, both qualitatively and quantitatively constituent materials can be made of composite materials with superior properties of traditional materials;
- Share in the automotive industry have metallic materials, but forecasts show that these materials will be replaced by composite materials;
- Car brake discs shipments are still gray cast iron products that offer the best price / performance ratio even after receiving additional alloying elements.

## REFERENCES

[1.] BREMBO. Il manual del disco freno. 1997. Capítulo 2.
[2.] MACKIN, T. J. Thermal cracking in disc brakes. Engineering Failure Analysis, February, v. 9, n. 1, p. 63-76(14),2002
[3.] JIMBO, Y.; MIBE, T.; AKIYAMA, K.; MATSUI, H.; YOSHIDA, M.; OZAWA, A. SAE International. SAE 900002, 1990. p. 22.
[4.] METZLER, H. The brake rotor-friction partner of brake linings. SAE Technical Papers, no. 900847, 1990
[5.] CHAPMAN, B. J.; MANNION, G. Titanium-bearing cast irons for automotive braking applications. Foundry Trade Journal, v. 23, p. 230-246, 1982
[6.] WYCLIFFE, P. Friction and wear of Duralcan reinforced aluminum composites in automotive braking systems.SAE Technical Papers, n. 930187, 1993.

[7.] YAMABE, J.; TAKAGI, M.; MATSUI, T.; KIMURA, T.; SASAKI, M. Development for disc brake rotors for trucks with high thermal fatigue strength. JSAE Review, v. 23, p. 105-112, 2002
[8.] SAKAMOTO, H. et al. Heavy-duty brake disk for high speed trains (in Japanese with English summary). Technical Report of Sumitomo Metal Industries, Ltd., v. 45, n. 6, p. 11-29, 1993.
[9.] Terciu,M., Curtu, I., Tendințe în utilizarea materialelor moderne la componentele auto interioare, Buletinul AGIR nr. 1/2011 ianuarie- martie pg. 60

ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering

copyright © UNIVERSITY POLITEHNICA TIMISOARA, FACULTY OF ENGINEERING HUNEDOARA,
5, REVOLUTIEI, 331128, HUNEDOARA, ROMANIA
http://annals.fih.upt.ro