Manufacturing Brake Pads Using Locally Sourced Economical Materials

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Abstract

The aim of this work is to manufacture brake pads from a local ecological eco-material. The most commonly used materials in brake linings are asbestos, metals, and ceramics. However, asbestos releases hazardous gases upon application, making it carcinogenic. For the production of this eco-material, the powder molding technique is used. The brake pads were produced using dune sand as the base material, following the standard procedure used by manufacturers, with the aim of exploiting the chemical and physical characteristics of dune sand, which is abundant in the Algerian desert. This represents 70% of the brake pad production, in addition to 30% of polyester resins in compression molding. The properties examined were microstructure analysis, compression strength, roughness, temperature testing, and water absorption. The preliminary results show that sand can be used as a material in brake manufacturing. The results obtained in this work were compared to those of other studies and commercial brake pads and showed a close correlation, indicating that sand can be used in brake pad production.

Keywords: Design, Brake pads, Molding, Lining, Materials.

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1. Introduction

Brake pads are essential components of braking systems used in modern automobiles. They are often made from materials such as asbestos, metals, or ceramics. However, the use of asbestos is now avoided due to its carcinogenic properties. Brake pads are designed to convert kinetic energy into thermal energy through friction, which allows the vehicle to slow down or stop (Zhang W. et al., 2019; Banerjee R. et al., 2017).

The two most common types of automotive brakes are drum brakes and disc brakes. Drum brakes are housed within a drum, while disc brakes are exposed to the environment. Brake systems have made great progress in recent decades, and car manufacturers are continuously seeking to improve the performance of their brakes.

Standards for brake pads vary by country and local regulations. In general, brake pads must meet certain requirements in terms of performance, safety, and the environment. For example, in the United States, Federal Motor Vehicle Safety Standard (FMVSS) No. 105 establishes minimum requirements for brake performance on passenger vehicles, while in Europe, brake pads must comply with the ECE R90 standard, which defines requirements for brake safety and performance (Liu B. et al.,2018;Ziegler M. et al., 2018).

When it comes to brake pad performance, some important characteristics to watch for are the coefficient of friction, lifespan, heat resistance, thermal stability, and performance in wet conditions. For example, in Europe, brake pads must have a minimum coefficient of friction of 0.35 to comply with the ECE R90 standard (Wu X. et al., 2019;Jiang, L. et al., 2022).

It is important to note that standards and requirements can vary depending on the type of vehicle and intended use. For example, racing vehicles may require brake pads with higher performance than standard touring vehicles.

The most commonly used materials for brake discs are steel and grey cast iron, but these materials may not always be suitable for high loads. Therefore, car manufacturers are looking to find more performance-enhancing brake disc materials, such as composites and ceramics (Zou, Y. et al.,2022).

The production of brake pads using eco-friendly materials is a process that uses environmentally friendly materials to replace traditional components that often contain harmful chemicals. The eco-friendly materials used for brake pad production may vary, but often include materials such as bamboo fibers, wood powder, coconut shell, recycled textiles, and bio-resins (Zhan, Y. et al., 2022 ; Chen, Y. et al., 2022; Dong, X. et al., 2022).

In this context, research is being conducted to create brake pads from innovative, environmentally friendly eco-materials. For example, sand dunes have been used as a base material for brake pad production, leveraging the physical and chemical characteristics of this material that is abundant in the Algerian desert (Tafraoui, A. 2009; Agha , N. et al.,2023;Zouini, R. et al.,2023).

The properties of sand-based brake pads have been examined and compared to those of commercial asbestos-based brake pads. The results showed a close correlation, indicating that sand can be used in brake pad production. In addition to their low density and high wear resistance, these innovative local materials also present an optimal cost for consumers and manufacturers.

In summary, the search for alternative materials for brake pad production is ongoing to improve performance and reduce environmental impact. Local and innovative eco-materials offer sustainable solutions for the automotive industry and contribute to a more responsible use of natural resources.

2. Experimental program

2.1 Materials

- The materials used in the formulation of a brake pad, (figure 1), (figure 2).
- Silicones and their hardener.
- Dune sand from the Western Erg region of Bechar, with chemical and physical characteristics (shows in tables 1 and 2), (figure2).
- Ground dune sand with a fineness modulus of 0.8 (S.D.B) (figure2);
- Ground red clay (A.B) (figure2).
- Binders (accelerated isophthalic polyester resin) (figure 2).

a b

Fig. 1 - Materials used in casting; a: Silicone, b: Hardener.

a b c d

Fig. 2- Materials used in Formulation; a: Resin, b: Red clay, c: Dune sand (SD),

Table 1 -Chemical characteristics of dune sand in %.

Oxides	SiO_2	AL_2 O_3	Fe_2 O_3	MgO	CaO	Na_2O	K_2O	SO_3	Fire loss
(%)	97.33	0.830	0.24	0.41	0.07	0.09	0.04	0.18	0.40

Table 2- Physical characteristics of dune sand.

Specific surface	Average size, D50(µm)	Real density	Hardness

BET(cm2/g)			
115	200	3	7

Table3- Chemical characteristics of crushed dune sand.

Oxides	SiO_2	AL_2O_3	Fe_2O_3	MgO	CaO	SO_3	K_2O	CI	Na_2O	Ti O_2
(%)	87.65	1.02	0.75	0.25	0.29	0.02	0.03	0.018	0.06	0.04

Table 4- Chemical characteristics of clay.

Oxides	SiO_2	AL_2O_3	Fe_2O_3	MgO	CaO	SO_3	K_2O	CI	Na_2O
(%)	54.64	16.82	5.64	1.73	6.88	0.05	2.47	0.018	0.05

2.2 Methods

2.2.1 Formulation

Brake pads are critical components of a vehicle's braking system, and their formulation depends on many factors such as the type of vehicle, weight, type of braking system, required performance, driving conditions, etc. However, generally, brake pads are made from composite materials, which may include the following elements:

Friction material: The outer layer of the brake pad is typically composed of a friction material, which is responsible for generating braking force. Commonly used friction materials include ceramic, sintered metal, carbon-ceramic, carbon-carbon, etc.

Backing material: The backing material is used to hold the friction material in place and to provide a solid base for the brake pad. Commonly used backing materials include fiberglass, carbon fiber, steel, etc.

Other additives: Additives such as lubricants, bonding agents, reinforcement materials, etc., may be added to enhance the properties of the brake pad, such as durability, corrosion resistance, thermal conductivity, etc… (Collignon, M. et al., 2013;Chang, Z. et al., 2021).

It should be noted that the exact formulation of brake pads varies depending on the manufacturer and car model, and it is therefore important to follow the manufacturer's specifications to ensure optimal performance and maximum safety. The formulation used is presented in Table 5.

Table 5- Formulation of molding sand.

Materials	Resin(%)	dune sand (%)	crushed dune sand (%)	red clay (%)
SD	30 à 35	71.42	/	/
SDB	35 à 38	/	63.68	/
RC	40 à 43	/	/	58.55

To prepare the mixture for molding, we slowly mix the material with resin (dune sand, crushed dune sand, clay) in order to avoid the formation of lumps and ensure that the material is

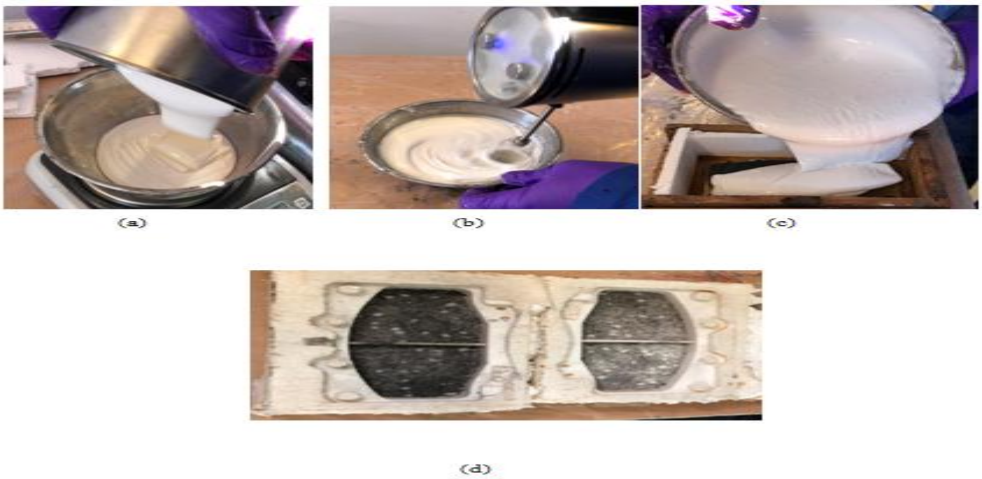

Fig. 3- Realizations of silicone molds outside and inside.

completely moistened to guarantee a certain permeability during degassing. Once the mixing is complete, we retrieve the material and place it in a tray. At this point, the material is ready to be used for molding.

2.2.2. Making silicone molds

The manufacturing process may vary depending on the materials used, but it generally starts with the preparation of the material mixture. The materials are mixed until they are homogeneous and the mixture is poured into molds for the production of brake pads. Then, polymerization is carried out at a high temperature to harden the materials and make them solid.

We made wooden molds with a thickness of 25 mm and dimensions of 145 mm long by 85 mm wide. Afterwards, we placed brake pads on their outer side before proceeding with the preparation of a homogeneous mixture of silicone and hardener (figure 3a and 3b). Then, we poured this silicone mixture into the wooden molds on the outside and on the inside (figure 3 c , figure 4 a) and left them to rest for 24 hours before removing the molds (Figure 3 d, figure 4 b).

(a) Brake pad model (b)Silicone Brake Pad Mold.

Fig. 4 - Results of silicone molds outside and inside.

2.2.3. Manufacturing of a brake pad

Depending on the chosen formulation, we mix different materials such as dune sand, crushed dune sand, or clay until the mixture is homogeneous (figure5b). Then, we pour the cold mixture into the molds (figure5c) and let it rest for 24 hours. After removing the pads from the silicone molds, we obtain the finished product (figure5e).

(a) (b) (c)

(d) (e)

Fig. 5- Manufacture of a brake pad.

Alternatively, we have manufactured brake pad linings without the base or backing plate (figure6, 7). The preparation of the material mixture is the same as in the first experiment, but this time we use an oven at 175 degrees for the polymerization of the composite resins (figure8) (Hu, K. et al., 2020; Wicker, P. et al., 2009). After this, we apply a special glue on the linings and backing plates (figure9), and then assemble the available pieces to bind the brake pads together in a cross shape, inside a metal mold (figure10). Next, we place the mold in an oven at 220 degrees for one hour for the bonding process. Figure 11 shows the final product.

Fig. 6- Brake pad linings.

Fig. 7 -Base or backing plate.

Fig.8- Polymerization oven.

Fig. 9 - Application of the glue.

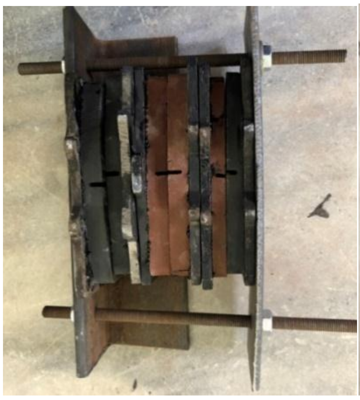

Figure 10- Clamping support.

Figure 11- Finished brake pads.

Another method for producing eco-polymer brake pads involves placing the brake pad supports into silicone molds (figure 12), then pouring in the polymer made from the studied materials and polymerizing it at 175°C (figure 13) (TP.,1959).

Fig. 12-Brake pad backing plate. **Fig. 13**- Polymerization.

Fig. 14- Grinding of brake pads.

Once the brake pads are manufactured, they must be tested to ensure they meet quality and safety standards (limpert, R. et al., 1992). Brake pads must be able to withstand heat and friction forces during braking, while offering efficient braking performance and a reasonable useful life (figure 14).

The manufacture of eco-friendly brake pads is a more environmentally friendly alternative to traditional brake pad manufacturing methods. Eco-friendly materials are often more durable and have a reduced environmental footprint compared to traditional materials.

2.2.4. Tests

2.2.4.1. Compression strength

The compression strength test method for brake pad samples involves using a tensile testing machine to apply an increasing load on the sample until it breaks or deforms permanently. The maximum load sustained by the sample before breaking is recorded to evaluate the compression strength of the material. However, it should be noted that compression strength is not the only important factor for overall brake pad performance, as other characteristics such as friction and thermal conductivity also play an essential role [Huang, J. et al.,2020; Jiang, L. et al., 2020).

Table 5 summarizes the measured mechanical resistance values obtained in bending and compression for the 3 mixtures.

Table 5 - Mechanical strengths of the mixtures.

Materials	S.D	S.D.B	A.B
Bending (MPa)	25.64	45.11	34.71
Compression (MPa)	107.28	114.0	129.6

2.2.4.2. Water absorption test.

The samples were weighed on a digital balance and immersed in water at room temperature for 24 hours. The samples were then removed, cleaned, and weighed again. The water absorption rate was calculated as follows:(Deepika .et al 2013; Wu, X. et al.,2021).

Water absorption = $\frac{M_2-M_1}{M_1} \times 100\%$ (1)

oùM_1= Sample mass (g),

M_2 = Sample mass after water absorption (g).

Fig. 15- Capillary absorption test.

Table 6 - Results of water absorption of brake pads.

Materials	S.D	S.D.B	A.B
Bending (MPa)	25.64	45.11	34.71

Compression (MPa)	107.28	114.0	129.6

It appears that the results of the capillary absorption test did not show a significant difference. This may indicate that the brake pad linings are not capable of absorbing water, as they are made of resin and do not contain any absorbent materials.

However, it should be noted that capillary absorption is only one aspect of brake pad performance, and there are other important characteristics such as wear resistance and friction that can also affect their operation. Therefore, it is important to evaluate the overall performance of brake pads using a comprehensive range of tests and evaluation criteria.

2.2.4.3. Roughness testing

Medium roughness Ra:

Arithmetic mean deviation refers to the average deviation of all points on the roughness profile from a mean line over the length. In other words, it is the average difference between peaks and valleys (Szymański, P. et al., 2020; Maniana, M. et al., 2017).

$$Ra = \frac{1}{N}\sum_{j=1}^{N} | rj | \qquad (2)$$

- **Root Mean Square roughness Rq :**

Height deviations over the evaluation length measured with respect to the mean line.

- **Average maximum heightRz**

Mean of the absolute values of the five highest peaks and the five lowest valleys over the evaluation length. Norms: ISO 4287-1997

Table 7 - Roughness test results.

sample	V_e[m/min]	N[Tr/min]	f [min/tr]	a[mm]	Measure	$R_{a(\mu m)}$	$R_{z(\mu m)}$	R_q (μm)
dune sand	30.14	320	0.03	1	1	1.91	8.41	2.38
					2	1.98	9.68	2.47
					3	1.01	4.61	1.22
					average	1.63	7.56	2.02

3 Technical control

Vehicle inspection is a mandatory regular examination conducted on vehicles to ensure they are safe and comply with road safety standards. During this inspection, several elements are checked, such as the brakes. The brake pads must be in good working condition for the vehicle to come to a safe stop in case of an emergency. Therefore, the results of the braking and wear tests performed on the brake pads can play an important role in the success of the vehicle inspection. The innovative brake pads designed in this study were installed on a vehicle and successfully passed the braking and wear tests, demonstrating their ability to meet the required safety standards for vehicle inspection (Figure 16; Figure 17; Figure 18).

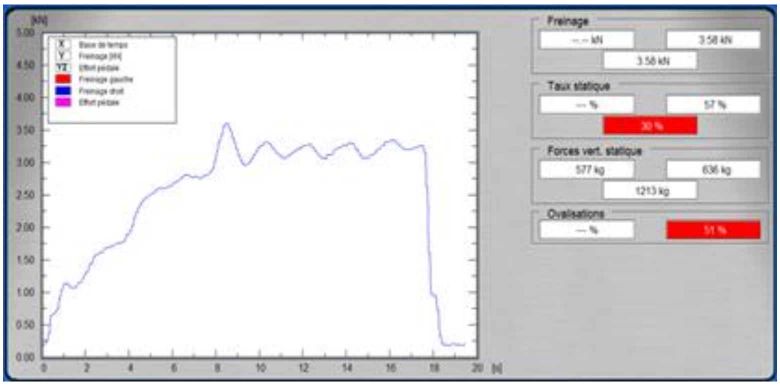

Fig. 16- Technical inspection of red clay brake pads manufactured by bonding the lining to the backing plates.

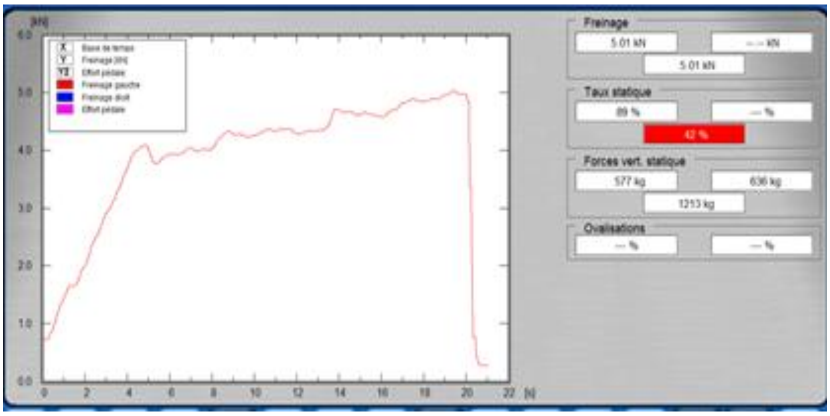

Fig. 17-Technical inspection of brake pads made from crushed dune sand and manufactured by bonding the lining to the backing plates.

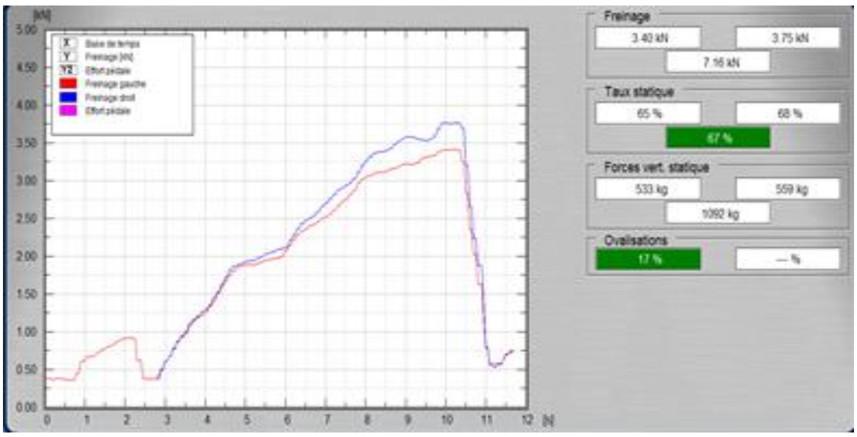

Fig. 18-Technical inspection of commercial brake pads that have already been used.

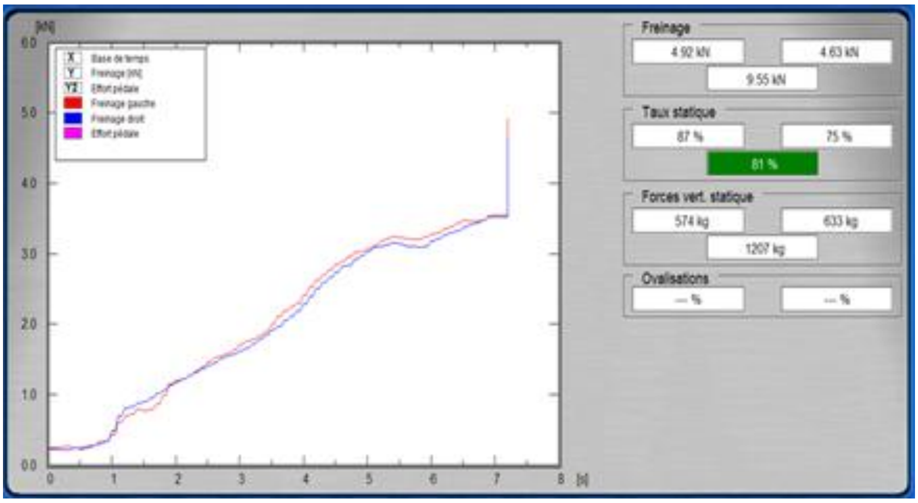

Fig.19-Technical inspection of brake pads made from crushed dune sand and manufactured by polymerization.

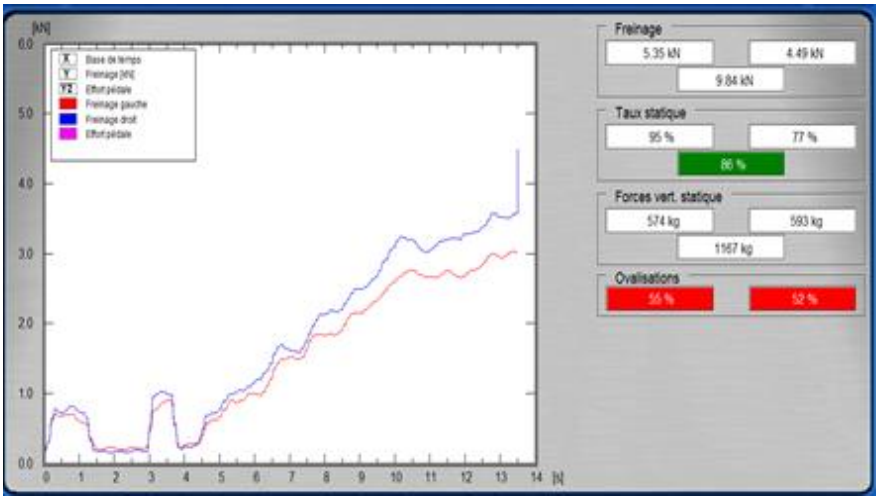

Fig.20-Technical inspection of new commercial brake pads.

4. Interpretation of the results

The results presented by the technical inspection show a significant difference between brake pads made from alternative materials and commercial pads already in use. Brake pads made from red clay showed only 30% effectiveness (Figure 16) compared to commercial pads at 67% (Figure 18). Similarly, brake pads made from crushed dune sand glued to supports showed only 42% effectiveness (Figure 17) compared to commercial pads at 67% (Figure 18).

However, brake pads made from crushed dune sand that were directly cast onto the supports and subjected to high-temperature polymerization (175°C) for 45 minutes showed 81% effectiveness (Figure 19) compared to 86% for new commercial pads (Figure20). These results show that the manufacturing method has a significant impact on the effectiveness of brake pads.

It is important to note that these results are only a first step in the development of alternative materials for brake pads. Researchers must continue their work to understand the reasons for differences in effectiveness and to optimize the manufacturing processes. They must also consider other important characteristics of brake pads, such as their heat resistance and durability.

It is also important to note that the use of alternative materials for brake pads can have significant environmental benefits by reducing dependence on petroleum-based materials. However, it is also important to ensure that these alternative materials do not compromise driver safety or brake effectiveness.

5. Conclusions

In conclusion, the results obtained in this study demonstrate the feasibility of designing innovative brake pads from local eco-materials, which exhibit encouraging mechanical properties and a perfect exterior quality without air bubbles on the surface. The tests performed confirmed that these brake pads were capable of withstanding high temperatures, were wear-resistant, and offered reliable behaviour during braking. The results of various mechanical and chemical tests also confirmed the reliability and mechanical properties of these brake pads.

This study represents a significant advancement in the development of more ecological and sustainable technologies for the automotive industry. The innovative brake pads designed in this study have the potential to reduce the environmental impact of the automotive industry by using local materials and reducing the amount of waste generated during manufacturing.

It appears that the results of the technical inspection show that brake pads made from red clay and crushed dune sand are not as effective as commercially used brake pads. However, it is interesting to note that brake pads made from crushed dune sand that were cast directly onto supports and subjected to high-temperature polymerization showed higher efficiency than commercial brake pads. It is possible that this manufacturing method improved the quality of the crushed dune sand-based brake pads by allowing them to polymerize more completely and uniformly. It is important to continue research to understand the reasons for these results and to optimize the manufacturing of brake pads using alternative materials.

Ultimately, this study offers a promising alternative to brake pads made from crushed dune sand with polymerization at 175°C for 45 minutes and may contribute to making vehicles safer and more environmentally friendly.

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