STUDIES AND RESEARCH ON THE MATERIALS USED IN THE MANUFACTURE OF CLUTCH DISCS

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Friction materials are engineered composites designed to generate controlled friction when in contact with another surface. They are typically used in applications like brakes, clutches, and other friction-based systems. The exact composition of the friction material varies depending on the type of brake pad, the vehicle's application, and the desired performance characteristics. Understanding the composition of friction materials is critical for designing and manufacturing components that deliver optimal performance, reliability, and durability. The present work aims to provide a new perspective on understanding and optimizing the properties of materials used in the automotive industry. Clutch discs are an essential element in the transmission system of automobiles, playing a fundamental role in ensuring their efficient and sustainable operation. Poor clutch disc performance can lead to premature damage to the transmission system and generate a safety risk for the driver and passengers. The current paper presents the methods of analysis and characterization of the materials used in the construction of the clutch discs, with an emphasis on determining the hardness and roughness of the surfaces.

Keywords: Clutch disk, hardness, surface roughness, surface topography

1. Introduction

In the automotive sector, friction materials are essential because they allow cars to stop, slow down, and maintain control. These materials are carefully developed to ensure optimal performance under severe situations. You can find them in clutches, brake pads, and other friction-based systems. The primary function of friction materials is to convert kinetic energy (motion) into heat energy, thereby slowing down or stopping motion.

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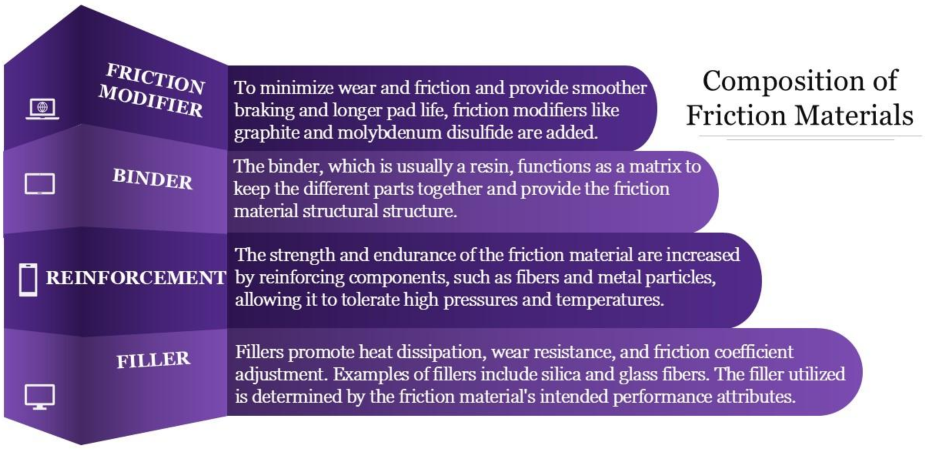

Fig 1. Composition of friction materials

For many industrial devices, including cars, this procedure is essential to ensure controlled and safe functioning [1,2].

Abrasives and solid lubricants are the two categories into which *friction modifiers* are separated. Generally, lubricants are used to stabilize the mover over a wide temperature range in addition to lowering friction levels. Abrasive materials are used to raise the coefficient of friction (Fig. 2). One of the matrix materials used in the powdered form of brake pads is *binder*. The method usually determines the choice of binder, which varies. More binder cannot be added to a formulation because doing so would cause the brake pad to fade and wear excessively. In a brake pad, the *reinforcement* serves as a strength enhancer. They are mostly fibers that provide a brake pad with a special combination of thermal stability, frictional properties, and structural integrity. Natural, organic fibers can be created synthetically using chemicals, or they can be inorganic. *Fillers* are materials that can be used to only fill spaces or that take up a significant amount of area in brake friction materials [3]. Their addition aims to lower the expenses related to the end product and manufacturing. The chosen filler material must merely support the other elements without detracting from their functionality; it cannot operate as a lubricant or an abrasive. They can be organic or inorganic filler. Additives can significantly modify the properties of the base matrix both in the automotive field and in other fields [4–12]. Friction materials are generally composite materials that must exhibit excellent mechanical, tribological, and physical properties for applications subject to friction, wear and lubrication. Because of the constant need for increased safety, lower environmental impact, and better performance, the field of friction materials is always changing [13].

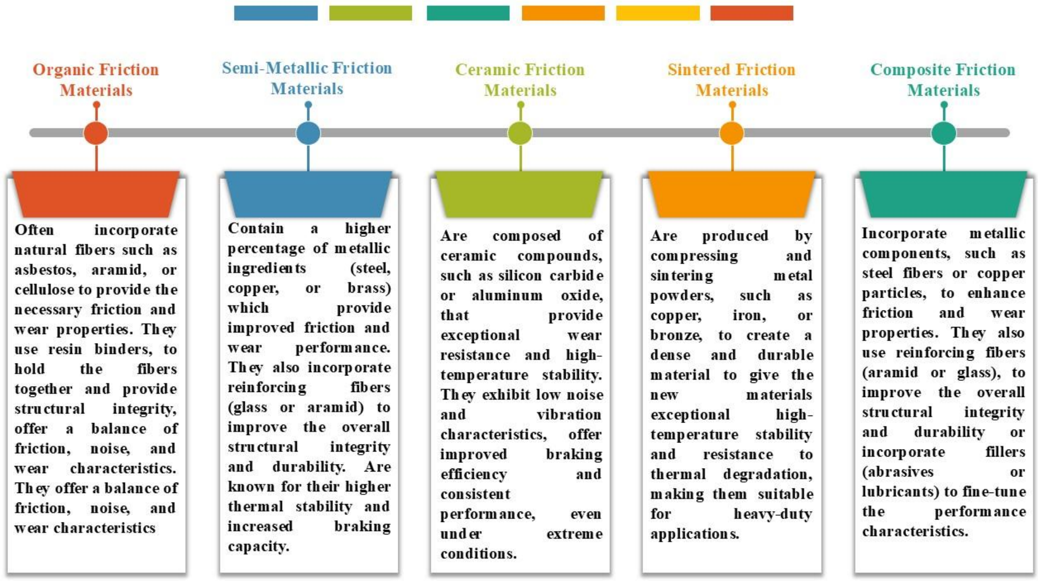

Fig 2. Automotive friction materials

New developments in the composition of friction materials center on breakthroughs in a few important areas [14–18], such as:

- *Sustainable Materials*: recycled and biobased materials are being used more often to minimize environmental effects and lessen reliance on virgin materials [14].
- *Nanomaterials*: Wear resistance, thermal conductivity, and friction coefficient may all be enhanced by including nanomaterials like graphene and carbon nanotubes [17].
- *Ceramic Composites*: Under high temperatures, the development of ceramic-based composites offers better wear resistance, heat resistance, and friction stability [18].

The increasing needs of contemporary automotive and industrial applications are being met by next-generation friction materials that offer remarkable performance, durability, enhanced wear resistance, lower noise, better thermal stability and sustainability thanks to these improvements.

Clutches are an essential element in the transmission system of automobiles, playing a fundamental role in ensuring their efficient and sustainable operation. Acting as intermediaries between the engine and the gearbox, clutches enable transmission systems to engage and disengage, thereby facilitating starting, braking and shifting operations and keeping components in good condition. The importance of this key component cannot be understated, as poor clutch performance can lead to premature damage to other parts of the transmission system, as well as safety risks for the driver and passengers.

In the current context of technological evolution and increasingly high demands in the field of engineering and industry, research and development of materials and production processes are becoming more important. Modern materials must have strict performance and durability requirements while ensuring compatibility with environmental and safety standards. Through the integrated approach of these aspects, the paper aims to provide a significant contribution to the understanding and optimization of material properties in industrial and technological applications.

The research topic started from an increased concern for safety in the automotive industry, as well as for the environment. As asbestos, a traditional material used in clutch disc composition has been phased out due to health risks, it has become imperative to identify and evaluate modern alternatives that provide similar or superior performance without compromising the safety and the health of those involved in the manufacturing and use of automobiles. According to the EU Directive, the elimination of asbestos products in 2005 led to the development of new materials with advanced properties to meet modern performance and durability requirements.

The clutch plays the role of compensating for the disadvantages associated with the operation of internal combustion engines. These drawbacks include difficulty starting under load, the existence of an unstable operating zone, and the generation of uneven crankshaft running. The integration of the clutch in the car transmission is imperative because of the specific mode of operation of the engine, which involves its engagement and disengagement.

Disengagement is necessary for situations such as the car coming to a complete stop, full braking, or changing gears. On the other hand, engagement is essential when starting from a standstill and after performing gear changes. The smooth process of coupling the primary shaft of the gearbox with the crankshaft of the engine, which operates at a high speed, allows the gradual transfer of the load without strong impacts to the gears and transmission components. This not only reduces their wear but also eliminates the risk of breakage.

By decoupling the transmission from the engine, the gears in the gearbox are allowed to be relieved of the load, making it easier to engage later without imposing significant forces between the teeth. Neglecting this step can make gear shifting almost impossible, leading to noisy operation and high stresses in the gearbox, which can lead to premature wear or even component breakage [1]

The clutch must meet several essential conditions to ensure efficient operation of the transmission:

- quick and complete disengagement.
- low effort disengagement.
- Reduced weight of the driven parts.
- Progressiveness in action.

- Perfect coupling in the coupled state.
- Elimination of heat generated.
- Vibration damping.
- Simple construction and easy to maintain.
- Safety.

Composite materials are increasingly present on the market, due to their notable advantages: light weight, resistance to wear and corrosion, as well as mechanical characteristics adapted to the needs of the product. The new generation of composite materials used in automotive area presents remarkable advantages such as: low volumetric mass, high tensile strength, low expansion coefficient, shock resistance, high durability, safety in operation, low energy consumption and resistance to corrosion and high temperatures. These materials are a promising option for a wide range of products, offering superior performance and saving energy in the manufacturing process. (Fig. 2).

2. Materials and methods

2.1. Macroscopical and microstructural characterization

An Olympus BX51 optical microscope was used to examine the microstructure of the samples under investigation. Using an energy dispersive spectrum (EDS) equipped Philips XL 30 ESEM TMP scanning electron microscope, the surface morphology and the elemental composition of the experimental samples were assessed.

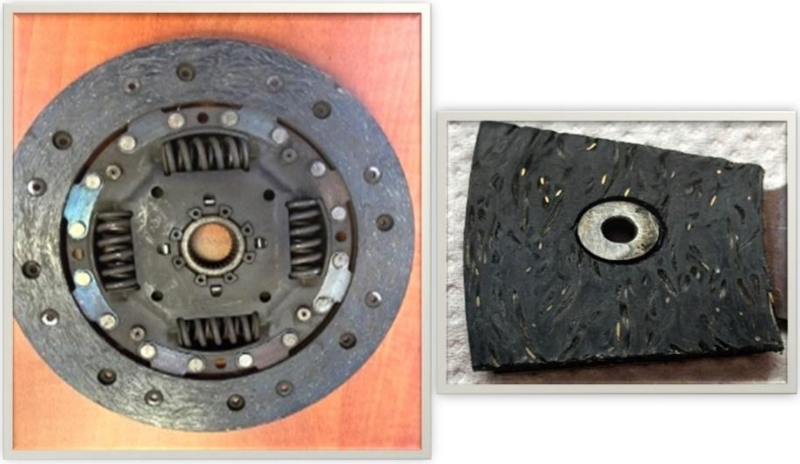

Fig 3. Clutch disc used for testing

2.2. Roughness analyses

An instrument from Taylor Hobson's Form Talysurf® i-Series PRO Range measures surface roughness. The roughness meter employs Metrology 4.0 software and a standard feeler transducer with a diamond tip with a 2 μm radius for measuring smooth surfaces.

2.3. Hardness measurements

For the chosen sample, hardness was determined by the Vickers method. This process involves carrying out experimental determinations in several areas of the sample to highlight the hardness, followed by the comparison of the obtained results. The Vickers method uses a diamond pyramid with a square-shaped base as the penetrator. Due to its clearly superior hardness compared to other industrial materials, diamond allows the application of the method without restrictions in the determination of hardness. This procedure is recommended for evaluating the hardness of materials with a probable hardness greater than 300 daN/mm^2. For the experimental hardness test was used a Micro-Vickers CV-400 DTS hardness tester.

3. Results and discussions

All the tested samples are extracted from a clutch disk presented in Fig. 3. The cutting of the metallographic samples was done so that no changes occur in the material's structure. It is recommended that the metallographic sample has a research surface of at least 1 cm^2 (usually their dimensions are 15 x 15 x 10 mm).

3.1. Microstructural characterization results

As can be observed macroscopically in Fig. 4 fibers are arranged randomly, and in some places pierce the material externally. In Fig. 5 you can see that longitudinal fibers are an agglomeration of smaller fibers arranged after a path. Fig. 5 highlights the surface morphology in the SEM images at 50X, 100X, and 500X. From these images, we can observe the nonuniform aspect of the surface with a relatively random distribution.

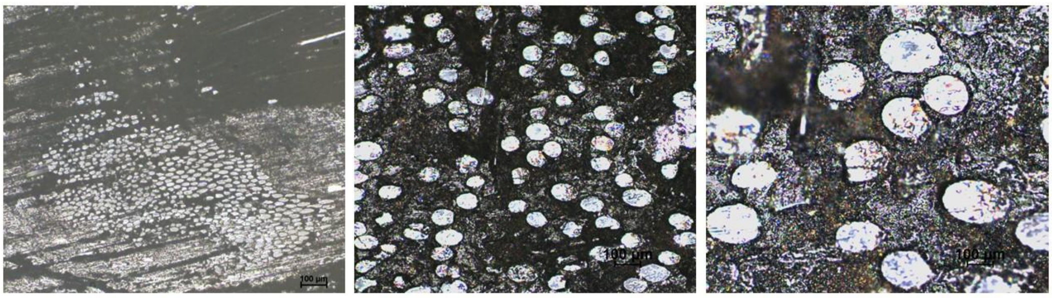

Fig. 4 The structure corresponding to the sample (5X, 10X, and 50X)

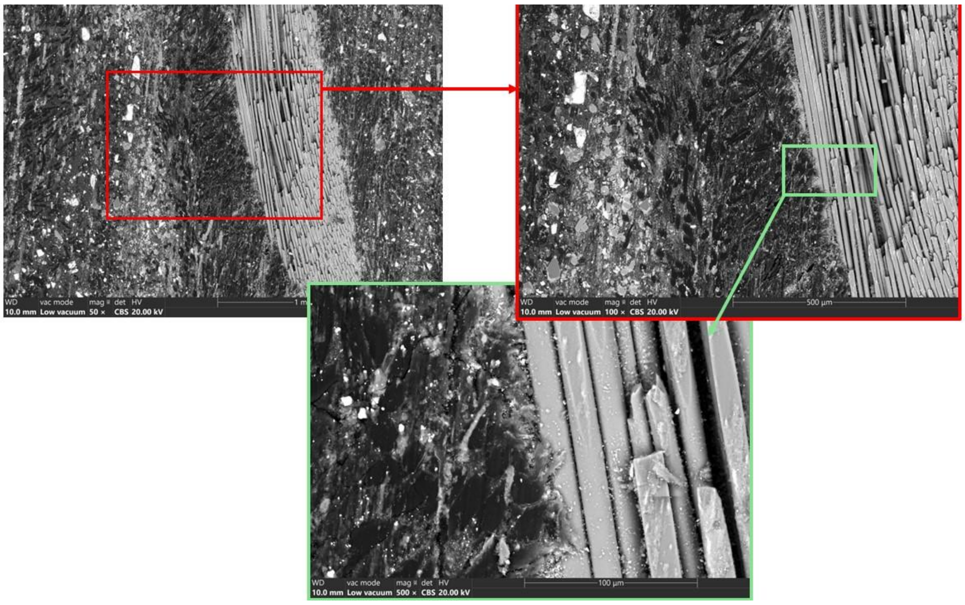

Fig. 5. SEM images of the sample at different magnification 50X, 100X, and 500X.

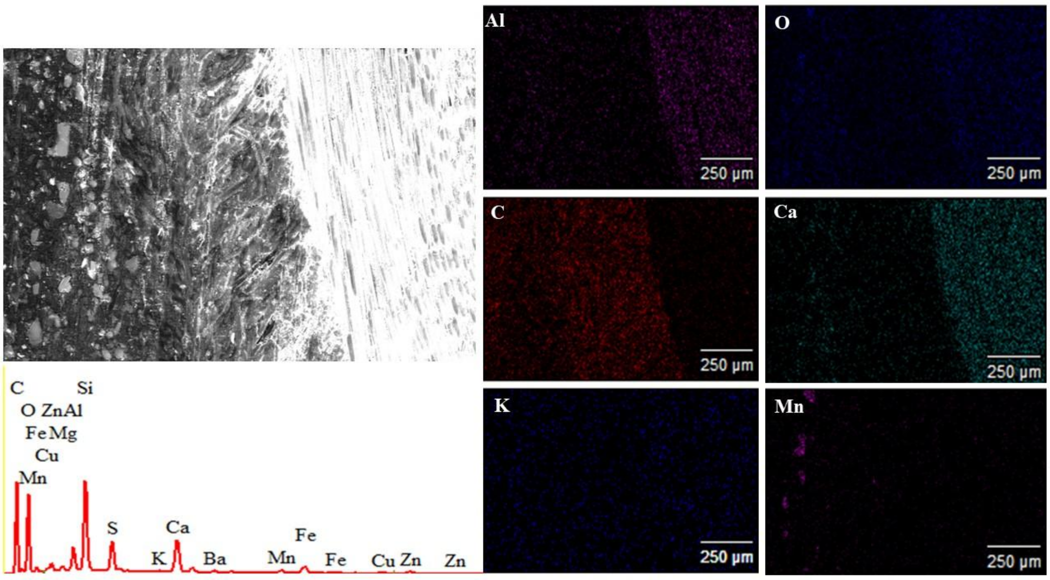

Fig. 6. Part 1: SEM image, associated EDS spectra, and EDS elemental mapping results for the samples

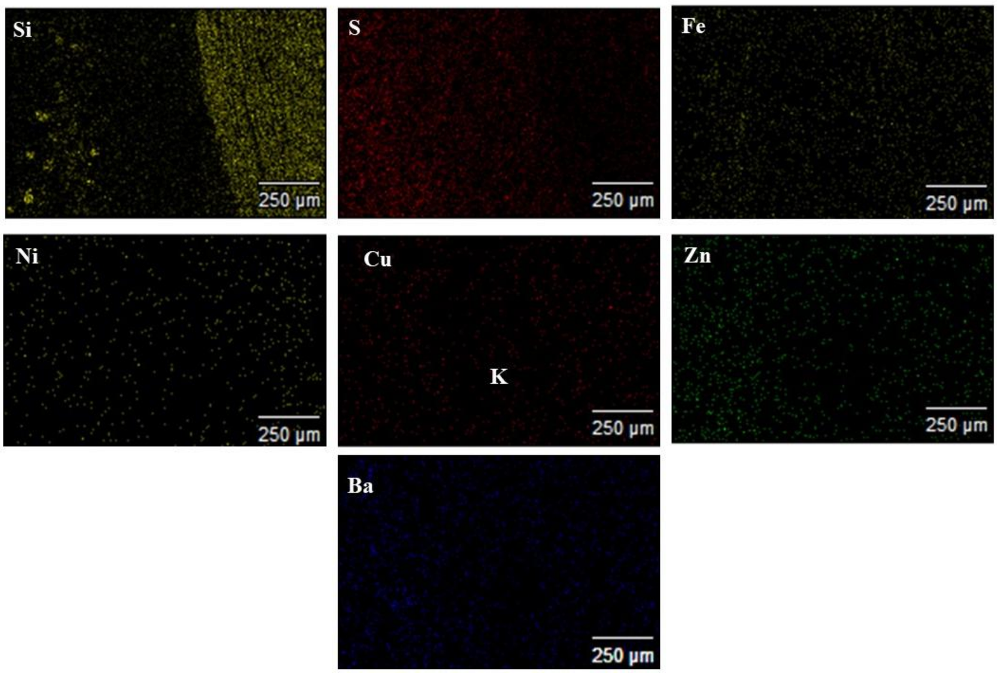

Fig. 6. Part 2: SEM image, associated EDS spectra, and EDS elemental mapping results for the samples

According to the EDS results for these samples, the clutch disc analyzed proved to be rich in C, Al, O, Mn, Si, S, K, Ca, Mn, Fe, Ni, Cu, Zn, and Ba.

Studying the composition of friction compounds is an intricate and intriguing subject. It entails the thoughtful selection and blending of numerous elements, each of which adds to the material's overall performance, robustness, and safety.

3.2. Roughness analyses results

For accurate data, 10 longitudinal and 10 vertical tests were performed as described below and the average of the results obtained are mentioned in Table 1. Fig. 7 presents the roughness profile for the longitudinal (a) and vertical determination (b). Fig. 8 presents the topography for the same determination.

Table 1

Sample	Ra [µm]	Rz [µm]	Rt [µm]
Average for longitudinal determination	1.9732	10.6511	40.0429
Average for vertical determination	0.9973	5.5765	22.9542

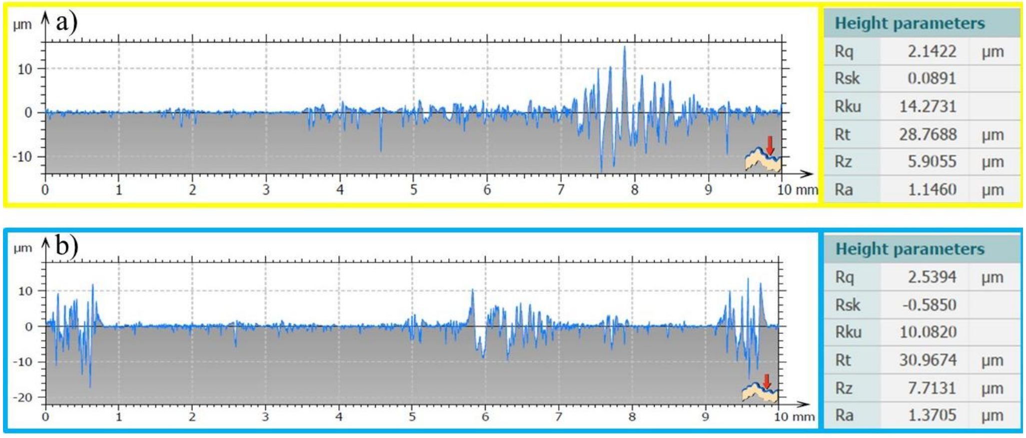

Fig. 7 Roughness profile for the longitudinal (a) and vertical determination (b)

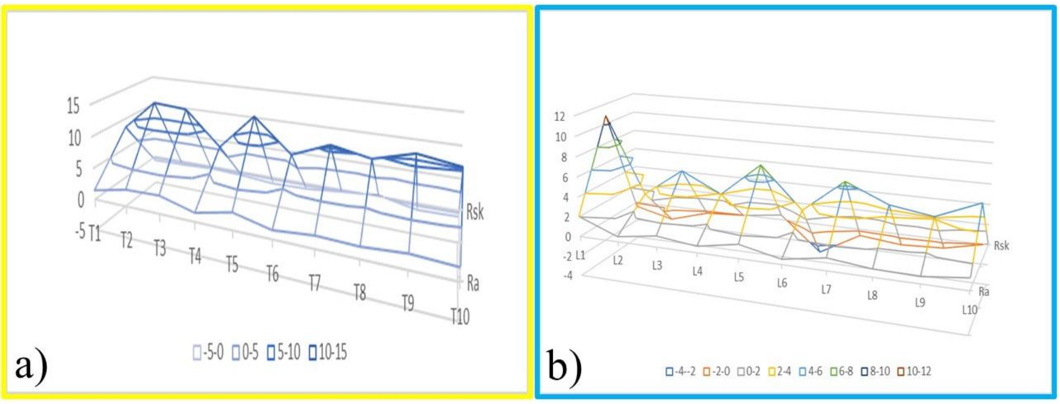

Fig. 8. The transversal and longitudinal topography after roughness measurements

Regarding roughness, mechanical wear occurs because of friction between the surfaces in contact. The studies show that the characterization of the surface behavior is related to the complex structure of the protrusions in the asperities. It is important to complete the descriptors with peaks spread around the midline (Rq), their clarity is characterized by the average and the average value of the profile Ra and Rq, indicators of the topography of the protuberance. In the present study, the mean Rq was 1.9688 µm for longitudinal determinations and 3.4876 µm for transverse ones.

After testing, the average Ra was 0.9973 µm for the longitudinal determinations and 1.9732 µm for the transverse ones, which places the material in the N7 longitudinal and N8 transverse classes, according to the ISO 468/1997 standard.

3.3. Hardness measurements results

To determine the hardness, a sample was taken from the clutch disc, the surface of the part was prepared to a roughness that would allow the determination and measurement of traces in good conditions. The samples were tested at 200 gf, with dwell time 35 seconds, five times. Analyzing the results, the MHV0.2 hardness has an average of 46 HV. The values obtained fall within specific articles of friction materials [1,11].

The obtained result regarding the hardness has an average of 46 HV is comparable with the typical values for composite materials based on phenolic resin, rubber powder, and metal fibers. The hardness values obtained reflect a material that adequately combines hardness and flexibility, ensuring both wear resistance and the ability to absorb mechanical shocks. This suggests that the material can be used successfully for brakes plates and clutch discs under normal operating conditions.

4. Conclusions

Friction materials are still developing since there is a need for better performance, more durability, and less environmental effect. The creation of friction materials specifically for use in high-performance automobiles, electric vehicles, and autonomous vehicles is one of the upcoming developments. To improve car safety, efficiency, and sustainability, friction material technology research and innovation are essential.

Macroscopic analysis revealed a rough surface with randomly arranged fibers, some of them perforating the outside of the material. At the microscopic level, the elemental composition revealed a composite material. In conclusion, the tested material shows an adequate and constant hardness characteristic, confirming its quality and homogeneity, as well as its suitability for use in brake and clutch applications. The values obtained reflect a well-manufactured and tested material capable of providing reliable performance in practical use.

The roughness analyses provide essential data for understanding the behavior of friction materials under wear conditions and can contribute to improving the design and manufacturing processes of clutch systems.

Research and development in this field are continuously pushing the envelope, resulting in the development of friction materials that are more dependable, efficient, and sustainable than before. We may anticipate seeing even more cutting-edge materials develop as technology develops, which will improve the functionality and security of several mechanical systems.

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