Saravanan P, 2022, 10:1
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

A Complete Study on Natural Fibre Reinforced Composites Used in Brake Pads

Mr. Saravanan P, Mr. Agatheesh Senthil Y, Mr. Prethish Haran M
Department of Automobile Engineering
Kumaraguru College of Technology
Coimbatore-641049.

Abstract- A Brake pad plays a vital role in stopping the vehicle effectively. The kinetic energy of the moving vehicle is converted in the form of heat. The brake system has been upgraded and is working much better than before. It is one of the critical parts in the car, due to its possible weakness, may become dangerous to the safety of passengers in extreme conditions. So, it is essential to design a Brake pad using a material with high strength and at the same time it should be environment friendly as much as possible. This paper aims to study comprehensive environmental impact of braking systems, to avoid the risk of mineral and synthetic fibres such as asbestos and carbon fibres, which may release hazardous dust during a collision between the brake pad and disk and to design eco-friendly brake pad as much as possible. The brake pads are what actually rub against the drums or rotors. They are made of composite materials and are attached to brake calliper or brake drum. Asbestos was previously used in brake pads because of its robust chemical and mechanical properties. It is insoluble in water and organic solvents, nonflammable, have an excellent tensile strength that surpasses that of steel. But asbestos is no longer considered safe for application in brake pad production due to hazardous dust and gases it releases, which cause carcinogenic cancer and other damages to health. This project is to build a non-asbestos natural fibre-imposed brake pad with organic ingredients and other composite materials which provides predominantly organic materials, involves natural and lesser treatment processes, eco-friendly and cost-effective means of solving the problem.

Keywords- Brake Pads, Natural fibre brake composites, low-cost brake pads.

I. INTRODUCTION

Brakes are the primary component that helps the moving vehicle to retard its motion. The element that helps the braking system to generate friction are the Brake pads (in disc) or Brake shoes (in rotors). The purpose of the brake pads is to convert the kinetic energy of the moving vehicle into heat energy through friction and releases the heat energy into the atmosphere [15].

Brake pads are made up of various composite materials that significantly increase the friction performance and reduce the wear rate and increase the stopping efficiency.

In olden days, asbestos was used in the manufacturing of brake pads. Asbestos is a naturally occurring silica material which has excellent wear resistance and can withstand higher temperatures. It is also abundantly available and very cheap. It doesn't soluble in any organic solvents and has good thermal stability and tensile strength. But the main cause for eliminating the asbestos is that, it causes serious health problems to humans.

The dust particles produced by the asbestos brake pads during friction can cause carcinogenic cancer and other serious health issues [3]. Workers exposed to asbestos environments in the automotive settings develop mesothelioma and other serious health problems. So, the asbestos brake pads were eliminated and the non-asbestos brake pads get into play a major role. Brake pads are an integral part of the automotive system [16]. The positive aspect of the conflict is expected to be positive resistance to exhaustion, low wear medium, rotor friendly, good pedal sensation, low vibration and noise, does not emit toxins and low cost.

There was a huge amount of work in the past by researchers around the world to show the influence / importance of these components in order to improve friction performance in the end which gives driving control and safety for both drivers as well pedestrians. Traffic congestion causes pollution on the roads and in parking lots.

Wearing of debris from tires, brake system and gripping straps contributes to an increase in the amount of soil particles and toxic metals. Various environmental agencies are very concerned about point sources such as pollution products from automotive industries, chemical industries, electronics and electronics industries, fertilizers and mines only [16]. However, in fact, real threats come from non-point sources that include aging from brake pads and tires motor vehicles.

Judging by the statistics, it is estimated that 70.5 million passenger cars were manufactured worldwide in 2018.A similar trend was observed in India as the number of vehicles produced increased from 2.05% March-April 2019 compared to last 2018 and it seems that India is in danger of becoming a leader (society of India automobile manufacturer) [16].

This increase in car production cans ultimately increasing the market demand for brake friction as it is closely related to the production and sale of vehicles. In addition, increased use of brakes due to traffic congestion increases the need for unit replacement.

II. BASICS OF BRAKE PAD

The basic physical and mechanical properties that a brake pad should possess are

- Minimum water absorption
- Minimum coefficient of expansion
- High temperature stability
- High hardness and strength
- High oxidation resistance
- Good coefficient of friction
- Longer life
- Resistance to corrosion
- Produce low noise

Apart from these properties, the brake pads should be cost-effective, eco-friendly and the availability of the raw material for the manufacturing should be considered.

III. TYPES OF BRAKE PADS

Based on the composition and the types of material used, the brake pads are broadly classified into three types:

- Semi-metallic brake pads
- Non-metallic brake pads
- Ceramic brake pads

All these types of brake pads were introduced after the restrictions of asbestos in the market.

1. Semi-Metallic Brake Pads:

Semi-metallic brake pads contain 30-70% of metals, and a graphite lubricant and other durable filler material. The metals like copper, iron, steel or other composites are used. Semi-metallic brake pads can perform well in both road as well as tracks. Among other brake pads, semi-metallic brake pads are the versatile ones.

Disadvantages:

- It is **bit noisier** than organic or ceramic brake pads
- It produces more **brake dust**
- It is **more abrasive** than other types of pads which will tends to wear brake rotors(discs) more quickly
- It is **expensive** than organic pads.

2. Ceramic Brake Pads:

As the name suggests ceramic brake pads are the ones which are made of ceramics compound and other filling materials bonded together. These brakes are widely used in high performance vehicles and racing cars that generates high heat while braking. It also produces less brake dust than other types.

Disadvantages:

- It is on the **most expensive** side than other type of brake pads.

- It does not produce as much **cold bite** as other brake pads do, making them not suitable for extremely cold conditions
- It is good in all-around braking characteristics, but not designed for **heavy-duty performance** braking systems.

3. Non-Metallic Brake Pads:
Non-Metallic organic (non-asbestos organic) brake pads are made from organic materials like rubber, glass, fibre, high temperature resins, and even Kevlar. They are softer than brake pads that partially consist of metal and because of that they make a lot less noise and are softer on the rotors. Organic brake pads can be produced at very low cost. They are very much suitable for all environmental and day to day road conditions. But comparatively they wear faster than other type of brake pads. And organic brake pads are not suitable for performance vehicles and it does not offer track performances.[12]

Disadvantages:
- Organic brake pads are prone to wear more quickly than any other type of brake pads.
- They perform well within a smaller range of temperatures.
- Comparatively, they have high compressibility level, which means the driver has to press on the brake pedal with more force to extract its best.

IV. MATERIALS USED IN BRAKE PADS

The fig 1 shows the common types of materials used in the manufacturing of brake pads.

1. Reinforcement:
Reinforcement is one of the standard materials used in the manufacturing of brake pads along with fillers and other materials [13].

The purpose of reinforcement materials is to provide high Strength, wear resistance, Minimum moisture absorption [Fig 1]. Materials like metal, glass, aramid and natural fibres are used as reinforcement materials. Most of the non-asbestos brake pad is made from natural fibre. The purpose of this paper is to increase the amount of natural fibre used in the manufacturing of brake pads.

Chemical treatments like Alkaline, Benzoylation, silane, acetylation, etc., have been performed and the result are as follows:

2. Fillers:
Fillers are used as functional modifiers which increase the manufacturability and to reduce the cost of production [Fig 1] [15]. Particles like Aluminium Oxide (Al_2O_3) is added to increase the Coefficient of Friction (μ) which is the force of friction caused by the scraping the surface of the material and the disc.

Considerable number of fillers is used to optimize the performance of brake pads. Barium Sulfate ($BaSo_4$), calcium carbonate, rubber dust, mica, Coconut Shells, Periwinkle Shell etc. are some of the examples. [3].

3. Frictional additives
These materials, raise the friction, or react with oxygen to help control interfacial films. Abrasive particle used, size and amount are used to play a crucial role in performance. During sliding of the friction pair, the temperature rises at the interface, resulting in the binder's degradation & softening, thus lowering the friction performance. Under such circumstances, the abrasives assist in maintaining the friction at a constant level.

Most commonly used abrasives are Al_2O_3, Silicon Carbide (SiC), Zirconium oxide etc. The non-abrasive types are the solid lubricants which can provide additional frictional characteristics even under high temperatures [Fig 1]. The frictional force which is generated while braking can be controlled by adding a frictional layer in between them. Commonly used Solid lubricants are Graphite, Molybdenum Disulfide (MoS_2), Antimony Sulfide (Sb_2S_3), Copper sulfide (CuS) Etc.

4. Binders:
Typical binder materials are phenolic resins in the case of automotive and truck pads. Binder resin provides a medium for binding and holding all ingredients together [Fig 1]. The interaction between fibre and binder matrix is critical for deciding the composite strength of friction material. The binder used percentage should be significant because if the binder material is lesser then it will weaken brake pad composite, and if it is higher than it will cause friction drop-off at high temperatures [13].

The binder should have high thermal stability, maintain structural integrity under thermal and mechanical stress, and corrosion resistance, less moisture absorption, and be inexpensive to produce.

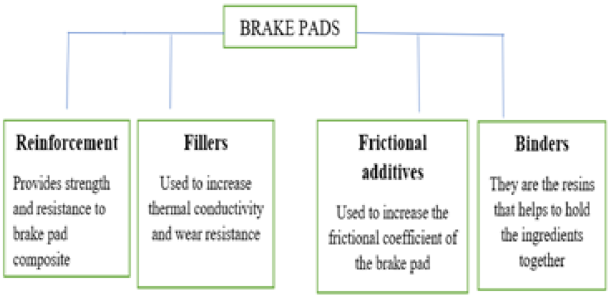

Fig 1. Brake pad composites.

V. LITERATURE SURVEY

J. Abutu et al. [1] says that raw materials such as coconut shell (reinforcement material), epoxy resin (Binder), graphite (friction modifier) and aluminium oxide(abrasive) are used to produce the organic brake pad. It was found that the samples are capable of producing less brake noise and vibration.

Samples production was done by a compression moulding machine. 27 different samples were produced by varying the amount of reinforcement material, binder, friction material, abrasive, process parameters. It is observed that the most advantageous performing coconut shell-reinforced brake pad can be obtained using 14 MPa moulding pressure (MP), 140 °C moulding temperature (MT), 8 min curing time (CT) and 5hr heat treatment time (HTT) as optimal process parameters.

The optimum brake pad has the following characters: Coefficient of friction is 0.624, Wear rate is 0.0659 mg/m, Ultimate tensile strength is 7.083 MPa, Compressive strength is 3.668 MPa, Hardness is 61.96 Shore D Scale, Flexural strength is 8.880 MPa, Impact strength is 0.029 J/mm [Fig 2].

Table 1.

S/N	Properties	Commercial product (X)	Coconut shell-reinforced brake pad (C)
1.	Ultimate tensile strength (MPa)	5.071	7.38
2.	Bending strength (MPa)	8.41	8.34
3.	Hardness (shore D scale)	62.14	63.31
4.	Compressive strength (MPa)	5.451	3.817
5.	Impact strength (J/mm)	0.082	0.032
6.	Coefficient of friction	0.634	0.614
7.	Wear rate (mg/m)	0.04184	0.03156

R.J Talib et al. [2] mentions that kenaf powder was used as a friction modifier. Kenaf powder was prepared through powder metallurgy route. Braking performance decrease when the temperature is above 230-degree Celsius which results in lower Coefficient of friction. To cope up this Graphite and Iron oxide were added with kenaf powder as friction modifier. Different volume percentage (0%, 5%, 10%, 15%) of kenaf powder were tested to obtain better results. The components bused in this composition were: Resin, activated carbon, Steel fibre, Iron Oxide, Iron Powder, Barium.

Various tests were conducted and the results implies that kenaf powder with 10% volume gives good results. The final composition was: Resin (10%), Activated carbon (20%), Steel fibre (20%), Iron Oxide (15%), Iron Powder (15%), Barium (10%).

The coefficient of friction for this composition was0.43(Normal) & 0.36(Hot); Though the fade percentage was high (22.78%) the thicknesses loss(0.21mm) was low. Even though strength seems to be increased with higher amount of kenaf fibre, the thickness loss is a considerable factor. Hence kenaf fibre powder with 10% volume composition was a good one in overall aspects.

Yashwhanth S. et al. [3] states thatorganic banana peels are used to make brake pads. In this, the banana peels are made dried and milled to a ball at 250 rpm to form the banana powder which is uncarbonized, BUNCP.The powder was packed in a graphite crucible and fired in electric resistance furnace at temperature of 1200C to form banana peels ash (carbonized, BCp). It was found that the co-efficient of friction of the samples increases as the weight% of resin increased in the formulation, Proper bonding was achieved with that of uncarbonized banana peels particles (uncarbonized, BUNCp) at 20 weight% resin additions, while that of carbonized banana peels particles (BCp) even at 30 weight% resin bonding has not been achieved to a high degree.

The properties like, hardness, compressive strength and specific gravity of the samples produced are seen to be increasing with increase in weight% resin addition, while the oil soak, water soak, wear rate and percentage charred decreased as weight% resin increased. It was found that the sample containing 25 weight% BUNCp and 30 weight% BCp have better properties.It was found out that specimen of BUNCP having Resin of 25 weight% and BCP having resin of 30 weight% was better than the other specimen among the rest. The Hardness, friction coefficient, Wear rate (mg/m), and the thickness swell in water of BUNCP are 98.8, 0.40, 4.15 and 3.21% respectively. The Hardness, friction coefficient, Wear rate (mg/m), and the thickness swell in water of BCP are 71.6, 0.35, 4.67, and 3.0% respectively.

Z. U. Elakhame et al. [12] says that sieve of palm kernel shell was used in production of brake pads as filler material replacing asbestos due to its carcinogenic nature. Palm kernel shell is the residue fibre remaining when kernel is been crack from the shell. It is recovered as by product in palm oil production. The coefficient of friction of palm kernel shells-PKS when using as brake lining material is seems to be in the range of 0.30 - 0.70.

150kg of palm kernel shells was used to extract the by product. Different compositions of sieves were tested (1mm, 710mu mm, 355 mu mm, 100 mu mm). After completing the tests 100mu mm PKS sieve composition found to be better in all aspects.

The results are: hardness 226-258; compressive strength 110-125; Density 1.350 - 1.750; specific gravity 1.8333-1.9492; swell measurement 0.17-0.39. These results are more or less close to the asbestos value. Hence PKS can be used as an alternative to existing fillers in brake composites.

V K et al. [10] states that the garlic's woody stalk (hard neck) was used to make the fibre, it is separated from the garlic and soaked in water for 11–13 days. The fibres extraction process is done through the retting process. it is again rinsed in water, also filtered and dried out at room temperature for 10h.

The parent ingredient used for the brake pads with their weight (%) include Barite (20%), Cashew modified phenol–formaldehyde (14%), Graphite (10%), mica (9%), vermiculite (8%), molybdenum disulphide (7%), wollastonite (6%), Brass Chips (5%), cashew friction dust (5%), crumb rubber (4%), alumina (3%). The various chemical treated fibres are added to these parent ingredients in the wt.% of 92% (parent ingredients) and 8%(fibres). The brake pad samples are produced using hot compression molding method and does not involve asbestos. Three primary chemical treatment such as alkalization, benzoylation, and acetylation are carried out. The three specimen's hardness are 81.40, 81.32, 81.37.

Naresh Kumar et al. [11] states that Kenaf fibre with lapinus was chosen has reinforcement material due to its light weight, ease of work, eco-friendly, good recycling properties and biodegradable nature. Phenolic resin as binder, barium sulphate as filler and alumina, vermiculite and graphite as modifiers are also used along with kenaf. To obtain better results, the composition of Kenaf was varied from 5-20%.

The parent composition percentage was kept constant (45%). The barium sulphate percentage and kenaf fibre percentage varies according to the addition of Kenaf. Initially barium sulphate was 50% when Kenaf was 5%. As Kenaf increases to 10% barium sulphate percentage reduces to 45%. The results implies that Thermal stability was high at 20% Kenaf composition. Shear strength (2110 Mpa), proof stress(7.18Mpa), ultimate tensile stress(15.8Mpa) shows good performance at 15% Kenaf composition.

Tensile Modulus(4350Mpa), ultimate compressive strength(160.8Mpa), failure strain (3.95%), impact energy (0.33J), flexural strength(71.38Mpa), flexural Modulus(2.9Gpa), shows good performance at 10% Kenaf composition. As per the conclusion Kenaf with 10% composition will be better for producing brake pad.

F. Elhilali et al. [15] discuss how the natural material can be added as an additive with the steel brake pads in order to protect the environment. The important role of the brake pad is to stop the vehicle when brake has been applied. So, the brake pad should be with enough strength. At the same time, it must be cost efficient, doesn't produce noise, bio degradable, and it must be eco-friendly.

The brake pad material can be broadly classified into two: support material and coating material Structural steel has been chosen as supporting material and asbestos, ceramic, Twaron and jute were chosen as coating material and they are tested one by one with structural steel. The analysis was carried out in ANSYS and the modelling was carried out in CATIA. Even though ceramic + structural steel have less strain and stress than jute, there are some important factors for selecting jute. Ceramic brakes are costly and can cause wear on Rotors but jute has low density, good dimensional ability, it can be recycled, it is a biodegradable and more over its cost efficient and eco-friendly.

VI. SUMMARY

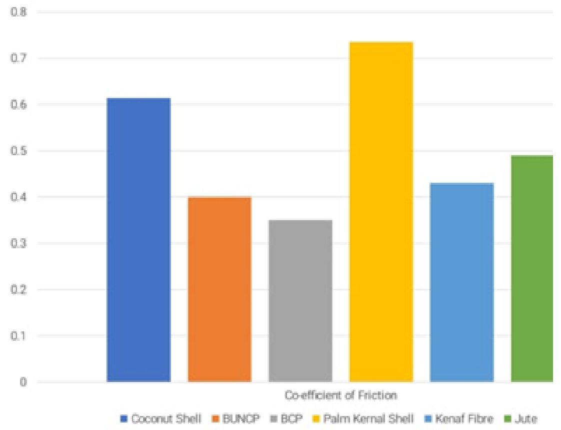

Fig 2. Co-efficient of Friction.

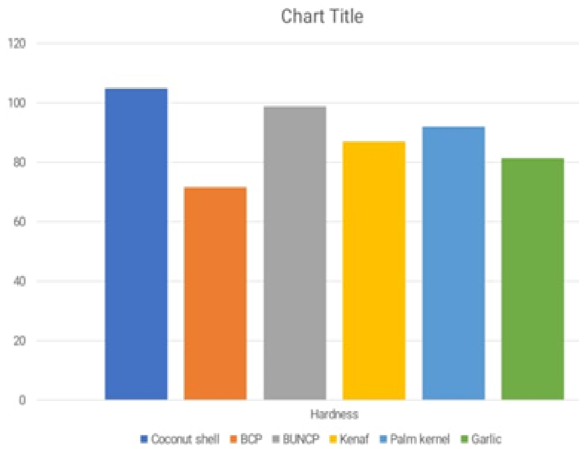

Fig 3. Hardness.

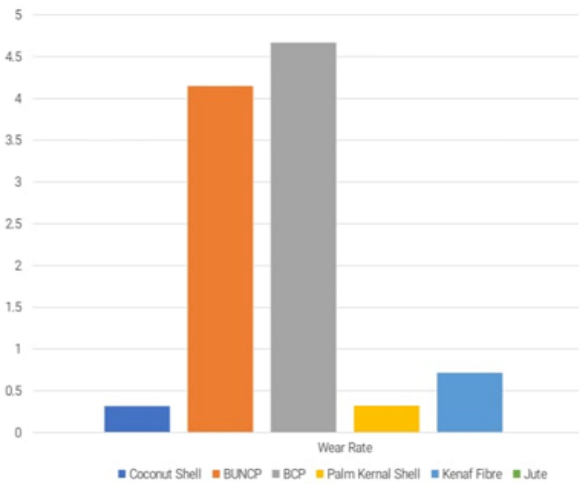

Fig 4. Wear Rate.

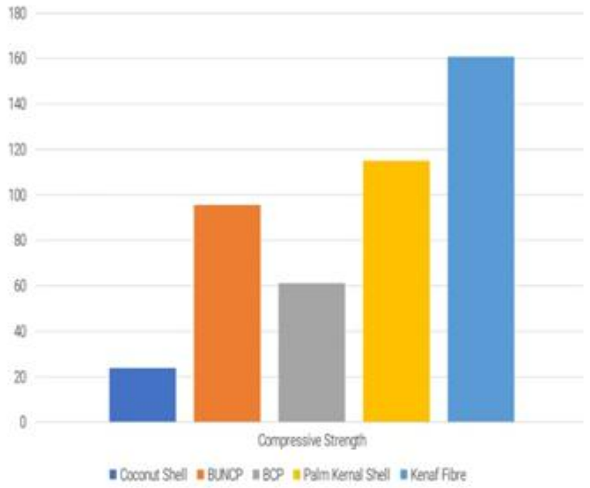

Fig 5. Compressive Strength.

None of the authors mentioned above checked for the presence of any hazardous material in the formulation of brake pads. Their work was mainly focussed on strength and frictional performance.

Even after the ban of asbestos fibres various toxics like heavy metal were still found to be utilised. So, this paper is mainly focussing on elimination of heavy metals as much as possible and mainly focussing on the use of organic materials. After considering and analyzing all the natural fibres, **coconut shell** seems to be good in all aspects [Chart 1, 2, 3, 4].

Formulation of the brake pads samples was done using rule of mixture and a weight percent of 52% reinforcement material, 35% binder, 8% abrasive and 5% friction modifier were used for the production. Raw materials which are selected for production of brake pads include coconut shell, epoxy resin (binder), graphite (friction modifier) and aluminum oxide (abrasive). It can be observed that the most advantageous performing coconut shell-reinforced brake pad can be obtained using 14 MPa moulding pressure, 140 °C moulding temperature, 8 min curing timeand 5 h heat treatment time as optimal process parameters.

The optimum brake pad has the following characters: Coefficient of friction is 0.624, Wear rate is 0.0659 mg/m, Ultimate tensile strength is 7.083 MPa, Compressive strength is 3.668 MPa, Hardness is 61.96 Shore D Scale. Finally, the optimal values of coconut shell-reinforced brake pad fall within standard requirements of brake pads as it compared favourably with commercially available brake pads.

VII. METHODOLOGY

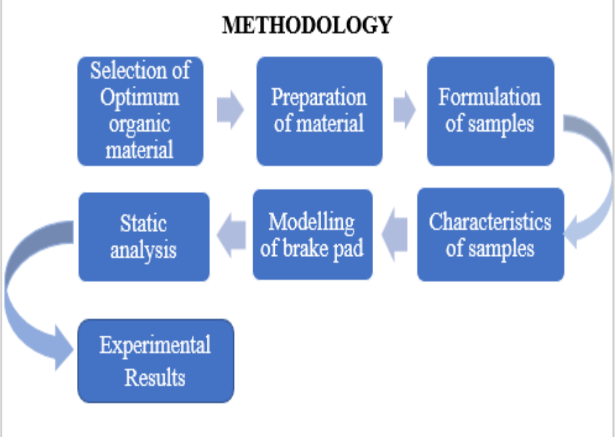

Fig 6. Methodology.

[Fig 3] In phase 1, Studying of various review and research papers to select the optimum organic material for the brake pads were completed. In phase 2 and 3, the formulation of additives and the proportion of the samples were finalized. In phase 4, the samples are analyzed and the characteristics of the samplers were tabulated and the best performing sample was taken into account.

In the phase 5, the brake pad can be modelled in the Solid works software and in phase 6, the modelled brake pad can be analyzed for stresses and strains using the Ansys software for the research purpose to obtain the desired result. Once the analysis is done, by giving the suitable parameters, the prototype can be fabricated and test it on various conditions to get a result in the final stage.

VIII. CONCLUSION

From overall readings and applied methodology, the better Natural fibre for brake pad was analyzed and verified with various characteristics. It was found that Coconut Shell was an optimum one and it was analyzed. The basic properties for a material to have for a brake pad been specified in table 1 and in the bar graph for coconut shell.

This paper was limited present study to compare, and present the former materials of the brake pads with the natural fibre proposed. Even though asbestos was good in performance due to some disadvantage it becomes a avoidable material. Hence this paper tries to cope up with asbestos material using coconut shell as much as possible.

IX. FUTURE DISCUSSIONS

This paper let this concept to future modelling and real time testing. The above values mentioned, analyzed were taken from analyzing. Binders, reinforcement materials and frictional additives can also be replaced using Natural fibres and can produce the brake pad with natural fibres as far as possible. This composition can be developed in future for implementation.

REFERENCE

[1] J. Abutu, S. A. Lawal, M. B.Ndaliman, R.A.Lafia-Araga, O. AdedipeI, A. Choudhury: Production and characterization of brake pad developed from coconut shell reinforcement material using central composite design: SN Applied Sciences volume 1, Article number: 82 (2019)

[2] R.J Talib, M.A.Selamat, N.A. Nordin, A. Jumahat, H. Sharudin,A.M. Zaharudin: Aptness of kenaf powder as a friction modifier in the fabrication of brake friction material by powder metallurgy route: Journal Tribologi 19, pp.121-131:2018.

[3] Yashwhanth S, Mithun Mohan M, Anandhan R, Senthil Kumaran Selvaraj: Present knowledge and perspective on the role of natural fibres in the brake pad material: Materials Today: Proceedings Volume 46, Part 17, 2021, Pages 7329-7337:2021

[4] J. Bessa, J. Matos, C. Mota, F. Cunha, I. Araújo, L. Silva, E. Pinho, R. Fangueiro, Influence of surface treatments on the mechanical properties of fibre reinforced thermoplastic composites, Procedia Eng. 200 (2017) 465–471.

[5] A.R. Martin, C.P. Moore, W.H. Finlay, A.R. Martin, C.P. Moore, W.H.F. Models, Application of waste tire rubber particles in non-asbestos organic brake friction composite materials, Expert Opin. Drug Deliv. (2018).

[6] S. Senthil Kumaran, K. Srinivasan, M. Ponmariappan, S. Yashwhanth, S. Akshay, Y.C. Hu, Study of raw and chemically treated Sansevieria ehrenbergii fibers for brake pad application Mater. Res. Express 7 (2020).

[7] A. Madeswaran, B. Natarajasundaram, B. Ramamoorthy, Reformation of Eco- Friendly Automotive Brake Pad by Using Natural Fibre Composites Evaluation of Developed NAO Brake Pad, 2018.

[8] D.S. Marewad, Asbestos free brake pad using Micro cellulose fibre for automotive industry, 4 (2018) 685–690.

[9] Sutikno, B. Pramujati, S.D. Safitri, A. Razitania, Characteristics of natural fiber reinforced composite for brake pads material AIP Conf. Proc. 1983 (2018).

[10] V K, S K: Characterization of Various Properties of Chemically Treated Allium sativum Fibre for Brake Pad Application: Journal of natural fibres Volume 2: 2020.

[11] Naresh Kumar, J.S. Grewal, Tej Singh, Nitin Kumar:Mechanical and thermal properties of chemically treated kenaf natural fibre reinforced polymer composites:Materials Today: Proceedings: 2021.

[12] Z. U. Elakhame, O. A. Alhassan, A. E. Samuel:Development and production of brake pads from palm kernel shell composites: International Journal of Scientific and Engineering Research 5(10):10:2014.

[13] Weitao Sun, Wenlong Zhou: Effects of friction film mechanical properties on the tribological performance of ceramic enhanced resin matrix friction materials: Journal of Materials Research and Technology: Volume 8, Issue 5, September–October 2019, Pages 4705-4712.

[14] Peter J. Blau: Compositions, Functions, and Testing of Friction Brake Materials and Their Additives: oak ridge national laboratory: September 2001.

[15] F. Elhilali, H. Fihri - Fassi, R. Ourihi: Towards the development of an optimized numerical model of the brake system pad with natural material: Materials Today: Proceedings 45(5): March 2021.

[16] P. Baskara Sethupathi, J. Chandradass, M.A. Saibalaji: Comparative study of disc brake pads sold in Indian market – Impact on safety and environmental aspects: Environmental Technology & Innovation (2020).