Global Journal of Advanced Engineering Technologies and Sciences

DEVELOPMENT OF BRAKE PAD USING ORANGE PEEL REINFORCEMENT POLYMER COMPOSITE

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Abstract

Studying about alternate materials for brake pads is necessary as the asbestos brake pads causing the carcinogenic effects and these are phased out. There are so many alternatives for asbestos are investigated from different journals. Fibers made up of agricultural wastes like banana peels, palm kernel shells, palm wastes, rock wool, aramid fibers, flax fibers etc are studied. Different alternatives for filler materials, Different binders like phenolic resin, epoxy resin are also studied. We propose a composite material where the brake pad is reinforced with the orange peel polymer. Utilization of natural fruit waste reduces the environmental problems and more effectively some of the fibers giving almost equal strengths and resistance as given by traditional synthetic fibers.

In this work a set of new composite were prepared with weight percentage of orange peel (44%), Al_2O_3 (15%), carbon powder (10%) and the remaining is the resin (31%) and a set of Experiments were carried out to study the Wear and hardness of the composites.

Keywords: Orange peel, hand layup process, composite materials.

Introduction

Brake pads are important parts of the braking system for all types of vehicles that are equipped with disc brake. Brake pads are steel backing plates with friction material bound to the surface facing the brake disc (Aigbodion and Akadike, 2010).

Brake pads generally consist of asbestos fibers embedded in a polymeric matrix along with several other ingredients. The use of asbestos fiber has been avoided due to its carcinogenic nature. A new asbestos free friction material and brake pads have been developed. It is envisioned that future developments in the manufacture of brake friction materials will closely mimic the current trends of the automotive industry (Dagwa and Ibhadode, 2006).

There are two basic types of automobile brakes: drum brakes and disc brakes. In drum brakes, the brake shoes are located inside a drum .When the brakes are applied, the brake shoe is forced outward and presses against the drum. One of the major differences between drum brakes and disc brakes is that drum brakes tend to be enclosed whereas disc brakes tend to be exposed to the environment (Bono and Dekyrger, 1990 and Aigbodion and Agunsoye, 2010,).

Until the late 1960s most cars used drum brakes on all four wheels. The pads for these drum brakes were organic (i.e., composed of natural materials) and often consisted of resins and asbestos as well as a variety of other materials to help improve braking and wear. In the late 1960s and early 1970s, automobile manufacturers started to incorporate disc brakes, especially for larger motor vehicles, because such brakes had a better braking performance. In 1975, the Federal Motor Vehicle Safety Standard 105, which required more stringentbraking requirements, helped expedite the transition to disc front–drum rear braking systems (Blau, 2001 and Kim et al., 2003).

Class A organic disc brake pads were the first used to make the switch from four wheel drum brake to disc front–drum rear systems. Class A organic brake pads were made from asbestos and were effective for low temperatures. As cars started to get smaller in the late 1970s, it became harder to cool the brake pads.

Class B organic pads worked better at higher temperatures, but had several problems including durability (Mathur et al., 2004, Dagwa, 2005 and Dagwa and Ibhadode, 2005). As a result, the use of semi-metallic brake pads became more popular. Semi-metallic disc brake pads have lower wear rates and good braking properties at both low and high temperatures.

Although the use of asbestos for brake pads has not been banned, much of the brake pad industry is moving away from asbestos brake pads because of concerns regarding airborne particles in the factories and disposal of wastes containing asbestos. There are several patents for asbestos free organic friction materials (Dagwa, 2005).

Changes in brake pad formulation were also driven by the promulgation of the corporate average fuel efficiency requirements in the late 1970s and mid 1980s. These requirements led the automobile industry to switch from rear wheel drive cars to front wheel drive cars. This switch required more front braking which resulted in higher temperatures and a preference for semi- metallic brakes (Gudmand - Hoyer et al., 1999).

A lot of research has been carried out in the area of development of asbestos-free brake pads. Coconut shell and palm kernel shell (PKS) have been used in the development of asbestos free brake pad materials (Dagwa, 2005, Dagwa and Ibhadode, 2005 and Aigbodion and Akadike, 2010). Research all over the world today is focusing on the ways of utilizing either industrial or agricultural wastes as a source of raw materials in the industry. This waste utilization will not only be economical, but may also result in foreign exchange earnings and environmental control.

Objective

Keeping in view of the current status of research the following objectives are set in the scope of the present research work.

1. Development of Break pad using Orange peel powder, Carbon,Phenol resin, Hardener, Aluminium oxide .
2. To study the influence of Hardness and Wear behavior of composites Break pad.
3. To select the best alternative from a set of alternative materials.

Material Description

Materials which are used in this experimental work are listed below

- Natural fiber (Orange peel powder)
- Phenol Resin
- Hardener
- Carbon
- Aluminium oxide

Natural Fiber(ORANGE PEEL)

Orange peel is a certain kind of finish that may develop on painted and cast surfaces, even screen protectors. The texture resembles the surface of the skin of an orange. Gloss paint sprayed on a smooth surface (such as the body of a car) should also dry into a smooth surface.

However, various factors can cause it to dry into a bumpy surface resembling the texture of an orange peel. The orange peel phenomenon can then be smoothed out with ultra-fine sandpaper, but it can be prevented altogether by changing the painting technique or the materials used.

Orange peel is typically the result of improper painting technique, and is caused by the quick evaporation of thinner, incorrect spray gun setup (e.g., low air pressure or incorrect nozzle), spraying the paint at an angle other than perpendicular, or applying excessive paint.

In some situations, such as interior house paint, the orange peel texture is generally desirable. In this case, a texture paint is generally applied with a spray gun. The texture is then painted over with the appropriate colour.

When painting walls, orange peel can also develop by using a roller with too little paint or too thick a paint and the surface dries before the texture can level.

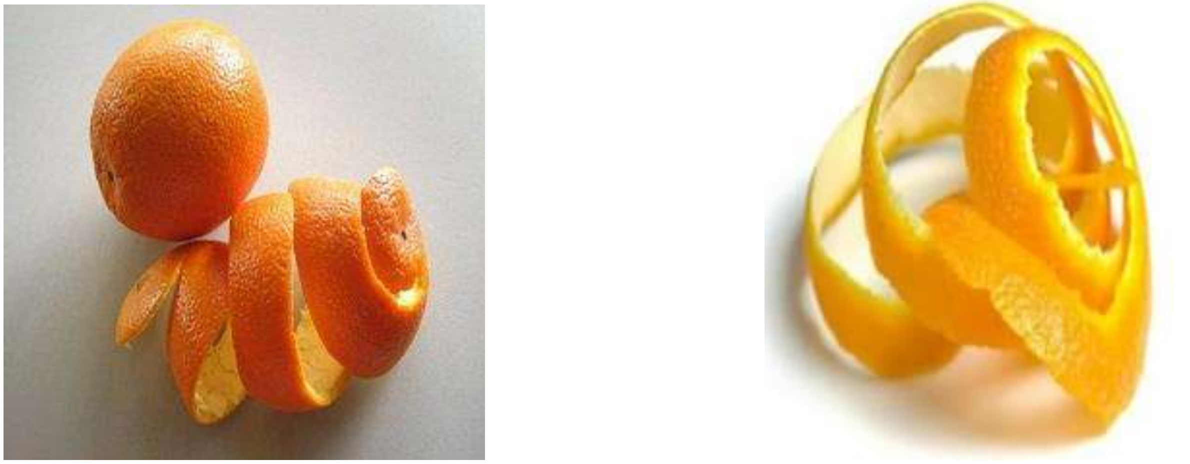


Figure.III. (a) Orange Peels

Fig. III(b) Sun dried orange peels

Fig.III(c) Powdered orange peels

PHENOL RESIN

Phenol formaldehyde resins (PF) are synthetic polymers obtained by the reaction of phenol or substituted phenol with formaldehyde. Used as the basis for Bakelite, PFs were the first commercial synthetic resins (plastics). They have been widely used for the production of molded products including billiard balls, laboratory countertops, and as coatings and adhesives. They were at one time the primary material used for the production of circuit boards but have been largely replaced with epoxy resins and fiberglass cloth, as with fire-resistant FR-4 circuit board materials.

There are two main production methods. One reacts phenol and formaldehyde directly to produce a thermosetting network polymer, while the other restricts the formaldehyde to produce a prepolymer known as novolac which can be moulded and then cured with the addition of more formaldehyde and heat. There are many variations in both production and input materials that are used to produce a wide variety of resins for special purposes.

Figure III(d). Phenol Resin

SIGNIFICANCE

Strength, heat and impact resistant, high resistance to chemical corrosion and to the penetration of moisture, machinable.

HARDENER

The hardener with IUPAC name NNO - bis (2aminoethylethane-1,2diamin) has been used with epoxy designated as HY951. This has a viscosity of 10-20 MPa at 25ºC.

Curing may be achieved by reacting an epoxy with itself (homopolymerisation) or by forming a copolymer with poly functional curatives or hardeners. In principle, any molecule containing a reactive hydrogen may react with the epoxide groups of the epoxy resin.

Common classes of hardeners for epoxy resins include amines, acids, acid anhydrides, phenols, alcohols and thiols. Relative reactivity (lowest first) is approximately in the order: phenol < anhydride < aromatic amine < cycloaliphatic amine < aliphatic amine < thiol. Whilst some resin/ hardener combinations will cure at ambient temperature, many require heat, with temperatures up to 150 °C being common, and up to 200 °C for some specialist systems.

Insufficient heat during cure will result in a network with incomplete polymerisation, and thus reduced mechanical, chemical and heat resistance. Cure temperature should typically attain the glass transition temperature of the fully cured network in order to achieve maximum properties. Temperature is sometimes increased in a step-wise fashion to control the rate of curing and prevent excessive heat build-up from the exothermic reaction.

Hardeners which show only low or limited reactivity at ambient temperature, but which react with resins at elevated temperature are referred to as latent hardeners. When using latent hardeners, the epoxy resin and hardener may be mixed and stored for some time prior to use, which is advantageous for many industrial processes.

Very latent hardeners enable one-component (1K) products to be produced, whereby the resin and hardener are supplied pre-mixed to the end user and only require heat to initiate curing. One-component products generally have shorter shelf-lives than standard 2-component systems, and products may require cooled storage and transport.

CARBON

Carbon is a chemical element with symbol C and atomic number 6. On the periodic table, it is the first (row 2) of six elements in column (group) 14, which have in common the composition of their outer electron shell. It is non- metallic and tetravalent - making four electrons available to form covalent chemical bonds. There are three naturally occurring isotopes, with 12C and 13C being stable, while 14C is radioactive, decaying with a half-life of about 5,730 years. Carbon is one of the few elements known since antiquity.

Carbon is the 15th most abundant element in the Earth's crust, and the fourth most abundant element in the universe by mass after hydrogen, helium, and oxygen. It is present in all forms of carbon-based life, and in the human body carbon is the second most abundant element by mass (about 18.5%) after oxygen. This abundance, together with the unique diversity of organic compounds and their unusual polymer-forming ability at the temperatures commonly encountered on Earth, make this element the chemical basis of all known life.

The atoms of carbon can be bonded together in different ways: allotropes of carbon. The best known are graphite, diamond, and amorphous carbon. The physical properties of carbon vary widely with the allotropic form. For example, graphite is opaque and black, while diamond is highly transparent.

The most common oxidation state of carbon in inorganic compounds is +4, while +2 is found in carbon monoxide and transition metal carbonyl complexes. The largest sources of inorganic carbon are limestones, dolomites and carbon dioxide, but significant quantities occur in organic deposits of coal, peat, oil and methane clathrates. Carbon forms a vast number of compounds, more than any other element, with almost ten million compounds described to date, which in turn are a tiny fraction of such compounds that are theoretically possible under standard conditions.

Fig III(e). carbon

ALUMINIUM OXIDE

Aluminium oxide is a chemical compound of aluminium and oxygen with the chemical formula Al2O3. It is the most commonly occurring of several aluminium oxides, and specifically identified as aluminium (III) oxide. It is commonly called alumina, and may also be called aloxide, aloxite, oralundum depending on particular forms or applications. It occurs naturally in its crystalline polymorphic phase α-Al2O3 as the mineral corundum, varieties of which form the precious gemstones ruby and sapphire.

Al_2O_3 is significant in its use to produce aluminium metal, as an abrasive owing to its hardness, and as a refractory material owing to its high melting point.

Al_2O_3 is an electrical insulator but has a relatively high thermal conductivity (30 Wm−1K−1) for a ceramic material. Aluminium oxide is insoluble in water. In its most commonly occurring crystalline form, called corundum or α-aluminium oxide, its hardness makes it suitable for use as an abrasive and as a component in cutting tools.

Aluminium oxide is responsible for the resistance of metallic aluminium to weathering. Metallic aluminium is very reactive with atmospheric oxygen, and a thin passivation layer of aluminium oxide (4 nm thickness) forms on any exposed aluminium surface. This layer protects the metal from further oxidation. The thickness and properties of this oxide layer can be enhanced using a process called anodising.

A number of alloys, such as aluminium bronzes, exploit this property by including a proportion of aluminium in the alloy to enhance corrosion resistance. The aluminium oxide generated by anodising is typically amorphous, but discharge assisted oxidation processes such as plasma electrolytic oxidation result in a significant proportion of crystalline aluminium oxide in the coating, enhancing its hardness.
Aluminium oxide was taken off the United States Environmental Protection Agency's chemicals lists in 1988. Aluminium oxide is on EPA's Toxics Release Inventory list if it is a fibrous form.

The most common form of crystalline aluminium oxide is known as corundum, which is the thermodynamically stable form. The oxygen ions nearly form a hexagonal close-packed structure with aluminium ions filling two- thirds of the octahedral interstices. Each Al_3+ centre is octahedral. In terms of its crystallography, corundum adopts a trigonal Bravais lattice with a space group of R-3c (number 167 in the International Tables). The primitive cell contains two formula units of aluminium oxide.

Aluminium oxide also exists in other phases, including the cubic γ and η phases, the monoclinic θ phase, the hexagonal χ phase, the orthorhombic κ phase and the δ phase that can be tetragonal or orthorhombic. Each has a unique crystal structure and properties. Cubic γ-Al_2O_3 has important technical applications. The so-called β-Al2O3 proved to be $NaAl_{11}O_{17}$.

Molten aluminium oxide near the melting temperature is roughly 2/3 tetrahedral (i.e. 2/3 of the Al are surrounded by 4 oxygen neighbors), and 1/3 5-coordinated, very little (<5%) octahedral Al-O is present. Around 80% of the oxygen atoms are shared among three or more Al-O polyhedra, and the majority of inter-polyhedral connections are corner-sharing, with the remaining 10 –20% being edge-sharing. The breakdown of octahedra upon melting is accompanied by a relatively large volume increase (~20%), the density of the liquid close to its melting point is 2.93 g/cm^3.

Figure III(f). Aluminium oxide

Fabrication Method

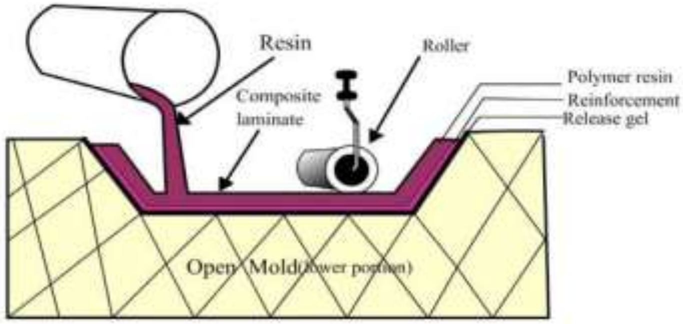


Figure iv(a). Schematic diagram for Hand lay - up fabrication method

Hand lay-up is the simplest and oldest open molding method of the composite fabrication processes. It is a low volume, labor intensive method suited especially for large components, such as boat hulls.

Glass or other reinforcing materials or woven fabric or roving is positioned manually in the open mold, and resin is poured, brushed, or sprayed over and into the glass plies. Entrapped air is removed manually with squeegees or rollers to complete the laminates structure. Room temperature curing polyesters and epoxies are the most commonly used matrix resins. Curing is initiated by a catalyst in the resin system, which hardens the fiber reinforced resin composite without external heat.

Hand lay-up technique is the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. First of all, a release gel is sprayed on the mold surface to avoid the sticking of polymer to the surface. Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the product. Reinforcement in the form of woven mats or chopped strand mats are cut as per the mold size and placed at the surface of mold after perspex sheet. Then thermosetting polymer in liquid form is mixed thoroughly in suitable proportion with a prescribed hardener (curing agent) and poured onto the surface of mat already placed in the mold.

The polymer is uniformly spread with the help of brush. Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present.. After placing the plastic sheet, release gel is sprayed on the inner surface of the top mold plate which is then kept on the stacked layers and the pressure is applied. After curing either at room temperature or at some specific temperature, mold is opened and the developed composite part is taken out and further processed.
The schematic of hand lay-up is shown in figure iv(a). The time of curing depends on type of polymer used for composite processing. For example, for epoxy based system, normal curing time at room temperature is 24-48 hours. This method is mainly suitable for thermosetting polymer based composites. Capital and infrastructural requirement is less as compared to other methods. Production rate is less and high volume fraction of reinforcement is difficult to achieve in the processed composites. Hand lay-up method finds application in many areas like aircraft components, automotive parts, boat hulls, diase board, deck etc.,

PERCENTAGE COMPOSITION

Development of Brake Pad using Orange Peel Reinforcement Polymer Composite Specimen was prepared by proper reinforcement of different material .The percentage composition of those materials for preparing Brake pad using Orange Peel Reinforcement Polymer Composite samples are given in the following table .

Table iv(a). Percentage Composition

S. NO.	**MATERIAL**	**PERCENTAGE (%)**
1	Al_2O_3	15
2	ORANGE PEEL	44
3	CARBON	10
4	RESIN	31

Fig iv(b).Test Specimen

Testing

i.Hardness test

Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance to bending, scratching, abrasion or cutting.

Hardness is not an intrinsic material property dictated by precise definitions in terms of fundamental units of mass, length and time. A hardness property value is the result of a defined measurement procedure.

SHORE HARDNESS TEST

Shore Hardness, using either the Shore A or Shore D scale, is the preferred method for rubbers/elastomers and is also commonly used for 'softer' plastics such as polyolefins, fluoropolymers, and vinyls. The Shore A scale is used for 'softer' rubbers while the Shore D scale is used for 'harder' ones.

Durometer is one of several measures of the hardness of a material. Hardness may be defined as a material's resistance to permanent indentation. The Durometer scale was defined by Albert Ferdinand Shore, who developed a device to measure Shore hardness in the 1920s. The term durometer is often used to refer to the measurement as well as the instrument itself. Durometer is typically used as a measure of hardness in polymers, elastomers, and rubbers.

Shore's device was not the first hardness tester nor the first to be called a durometer but today that name usually refers to Shore hardness (other devices are simply called hardness testers).

The results obtained from this test are a useful measure of relative resistance to indentation of various grades of polymers. However, the Shore Durometer hardness test does not serve well as a predictor of other properties such as strength or resistance to scratches, abrasion, or wear, and should not be used alone for product design specifications.

Shore hardness is often used as a proxy for flexibility (flexural modulus) for the specification of elastomers. The correlation between Shore hardness and flexibility holds for similar materials, especially within a series of grades from the same product line, but this is an empirical not a fundamental relationship.

DUROMETER SCALE:

There are several scales of durometer, used for materials with different properties. The two most common scales, using slightly different measurement systems, are the ASTM D2240 type A and type D scales. The A scale is for softer plastics, while the D scale is for harder ones.

However, the testing standard calls for a total of 12 scales, depending on the intended use; types A, B, C, D, DO, E, M, O, OO, OOO, OOO- S, and R. Each scale results in a value between 0 and 100, with higher values indicating a harder material. The testing machine diagram is shown in fig .v(a)

Figure V(a). Hardness Test (Shore' s D Hardness machine)

WEAR TEST

Wear is related to interactions between surfaces and specifically the removal and deformation of material on a surface as a result of mechanical action of the opposite surface.

In materials science, wear is erosion or sideways displacement of material from its "derivative" and original position on a solid surface performed by the action of another surface.

Wear of metals occurs by the plastic displacement of surface and near-surface material and by the detachment of particles that form wear debris. This process may occur by contact with other metals, non-metallic solids, flowing liquids, or solid particles or liquid droplets entrained in flowing gasses.

PIN– ON –DISC WEAR TESTING MACHINE

For the pin-on-DISC wear test, two specimens are required. One, a pin with a radiused tip, is positioned perpendicular to the other, usually a flat circular DISC. A ball, rigidly held, is often used as the pin specimen. The test machine causes either the DISC specimen or the pin specimen to revolve about the DISC center. In either case, the sliding path is a circle on the DISC surface. The plane of the DISC may be oriented.

The pin specimen is pressed against the DISC at a specified load usually by means of an arm or lever and attached weights. Other loading methods have been used, such as, hydraulic or pneumatic.

Wear results are reported as volume loss in cubic millimetres for the pin and the DISC separately. When two different materials are tested, it is recommended that each material be tested in both the pin and DISC positions.

The amount of wear is determined by measuring appropriate linear dimensions of both specimens before and after the test, or by weighing both specimens before and after the test. If linear measures of wear are used, the length change or shape change of the pin, and the depth or shape change of the DISC wear track (in millimetres) are determined by any suitable metrological technique, such as electronic distance gaging or stylus profiling.

Linear measures of wear are converted to wear volume (in cubic millimetres) by using appropriate geometric relations. Linear measures of wear are used frequently in practice since mass loss is often too small to measure precisely. If loss of mass is measured, the mass loss value is converted to volume loss (in cubic millimetres) using an appropriate value for the specimen density.

Wear results are usually obtained by conducting a test for a selected sliding distance and for selected values of load and speed. Other test conditions may be selected depending on the purpose of the test.

Fig. V(b) Pin on disc apparatus

Result And Discussion

EFFECT OF COMPOSITES ON HARDNESS OF BREAK PAD

In order to confirm uniform mixing and proper curing during manufacturing of brake pads with Orange peels ,carbon, aluminium oxide and resin reinforced composite , the hardness of brake pads was measured using a Shore D hardness tester (Macrona) according to the ASTM E 18 – 2014 at Ambient Temperature of 26ºC .The test report are taken in Approved Lab. The average value is reported in Table IV(a).

TABLE VI (a). Shore D Hardness Number

S.NO	**SAMPLE**	**OBSERVED VALUE , SHORE D HARDNESS NUMBER**			**AVERAGE, SHORE D HARDNESS NUMBER**
		1	**2**	**3**	
1.	Brake Pad Using Orange Peel Reinforcement Polymer Composite	**82**	**80**	**76**	**79.3**

EFFECT OF COMPOSITES ON WEAR OF BREAK PAD

In order to confirm uniform mixing and proper curing during manufacturing of brake pads with Orange peels ,carbon, aluminium oxide and resin reinforced composite , the wear of brake pads was measured using a Pin – on - Disc . The test report are taken in Approved Lab. The average value is reported in Table VI(b).

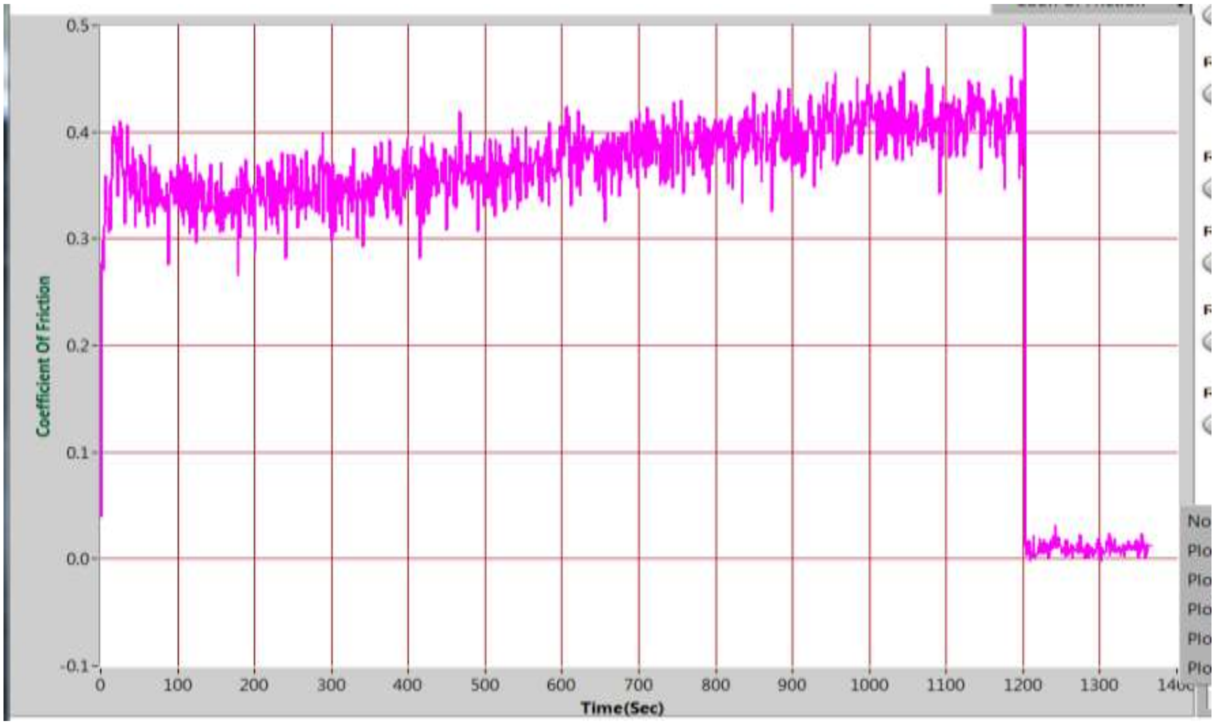
Table VI (b). Wear test

Material	**RPM**	**Load (N)**	**Time Duration**	**Sliding velocity (m/s)**	**Wear in (microns)**	**COF**	**Frictional Force (Average) N**
Brake Pad Using Orange Peel Reinforcement Polymer Composite	300	20	20 Min	1.571	173.0	0.3305	7.5

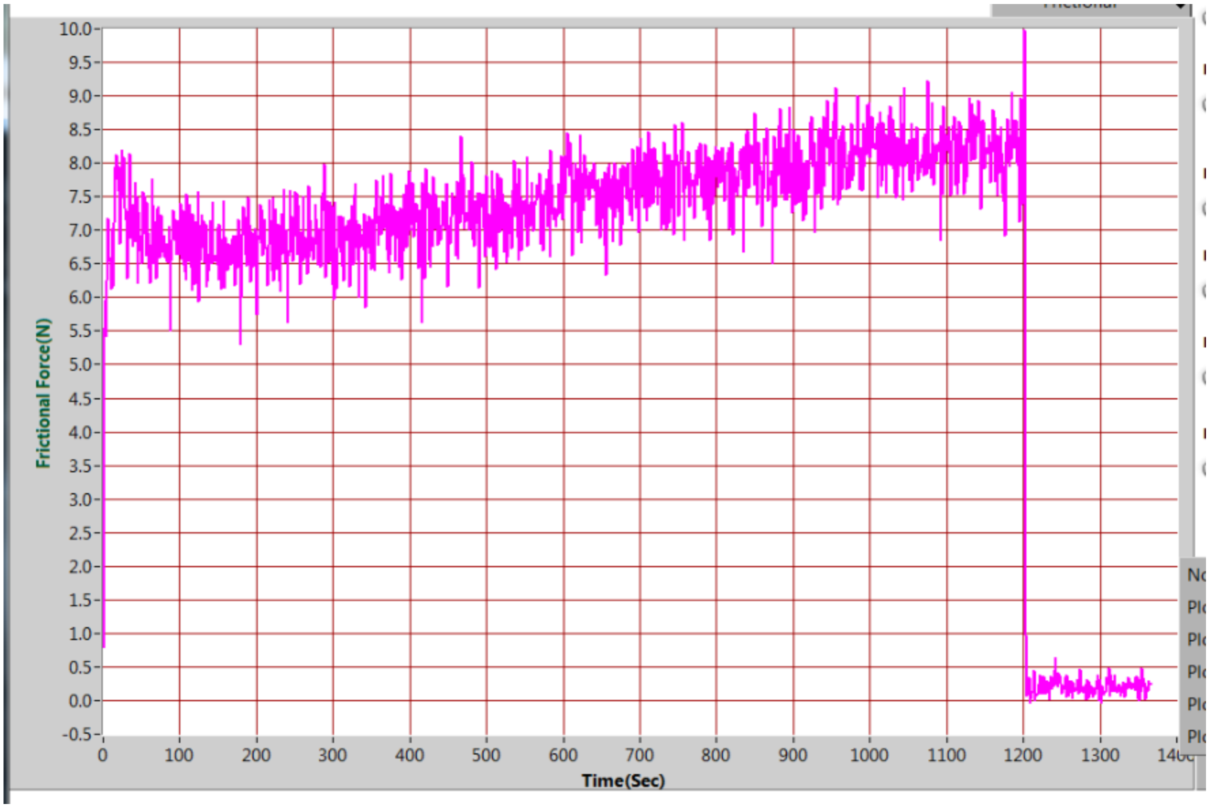
Track Radius D = 0.05 M (50 mm)

SPECIFICATION

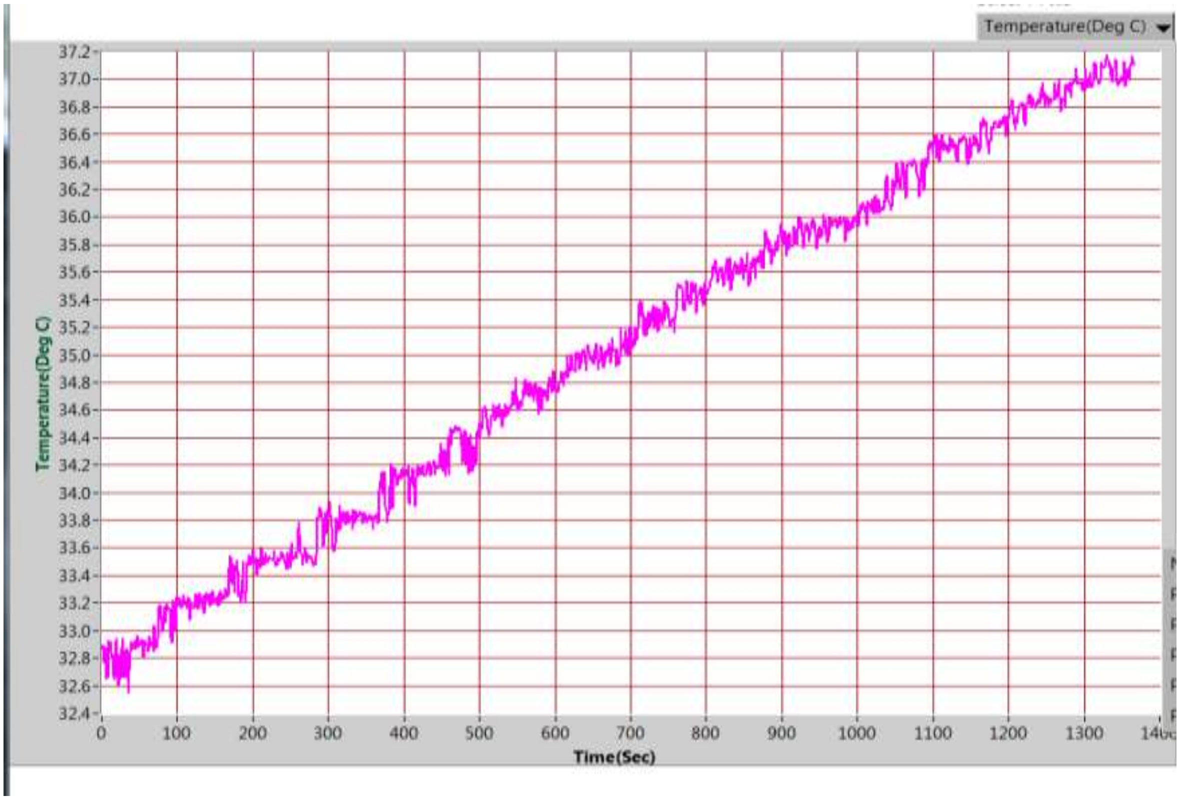
PARAMETER	**UNITS**
Pin Size	3,6,10,12 mm Dia
Disc Size	165 × 8 mm
Disc Rotation Speed	0 - 2950 RPM
Wear Track Dia Mean	50 - 100 mm
Load	1 - 200 N (Any Steps Possible)
Sliding Speed Range	0 - 10 (m/s)
Frictional Force	0 - 200 N
Wear Measurement	0 - Micrometer (1µ LC)
Temperature Power	Ambient - 300oc
Power	230 V,50 Hz S Phase



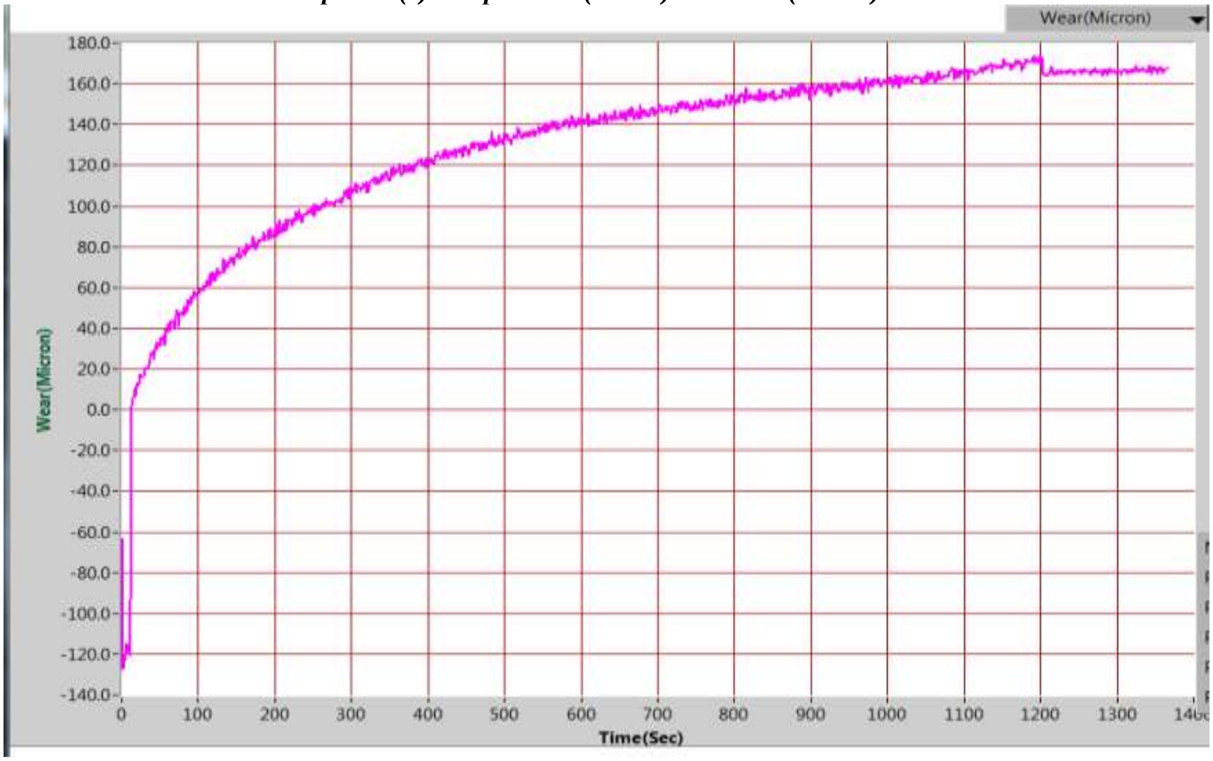
Graph vi. (a) Coefficient of Friction and Time (in Sec)



Graph vi. (b) Frictional force (N) and Time (in Sec)



Graph VI. (c) Temperature (in º C) and Time (in Sec)



Graph VI. (d) Wear (in Micron) and Time (in Sec)

In this paper different agricultural wastes are studied as alternative for asbestos brake pads and the orange peels are selected for its unique properties. The brake pad reinforced with orange peel is fabricated by the hand layup process.

Also the tests like hardness test and the wear test are conducted and the results are obtained. The results are shown that the performance is almost equal to asbestos brake pads without any environment and health effects.

It is evident from the test results that our composite brake pad is far better when compared to the conventional asbestos brake pads.

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