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DEVELOPMENT, PRODUCTION AND TESTING OF BRAKE PADS FROM PISTACHIO SHELL COMPOSITE

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ABSTRACT

The estimation of the properties of eco-friendly brake lining by make use of pistachio shell powder in direction to replace asbestos, which is carcinogenic in nature and asbestos manifestation is highly toxic which cause mesothelioma and asbestosis. Due to this asbestos lost goodwill and some alternative material progressively used. In this work asbestos free brake lining was developed by using pistachio shell powder along with silicon dioxide, graphite, copper and phenolic resin. Compressive moulding process used for producing brake sample in which the mechanical and physical properties of sample specimen were studied. The results obtained from harness, density, flame resistance, absorption (water and oil) test compared with existing properties of brake lining.

KEYWORDS: Composite, Asbestos-free, Pistachio shell, Wear and friction, Thermal conductivity.

1. INTRODUCTION

Friction pads of automobile are very high importance in braking system, and brake is most important safety and highly requiring performance system in automobile. Friction pad is essential for all type of vehicle which are equipped with brake disc. Due to friction of brake pad and brake metal plate kinetic energy of vehicle get converted into thermal energy, this is due to operation of wear and tear. These friction material are relevant for transmission and braking in various equipment. Because of technological development compositions of brake are keep changing. Brakes of any vehicle is able stop while in motion or it most hold the vehicle in position, when vehicle stopped on slop or in traffic. Presently asbestos fiber used as filler in brake pads. Asbestos was broadly used in brake pads due to its heat decreasing property and quiet operation. Asbestos is group of six naturally occurring fibrous mineral. These are mostly composed of mixture of silicates.

Asbestos exposure is the reason for mesothelioma (It is rare cancer which is associated with exposure to amphibole asbestos) and asbestosis. Asbestos also cause other forms of cancer as well as progressive lung cancer. Due to this health risk, nowadays asbestos is being replaced by non-asbestos friction material. This is the reason behind development of asbestos free material which are used in brake pads and clutches in automobile industry during manufacturing. These additional materials are metals, ceramics, carbon and organic material. When we use this material to manufacture brake pad have different advantage and disadvantage. Hence more research is carry out for replacement of asbestos and optimize the performance requirement. By make of utilization of organic waste products we can develop friction material suitable for friction pad in braking. Organic waste is solution to control harmful health disease but also helpful in reducing the dependence on depleting resource. Which are renewable resource and non-renewable resource.

Onyeneke F. N. et. al. [1] have manufactured brake friction lining using base material is perriwinkle and coconut shell powder, binder material epoxy resin and araldite, fibre reinforcement is zinc and carbon. Abrasives are Copper, Aluminum and cashew nut shell were used as abrasives and filler is rubber dust from the shoe. Samuel A. E. et.al [7] have make use of palm kernel shell (PKS) in place of asbestos. PKS sieve particle was used in production of brake pad with binder (phenolic resin), reinforcement graphite and steel), Silicon carbide (SiC) as additives using compression moulding. Rudramurthyet. al. [10] have studied one of the natural legnocellulosic material coconut shell powder (CSP) in brake pads. They use CSP as filler in brake pad in constant proportion. They fabricated brake pad material using Phenol Formaldehyde and Epoxy Resin as matrix varying combination of reinforcement (glass fibre).

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1.1 Pistachio Shell Powder as Brake Lining Ingredient

Natural resources has been used to produce fillers and fibers, including wood flour, groundnut, husk ash, rice straw, rice husk, cotton, jute, and cellulose. These materials is helpful to improve the mechanical properties of composites, entail low costs, increase impact strength, improve physical properties and enhance other mechanical properties (hardness, percentage elongation, tear strength, and tensile strength).

Among the agriculture resides, most of the part of world can produce pistachio nut so availability of pistachio nut on large scale. Iran, Turkey, and the USA are producing pistachio nut large quantity. This due to specific whether condition and land requirement for cultivation of pistachio is available in this country. Based on Food and Agriculture Organization (FAO) of United Nation statistics (2006), Iran and turkey produced nearly 192,000 Mt of pistachio in 2004, which is approximately 63.32% of the world's production of pistachio nut.

Mohamad Alsaadi[8] have studied natural pistachio shell particle on microscale. Mechanical properties of composites was experimentally investigates. Pistachio shell particles have high strength and modulus properties. Fabrication of polymer composites with this filler is suitable for many engineering applications. Pistachio Shell powder was sieved in smallest particle size as possible so we can get homogeneous mixture with polymer.

2 MATERIALAND PROCEDURE

2.1 Materials

The various material used for production of brake lining are: Pistachio shell as filler, Copper as reinforcing fiber, Phenolic resin (phenol formaldehyde) as binder, Graphite and Silica (SiO_2) as frictional additives are shown in Figure 1 below.

Figure 1 photo of ingredient

Copper is ductile soft and malleable metal having high electrical and thermal conductivity. Copper improves pads thermal conductivity and so help in decreasing contact temperatures. Copper induces smooth sliding with small noise generation.

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Phenolic resin have excellent heat resistance, superior mechanical strength and also have dimensional stability. They have high resistance to various acids, water and solvents. At higher temperature resin maintain good mechanical strength. On compare with other resins phenolic resin have good flame resistance.

Graphite is commonly used as a lubricant mostly in case of dry lubrication. For stabilizing friction coefficient graphite is mostly used because graphite form lubricant layer on opposite material rapidly. Graphite was chosen because graphite have good thermal conductivity and lubrication properties. For regular atmospheric condition graphite is best suitable. At higher humidity graphite have good lubrication. Graphite has protection against fretting corrosion. Graphite is stable at high-temperature.

Silica is having high resistant to heat, with 1650 °C melting point and also silica possess high hardness so it is used in manufacturing of brake pads as an abrasive.

2.2 Raw Material Preparation

A 2 kg quantity of pistachio shell obtained from nearer glossary shop. The pistachio shell was cleaned and wash for removal of salt and kept in sunlight for dry. The shells was crushed into powder by make use of domestic grinding machine and then sieved into various sieve sizes of small aperture of 120 microns, 60 microns, 40 microns for 10 minutes.

Production of composite consist of mixing of material, compaction of material (cold pressing), and sintering (hot pressing) cooling, cooling, post curing and finishing of specimen. All constituent gradients pistachio shell powder, copper, phenolic resin, graphite, silicon dioxide are added together in % of wt. ratio as shown in Table.1. The combination were properly mixed in domestic mixer for 15 minutes to form homogenous mixture formed. Now this mixture is poured in die. And cold pressed with hydraulic press. Now place ring specimen on hot pressed hydraulic machine as shown in Figure 2 for sintering temperature range 150 ℃ to 160 ℃. Now take out final specimen and kept for cooling as shown in Figure 3. After cooling we form cuboid shape specimen of different composition by cutting and finishing as shown in Figure.4.

Table1three different composition

Ingredient	S 1	S 2	S 3
Copper	25	25	25
SiO_2	10	10	10
Graphite	10	10	10
Phenolic Resin	20	25	30
Pistachio shell powder	35	30	25
Total	100	100	100

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Figure 2 hot pressed hydraulic machine

Figure 3 manufacture ring

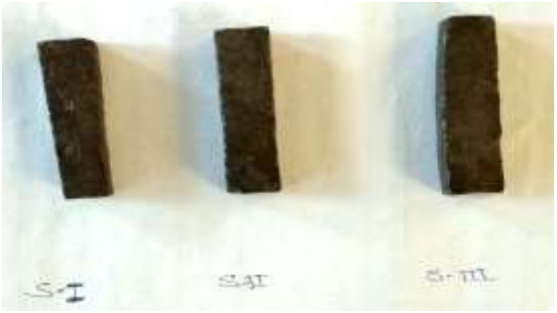

Figure 4 finished specimen

2.3 Rockwell Hardness Test

Rockwell hardness test is used for calculating resistance of material to indentation. In indentation hardness tests used to measure deformation occurs at indenter tip while material is under test with a particular type of indenter. Test Procedure is followed according to ASTM E18. The Rockwell test procedure is very simple and common for Rockwell indenter or scale being used. First we brought indenter into contact with the material which is used for testing purpose and small force is putted to the indenter. Usually this small force is kept constant for some time, after that force is removed and the deepness of penetration is measured. After this major force is applied. This applied force is hold constant for some period of time, now remove additional major force, and kept small force (minor load) constant. This small force kept for some time, the deepness of penetration is measured second time. Now remove the indenter from the test material. We get value of penetration 'h' which is difference between the depths of penetration measurements value. Rockwell hardness number is calculate by making use of value"h".

Rockwell hardness = 100 - $\frac{h}{0.002mm}$ ……. (1)

Scale symbol = HRB
Type of indenter = spherical steel ball with diameter of 1.588 mm
Preliminary force = 98.07 N (10 kgf)
Total force = 980.7 N (100 kgf)

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2.4 Thermal Conductivity

When material used at high temperature application thermal conductivity plays a crucial role. The thermal conductivity is dependent on factors like amount and type of fillers, technique of processing. Guarded hot plate (GHP) instrument is used for calculating thermal conductivity of manufactured material shown Figure 3. Principle working of thermal conductivity instrument is shown in Figure 5. One surface is kept at constant temperature of specimen and another surface is given stationary heat flux. Here one dimensional Fourier law is described. Remaining part of rod is thermally insulated by make use of asbestos tape.

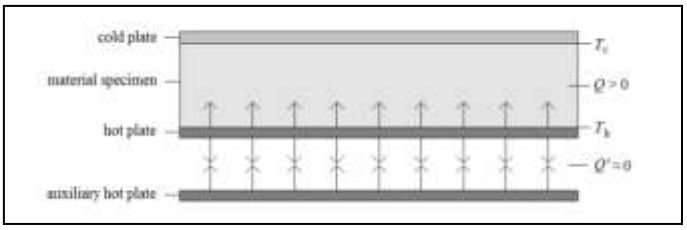

Figure 5 principle of thermal conductivity

Determination of coefficient of thermal conductivity as given below:-

The heat condition equation is given by,

$$Q = KA\frac{dT}{dx} \ldots\ldots (2)$$

Where,

Q = heat flow rate through the rod, watts.

= V * I

Where, Voltage (V) in volt (V) and

Current (I) in ampere (A).

K = Coefficient of thermal conductivity of specimen, $watts/_{m^2\ 0c}$.

A = Cross-sectional area of the specimen perpendicular to the heat flux in m^2

d = Thickness of the specimen in m^2.

ΔT = Temperature difference between hot and cold surface of the specimen is respectively

2.5 Oil and Water absorption test

Oil absorption test and water absorption test are utilized to calculate the amount of oil and water absorbed under particular conditions. Water absorption mostly affect by materials type and utilized additive.

Test Procedure is followed according to ASTM D570-99. For absorption test, specimen dried in furnace at specific temperature and specific time then allow for cooling. The oil and water absorption of specimen were resolved on by soaking the specimen in oil and water for 24 hours. $W_0$is initial weight of every specimen before socking water. Specimens were removed from oil and water after 24 hours Figure 6 and Figure 7 respectively and clean surface to remove oil and water reweighed and recorded as W_1. Differences in initial and final weights for each specimen were then used to determine absorption rate of absorption.

Figure 6 oil % absorption

Figure 7 water % absorption

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Specimen size:S 1 - L-13, B-6, H-55
S 2 - L-13, B-6, H-49
S 3 - L-13, B-6, H-47

The formula for measurement is given as;

$$\text{Percentage absorption} = \frac{(W1-W0)}{W0} * 100 \ldots\ldots (3)$$

Where,
W_1= mass of specimen after removing from water or oil
W_0 = mass of specimen in air

2.6 Flame resistance

When oxygen combine with other substance to produce heat and causing ignition called burning process. Unless and until substance is in contact with oxygen, oxidation take place at material surface. The rate of oxidation is very low at ambient temperature. A good brake pad should possess good resistance to high heat and temperature.

Furnace can be utilized to find out flame resistance of brake lining. Material was placed in the furnace as shown in Figure.8. The specimen weight before burning and after burning were recorded after 10 min after burning.

$$\text{Flame resistance} = \frac{(W1-W0)}{W0} * 100 \ldots\ldots (4)$$

Where,
W_1= mass after removing from furnace of specimen
W_0 = mass in air of specimen

Figure 8 furnace used for flame resistance

2.7 Density

The density of any material is the mass per unit volume of that material. Specific gravity is a measure of the ratio of the mass of a material to weight of a reference volume of material at 26 °C. Specific gravity and density are especially relevant a lower density or specific gravity mean more material per mass or varied part weight.

Test Procedure

Test Procedure is followed according to ASTM D792. First note down weight of specimen in air then note down weight of specimen in fully immersed in distilled water with sinker at room temperature. Also measure weight of sinker containing water. Density and Specific Gravity are calculated by make use of above value.
Specimen size: Any convenient size

$$\text{Specific gravity} = \{ \frac{Wa}{[(Wa+Wc)-Wb]} \} \ldots\ldots. (5)$$

Density = Specific gravity * 1000
Where,
W_a = mass of specimen in the air.
W_b = mass of specimen and sinker containing water.
W_c = mass of totally immersed specimen and sinker.

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2.8 Wear and Coefficient of Friction

The TR-20LE, Wear and friction monitor apparatus represents a substantial advance in terms of simplicity and convenience of operation, ease of measurement, both wear and friction force. Tribometer is an instrument that measure wear and coefficient of friction and frictional force i.e. tribological properties between two surfaces in contact. The equipment can apply load nearly 200 N and speed can vary from 200 to 2000 RPM. We can conduct tests under dry as well as wet conditions.

We can vary rotational speed, normal load & wear track diameter for testing purpose. We can get direct value of wear and Normal friction force recorded on a PC. These are continuously monitored because of electronic sensors. In this setup pin is made up of soft material and the disc is made up of a hard material such as MS or CI. The pin is stationary part and which is held by pin holder and the disc is a rotating part.

Mounting of the specimen is shown in Figure 9 and pins are 13 mm in width and vary in length from 47 mm to 54 mm.

Figure 9 mounting of specimen ontribometer

3 RESULT AND DISCUSSION

3.1 Hardness

Phenolic resin percentage volume increases in substance value of hardness varied non-uniformly. Reading taken on Rockwell hardness tester i.e. as phenolic resin content increase from 25% to 30% hardness value slightly decrease and later resin content increase from 30% to 35% hardness value increases shown in Figure 10. Hardness value for composition S 1, S 2, S 3 are 85.93, 85.43, 86.86 respectively. As phenolic resin increase we get high value of hardness due to fact that binder is thermosetting polymer which shows high strength after curing. High value of hardness was assigned to increasing in close packing and bonding.

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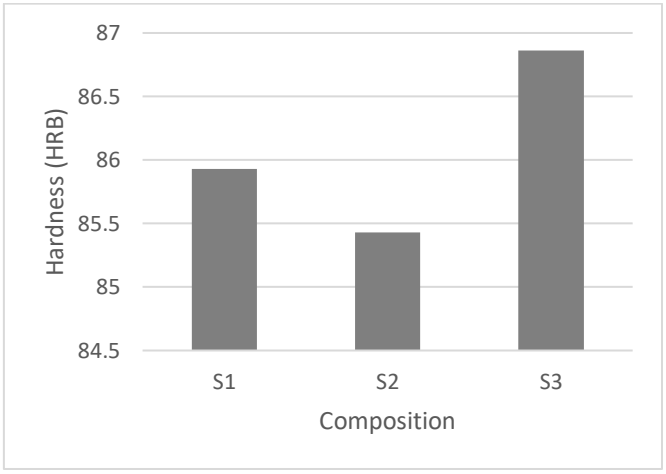

Figure 10 variation of hardness

3.2 Thermal Conductivity

The thermal conductivity of composite substance or material was experimentally investigated in this study. The experimental result is as follows

Observations:

Main heater Input (Q) = V × I (Watts)

V = 8 V I = 2 A

Thickness of spacer (dx) = 6 mm =0.006 m

Outer diameter of disc (D) = 100 mm = 0.1 m

Inner diameter of disc (d) = 80 mm = 0.08 m

Area of Spacer = $\frac{\pi}{4} \times (D^2 - d^2)$

Thermal Conductivity = $\frac{V*I*dX}{A*dT}$ W/mK

From Table 2 we come to know that thermal conductivity vary non-uniformly, but if brake pad have high thermal conductivity then brake pad cause transfer of heat to brake fluid result in evaporation of fluid, which cause decrease in performance of braking. And if brake pad have low thermal conductivity then it cause to raise in pad temperature, as increase in thermal resistance builds up the temperature at contacting surface. Therefore brake pad should possess most favourable thermal conductivity.

Table 2 reading recorded at thermocouple

Temp.→ S.N.↓	T_h	T_c	dT = T_h- T_c	Thermal conductivity
S 1	104.4	26	78.4	0.433
S 2	105.2	26	79.2	0.429
S 3	103.4	26	77.4	0.439

3.3 Oil Absorption and Water absorption

Oil absorption and water absorption percentage decrease as resin volume % increase in composition as shown in Figure 11 and Figure 12 respectively. This because of close packing of interface element achieved result in decreased pores. Also bonding between the pistachio shell and resin increased will lead to reduce in level of porosity.

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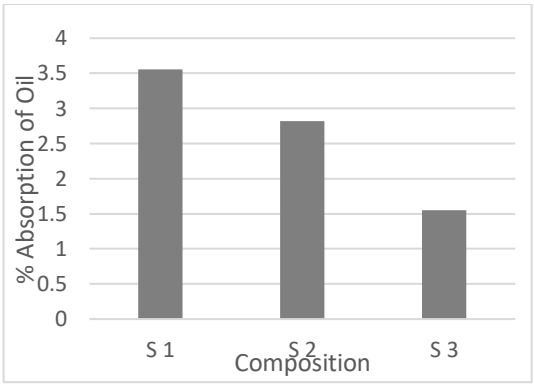

Figure 11 variation of % oil absorption

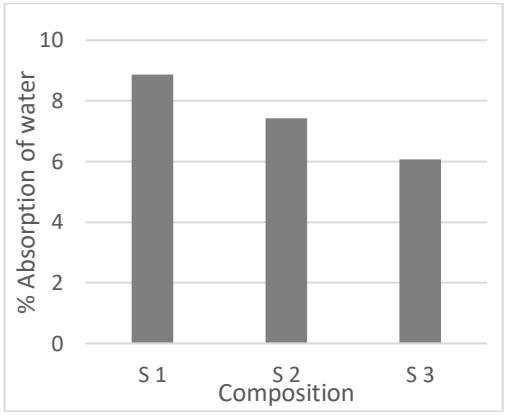

Figure 12 variation of % water absorption

Swelling of material in oil absorption test and water absorption test is result of spring back effect and hygroscopic effect.

3.4 Flame Resistance

We observed that as resin volume percentage increase in composition flame resistance increases as shown in Figure 13. This is due to proper bonding of all material present in brake pad manufacturing. Flame resistance of composite S 1, S 2, S 3 are 18.48, 21.36, 25.23 respectively.

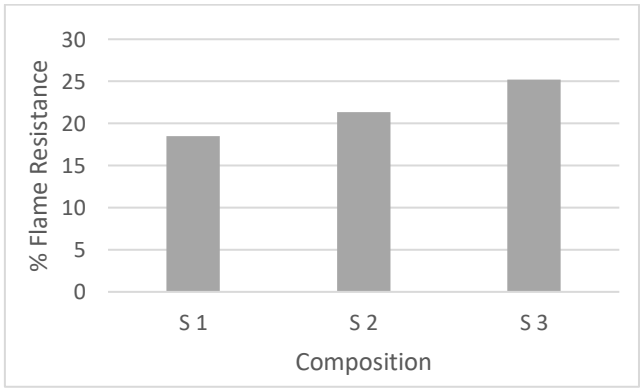

Figure 13 variation of % flame resistance

Graph indicates that carbonized pistachio shell powder particle with resin increasing percentage in increasing stability of the brake pad, which also indicate that thermal stability.

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3.5 Density

The density any composite material is depend upon molecular interaction between particle and porosity induced in that specimen. As percentage of resin increases density of composite material increases. Increase in density shows that increase in bonding of material and decrease in porosity. Density of composition S 3 is highest, this indicate that packing of pistachio shell particles is good is good in the composite. Variation of density is shown in Figure 14.

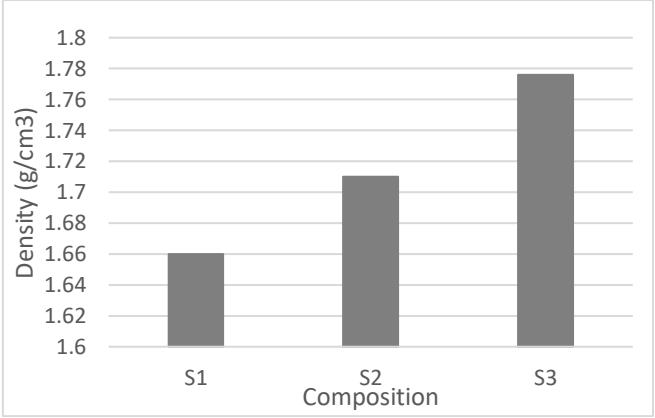

Figure 14 variation of density

3.6 Wear and Friction

Effect of Applied Load –

The effect of load applied on tribological properties of 3 sample is studied. 10 N, 30 N and 50 N loads are used for application, at 600 RPM rotational speed and 70 mm track diameter kept constant for study of effect of applied load. Graph shows the variation of Wear and Coefficient of friction of sample against cast iron disc at applied load 10 N, 30 N and 50 N and 600 RPM rotational speed.

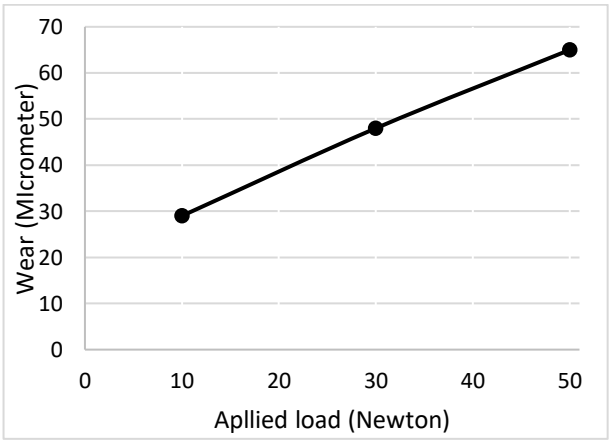

Figure 15 variation wear vs load

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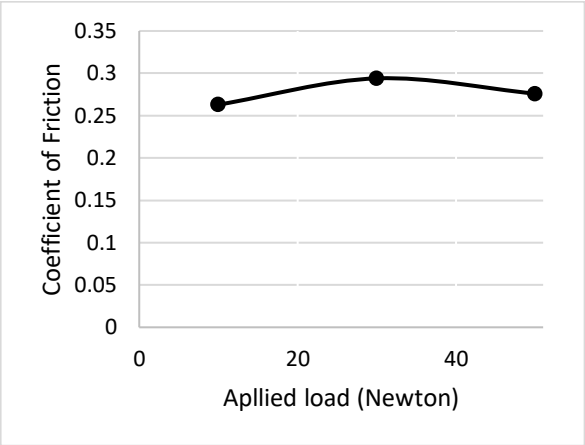

Figure 16 variation cof vs load

It is observed that wear is maximum at 50 N applied load and coefficient of friction increases first as load increase and decreases after loading further. As load increases heat developed at frictional surface is more and strength at surface decrease cause to more wear. After increasing load wear increase this cause increase in roughness which result in decrease or constant coefficient of friction.

Effect of rotational speed –
The effect of rotational speed on tribological properties of 3 sample is studied. 400 RPM, 600 RPM and 800 RPM rotational speed are used for application, at 50 N load and 70 mm track diameter kept constant for study of effect of rotational speed.

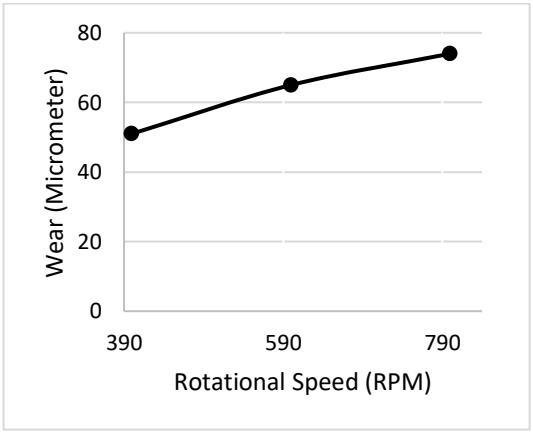

Figure 17 variation wear vs speed

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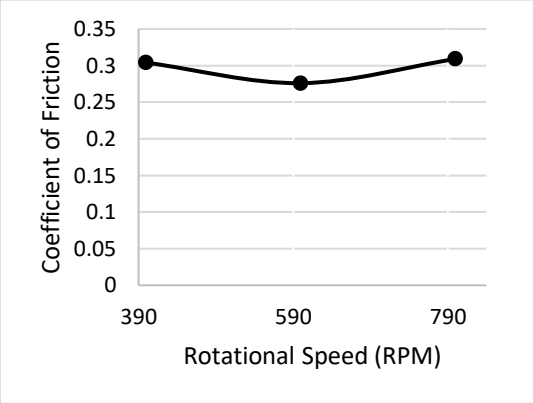

Figure 18 variation cof vs speed

From above graph observed that wear is increasing as rotational speed increase and Coefficient of friction decreases and then increases. These is because of duration of rotational speed is same in all case but as speed increase rotation completion in circular path increase cause increase in length of friction.

4 CONCLUSIONS

From the observation, result and analysis of research we came on following conclusion:

- Density of component is in range of 1.66 to 1.78 g/cm^{3}which is 42% lighter than currently using brake pad.
- As phenolic resin binder increase in composition value of COF increases and wear is decrease.
- Hardness, flame resistance and thermal conductivity increases as binder volume percentage increase in composition due to closed packing of element present in material.
- Water absorption and oil absorption is decrease as resin percentage increase in composition due to decrease in porosity of element of material.
- In present work deviation is within acceptable range. So we can effectively use pistachio shell as filler alternative to current using filler.

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