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Production of Motor Vehicle Brake Pad Using Local Materials (Perriwinkle and Coconut Shell)

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--ABSTRACT--

The production and testing of motor vehicle brake pad using locally available raw materials is presented. The disc brake friction lining with the geometrical specifications of Audi 90 model was produced using palm kernel and coconut shell powder as base materials, araldite and epoxy resin as binder materials and carbon as fibre reinforcement. Aluminum, copper, zinc and cashew nut shell were used as abrasives and rubber dusts from shoe as filler. The commercial asbestos brake pad produced by Ibeto group of Companies served as control. Two groups of samples of 25 each and sub group of five samples each were produced. The two major groups were made to have different percentage composition of carbon, palm kernel shell, coconut shell, araldite and epoxy resin. The five sub group samples were produced from different grit/particle sizes. Test results revealed that second major group composition with grit/particle size of 0.25 and 0.35 gave the best result in the test instruments used and in proof test on Audi 90 model. Further test on the second major group composition gave static and dynamic friction coefficient of (0.4-0.65) and (0.35-0.55) respectively as compared to static and dynamic coefficient of 0.5 -0.75 and 0.45-0.65 respectively of the reference commercial asbestos lining produced by Ibeto. The scratch hardness, bonding strength to the back plate and wear rate of the specimen were in the range (80-85), (25-27) kg/cm^2, (0.03-0.06) mm/min. respectively and for asbestos brake pad wear rate range from 0.04-0.08mm/min.

Keywords: *Brake pad, Brake friction, Perriwinkle shell, wear rate, scratch hardnes, bonding strength.*

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I. INTRODUCTION

Environmental pollution is a serious health hazard to humans. Products which wear out and release particles to the atmosphere must be made with materials that are not poisonous to living creatures and human beings. It is universally understood and confirmed that asbestos which is earlier used for the manufacture of brake pad and brake linings of motor vehicle brakes produces asbestos dust that if inhaled by human beings causes cancer of the lungs and brain.The cost of acquiring asbestos as raw material for the production of brake pads and brake shoe lining for motor vehicle brake systems increase cost of production and subsequently increase in selling price of brake pads and brake lining.

Use of local materials can subsidize price.There are desired mechanical properties, and chemical properties which some material possess that make them suitable for brake pads and brake lining. Examples of such properties are hardness, resistance to abrasion, environmental friendliness. Rabinowioze (1956) reported that friction arises from surface interactions between two contacting material and is affected by volume and surface dependent properties. Volume dependent properties are elastic and it modifies the hardness and thermal characteristics, Iloeje*et al.* (1989). Surface properties of importance are the chemical reactivity, surface energy, tendency to absorb molecules from the environment and compatibility of the contacting surface forces which causes friction due to adhesion, local fusion asperity and interlocking, Iloeje (1989). Friction linings for automobile brakes must have a reasonably high friction coefficient typically within the range 0.40-0.47, which is stable over wide variations of temperature and pressure. They should also have low wear rates, low moisture sensitivity, low shrinkage, adequate mechanical strength, good bonding to the back plate among other properties, Sinclair (1964).

Since no single material can have all the properties required, linings are usually made of mixture of materials in granular form, which are compound and subject to specified pressure. The additive added include hard rubber dust, fully cured resin brass chips for reduction of wear, carbon black to increase tensile strength and bonding agents such as sulphur and zinc oxide. The bonding agents also protect the linings against abrasive wear, corrosion, oil and moisture penetration, and chemical attack. Wood and leather were used as brake pad materials prior to the establishment of friction materials industry. However, their poor temperature resistance was only one of a number of factors which causes them to have limited application that necessitated the use of cast iron in 1870 to replace Wood and Leather. Nevertheless cast iron can undergo phase transformation leading to heat cracking of the brake drum or disk. This attribute of cast iron led to the introduction of cotton based material impregnated with bitumen solution by HarbetFrood (1897). However the need for operating temperature to exceed the permissible limit for cotton based materials due to high operating conditions led to the substitution of cotton with asbestos fibres. Medical research revealed that asbestos can lodge in the lung and induce adverse respiratory condition, Peter (2001). This attribute of asbestos led to the introduction of other materials but none is exactly like asbestos though they offer similar performance characteristics. In 1950 Resin-bonded metallic brake lining was introduced to replace asbestos; however the wear of the disc made them not to be suitable for use. In addition glass fibre was introduced in 1970 but its brittleness led to their limited application while aramid fibre which was introduced in 1984 as brake pad material was found to have the same comparative advantage as asbestos but it is very soft. Sepiolite was also proposed in 1974 to replace asbestos because of the similar property it exhibit with asbestos but its limitation is that it causes inflammation of the lungs and pulmonary interstitial fibrosis which is also caused by crocidolite asbestos. Potassium titanate which was also in use is associated with a cancer called mesothelioma and in 1992, Ceramic fibre was introduced as an alternative to asbestos but its brittle nature necessitated its limited application. Furthermore, paper type was introduced in 1998 to replace asbestos though it is associated with the problem of degrading very quickly at temperature above 150^0C. This brought about the introduction of Sintered materials in 2001 which degrades at a much higher temperature but also has high production cost. The Fabric type was introduced in 1999 but its high porosity gave rise to a high flow rate and permeability of fluid which was among its limitations. Since no single material could achieve all the desired attributes for an automobile brake pad, different constituents of materials were therefore introduced to overcome the challenges encountered in finding suitable materials as an automobile brake pad. The Resin binder, with the introduction of Phenolic resin which decomposes at temperatures beyond 450^0C high braking force during application of brake but decomposes into fumes likely to release its constituent which are poisonous. In an effort to overcome the phenolic resins, the following were introduced. Condensed poly-nuclear aromatic resin (COPNA) which introduced poisonous fumes like phenolic resins. Silicone-modified resin has a better heat and chemical resistance than the conventional resin. Also Cyanate ester resin introduced is stable at elevated temperatures, chemically inert but it is brittle like phenolic resin. In addition Expoxy-modified resin which is still introduced has high frictional stability while Thermoplastic polyimide resin introduced induce excessive brake disc wear but has low thermal polyimide conductivity compared to phenolic resin, in 1984 the fillers, with the carbonate, Molybdenum trioxide and Titanate, helped to increase the temperature of the brake pad material to 135^0C, suppressing low frequency brake noise and also providing heat stability for the material. The need to reduce fluctuation in friction coefficient and braking noise brought about the introduction of the organic filler in 1995. The lubricant like graphite and metal sulphide were added in the year 1998 and 1999 respectively to stabilize the developed friction co-efficient. The Abrasives were also added in the year 2002 to increase friction co-efficient and to reduce the wear of the counter material from the surface.

Finally, the introduction of Perriwinkle and Coconut shells which are used as the base materials in this research work have high strength but are also characteristically resistant to wear and non-poisonous. They are easily reducible to granular form and can be compounded with many of the known additives to form friction linings. They can also be obtained locally. The work has its major focus on the use of locally available materials, and concentrates on the production of a brake pad of a particular model of motor vehicles (Audi 90 model) from a particular manufacturer.

II. MATERIALS AND METHODS

2.1 MATERIALS

The materials used for the production of the brake pads were carefully selected and they include perriwinkle and coconut shells powder, araldite and epoxy resin as binder materials, carbon as fibre reinforcement, aluminum, copper and zinc as abrasives, rubber dust from shoe as filler. Mechanical properties of the palm kernel shell and coconut shell are shown in Table 1. Important factors considered in selecting these materials include high coefficient of friction, low wear rate, good heat dissipation while retaining the mechanical strength, ability to dry up as quickly as it passes through water.

2.2 EXPERIMENTAL METHODS

2.2.1 EQUIPMENT

The equipment used include hammer mill, Rockwell hardness testing machine, compression testing machine and abrasion testing machine, friction plane apparatus and disc brake test apparatus.

2.2.2 EXPERIMENTAL METHODS

The perriwinkle and coconut shell were first crushed to powdered condition of different grit sizes using a hammer mill,after which the crushed products were sieved using sieving tray of different mesh sizes to get five different grit sizes for the production of fifty (50) different samples of brake pads for comparative analysis. The grit sizes selected for the brake pad production are: 0.25mm, 0.35mm, 0.45mm, 0.55mm, 0.65mm. The different sieved out grit sizes of the crushed perriwinkle and coconut shells were weighed out alongside with the other materials using weighing machines. This was done to determine the mixture ratio of the composition. The mixed material was packed into the mould and compacted using hydraulic press machine. The materials were weighed out in two different composition groups for the preparation of fifty (50) samples of the specimen. Each group consists of twenty five (25) samples with a subgroup of five (5) samples in each of twenty five (25) member groups having varying particle/grit size in each sample. Each of two major groups of twenty five (25) samples were made to have varying percentage of araldite, epoxy resin, carbon, rubber dust, palm kernel shell, and coconut shell. This is to determine the composition of the brake pad that gives the best result in performance. The materials for the first group of twenty five (25) samples of varying grit size and the same percentage composition of araldite, carbon, rubber dust, and other materials were mixed for each sub group of five different grit sizes, and packed into their different moulds. These materials were compacted under compression pressure of 250kgf/cm^2 each in a motorized mixing machine for one hour before curing operation. The mixture compositions for the two groups of twenty five samples are shown in Table 2 and Table 3 respectively.

Tests were performed on the specimen to determine its density, static co-efficient, dynamic co-efficient, of friction, scratch hardness and wear thickness. These tests were also performed on the asbestos brake pad produced by Ibeto Group of Company Nnewi, Anambra State for comparison. All the tests were carried out using test apparatus available at the Ibeto Group of Companies friction material producing unit.

III. RESULTS AND DISCUSSION

3.1 RESULTS

The test results are displayed in Tables 1 – 13. A standard Ibeto manufactured brake pad of asbestos of the same dimension and standard was test run with the specimens produced and both have the same hardness range of 80-85 each when tested on the durometer.Presented in Fig. 1, Fig. 2 and Fig. 3 are the plotsof the fabricated brake pad (Wear in mm) against time (s). Fig. 3 is the control (asbestos). The Specimen produced and that of Ibeto manufactured were both put into the bonding machine and their bonding power were determined from the bonding testing machine as 30kg/cm^3 for Ibeto manufactured and 25kg/cm^3 to 27kg/cm^3 by the Specimen.

3.2 DISCUSSION

3.2.1 Wear Rate Effect

The graphical representations shown in Fig. 1 – Fig. 3 illustrate the wear behaviour of the different brake pad materials' composition and that of the asbestos (the control). The dynamics and how the constituent materials affect the general performance of the brake pad materials can be understood from these figures.

As can be seen from Fig. 1, the wear on the asbestos brake pad material was proportional to the duration of applied braking load up to a certain point (0.02 mm/min), after which a sharp increase in wear is noticed. The sharp increase in wear shows that the brake pad material (asbestos) has exceeded its ability for effective heat conduction at the application of the braking load at such a long period of time that will generate high rate of heat energy. This is because asbestos material can only withstand temperature which lies within the range of 500^{o}C. Similar results were obtained for the first group samples (Fig. 2). However, as can be seen from Fig. 1 and Fig. 2, the control (asbestos) has more heat conductivity ability when compared to the first group samples.

For the second group samples, Fig. 3 shows that wear on the brake pad material was proportional to the applied brake load over a short duration. This was followed by a constant wear rate as the duration of the braking load application is increased. The reason is that as the rate of application of the braking load is increased, the rate of conduction of heat from the surface of the brake pad becomes enhanced by the constituent materials which the brake pad is made up of and thus the brake pad can withstand high wear out at constant application of the brake load for a long period of time.

The wear rate of the specimen ranges between 0.025 mm/min to 0.06 mm/min while that of the conventional brake pad produced by Ibeto that has a wear rate of 0.03 to 0.08 mm/min. It can be seen that the specimens gave lower rate than the commercial Ibeto product. The superior wear property of the specimens is largely due to the good thermal conductivities of individual material constituents that make up the specimens. The main components that helped to improve the thermal conductivity of the brake pad are copper, aluminum and zinc.

3.2.2 Bonding Effect

The bonding effect of the specimens was from 25kg/cm^3 to 27kg/cm^3. The conventional brake pad made from asbestos material produced by Ibeto group of companies has bonding effect of 30kg/cm^3. The disparity in these results may be attributed to the choice of resin and compacting pressure used. Phenolic resin is the best binding agent for brake pad production. However, due to its scarcity in the local market, an alternative resin (epoxy resin) was used. Epoxy resin decomposes at a temperature of 269^{o}C while phenolic resin decomposes at a temperature of about 450^{o}C. The poor thermal characteristics of epoxy resin may result to the separation of materials used in the production of the brake pad and thus reducing the bond strength of the brake pad material. A compacting machine with a heating ring is required for brake pad production. The machine helps to impact high bond strength to the brake pad material. Due to non-availability of a compacting machine, G-clamp technique was used. This may have also contributed to the low bond strength of the produced brake pad material.

3.2.3 Scratch Hardness

The scratch hardness of the specimen and that of the lbeto product asbestos brake pad ranges from 80 to 85 using the durometer in the measurement of the hardness of the two brake pad material.The scratch hardness value obtained is due to the good strength property exhibited by reinforcing fibre and filler materials that were selected for this work. It can be observed that the two major filler materials (coconut and palm kernel shell) used for this work have good strength to weight ratio characteristics. Furthermore, since the specimen has an equal comparative advantage as that of the conventional brake pad produced by lbeto group, there is still theneed to determine an optimum scratch hardness value for the specimen through the wear characteristics nature of the specimen, since wear rate of material significantly affect the extent of hardness of the specimen.

3.2.4 Co-efficient of Dynamic Friction

The co-efficient of dynamic friction of the specimens ranges from 0.4 to 0.65 and that of conventional brake pad produced by Ibeto group is 0.45 to 0.65. More efforts can also be made on improving the co-efficient of friction of the specimens by adding lubricating material like cashew nut to help in reducing the co-efficient of friction to the desired level.

IV. CONCLUSION

The design and fabrication of an automobile brake pad using locally available materials have been successfully undertaken in this work.Perriwinkle shell and coconut shell were locally sourced for this work and were used as base materials, araldite and epoxy resin as binder materials, carbon as fiber reinforcement, aluminum, copper, and zinc were used as abrasives and rubber dust from shoe as filler.

From the analysis of the experiment conducted, it was revealed that the co-efficient of friction of the pad material ranged from 0.4-0.65, scratch hardness of 80-85, bonding strength of 25-27Kg/cm^2 and wear rate of 0.025mm/min to 0.06mm/min as compared to the conventional brake pad material that has hardness of 80-85, bonding strength of 25-27kg/cm^2 and wear rate of 0.03-0.08mm/min. These results are in agreement with those of asbestos friction materials produced. It is therefore deducible that this material can be used on Audi 90 model.

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Table 1: Mechanical properties of perriwinkle shell and coconut shell.

Material	Hardness in Rockwell	Abrasion resistance	Compression strength
Perriwinkle shell	$35kg/cm^2$	87.5%	$30kg/cm^2$
Coconut shell	$20kg/cm^2$	65.0% 65%	$5kg/cm^2$ $5.0kg/cm^2$

Table 2: Showing first group of twenty five samples mixture composition of the brake pad

Function	**Material**	**Amount (g)**	**% composition**
Binder	Araldite	150g	15%
	Epoxy resin	150g	15%
Fiber reinforcement	Carbon	20g	2.0%
Abrasives	Aluminum	25g	2.5%
	Copper	25g	2.5%
	Zinc	15g	1.5%
	Zirconium oxide	25g	2.5%
Lubricant	Cashew nut shell	10g	1.0%
Filler	Rubber	40g	4.0%
Base material	Palm kernel shell	270g	27%
	Coconut shell	270g	27%
	Total	1000g	100%

Table 3: Showing second group mixture composition of the brake pad

Function	**Material**	**Amount (g)**	**% Composition**
Binder	Araldite	100g	20%
	Epoxy resin	200g	20%
Fiber reinforcement	Carbon	30g	3.0%
Abrasives	Aluminum	25g	2.5%
	Copper	25g	2.5%
	Zinc	15g	1.5%
	Zirconium oxide	25g	2.5%
Lubricant	Cashew nut shell	10g	1.0%
Filler	Rubber	30g	3.0%
Base material	Perriwinkle shell	340g	34%
	Coconut shell	200g	20%
	Total	1000g	100%

Table 4: Static friction co-efficient representation for first group samples

	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5
Length (L)mm	5.5	5.5	5.4	5.5	5.4
Height (X)	14.5	14.5	14.9	14.9	14
Co-efficient of Static friction	0.30	0.34	0.35	0.36	0.38

Table 5: Static friction co-efficient representation for second group samples

	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5
Length (L) mm	5.5	5.4	5.5	5.5	5.4
Height (X)	14.5	14	14.9	14.5	14
Co-efficient of Static friction	0.40	0.45	0.5	0.55	0.65

Table 6: Dynamic friction co-efficient representation for first group samples

	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5
Mass of brake pad (N)	2.86	3.0	3.5	3.65	3.8
Mass of weight added (N)	2.10	2.00	1.50	1.20	1.00
Co-efficient of dynamic friction	0.28	0.29	0.30	0.34	0.36

Table 7: Dynamic friction co-efficient representation for second group samples

	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5
Mass of brake pad (N)	2.86	3.00	3.50	3.65	3.8
Mass of weight added (N)	2.10	2.00	1.50	1.20	1.00
Co-efficient of dynamic friction	0.35	0.4	0.45	0.5	0.55

Table 8: Static and dynamic friction co-efficient representation of asbestos (control)

Static friction		Dynamic friction	
Length (L) mm	5.5	Mass of brake pad (N)	2.86
Height (X)	14.5	Mass of weight added (N)	2.10
Co-efficient of Static friction	0.5-0.75	Co-efficient of dynamic friction	0.45-0.65

Table 9: Wears characteristics of specimen sample first group

Time (Second)	Specimen 1 Wear(mm)	Specimen 2 Wear(mm)	Specimen 3 Wear(mm)	Specimen 4 Wear(mm)	Specimen 5 Wear(mm)
120	0.08	0.12	0.14	0.16	0.18
180	0.10	0.11	0.13	0.157	0.18
240	0.22	0.24	0.26	0.29	0.32
300	0.35	0.36	0.37	0.39	0.41
360	0.43	0.44	0.47	0.49	0.48
Particle size	0.25mm	0.35mm	0.45mm	0.55mm	0.65mm

Table 10: Wears characteristics of specimen sample second group

Time (Second)	Specimen 1 Wear(mm)	Specimen 2 Wear(mm)	Specimen 3 Wear(mm)	Specimen 4 Wear(mm)	Specimen 5 Wear(mm)
120	0.050	0.055	0.06	0.065	0.085
180	0.06	0.058	0.066	0.067	0.085
240	0.063	0.060	0.067	0.068	0.084
300	0.065	0.062	0.067	0.068	0.084
360	0.065	0.061	0.068	0.068	0.084
Particle size	0.25mm	0.35mm	0.45mm	0.55mm	0.65mm

Table 11: Wears behavior of asbestos

Asbestos wear (mm)	0.06	0.07	0.08	0.12	0.15
Time (second)	120	180	240	300	360

Table 12: Summary of bonding result for first group

	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5
Bonding kg/cm^2	25	23	22	20	18

Table 13: Summary of bonding result for second group

	Specimen 1	Specimen 2	Specimen 3	Specimen 4	Specimen 5
Bonding kg/cm^2	27	26	25	24	23

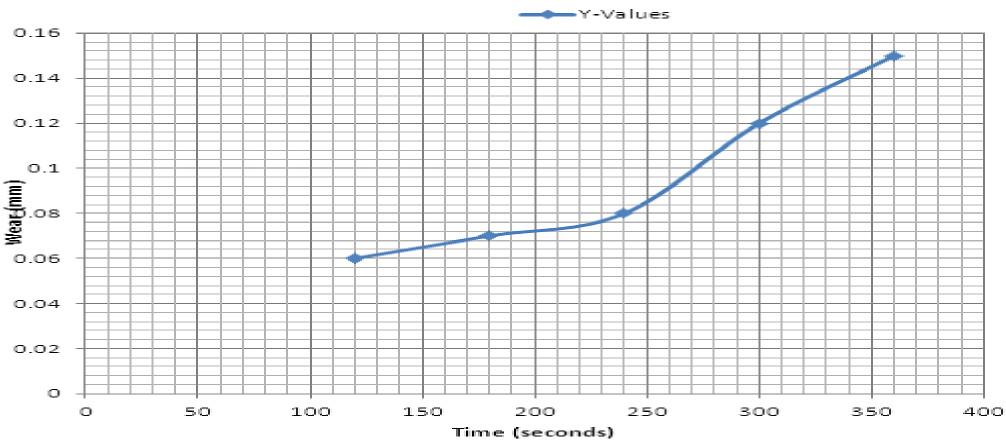

Fig. 1: Wear (mm) against time (s) for asbestos (control)

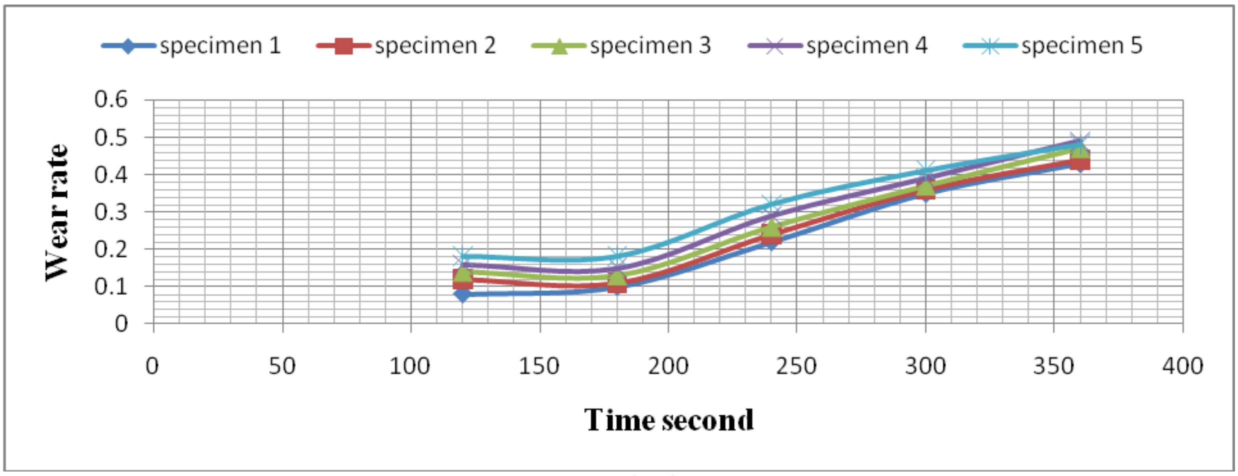

Fig. 2: Wear against time for first group sample

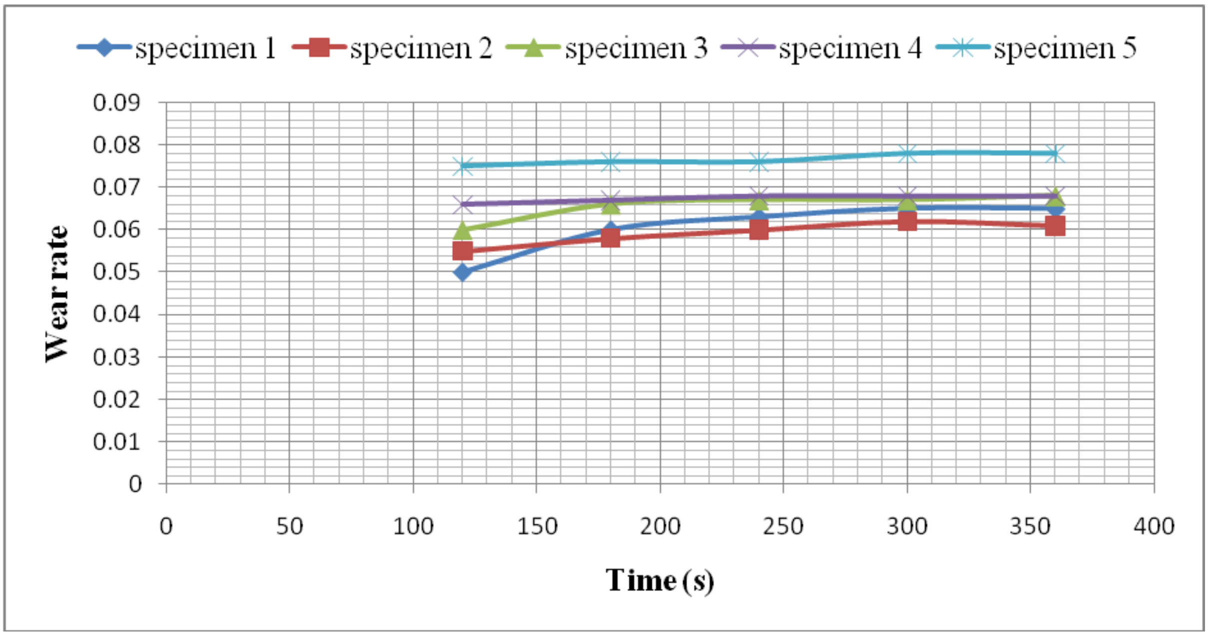

Fig. 3: Wear against time for second group sample