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Tribological Study of Banana Peel Broth of Musa Acuminate

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Abstract:- The experimental study carried to investigate the tribological properties of banana peel broth, extracted from the banana peel of Grand Naine or Musa acuminate, most common banana species grown in India. The broth was extracted from peels by mixing the insides of peels with remaining banana peel shreds. The results show that at steady state, the coefficient of friction was much lower than the direct contact coefficient of friction of surfaces. Through the experimental study, it has been observed that the wear, as well as the coefficient of friction, were reduced near to 0.11 in comparison to dry condition at 0.23.

***Keywords**:- Tribology, Lubrication, Biodegradable, Sustainable development, Banana peel*

I. INTRODUCTION

Lubrication comprises a significant portion of the study in tribology as it offers solutions to the problem of friction and wear. However, the choice of lubricant is a difficult task, as it may have multidimensional implications. The definition by Stachowiak & Batchelor introduces a lubricant as "a substance (such as grease) capable of reducing friction, heat, and wear when introduced as a film between solid surfaces."[1] A lubricant reduces the coefficient of friction of two bodies in contact and is under the influence of some form of relative motion. Lubricant may participate in more than one form, for example acting as a coolant and for cleaning of foreign particles, making lubricant an integral part of today's mechanical machines development. Many times, additives are being added to the lubricant to boost some or all the properties of the lubricant. Additives by Stachowiak & Batchelor is defined as "A chemical substance deliberately added to the oil in small amounts to effect a desired change in its properties."[1] The boost in the ability of the lubricant can range from an increase in the ability to reduce the coefficient of friction or to increase the thermal stability of the base lubricant. The additive added may range from 0.1 to 30% of the total composition of the lubricant depending upon the place of application. However, the additives utilized in the lubricants ought to be perfectly compatible with one another and lubricant in the finished oil. The additives are characterized by their relative additives inter-compatibility and additives miscibility int each other and the base lubricant.However, most additives added are inorganic molecules and mineral oils which are harmful, having high eco-toxicity and low biodegradability. The lion's share of additives have low mammalian harmfulness and usually are less unsafe when ingested than popular family unit items. Some grease additives are associated with being destructive to aquatic creatures and must demonstrate a level of determination. However, these additives are of low quality and low water dissolvability and when taken care of and discarded by makers' suggestions are considered not to display a substantial ecological hazard. Oil additives can be discharged into the earth amid produce, transport, and utilization, and subsequently, it is vital to assess these materials for their potential in causing antagonistic ecological impacts. This phenomenon presents itself because aquatic creatures are nearly related to their running condition, and they are typically presented to higher centralizations of poisonous discharged materials for substantial timeframes. For the more significant part of lubricant additives, degradation rates are typically meager since they have exceptionally constrained water solvency, typically under 1 mg/l. This confines their bioavailability to micro-organisms and builds the length of time in which they will degrade.[2] Furthermore, their higher molecular weights separate from water to solids. The fundamental issue is that they are not promptly available to microbial degradation. However even quickly degradable materials may exhaust the available oxygen in water bodies quickly and influencing aquatic living beings through suffocation, or they may corrupt quickly into side-effects that might be extensively more poisonous to aquatic species than the parent materials. Plant-oils or plant-based lubricants can be used to address these problems. Vegetable fats and oils are mostly, triglycerides, that is, tri-esters of long-chain carboxylic acids (unsaturated fats) joined with glycerol. The majority of these oils contain no less than four and in some cases, upwards of twelve diverse unsaturated fats. Vegetable-based oils are hydrolytically steady, froth more, and have brought down filterability contrasted with mineral oils.[3] Natural straight-chain mixes with polar end gatherings, for example, corrosive oleic amide, are broadly utilized as contact changing added substances in greasing up oils. These mixes are adsorbed from hydrocarbon arrangements on a metal surface. It is commonly accepted that these adsorption layers are in charge of the enhanced greasing up properties of oils containing these substances.[4] These types of lubricants are readily biodegradable without any impact on the environment and lower toxicity.

II. LITERATURE REVIEW

Hamid at el.[5] discussed the composition and hazards of lubricant additives. The currently used additives are mostly based on petroleum-based products and artificially created chemicals. These additives have high eco-poisonous quality, low biodegradability. Most of these oil additives have degradation rates, which are usually pitiful due to exceptionally high water dissolvability resistance. This property limits their components availability to micro-organisms and extends the period in which they undergo degradation. Moreover, they also have higher molecular weights making their traces from mixing with water and rising a central issue where they are not expeditiously accessible to microbial action. As discussed, these additives are common of low water dissolvability and should be dealt with and disposed of by environmentalist's recommendations are considered not to show natural danger. However, when disposed of without consideration can lead into pollution when released into the water or earth amid creation, transport, and usage, and hence, it is imperative to evaluate these materials for their potential in causing adversarial environmental effects. A possible solution to these kinds of problem is discussed by Madanhire et. al.[6] is to use lubricants and additives based on naturally occurring substances. Oils produced by plants are possible replacements for these kinds of problems. Since, these types of oils are non-polluting, easily degradable, and generally, have no such impacts like synthetics oils and harmful additives on both terrestrial and aquatic lifeforms[6]. Lubricants and additive liquids extracted from plant oils are, for the most part, quickly and biodegradable and are likewise of low eco-harmfulness. At present, the utilization of pure local plant oils is restricted to use to total loss applications (lubricants for cutting apparatuses, concrete mold discharge oils) and those with low thermal pressure. M.A. Maleque et. al.[7] worked on Vegetable-based bio-degradable lubricating oil additives. The research was conducted on the fact that vegetable oils provide advantages such as vegetable oils are non-toxic, biodegradable, and derived from food and plant sources, renewable nature. Since the source of vegetable oil are plants and crop and promoting self-reliance for places with lack of petroleum fuel reservoirs, also as ample production capacity exists which is further increasing with much transforming future technologies. His research was based on many oil-producing seeds, namely rapeseed, castor, olive, and palm oil. However, in comparison to Maleque, Valeru used synthetic additives for coconut oil. Suresh Babu Valeru et al.[8] works on the principle of using artificially created modifiers and additives for increasing the poor performance characteristics of coconut oil as an industrial lubricant. He used a synthetic additive 2,6-Di-tetrabutylphenol along with some other additives like POA4 and PPD. An increase in properties like oxidation stability was observed, 2,6-Di-tetrabutylphenol being an anti-oxidant. Other properties like lower pour point were also observed with noticeable improvement. Kiyoshi Mabuchi et al.[9] used banana fruit peel from a giant cavendish banana, to measure the impact of the banana peel as a lubricant on a linoleum plate. They concluded, after the microscopic analysis, that polysaccharides follicular gel in the banana peel played the dominating role in contributing to the property of the banana peels as a slippery surface. They found that the polysaccharide follicular gel on the application of pressure changed into a homogeneous sol, which acts a lubricant itself. However, to correctly analyze the contents of the peels, to understand greatly about the characteristics of the banana peel, it is required to know about the composition of the material used for the experiment. Knowing about optimal conditions of the specimen helps to achieve the optimal results. B. A. Anhwange[10] analyzed the composition of Musa sapientum peels, which is another breed of banana commonly found in southern Asia. A general content of several minerals in milligram per gram was potassium(78.10), calcium(19.2), sodium(24.3), iron(0.6). manganese(76.2), bromine(0.04), rubium(0.21), strontium(0.03), zirconium(0.02) and niobium(0.02) was found. The peel of the banana was also analyzed to be rich in protein(0.9), crude lipid(1.7), carbohydrates(59.0) and crude fibers (31.7). Presence of such a high concentration of carbohydrates can be extended to all the families of the banana in their peels with little deviation. M.M.B. Mustafa et al.[11] further extended the study of Kiyoshi Mabuchi et al.[5] about the potential of banana peel as a lubricant. Unlike using the banana peel as a lubricant itself, they used the banana peel broth as an additive to a lubricant with known tribological properties. They used the banana peel broth in conjugation with paraffin oil, as a 20% solution, mixed using dispersion method achieved using an ultrasonic homogenizer. Their study concluded that the mixture showed conclusive results at high temperatures and speed of operation. They concluded that the banana peel broth must be reducing the contact of friction of surfaces by creating a separation boundary layers at high temperatures, loads and speeds. H. A Hamid et al.[5] also used another breed of banana, a crossbreed of Musa acuminata and Musa balbisiana, for a similar tribological study. However, unlike the previous two studies where the banana peel was used in whole, their study included the use of bio-oils. Under their study, they measured the impact of applied load and temperature on the characteristics of MBS oil, a bio-oil extracted from the banana peel of the banana cross-breed. Their study included a pin-disk analysis using the MBS oil as a lubricant as per G99 ASTM standards. Their study found that the values of the coefficient of friction at all temperatures were reduced drastically. It can be concluded that lubricants and additive liquids extracted from plant oils are for the most part quickly biodegradable and are likewise of low eco-harmfulness, but their stability at higher temperature ranges is debatable. All the studies later discussed used banana peels as a potential source of bio-lubricant. While the study by Kiyoshi Mabuchi et al.[9] study also included several other fruit peels under observation, the study in the paper concentrates over the potential use of banana peel and its extracts as lubricants or additives for existing lubricants. However, the thermal and oxidation stability of these kinds of oils and additives are short-lived compared to mineral oil, which can sit for years if properly handled. Also, to check the competencies and characteristics of the oil, which are tribologically relevant, it is required to choose appropriate tests and other requirements necessary to conduct those tests. However, the biggest hurdle to commercialize such alternatives is either the methods require for their production are too costly to set up or too complex to be used at small scales for productive uses. Proper tests and techniques are also required for accurate results and measurements of capabilities of the oils used as lubricants or additives. Several tribological properties are measured to understand the capabilities of the specimen to be used as a feasible and practical solution. To achieve this, several tribological testing techniques can be used. Several forms of tribometers exist and can be used for analysis and simulation of different kinds of scenarios.

III. METHODOLOGY AND EXPERIMENTATION

The analysis was drawn on a lubricant sample extracted from banana peels sighting many reasons. The banana is a naturally occurring substance and is farmed in large scales for consumption. However, the peels left behind have not had many apparent uses. The said procedure allows for potential in uses for extracting products for commercial uses from it. As discussed above, many scholars have pointed out the potential in banana peel for the choice of lubricant. To analyze the capability of banana peels as a lubricant, an extract in the form of banana peel broth was created for more straightforward analysis. The banana peel broth was extracted manually without the usage of any expensive equipment. Use of any form of chemical was also avoided for the sake of reducing the cost of extraction and restricting any harmful chemical usage. The process of banana peel broth extraction was kept simple with minimum steps involved to allow the emulation of the process easy. The process requires many banana peels, restricting its usage to places with a significant number of banana peels. The process works as follows: -

- At first, a significant number of banana peels were collected for the extraction. It is to be noted that fresh banana peels have been considered favorable for the process; however, in case of unavailability of such, other banana peels can also be used.
- From the collected banana peels, inside part of the peels were scratched off and collected separately and mixed. The scratched-off product was blended, using a motorized blender.
- The rest of the part of the banana skin left was then crushed, and then the extract from that was collected. The skin residue which is then left-off can be used as a fertilizer or can be fed to the biomass plant.
- The extract collected from the left-off banana skin was then added to the scratched-off product and then mixed with a small amount of water and was blended.
- The blended mixture was then heated to thicken into a paste. This paste was left off to cool. Continuous stirring of the mixture while heating is required to keep the mixture from burning and allowing the gases produced to exit.

The banana peel broth is used as a lubricant, to check for its tribological properties with a comparison to a typical setup of pin and disc tribometer running dry. The pin was prepared with a casting method using the molds of predefined dimensions as described in the data specification by the manufacturer of the measuring apparatus. The dimension of the disc and pin along with any specific details, mentioned in Table 1.

Pin Specifications	Diameter (mm)	8,10,12
	Height (mm)	50
	Material	Cast iron
Disc Specifications	Diameter(mm)	100
	Thickness(mm)	8
	Material	Mild Steel
Lubricant	Base	Grand Naine Peel Broth

Table 1:- Specification of the apparatus used in the experiment

The study entails the use of pin on disc experiment to generate conclusive results to determine the characteristics and properties relevant to the specimens tribological study. The pin on disc experiment is a wear testing method to observe the coefficient of friction, wear rate and other tribological properties with the addition of some external attachments characteristic to the material being observed, in this case, the lubricant specimen. Here the pin is made of cast iron is being brought in contact with a disc of mild-steel. The pin's tip shape can be anything, depending upon the type of contact being studied. The pin used in this study has a flat circular tip. The lubricating specimen that is being observed is applied over the surface of the disc, and then the pin is brought in contact to disc and disc is rotated. However, any other method for application of lubricant can be used depending upon the availability of apparatus. The apparatus works under G99 ASTM standards. The experiment was conducted at ambient conditions; the temperature was measured at 21.74 °C. The disc and pin were first cleaned with the help of acetone to remove a thin layer of oxides and other foreign particles that may have formed on the surfaces of disc and pin alike. The Disc was then loaded into the seat for disc and mounted using the screw into the screw slots in the disc. Then the pin was loaded into the pin holding arm and fitted-in. The pin and disc are brought in contact at the point with the help of data from the sensors and the computer. The values for various variable data points are then selected. The RPM of the disc rotation was selected at a lower value of 300 RPM. This is done to ensure that chances of the lubricant flying off from the disc surface are removed or minimized, which may result in lubricant not engaging in contact with pin and disc. This is also in consideration of lower thermal load stability of the organic-based lubricants an initially stated in the previous studies. The distance traversed by the pin on disc surface is taken at 20 m. The value of the various track diameters of the pin on the disc is taken at 40,60 and 90 mm. The dead weights that are being applied to simulate force by the pin on disc at the point of contact are taken 20 N and 40 N or a pressure up to 2550 – 5100 N/m2. Also, since the lubricant is found to be too thick to be pumped via the pump inbuilt to the machine, the sample is manually pumped using a syringe injector for pumping the lubricant at the point of contact. Then from the ensemble of the values and observation that the sensors are providing, some of the parameters are chosen, which may best describe the case to be observed. Here the parameters which were chosen for observation are wear, frictional force, and coefficient of friction. Frictional force and coefficient of friction are taken into account mainly for studying the lubricating ability of the sample lubricant. The experiment was then conducted with varying the applied dead weights or the track diameter or both, as mentioned in Table 3.2. After every observation with the variables of the pin and disc were changed during the experiment for the next setup and observation, this gives us values of the observed parameters when the sample lubricant is subjected to the variable condition allowing us to measure its performance and stability in working conditions.

Condition	Value
Temperature of operation	21.74 °C
Machine used	High-temperature Rotary tribometer
Lubricant feeder	Syringe injector
RPM of disc	300 rpm
Distance travelled by pin	20 Meter
Track diameter - 1	40 mm
Track diameter - 2	60 mm
Track diameter - 3	90 mm
Dead weights used - 1	20 Newton
Dead weights used - 2	40 Newton
Parameters measured - 1	Wear in micron(μ)
Parameters measured - 2	Frictional force in Newton
Parameters measured - 3	Coefficient of friction

Table 2:- Parameters to which the sample is subjected to during the experimentation and analysis

IV. RESULTS AND DISCUSSION

The banana peel broth which was prepared was tested on a high-temperature rotary tribometer for analyzing the tribological properties of the lubricant. The lubricant was subjected to variable loads and speeds for understanding the nature of the lubricant under different working conditions. Different observations were recorded for different conditions and are plotted to find out its nature. The quantities that were put under observations were Wear, Coefficient of Friction, and Frictional force experienced. All the results were measured digitally by the high-temperature rotary tribometer. The results were measured about change in time. The results can be compared to standard values for the interaction between the two sliding surfaces, here mild steel and cast iron. The standard value of the coefficient of friction between the surface of cast iron and mild steel is expected to be close to 0.23[12] for dry conditions. As evident from Table 4.1 and Fig. 4.7, the observed coefficient of friction is less than the dry friction coefficient between the two surfaces. The values of the coefficient of friction between the materials are always less than the standard value and follow a pattern of decrease and then increase with the increase in speed. This nature has been observed for both 20-newtons and 40-newtons analysis at the track diameter of 40,60,90 mm.

A. Wear Analysis

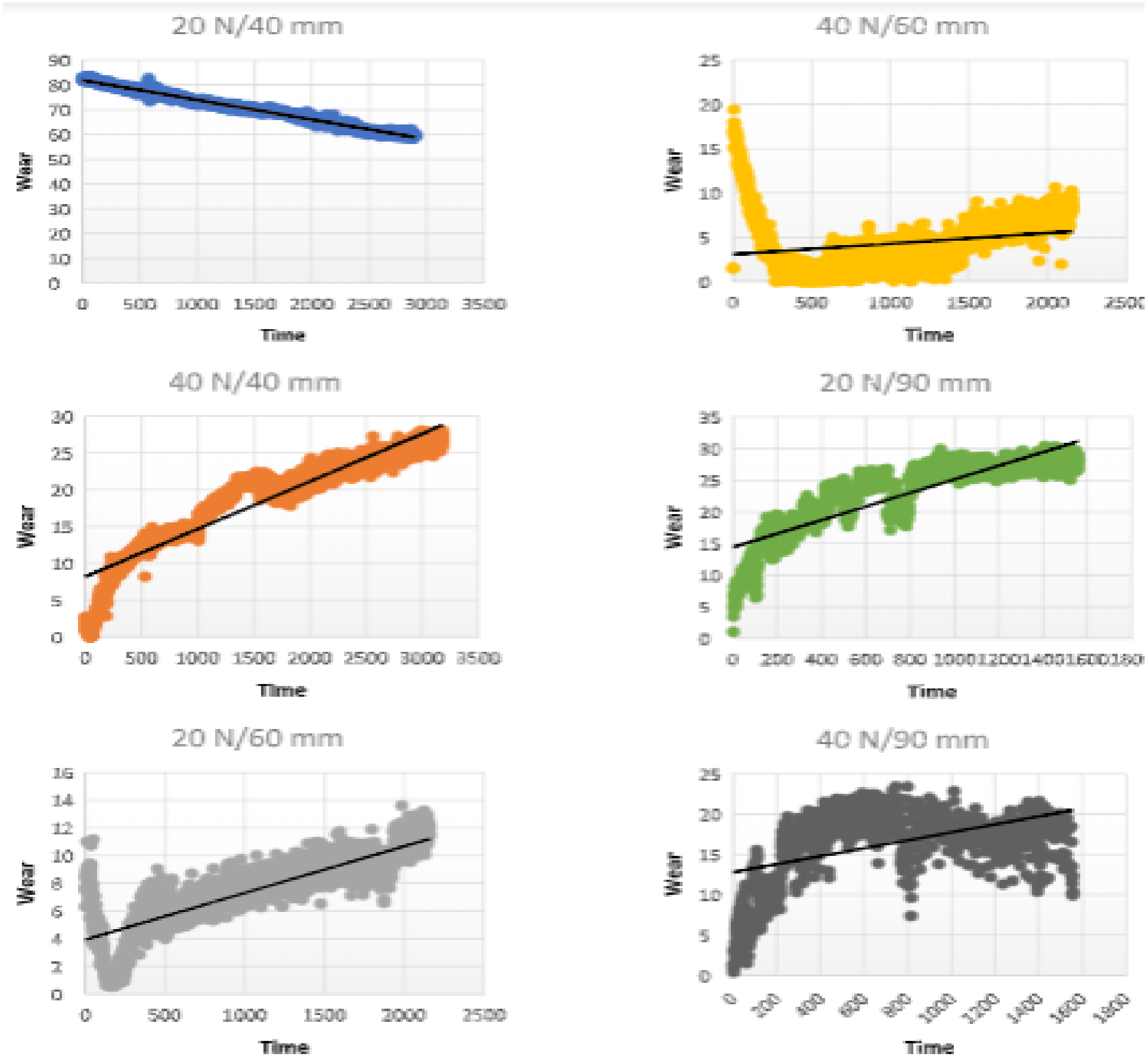

Fig 1:- Wear vs. time trends for different loads and track diameter (load/diameter) at 300 RPM

The trendlines for varying loads and track diameters of pin disc experiment are shown in Fig. 1, for wear analysis with respect to time during pin and disc contact with grand naine peel broth acting as lubricating agent. At lower speeds, the trendlines are in order of 2 and reaching up to order of 5 in case of 20 N/60 mm. The wear is seen to be getting constant or reducing in most of the cases with anomaly in case 20 N/60 mm.

B. Coefficient of friction Analysis

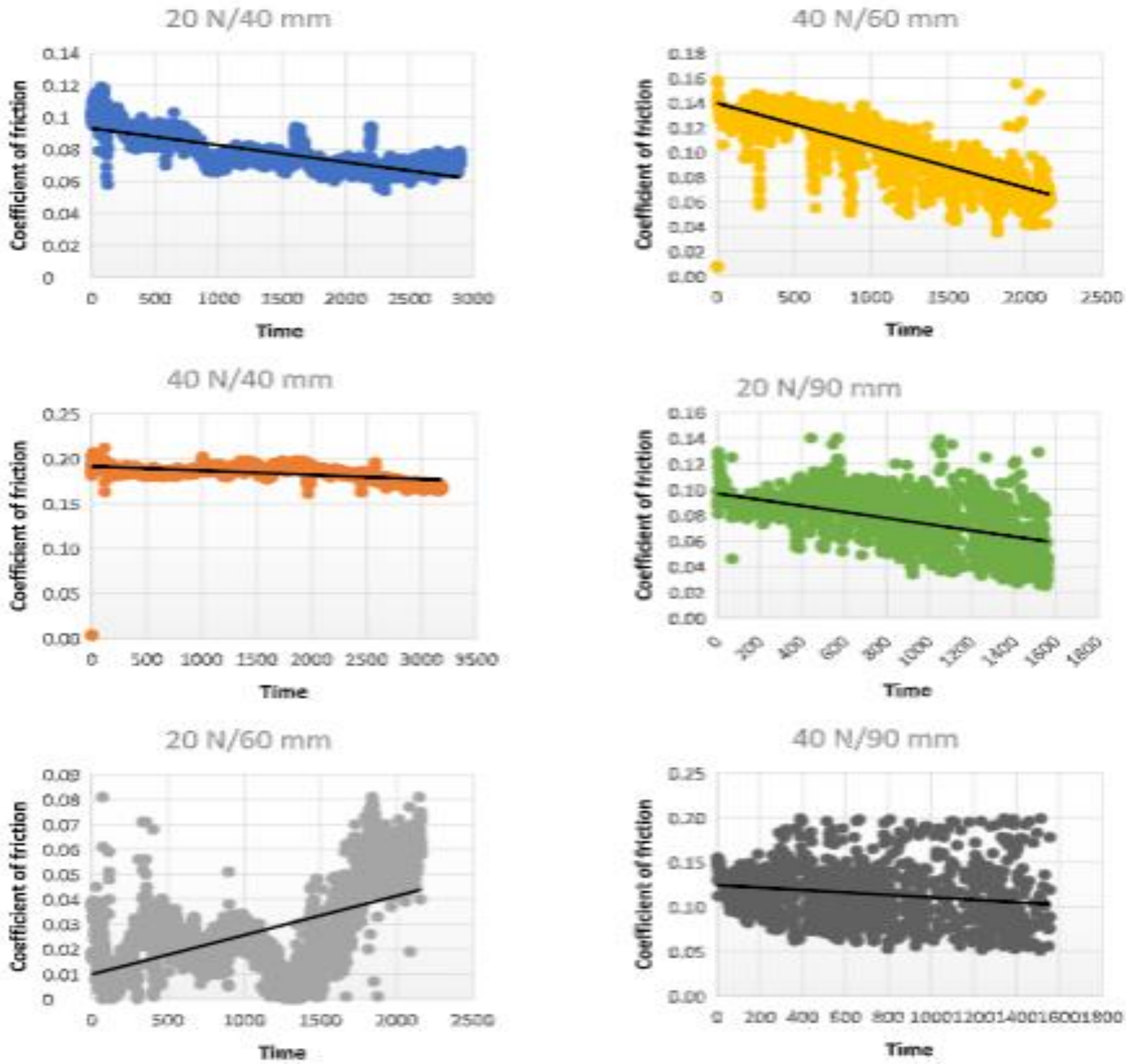

Fig 2:- Coefficient of friction vs time trends for different loads and track diameter (load/diameter) at 300 RPM

The trendlines for varying loads and track diameters of pin disc experiment are shown in Fig. 2, for the coefficient of friction as well as frictional force (no graphs are shown since the graphs are identical and can be plotted by multiplying to applied load) analysis with respect to time during pin and disc contact with grand naine peel broth acting as lubricating agent. At lower speeds the trendlines are in order of 2 and reaching up to order of 5 in case of 20 N/60 mm. The coefficient of friction is seen to be getting constant at around 0.08-0.1 or reducing in most of the cases with anomaly in case 20 N/60 mm. This was observed due to inclusion of some foreign particles between pin and disc giving such bizarre results. This problem is later rectified by cleaning of the pin and disc contact faces thoroughly by acetone.

	Dead weights applied	
Track diameter in mm	**20 N**	**40 N**
40	0.077875718	0.183973
60	0.029297573	0.104928
90	0.088996034	0.153887

Table 3:- Observed average values of coefficient of friction with varying loads and track diameter

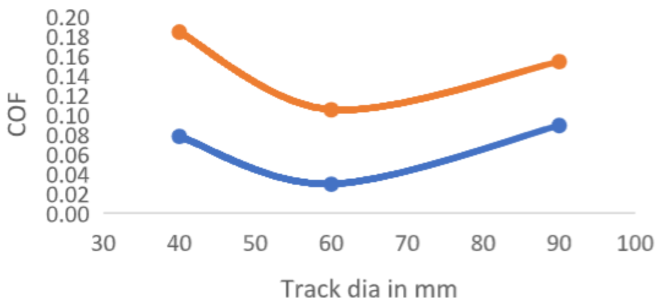

Fig. 3:- denotes the nature of Coefficient of friction concerning the dead weight applied in Newtons

The average values of coefficient of friction are observed to be decreasing at first and then again increasing, with the increase in track diameter, effectively denoting the increase in speed for the constant rotational speed of 300 rpm. The trend observed showed that the lubricant is best suited for speeds in this region and may not work up to optimum otherwise. The higher values of the coefficient of friction at a lower speed can be attributed due to self-viscosity of the lubricant. However, higher values at higher speeds can be attributed to degraded functionality at higher speeds potentially due to burning off due to the heat generated by friction. The temperature at the tip of the surface of the pin can reach up to 1125 °C, which can cause the oxidation of lubricant, and may spoil it in case the lubricant is not well fed into the system. Occasional outliers can also be observed in the graphs in case of the coefficient of friction and many in case of higher speeds denoting the lack of reach of lubricant at the point of contact of two surfaces. The observations drawn can be due to lack of supply of lubricant, which can be credited to inefficient pumping or due to the high viscosity of the lubricant, hampering its flow between the contact at high speeds.

V. CONCLUSIONS AND FUTURE SCOPES OF STUDY

➢ *Conclusions*

The tribological analysis of the system has to be applied at the interface of tribo pairs. More emphasis by the researchers is given on sustainable and biodegradable lubricants. From the tribological analysis performed the following points have been concluded that the lubricating broth developed from the Grand Naine banana peel, although made using simple processes, have shown considerable properties as a lubricant for its usage. Unlike the lubricating properties of banana peel itself, the broth showed considerable improvement due to its liquid state allowing it to penetrate in smaller places than the solid banana peel. But the viscosity of the banana peel broth is considerably higher than any lubricating oil, making its application in usage difficult. This possess a challenge for finding ways to lower the viscosity to the level where ordinary oils pumps can be used for the job of oil pumping. From the mathematical analysis, the wear and coefficient of friction showed appreciable results for lighter loads like 20N and 40N loads and lower speeds of 300 rpm. At higher speeds and higher loads, the curve structure is much more variable, giving a proof about the inclusion of other factors which may have not been considered during analysis. Also, all the graphical interpretations are either linear, especially in case of coefficient of friction and frictional force. The wear has shown a general trend line of degree 2 polynomial, which is generally getting near constant after certain period of usage. This shows that the analysis of the broth is possibly simple if all the factors are considered during analysis by creating a controlled environment study.

➢ *Future Scope for the study*

Bio-lubricants can find applications in various fields; while the research of plant-based lubricants is still underway and more research is being done in this field. There is much potential in the usage of plant-based as different results have shown. Such lubricants can be tested for direct usage or as a lubricating additive to another lubricant. Also, stability can be measured to learn about the possible places of application of such product. Stabilities improvements in places like microbiological and thermal load stabilities still remains a great concern in using them in industrial places. Also, oxidative stability should also be concern in derivatives which are unlike banana lack natural antioxidants.

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