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Tribological Behavior of Polymer and Polymer Composite Material under Static Loading in the Context of Rolling Contact Bearing: A Review

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ABSTRACT

Rolling contact bearings work well and are reliable because of how they behave tribologically, especially when they are not moving. For these materials to work well and last as long as possible, it is important to understand how tribological processes work in this case. The review starts with an introduction of tribology, how it applies to the study of polymers and composites made of polymers, and why static loading conditions in rolling contact bearings are so important. It then talks about the specific tribological qualities that these materials show in rolling contact bearings under static stress. This includes their mechanical properties, wear processes, frictional behavior, and contact pressure distribution. The effects on tribological behavior of things like material makeup, contact pressure, temperature, surface roughness, lubrication, and external conditions are talked about in detail. We look at the experimental techniques and testing methods used to figure out how polymers and polymer mixtures behave tribologically in rolling contact bearings under static pressure. The review also gives a full study of the available literature, talking about how well different polymer materials work, what their limits are, and how they could be improved. The review also talks about the difficulties and limits of using polymers and polymer blends in rolling contact bearings with static loads. It also talks about the improvements made to materials, surfaces, and greasing methods to improve the tribological performance of bearings and make them last longer. This review study has three goals. The first is to provide an overview of the tribological behavior of polymers and polymer composites under static stresses, with an emphasis on rolling contact bearings. Second, suggest a few study areas that the experts can look into to build a database. Third, to help students, engineers, and practitioners use the new information to choose the right materials and build the best bearing systems. The review is a good way to learn about how material qualities, pressure conditions, and tribological performance interact with each other when rolling contact bearings are used in different industries.

KEYWORDS

Tribology, Static load, Polymers, Polymer Composites, Rolling contact bearing.

Introduction

Tribology is a very important part of making sure that rolling contact bearings work well, last a long time, and are reliable. Rolling contact bearings are used in a variety of businesses and uses, from cars and airplanes to tools and power plants. By lowering friction and supporting loads between spinning or moving shafts and their frame, they make motion smooth and easy to control. However, the surfaces of rolling contact bearings are exposed to large forces, pressures, and moving motions, which can lead to a lot of wear and energy waste if they are not handled properly.

The main goal of tribology is to figure out how rolling contact bearings wear and find ways to stop it. Wear happens when two surfaces slide or roll against each other, which takes away material and damages the surfaces. By studying how rolling contact bearings wear and coming up with good ways to stop it, like using the right lubricant and choosing the right materials, the service life of these bearings can be greatly increased. In rolling contact bearings, lubrication is an important part of tribology. By putting a thin, protected film between the surfaces that touch, proper greasing reduces friction and wear. Tribological studies look into the qualities of lubricants, how films form, and how lubrication affects the total performance of bearings under static loads. Tribology gives us information about how rolling contact bearings work and how they behave when they are not moving. It helps people understand how contact pressure is spread, where stress is concentrated, and how the different parts of a bearing work together. This information helps optimize the design of bearings, which leads to better load-carrying ability, less noise and shaking, and better performance. Tribology helps people figure out why rolling contact bearings break down and keep track of their state. By looking at wear patterns, surface damage, and the way lubricants break down, tribologists can figure out why things break and come up with the right upkeep and inspection plans. This method helps avoid major breakdowns, cut down on downtime, and make sure that repair plans are as good as they can be.

When it comes to rolling contact bearings, tribology is the most important thing. It works on reducing friction, stopping wear, getting the best lubricant, and improving the general performance and stability of bearings under steady pressure circumstances. By learning more about tribological events, experts and engineers can come up with new ways to make rolling contact bearings work better, last longer, and work better in different situations.

The primary purpose of this research is to provide an in-depth examination of the tribological behavior of composite materials, particularly polymers and polymer composites, under static stress conditions for roller bearings. This review paper is put together in the following way. In Section 2, the literature study for tribological behavior under static loads is looked at in more detail. In Section 3, tribology tests are explained. In Section 4, we talk about the study gap, and in Section 5, we come to a conclusion and talk about what's next.

1. Literature Review

Polymer-based materials have gained popularity in a number of tribological applications because of their natural properties, such as their ability to self-lubricate, good wear protection, low friction, and great security against rust. But even though they are used a lot, there are still a lot of important questions about how they work and how to build them that haven't been answered. Because there are so many different polymers and polymer-based compounds used and so many different uses, it is hard to figure out what the basic tribo-mechanisms are.

Researchers have looked into adding fibers, fillers, and nanoparticles to thermosetting or thermoplastic core materials to enhance the tribological performance of plastics. This approach helps to strengthen the surface of the material, which improves its general tribological behavior.

When these open questions are answered and the ruling processes are understood, polymer-based materials can be used more effectively in different tribological uses. This will lead to more progress in this field.

Reviewing the polymer and polymer composite tribological behavior under static loading, specifically in the context of rolling contact bearings, is necessary to figure out how well the materials work in load-bearing applications, evaluate their wear resistance, friction characteristics, and deformation under static loads, which allows the development of optimized bearing systems and improves their reliability and durability. A comparison of the performance of various polymers and composites is required so that the optimal materials for certain static loading usage in rolling contact bearings may be identified.

Tribological Behavior under static loading

K. Friedrich [1] provides a comprehensive assessment of the various polymers and polymer combinations utilized in engineering applications where friction and wear are significant. The author discussed the importance of polymer tribology in general, the distinct design principles used for polymer composites to reduce friction and wear when sliding against smooth metallic surfaces. Author also covered the synergistic effects of nanoparticles and conventional fillers and fibers in producing optimal tribological performance. Based on these fundamentals, The study looks at traditional uses of polymeric tribo-components in mechanical and automotive engineering, such as cages for high-precision ball bearings, filament wound bushings for extreme environments, etc.

Also, the author looks at specialized developments of tribo-components, such as how to make polymer bearings electrically conductive, how to add microcapsules to the polymer matrix to improve self-lubrication and self-healing, how to use modern additive manufacturing techniques to make polymer components that are prone to friction and wear, how to use and describe for high-temperature polymer coatings, and how to use polymer composites in friction and wear loaded situations.

The author also examines the difficulties in using and testing bulk and thin film polymer-based tribo-components such as ball-bearing cages, bushings, sliders, gears, electrically conductive bearings, and coatings. The author goes beyond the basic factors that affect tribo-materials, such as contact pressure, sliding speed, environmental conditions and the material they are rubbing against. For example, he talks about 3D printing and new ways to make tribo-materials self-lubricating and self-healing by adding microcapsules.

As polymer compounds are used more and more in tribology, it is clear that a deeper knowledge of polymer tribology is becoming more and more important. The study discusses the progress made in the previous 30 years in both scholarly knowledge and commercial utilization of polymer composites for various tribological applications. Nonetheless, the author emphasizes the need for more research to fully fulfill the promise of reinforced polymer materials in the broad subject of tribology.

B. Aldousiri et al. [2] did a full study of the polymeric composite's tribological behavior and looked into possible future additives that could be used in industry and engineering. People are paying a lot of attention to the growing need to understand the tribological properties of polymers and their mixtures. The paper gives a short overview of the latest research on how polymeric materials made from manufactured fibers behave in terms of tribology. The author talks about the chemicals, fibers, interfacial bonding, tribology environment, working parameters, and composite shape, which all affect the wear and friction qualities of these materials. Also, the study offers new bio-based reinforcements (fibers) and shows early results that suggest bio-based reinforcements could be a good way to replace traditional reinforcements. The results show that it's likely that bio-reinforcements could be used instead of standard ones, which is exciting for the business.

Jozef Broncek et al [3] conducted a laboratory experiment on the tribological characteristics of numerous composite materials under varied settings. The study looked at two composite materials in particular: one with a polyamide base structure and carbon fibers for reinforcement, and the other with glass fibers. The main goal of these tests was to find out useful information that could be used to help build materials for bearing cages.

The study looked into the frictional qualities of these hybrid materials and whether or not they could be used to make roller bearing cages. The study looked at the effects of load and lubrication on the investigated materials by comparing the testing results of tribological features under different loads (5 N and 10 N) and using two types of balls (steel and ceramic). Notably, the friction coefficient figures varied greatly depending on the surroundings, the force of the load, and the type of ball used. Also, friction coefficients were much lower in lubricated circumstances for both composite materials and both of balls than they were in non-lubricated conditions.

Kamaljit Boparai et al. [4] compared the tribological qualities of parts made with the fused deposition modeling (FDM) method from Nylon6-Al-Al_2O_3 and ABS. The study's primary goal was to discover how parts made by FDM with different amounts of Al and Al_2O_3 wear when they slide against each other when they are dry and at room temperature. The study used 5, 10, 15 and 20 kg loads with a moving speed of 1.36 m/s for 5 and 10 minutes. The findings revealed that every FDM-made Nylon6-Al-Al_2O_3 parts were more resistant to wear than their FDM-made ABS peers. Also, the study found out how filler materials affect different types of wear, such as binding and friction. The study also discovered that varied quantities of composite materials were more resistant to wear and had lower friction coefficients and friction forces than commonly available ABS materials used in FDM components.

Yu Jianghong et al. [5] did a study on the function of PTFE composite material that had wollastonite added to it. The focus of the study was on using Polytetrafluoroethylene (PTFE) in a newly manufactured elastic composite cylinder roller bearing. The PTFE was changed to improve the roller bearing's resistance to shaking, wear, and total life span.

WF/PTFE composite materials with the same dimensions could retain greater weight than WP/PTFE composite materials with the same dimensions, according to the results. Small dimensions of WF-PTFE composite materials showed the optimum bearing capacity and wear characteristics for mild loads. For heavy loads, large dimensions of WF-PTFE composite materials outperformed tiny WF fillers in terms of bearing capacity and wear characteristics.

Using PTFE filler materials instead of the standard way cut rolling stress by 17.1% when the load was light and by 27.7% when the load was heavy. These results are a good starting point for making changes to the materials used in elastic composite cylindrical roller bearings.

P. D. Pansare et al. [6] did a study on how Polytetrafluoroethylene (PTFE) behaves when it rubs against itself. PTFE has a low coefficient of friction when it rubs or slides against a hard surface, but it wears out quickly. Different fillers are added to PTFE to make it more resistant to wear. The study looked at how load and moving speed affect friction and wear in PTFE and PTFE hybrid materials with fillers like 25 percent carbon , 35 percent carbon , 40 percent bronze , 15 percent glass fiber, and 15 percent glass fiber + 5% MoS_2.

A pin-on-disc friction and wear test apparatus was employed for the studies, and the data was studied with the help of Design Expert software. The results showed that adding carbon, brass, and glass fillers to pure PTFE slowed wear down by a lot, even though the coefficient of friction went up a little bit. The material with the best wear protection in the tests was PTFE filled with 15% glass fiber and 5% MoS_2. This was followed by 35 percent carbon, 25 percent carbon, 15 percent glass fiber, 40 percent bronze, and pure PTFE.

Based on what they learned from the study, the authors suggested that 15% glass fiber + 5% MoS_2 filled PTFE would be the best self-lubricating material for sugarcane milling roller journal bearings to improve their wear life. Scanning Electron Microscopy (SEM) was used as part of the research to look at hybrid microstructures and study how they fail.

Isabel Clavera and colleagues [7] investigated the wear behavior of nylon matrix composites (PA66, PA46, PA12) and various nano additives and reinforcing additives (graphite, graphene, MoS2, and ZrO2) in order to find a good self-lubricating material for bearing cages. Pin-on-disc tests, as well as SEM and EDX investigations, were used to evaluate the degree of wear.

The study's findings revealed that alloys made with PA12 worked better than those made with PA66 and PA46. Also, when ZrO_2 was added, wear numbers went down because metal particles moved from the counterface to the plastic pin. This made the wear resistance better.

At the end of the study, PA12-based composites with ZrO_2 were found to be a good option for getting self-lubricating qualities in bearing cages. This gave useful information for developing better materials for this use.

N.V. Klaas et al. [8] did a study on how glass-filled polytetrafluoroethylene (PTFE) behaves in terms of wear. For the study, wear tests were done in a lab at room temperature with no lube and in pure water, having a sliding speed of 0.2 m/s on average and contact pressures ranging from 2.6 to 6.4 MPa. Glass threads, glass beads, and glass flakes were employed in the experiment. Each type of glass made up 25% of the study's weight.

The propensity of the various glass-filled PTFE compounds to generate transfer films on the counterface was discovered to impact how effectively they wore when slid against each other. Glass bead-filled PTFE produced thicker films with higher wear rates than other glass-filled types. Glass threads and solid glass beads, Hollow beads, nonetheless demonstrated the most wear at both low and high pressures owing to crumbling and crushing during the rolling process. The wear rate of PTFE in the presence of glass flakes was substantial but constant up to 4.5 MPa. After that, the rate of wear accelerated.

There was no discernible relationship between the size of the glass support and the rate of deterioration. However, the addition of high aspect ratio glass fibers to the PTFE matrix increased wear somewhat. The incorporation of a solid lamellar lubricant into the glass strands further lowered the chance of PTFE wear and friction.

Using an optical microscope, the researchers discovered that the transfer film's development was caused by minute bits of polymer being caught in the troughs of the metal asperities. XPS study of the makeup of the transfer film showed, among other things, that there was metal fluoride on the metal surface. These results explain how the processes that affect the tribological behavior of glass-filled PTFE composites work, which is helpful for making the materials better and finding new uses for them.

Zainab M. Shukur et al. [9] did a study on the tribological behavior of poly-ether-ether-ketone (PEEK) and PEEK composites with 30% carbon fiber (PEEK CA30%) when moving against AISI 52100 STEEL in non-lubricated and marginally lubricated conditions. The study looked at how PEEK and PEEK CA30% wear and the friction coefficient when they slide back and forth against each other using different lubricants, such as deionized water, ethylene glycol, silicone, and SN100 base oil. On the high-frequency tribometer TE77, the tribological tests were done with a pin-on-plate arrangement. Alicona G5 was used with an optical 3D micro-coordinate measurement tool to look at the surface texture and wear processes.

The results showed that lubrication has a big effect on how well the materials work in terms of tribology. With silicone lubricant, the coefficient of friction of PEEK450 was lowered by 50% compared to SN100 oil lubricant. It was found that PEEK450 with silicone and SN100 oil had the same resistance to wear. But for PEEK CA30%, the wear resistance was the same for both silicone and SN100 oil. However, silicone performed better and was the best lube.

The study gave important information about how different lubricants affect the tribological qualities of PEEK and PEEK alloys, which could be used to improve wear protection in different industrial uses.

Lorena Deleanu et al. [10] investigate polymer-based materials' tribological characteristics in depth and attempt to help them operate effectively in real-world applications by conducting several experiments and analyzing the findings. The study highlights the need to address tribological parameters such as temperature in contact, friction coefficient, wear and application-specific contact durability throughout the design process.

Adding materials to polymers, according to the study, can reduce wear by more than an order of magnitude. However, when stronger fillers such as glass beads, short fibers, or boulders are introduced, the friction coefficient increases somewhat when compared to a polymer that has not been combined with anything else.

Experiment results are used to show how important compound design is. For example, the coefficient of friction between polybutylene terephthalate (PBT) and steel was between 0.15 and 0.3. But the friction coefficient was higher for the mixture made of PBT and tiny glass beads. When a solid grease polymer (PTFE) was added to these compounds and also to PBT on its own, the coefficient of friction was dropped to a maximum of 0.25.

The study also revealed that under a dry sliding regime of 2.5….5 N, the wear measure, namely the block's linear wear rate (as measured by a block-on-ring tester) was decreased significantly from 4.5 μm/(N_km) to less than 1 μm/(N_km) for all tested sliding speeds. Because it wore well, the combination of PBT, 10% glass beads, and 10% PTFE stood out as the most promising material in this group.

The study shows how important the construction of polymer composites and the choice of the right test settings are. The study also looks at how polymer-based materials and their peers break down in the tribolayer. This gives a full picture of how they behave in tribological uses.

Wang Shibo et al. [11] did a study to look at how rolling motion affects the way polytetrafluoroethylene (PTFE) wears. Tribological properties of PTFE disks moving against AISI1045 steel pins were studied with three different motions: spinning in one direction, moving back and forth linearly, and twisting. It was found that the features of the wear-testing machine, such as how the contact surfaces were set up and how they moved relative to each other, affected the wear traits.

The study showed that the friction values for straight spinning, smoothly revolving, and twisting motion were 0.1, 0.118, and 0.12, respectively. Out of the three motions, straight moving caused PTFE to lose the most mass, while rotational motion caused the least mass to be lost.

Also, the study found that PTFE wears differently depending on how it moves. When the motion was only in one direction, there was a little digging. When the motion was straight repeating, there was a lot of abrasive wear, and when the motion was rotational, there was mostly adhesive wear.

According to finite element analysis, the edge effect of the steel pin induced a greater normal stress, which caused a higher shear stress in the PTFE disk. When the steel pin moved into and out of the contact zone, the plastic ratcheting mechanism activated. When the pin moved back and forth in one direction, more wear mass was lost. However, when this plastic ratcheting device was twisted, nothing happened.

Furthermore, the experiment indicated that several transfer films with different topographies were formed on steel pins utilizing three distinct movement movements. Overall, the study gives useful information about how PTFE wears in different sliding motions. This can help us understand and improve the use of PTFE materials in different tribological uses.

Federica Amenta et al.[12] did a study that looked at how unreinforced polyketone-based materials and reinforced PTFE composites slide on covered steel surfaces. The study's purpose was to investigate how the materials reacted in settings similar to rotating lip seals and how each connection wore down.

The researcher employed a PTFE-based polymer bonded with glass fibers and a solid lubricant in the investigation, as well as an unreinforced polyketone, were evaluated in a "pin-on-disc" setting against surfaces prepared with various materials. Specifically, plasma thermal spraying was used to make a chromium oxide coating, Physical Vapor Deposition (PVD) was used to make a CrN/NbN superlattice coating, and a hybrid PVD/PECVD process was used to create a covering of Diamond-Like Carbon (DLC).

In terms of individual wear rates and friction factors, the results showed that the PTFE matrix blend did better overall than polyketone. Even though the polyketone material had worse tribological behavior than the PTFE

matrix blend, it could be used without binders to make it stronger.
The authors' research showed how important it is for a transfer film to form on the counter-surfaces, since it can stop the polymer from wearing away further if it sticks well to the counterpart. But the tribofilm changed the friction coefficient in different ways for the two materials. When it formed, it made the friction coefficient smaller for PTFE and higher for polyketone. Overall, this study shows how reinforced PTFE composites and unreinforced polyketone-based materials react to covered steel surfaces from a tribological point of view. It also shows how important transfer-film formation is and how it affects how each material behaves when it comes to friction.
L. Reinert et al. [13] investigated the tribological performance of self-lubricating materials enhanced with carbon nanoparticles in metal matrix composites. The researchers sought to determine what generated the most friction and wear during an elastic and elastoplastic dry slide of nickel matrix composites enhanced with carbon nanotubes (CNT), nanodiamonds (nD) and onion-like carbon (OLC).
Multi-wall carbon nanotubes, nanodiamonds and onion-like carbon were chosen for their carbon hybridization state (sp2 vs. sp3), shape, and size ("0D" vs. "1D") to demonstrate a diverse spectrum of carbon nanomaterials and their various properties.
Greenwood-Williamson-based contact simulators were used to compute the Friction, wear and required contact loads were studied using scanning electron microscopy, transmission electron microscopy, energy-dispersive spectroscopy, and laser scanning microscopy.
Only CNT lubricated well as a support phase in composites, with varied lubrication mechanisms for the various contact situations examined. The lubricating action of CNTs was found to depend on their high aspect ratio, which makes it possible for the particles to come into close tribological touch. The lubrication effect got better as the amount of CNT in the material went up. Compared to the unreinforced nickel standard, the maximum steady-state decrease in friction was 50%.
Overall, the study gives us important information about the lubrication properties of metal matrix composites enhanced with carbon nanoparticles and shows how CNT plays a key role in reducing friction significantly under different contact conditions.
Maria Rodiouchkina and colleagues [14] investigated the tribological behavior of self-lubricating polymer composite-bearing materials and the generation of transfer layers during long-term dry sliding on stainless steel. Fiber-reinforced thermosets and thermoplastics containing PTFE are frequently used in naval and hydropower applications because they can self-lubricate in both dry and wet conditions. Composite bearings have improved over the years, making them quite popular in these industries since they are easy to maintain and endure a long time.
These materials' dry sliding behavior on stainless steel was examined in this study while they were moving back and forth. During extended slide experiments that approximated years of usage, the aim was to see how wear and friction functioned and how transfer layers accumulated. The experiments were halted every 20 hours to imitate working shutdowns. The counter surfaces were also evaluated to examine the development of surface texture and transfer layers by 3D optical interferometry and SEM.
The results of the tests showed that the wear rates of both materials dropped significantly with time. The synthetic material's coefficient of friction (COF) decreased with time due to quicker material movement after 80 hours. The fiber-reinforced thermoset, on the other hand, had substantially less material transfer. After 20 hours, the highest material translocation was seen. Surface analysis revealed that the wear particles from the steel and the material's supports were causing the counter surface to become exceedingly rough. This led the thermoset's COF to rise at the same time. Cross-sectional studies revealed that the transfer layers were thinner and the steel was more worn at the wear tracks' center, where the slide was.
When compared to short-term tests, these results help us get a better idea of how these materials work in terms of tribology over long periods of time. Also, it was found that the choice of counter surface material has a big effect on how the wear layer and transfer layer form.
M. Pazderova et al. [15] looked into the tribological behavior and wear resistance of zinc-based composite coats with polytetrafluoroethylene (PTFE) particles. The study looks at many different types of coatings with different compositions, formation conditions, and ways to measure them. For a full understanding of the tribological behavior of the coatings, it was important to know exactly what they were made of, how much PTFE was in them, and where it was located in the composite coatings.
To do this, a number of scientific methods, such as measuring the friction coefficient, optical microscope, and

infrared spectroscopy, were used to describe all the important factors. Each method worked in different ways to describe the coats that were tried.

The test results make it clear that adding PTFE particles to the zinc layer makes the coefficient of friction and self-lubricating qualities better. But these effects change based on how many PTFE bits are in the composite coats. The study shows how important it is to know exactly how much PTFE is in coatings and where it is in them in order to understand and improve their tribological performance.

N. Rajini et al. [16] looked into how natural fiber-reinforced polyester composites behave in terms of tribology. Cyperus pangorei (CP) fiber was used as the support, and polyester was used as the thermosetting matrix. CP fiber made up 40% of the weight of the composites, which were made using the compression molding method.

The technical features of the hybrid examples, such as density, stiffness, and wear, were measured. A pin-on-disk wear test device was used to perform the dry sliding wear test with a constant sliding distance, different sliding speeds (1, 2, and 3 m/s), and a contact pressure range (0.13-0.38 MPa). Following the wear test, the roughness of the surface of the worn objects was measured.

The study showed that the rate of specific wear went up as the specimen's applied load went up. Also, the coefficient of friction went down in a way that wasn't linear when the contact pressure went up and the slide speed went down.

A scanning electron microscope was used to assess the form of the worn samples. The goal of the study was to learn more about how natural fiber-reinforced polyester composites wear and change on the surface under different tribological situations.

Muammel M. Hanon et al. [17] did a study to find out how 3D-printed polymers behave in terms of tribology. With the fused deposition modeling (FDM) technology, samples were made out of Acrylonitrile Butadiene Styrene (ABS) and Poly Lactic Acid (PLA). PLA material could be printed in two colors, white and gray, but ABS could only be printed in white.

The primary goal of the study was to determine how friction affects 3D-printed samples by examining the rubbing qualities of various 3D-printable fibers. To quantify tribological properties such as the difference between static and dynamic friction coefficients, as well as wear values, an alternating-motion device was utilized.

It was done to compare how the 3D-printed materials behaved in terms of tribology. The results showed that there wasn't much difference between the white ABS and PLA samples that were made. But the grey PLA was very different, with a noticeable rise in the average coefficient of friction and wear.

Overall, this study provides valuable insights into the tribological performance of 3D printed polymers, highlighting the impact of filament color and material choice on frictional behavior and wear properties.

Xianqiang Pei and Klaus Friedrich [18] did a study to find out how high-performance plastics like polyetheretherketone (PEEK), polybenzimidazole (PBI), and two types of polyparaphenylene (PPP) wear when they slide against each other. Using PEEK as a standard, the wear resistance of these plastics at different PV levels was studied. The results showed that, compared to PEEK, PPPs, which are known for their high mechanical stability at room temperature, had a low resistance to wear. On the other hand, PBI had the lowest rate of wear. The reason given by author that it was very resistant to heat and kept its mechanical properties even when it was hot.

R. Jojith et al. (19) did a thorough review of how functionally graded composites (FGCs) behave in terms of tribology. As part of the study, the tribological performance of FGCs was looked at under both abrasive and rotating test conditions. This was done by looking at many different studies done by different researchers over the years. The results showed that FGCs showed different wear analysis trends based on the process conditions and study factors.

The review paper gave a general framework for figuring out the process factors and figuring out how well FGCs wear by looking at how they wear. By putting together studies from different sources, the authors gave useful information about how functionally graded composites behave in terms of tribology and showed how important it is to look at different process conditions and factors when doing wear analysis.

Pin-on-disc tribometers are employed to analyze the majority of tribological behavior, according to a review of the literature.

2. Methodology: Tests of the Tribology [20]

There are different kinds of tribometers that can be used to measure how things behave when they rub together. The most popular of these is the pin-on-disk tribometer, which can be used to study both steady and moving loads. In tribological studies, operational factors are very important because they show how materials work in certain situations. These factors can be measured in numbers and put into groups. Test elements like load, speed, type of motion, time, and weather conditions during testing can be used to do this.

For a full understanding of the tribological properties, wear and friction studies were done both when the slide was dry and when it was lubricated. Two different tribometers can be used to see how the materials worked in different scenarios.

Along with the effects of slipping, the effect of working temperature on tribological behavior was also looked into. A special tribometer was used to change the working temperature from room temperature to higher levels. This made it possible to see how wear and friction change at different temperatures.

Tribological study tries to figure out what causes wear and friction by looking at how different things work. This method gives a complete picture of how the material acts in different scenarios. By studying these factors in an organized way, researchers can improve the design and performance of materials in many real-world situations.

3. Limitations and Research Gaps

Based on the above study of the literature, the following research gaps have been found:

- There isn't much written about the tribological study of reinforced polymeric materials.
- An interesting area of study is the use of different bio-reinforcements (fibers) instead of standard ones.
- No research has been done on the relationship between static and dynamic stress and how polymers and polymer composites behave from a tribological point of view.

4. Conclusion

Here's an overview of the literature study and Future directions:

- Under steady or constant pressure conditions, researchers look at how different polymers and polymer composites behave from a tribological point of view.
- When made with different amounts, polymer composite materials are more resistant to wear and have lower friction coefficients and friction forces than ABS, which is used widely for FDM parts.
- The research serves as the foundation for the elastic composite cylindrical roller bearing's changed material. When carbon, copper, and glass filler are added to pure PTFE, the wear rate goes down a lot and the coefficient of friction goes up a little.
- In the last few decades, a lot of research has been done on how polymers behave in dry slide surfaces. But the effects of lubrication may make the tribological behavior of polymers in oiled contacts very different from how they behave in dry contacts.
- Lubricants can influence polymer friction and wear in a lot of different ways by interacting with the surfaces that touch each other. But scientists don't know much about how polymers behave when they are lubricated, either because they focus on fixing problems in the real world or because they want to keep the information secret.
- From a tribological point of view, the different polymer materials are put to the test. Still, different polymer and polymer hybrid materials need to be studied under dynamic pressures for different industrial uses.
- Design of Experiments (DOE) methods are used to find out about tribological factors.
- So, more study is needed to fill in the gaps in what we know about the tribology of polymers in dry and wet environments.
- If a dynamic loading machine is not available, the relationship between static and dynamic

loading should be looked into.

Overall, this study work tells us a lot about how polymer and polymer composite materials behave under static loads in roller bearings from a tribological point of view. This review shows how to build and make polymer composite bearings that can handle high loads, reduce friction, and last longer by looking at the main factors that affect how well they work. The findings presented in this paper will be valuable to researchers, engineers, and professionals working in the field of roller bearings, aiding in the advancement of polymer and polymer composite materials for improved static loading applications.

In conclusion, polymers and composites of polymers show a lot of promise as possible materials for rolling contact bearings, especially because they have good tribological qualities. But a focused effort to fill the study gap about how they respond to static loads will be necessary to move their practical use forward and get the most out of them in different engineering uses.

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