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Tribological Characterization of PEEK Polymer Composite for Bush Application

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Abstract: *This study presents a "Tribological Characterization of PEEK Polymer Composite for Bush Application" specifically Polyether ether ketone (PEEK) reinforced with Glass fiber, MOS2, Graphite, Bronze when tested using Pin On Disc Tribometer. Polyether ether ketone (PEEK) is a high-performance polymer with excellent mechanical strength and wear resistance, making it a suitable material for tribological applications. The study evaluates the coef ficient of friction (COF) and wear rate of PEEK composites under varying loads, speeds, and lubrication conditions, and comparing it with Gunmetal material specifications. In this work attention is given to suggest self-lubricating PEEK composite bush in place of the existing hydrostatically lubricated gun metal or brass bush used for sugar mills. PEEK + Glass Fiber composite gives Excellent Chemical Resistance: Resistant to many acids, bases, and solvents. Experimental work is carried out by varying loads of 30N, 60 N, 80 N at sliding velocity 1.2, 1.6, 2.0 m/s, keeping rest of the parameter's constant. Rubbing the test pins of PEEK composites against EN 8 stainless steel disc surface in dry condition using a pin-on-disc Tribometer..*

Keywords: PEEK (Polyether Ether Ketone), Polymer Composite, Tribology, Wear Resistance, Friction Coefficient, Bush Applications, Abrasive Wear, Lubricated Wear

I. INTRODUCTION

Poly-ether-ether-ketone (PEEK) is a high-performance semi-crystalline thermoplastic polymer that has gained significant attention due to its unique combination of mechanical strength, thermal stability, chemical resistance, and excellent tribological characteristics. As a prominent member of the poly (aryl ether ketone) (PAEK) family, PEEK has become one of the most widely used advanced engineering materials of the 21st century, especially in fields such as aerospace, automotive, petrochemical, biomedical, and industrial manufacturing. Its exceptional ability to maintain mechanical integrity under high-temperature and high-pressure environments makes it particularly attractive for components subjected to continuous friction, load, and chemical exposure. However, with the rapid development of technology and increasing performance demands in industrial applications, especially in rotating machinery and hydraulic systems, there is a growing need to enhance the functional properties of PEEK to meet more complex operational conditions. In particular, the pump industry frequently faces challenges related to friction, wear, corrosion, and component degradation due to exposure to aggressive fluids, high-speed rotation, and thermal fluctuations. Traditional materials used for pump bushings, such as metals and elastomers, often suffer from corrosion, lubrication dependency, dimensional instability, and reduced life span in such demanding environments. In this context, PEEK emerges as a highly suitable alternative due to its inherent resistance to hydrolysis, solvents, and high temperatures, combined with a self-lubricating nature that enables it to function effectively even under dry or marginally lubricated conditions. Its low coefficient of friction and high wear resistance are crucial for reducing energy losses and prolonging component life in rotating assemblies like pump bushings. Moreover, PEEK's excellent dimensional stability ensures precision alignment and reduced vibration, which are critical factors in the performance and durability of high-speed rotating equipment. Nonetheless, pure PEEK alone may not always meet the extreme performance requirements, which

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has led to the development of PEEK-based composites modified with various reinforcements. The inclusion of glass fibers and carbon fibers enhances mechanical properties such as tensile strength and stiffness, while the addition of solid lubricants like polytetrafluoroethylene (PTFE), molybdenum disulfide (MoS_2), and bronze particles significantly improves its tribological performance. These composite formulations enable tailoring of material behavior for specific applications where both mechanical strength and low friction are essential. For instance, PTFE and MoS_2 contribute to lower friction and smoother operation, while bronze particles enhance thermal conductivity and load-bearing capacity—ideal for reducing wear and preventing thermal degradation under continuous operation. Despite the clear benefits, challenges remain in the form of high material costs, difficulties in achieving uniform filler dispersion, and replicating real-world tribological conditions in laboratory testing. Accurate simulation of operational parameters such as load, speed, temperature, and lubrication remains essential to validate the suitability of PEEK composites for such applications. In light of these considerations, this study aims to evaluate the tribological performance of PEEK composites reinforced with PTFE, glass fiber, MoS_2, and bronze, focusing specifically on their applicability in pump bushing systems. By analyzing wear rates and coefficient of friction under controlled testing conditions, the research seeks to determine the most effective composite formulation that offers a balance of strength, thermal resilience, and wear resistance. The ultimate goal is to provide an advanced material solution for industrial pump applications, where reliability, low maintenance, and operational efficiency are critical, thereby extending equipment life and reducing downtime in harsh working environments.

The tribological characterization of PEEK polymer composites for bush applications reveals critical insights into their behavior under diverse operational conditions. PEEK, recognized for its exceptional mechanical and thermal properties, demonstrates enhanced tribological performance when reinforced with materials such as carbon fibers, PTFE, and graphite. Research findings suggest that these composites exhibit significantly lower coefficients of friction and improved wear resistance compared to pure PEEK, rendering them more suitable for high-demand engineering applications. Notably, carbon fiber-reinforced PEEK (at 30% by weight) shows nearly 50% greater wear resistance than unfilled PEEK, while PEEK composites modified with PTFE and graphite perform exceptionally well under high-pressure conditions (1,2). The inclusion of potassium titanate has also been reported to enhance wear behavior through the formation of a stable transfer film (3). Furthermore, manufacturing methods like injection molding play a significant role in the final composite structure and its tribological outcomes, where homogeneity influences wear patterns (4). Lubrication is another crucial factor, with studies indicating that under lubricated conditions, UHMWPE composites markedly reduce both friction and wear rates when compared to pure PEEK (5). Overall, while PEEK composites hold substantial promise for tribological applications, especially in bushing systems, their performance remains dependent on a combination of material composition, processing techniques, and service environment. Continued investigation into these variables is essential for optimizing composite formulations tailored for specific industrial needs. Karandikar P M et al (6) done research on PEEK with reinforced materials and modifications have shown promising results in various medical applications, offering improved mechanical properties, biocompatibility, and antimicrobial properties. Its unique combination of properties makes it a versatile material for medical devices and implants, and ongoing research continues to explore its potential in new applications. Pawar D. et al (7) Done work on, Experimental investigation and prediction of wear behavior of polymeric composites :2022; As per the comparative study of PTFE with different percentage of glass fiber the PTFE with 25% GF sliding themselves gives the optimum result. The experimental analysis of wear of PTFE with different percentages of glass fiber sliding themselves leads to the following: Normal load has more influence on the wear of PTFE with different percentages of glass fiber sliding themselves under dry and wet lubricated conditions and influence of interactions of wear parameters are negligible as per parameter ANOVA. Confirmation tests are carried out and it is found that the model developed by Taguchi L9 orthogonal array is satisfactory inadequate. This concludes that model developed can be used to predict the sliding wear behavior of PTFE composites effectively. From the Taguchi analysis different levels of parameters combination resulted as per the material to get optimum result as a small sliding wear. However, as per this study for higher load application PTFE with 35% GF and for high velocity PTFE with 25% GF is suggested under dry condition to get minimum wear. Mir A et al (8) Friction and wear characteristics of polyether ether ketone (PEEK): This paper explores the tribological behavior of PEEK (Polyether ether ketone) composites under various conditions, aiming to assess their

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viability as replacements for traditional materials like mild steel and gunmetal in pump applications. The study employs Pin-on-Disc and Reciprocating Tribometers to evaluate friction and wear characteristics. The key findings highlight the performance of PEEK in terms of wear resistance, coefficient of friction, and material degradation under different loads and sliding speeds The authors of the paper

(9) A Dynamic OD Prediction Approach for the Urban Networks Based on the Automatic Number Plate Recognition Data" by Liu et al. explores advanced methods for predicting origin-destination (OD) flows in urban traffic systems. The authors highlight the critical role of OD matrices in traffic management, focusing on real-time applications. Lin et al (10): Sandwich structure of (PEEK)-based dissimilar tribomaterials was successfully prepared by vibration welding for investigating the friction and wear properties by releasing particles onto the polymer/steel interface. The tribological properties of the welds were studied on a pin- on-disc tribometer under various loading conditions. The results demonstrate that the nano-sized rigid particles create an obvious synergetic effect with the short carbon fibers (SCFs) and graphite on reducing the friction and wear of PEEK/SCF/graphite composite. The mechanisms on improving tribological properties were revealed based on the analysis of the polymer worn surfaces and tribo films. The present study provides a new insight in tailoring polymer-based tribomaterials by using a particle depot concept in engineering of tribological components. Yang et al review highlights the evolution of CPCs [Common polymer matrices for CPCs include PEEK (Polyether ether ketone),epoxy, polyurethane (PU), and polytetrafluoroethylene (PTFE)], their advantages over traditional composites, and the role of different material combinations in achieving desired mechanical properties. Mohammed Abdul et al This research explores methods to enhance the tribological performance of PEEK by incorporating fillers and surface modifications. The study evaluates friction and wear characteristics under different conditions, aiming to optimize PEEK's performance for applications requiring high wear resistance, such as pump bushings and bearings.

Zalaznika M et al This research paper investigates the tribological behavior of PEEK composites, focusing on their friction and wear properties under different conditions. The study examines how factors such as applied load, temperature, and lubrication influence the material's performance in sliding applications. Wear Performance, Effect of Load and Temperature, Surface Interaction, Comparison with Other Materials: The study compares PEEK's performance with other materials, demonstrating its superiority in specific conditions, particularly in high-temperature applications. Massocchii Davide. et al: The study builds on prior research about the limitations of Babbitt coatings in hydrodynamic bush, particularly in high-wear conditions. PEEK composites with carbon fiber reinforcement show promise as an alternative, offering higher wear resistance and mechanical strength. The impact of different lubrication conditions on these materials is evaluated to determine their suitability for industrial applications. Chaudhari Dinesh et al: The study analyzed the performance of plain and diamond-textured journal bearings made from brass, bronze, and gun metal using Computational Fluid Dynamics (CFD). The findings are:1. 'Effect of Knurling (Texture)': The knurled surface increases the oil film contact area, enhancing heat dissipation. The knurled pockets also help retain lubrication, reducing friction and wear.2. 'Tribological Performance': The textured (diamond knurled) bearings perform better than plain bearings, reducing operating temperatures and improving lubrication retention. 'Final Recommendation': Using textured journal bearings instead of plain ones improves heat dissipation and reduces friction, leading to enhanced tribological performance. This study supports the adoption of knurled surfaces in journal bearings for better efficiency and durability. Koikei Hitonobu et al: From the obtained experimental results the following conclusions can be drawn: 1. the loaded output axis torque affects the PEEK bush wear in the robot joint, 2. the PEEK bush surface roughness and the loaded torque on the output axis are strongly related to the backlash (i.e. transmission error).3. the minimum backlash value was recorded after 500 cycles under 0 kg fcm loaded torque as a result of the friction between the 7075 aluminium alloy cam plate and the PEEK bush, 4. after the running-in process, the backlash increased along with the load. The gap between the bush and the cam plate grew larger due to the rough bush surface. To investigate the tribological performance of newly developed PEEK-based composites reinforced with fillers such as PTFE, carbon fiber, and bronze by evaluating their wear resistance, coefficient of friction, and frictional force under varying loads, sliding speeds, and temperatures, with the aim of identifying optimal filler combinations for high-temperature applications.

II. MATERIALS AND METHOD

Filler Material	Properties Enhanced	Advantages	Limitations	Typical Applications
Glass Fiber (GF)	Strength, stiffness, dimensional stability	High strength, low CTE, good wear and creep resistance	Slightly increased brittleness	Aerospace, industrial parts, automotive bushings
Bronze	Thermal conductivity, strength, wear	Excellent heat dissipation, high mechanical strength	Reduced corrosion resistance in harsh chemicals	Bearings, thrust washers, wear rings
MoS_2	Self-lubrication, tribological performance	Lower friction, better wear and galling resistance	No significant mechanical strength improvement	Seals, bearings, dry sliding parts
PTFE	Friction reduction, self-lubrication	Very low friction, chemical resistance, transfer film	Low mechanical strength, poor bonding	Low-load bushings, sliding rings, dry contacts

Material Composition and parameters for tribometer test -

Specimen:	Composition:
M1	PEEK(70%wt.)+PTFE(15%wt.)+Glass Fiber(15%wt.)
M2	PEEK(65%wt.)+PTFE(15%wt.)+Glass Fiber(15%wt.)+MOS2(5%wt.)
M3	PEEK(50%wt.)+PTFE(15%wt.)+Glass Fiber(15%wt.)+MOS2(5%wt.)+Bronze(15%wt.)

DOE DESIGN

Expt no.	Material	Velocity [m/s]	RPM(speed)	Track Dia.	Load [Newton]
1.	M1	0.2	87	20	30
2.	M2	0.2	133	32	30
3.	M3	0.2	199	44	30
4.	M2-2nd	0.2	87	36	60
5.	M3-2nd	0.2	133	48	60
6.	M1-2nd	0.2	199	24	60
7.	M3-3rd	0.2	87	52	80
8.	M1-3rd	0.2	133	28	80
9.	M2-3rd	0.2	199	40	80

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TEST MACHINE-

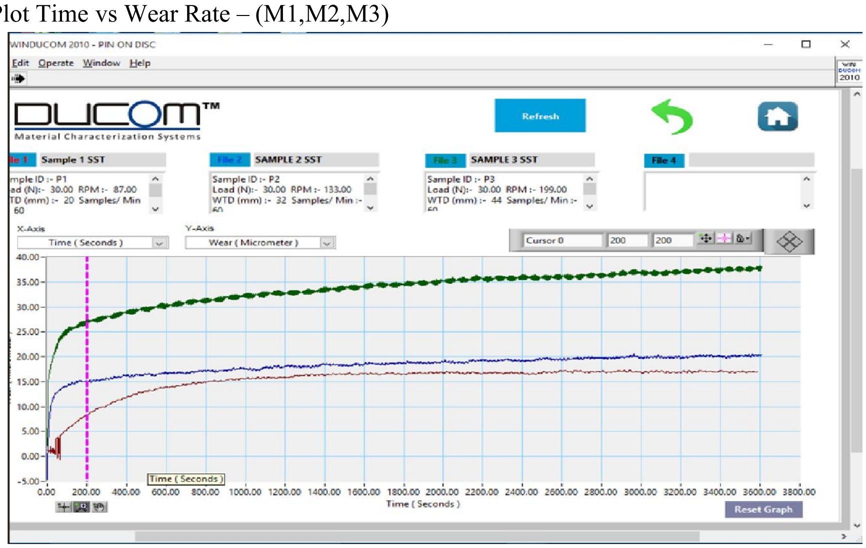
Fig. Pin on Disc Tribometer

Pin on Disc Tribometer (PoD)Test Machine:

1.Specimen: Pin size: 6mm x 30mm
2.Disc Speed: 300 RPM.
3.Normal Load: 10 N.
4.Frictional Force: Measured throughout the test.
5.Wear Measurement: Mass loss calculated pre- and post-test.
6.Temperature: Room temperature (22°C).
7.Environmental Chamber: Not utilized (ambient conditions).
8.Lubrication Unit: Light mineral oil applied before testing

III. RESULT

A. Comparison Plot Time vs Wear Rate – (M1,M2,M3)



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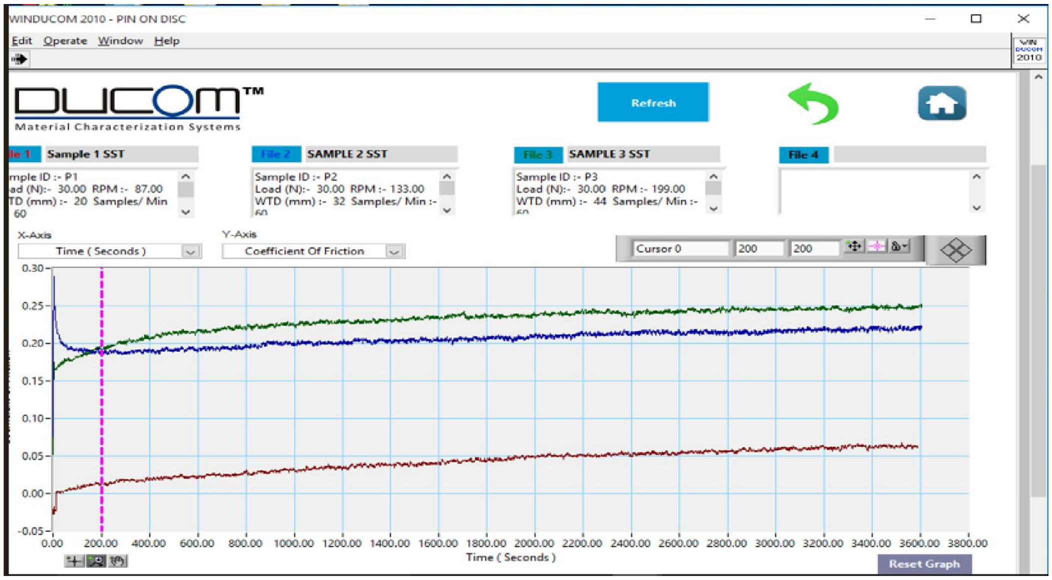
B. Comparison Plot Time vs COF– (M1,M2,M3)



IV. DISCUSSION

Based on the tribological analysis conducted using the Pin-on-Disc apparatus, it is evident that the composite M3, comprising PEEK (50%), PTFE (15%), Glass Fiber (15%), MoS_2 (5%), and Bronze (15%), demonstrates superior performance in terms of both wear resistance and coefficient of friction. The wear graph indicates that M3 experiences the least wear (~13 µm), significantly lower than M1 (~37 µm) and M2 (~17 µm).

This improvement can be attributed to the synergistic effects of MoS_2 and bronze, which contribute to enhanced load-carrying capacity, improved thermal conductivity, and better lubrication at the sliding interface. The reduced PEEK content in M3, compensated by bronze, seems to provide a more stable and durable composite matrix.

Similarly, the coefficient of friction (CoF) data reveals that M3 maintains the lowest and most stable CoF (~0.13) throughout the test duration, compared to M2 (~0.22) and M1 (~0.25). The presence of MoS_2, a known solid lubricant, and bronze significantly reduces friction by forming a lubricating film during sliding. M1, which lacks these additions, shows the highest CoF and wear, indicating that while glass fiber provides reinforcement, it alone is insufficient for optimal tribological performance. Therefore, M3 emerges as the most promising composite for applications such as bushings, where both low friction and high wear resistance are critical.

V. CONCLUSION

The experimental results clearly demonstrate that the incorporation of solid lubricants such as MoS_2 and bronze into the PEEK/PTFE/Glass Fiber composite significantly enhances its tribological performance. Among the three tested materials, M3 (PEEK 50% + PTFE 15% + Glass Fiber 15% + MoS_2 5% + Bronze 15%) exhibited the lowest wear (~13 µm) and the most stable, lowest coefficient of friction (~0.13), outperforming M2 and M1. This indicates that the combined effect of MoS_2 and bronze not only improves the lubrication at the contact surface but also reinforces the composite's structural integrity under sliding conditions. The addition of bronze appears to play a critical role in dissipating heat and supporting the mechanical load, while MoS_2 reduces friction by forming a protective tribofilm. In contrast, M1, which lacks these additives, showed the poorest performance with the highest wear and friction values. Therefore, it can be concluded that M3 is the most suitable material formulation among the three for tribological applications like bushings, where enhanced wear resistance and low friction are essential.

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