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A Review on the Material Selection for the Construction of Journal Bearing for Better Power Transmission and Wear Reduction

CH Kalyan Kumar[1], CH Bhaskar[2], B Kireeti [3], D Raju [4], A Syamsundar [5], S Jayachandra [6], D Vijay Raj Kumar[7]

[1,2,3,4,5,6,7]Student, Department of Mechanical Engineering, GMRIT, Andhra Pradesh, India

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ABSTRACT:

Most of the moving parts including automobiles and machinery requires bearings for the effective functioning. The main purpose of using bearings is to enhance the performance of bearing, for better power transmission, to bear heavy loads etc... The most common problems that causes bearing failure are wear and strain, frictional losses and power transmission losses besides these long-term use, improper lubrication, inappropriate materials etc... also contribute to the failure of the bearing and its functioning. Evolution of material and design is taking place since dawn to reduce the causes of bearing failures and to enhance the efficiency and performance of bearing. Material used in the construction of a bearing plays a key role to reduce the causes of bearing failures and to enhance the efficiency and performance of bearing. Material used in the construction of a bearing plays a significant role in its functioning. Bearings initially made of steel then bronze and so many materials were also entered into industry to meet the requirements now the turn came to polymers. Polymers are used because of their properties like lightweight, easy to replace, fully consumable and self-lubricated. Among those polymers PEEK (Polyether Ether Ketone) is most widely used polymer in the bearing manufacturing industry because of their properties like high thermal resistance, mechanical strength chemical resistance and it is easily machinable. In this review we reviewed so many papers with respect to the material used in the construction of the bearing and found that PEEK polymer is most suitable for the construction of the bearing. It also exhibits exclusive when working in collaborations with metals, polymers, and ceramics.

Introduction:

Generally, a bearing is a machine element that constrains the relative motion into a desired motion by reducing the friction generated between the moving elements. The name-bearing itself means to bear which means bearing as a machine element that supports or allows one part to bear another part. The main purpose of the bearings is to prevent direct contact between the elements that are in relative motion. Bearings reduce or prevent friction, heat generation, and ultimately the wear and failure of the bearing. Modern journal bearings face ever-growing demands for higher performance and the material must be environmentally friendly. The bearings nowadays are expected to work at higher temperatures bearing heavy loads with reduced friction generation for a long lifetime. In the olden days manual analysis of bearing was a time-consuming process but now it is an effortless process because there were so many simulations software available in the market. Bearing also depends on the initial conditions like initial roughness, loading, lubrication, and material too. Bearings are necessary for the proper operation of all moving parts in vehicles and machinery. Bearings support heavy loads, improve vehicle efficiency, and lessen friction. Bearings are used in many important sub-systems, including engines, gears, transmissions, wheels, steering, electrical motors, and pumps, among others. The most common problems caused by bearing failure are wear and strain, frictional losses, and power transmission losses. Long-term use, improper lubrication, inappropriate materials, etc. all contribute to the failure of the bearing function. In order to improve the performance a review is done to suggest a suitable material for bearing construction. During this review, so many materials from the initial stage of manufacturing to the present generation were seen. In the recent advances in bearing manufacturing polymers are mostly used for bearings. Among them, PEEK is chosen most widely. PEEK, is a highly machinable semi-crystalline thermoplastic with superior thermal resistance, mechanical strength, and chemical resistance. PEEK material is utilized in a variety of uses, including compressive plate valves, pumps, piston parts, and bearings.

Objective of the review:

- To examine and understand the necessity of emergency of new materials in the bearing production.
- To understand the uses of polymers in the construction of bearing.
- To suggest PEEK in the production of bearing.

Necessity of new material:

Why do we need to switch to polymers? Because polymers are lightweight, self-lubricating, easy to replace, and fully consumable. Once dominated steel and phosphor bronze are now giving way to polymers like PEEK, PTFE (Poly tetra Floro Ethylene), etc... most important property of these polymers is that they are self-lubricated and exhibit high thermal resistance, mechanical strength, and chemical resistance. These polymers also reduce wear and friction generation. When we look into marine applications then we will be able to know the necessity of polymers. Generally, bearings require lubrication for better performance but when the bearings are used in water then we need a special lubrication arrangement for the bearings. In the meanwhile, almost all the bearings that are used today are metallic bearings that are susceptible to corrosion which is a major problem that the marine industry is facing today. This corrosion reduces the strength of the bearing and weakens the bearing thus reduces the life of the bearing.

Literature Survey:

1)Seung Yoon On (2018): Paper presented on Dynamic characteristics of composite tilting pad journal bearing for turbine/generator applications. To improve dynamic performance and durability, composite tilting pad journal bearings made of carbon fibre/epoxy composites and a backup metal are created in this study. The modal analysis revealed that the hybrid composite tilting pads have a higher natural frequency, which can reduce flutter in real-world operation. The hybrid composite tilting pad journal bearing withstood friction in the absence of lubricating oil for 317 seconds without causing significant rotor damage. When compared to the white metal tilting pad journal bearing, the composite tilting pad journal bearing effectively reduced rotor vibration while increasing the stability and durability of the bearing system.

2)Xingxin Liang (2019): Paper presented on Thermo-Elasto-Hydrodynamic analysis and optimization of rubber supported water-lubricated thrust bearings with polymer coated pads. The lubrication performance of rubber-supported water-lubricated thrust bearings (RWTBs) with polymer coated pads is investigated in this paper, as is the offset ratio of rubber cushions. The findings of this paper confirmed that the proposed TEHD model is a useful tool for calculating lubrication performance and optimising RWTB rubber cushion offset ratios. The rubber cushion offset ratio has a significant impact on bearing performance. Elastic deformation and thermal deformation are principal factors affecting the lubrication performance of water-lubricated bearings with ‘soft' materials such as polymer materials with small elastic modulus and large thermal expansion coefficients. The water film thickness ratio of thrust bearings is also an important parameter to judge the lubrication performance.

3) Sri EndahSusilowati (2022): Presented paper on Mechanical and microstructural characteristics of Cu–Sn–Zn/ Gr metal matrix composites processed by powder metallurgy for bearing materials. In this study, graphite (Gr) was used as the solid lubricant throughout the powder metallurgy (PM) process on a single type of bronze bearing material, Cu-Sn-Zn. In the wt.% graphite 0.5 and 1.0, this study found that the values for hardness, density, and yield strength increased while the values for rate of wear and porosity reduced. When the weight percentage was 1.5 or 2.0, however, the values for hardness, density, and yield strength increased while the rates of wear and porosity dropped. In contrast to samples with a graphite weight fraction of 2.0%, microstructure sintered with a graphite weight fraction of 1.0% revealed small pores and a more uniform distribution of pores. Consequently, the mechanical characteristics of the Cu-Sn-Zn-C composite may be influenced by the weight fraction of graphite.

4) A.V. Maksimkin (2017): Presented paper on Wear performance of bulk-oriented nanocomposites UHMWPE/FMWCNT and metal-polymer composite sliding bearings. This study investigates the possibility that coating a surface with bulk orientated, polymer-based nanocomposites can lower the wear rate and friction coefficient. The deformation component of friction is reduced when the hardness of bulk-oriented nanocomposites increases, which lessens the reliance of the friction coefficient on the load. The material's fatigue resistance increases with an increase in its mechanical characteristics. Compared to its lamellar structure, UHMWPE's nanofibrillar structure is more resilient to fatigue wear.

5) Jisu Par (2022): Paper presented on Development and Performance Measurements of Gas Foil Polymer Bearings with a Dual Rotor test rig Driven by Permanent Magnet Electric Motor. The rotor dynamics stability of journal gas foil-polymer bearings (GFPBs) used in a dual-rotor bearing system was investigated in this paper. In terms of stability, GFPBs have a significant advantage. Based on these findings, the authors of this study strongly advise using GFPBs as a lubricant in environments where rotor dynamics are unstable or the system is subjected to shocks or periodic disturbances. The operating temperature conditions must be suitable for the use of polymers.

6) PawełZmarzły (2020): Paper presented on Multi-Dimensional Mathematical Wear Models of Vibration Generated by Rolling Ball Bearings Made of AISI 52100 Bearing Steel. The paper describes the creation of multidimensional mathematical models for assessing the impact of numerous factors on the vibration generated by 6304ZZ type rolling ball bearings. Increased waviness and roundness deviations in the race cause a noticeable increase in vibration. The increased radial clearance causes an increase in vibration recorded in the high vibration frequency band, which could be caused by the balls skidding on the racetrack's surface. Increased vibration is caused by an increase in the total curvature ratio, which may be due to a reduction in friction between the surface of the balls and the race surface. Because excessive values of bearing vibrations contribute to the propagation of the bearings wear process, so raceway waviness and roundness deviations have an indirect impact on bearing service life.

7) Christopher DellaCorte(2014): Presented paper on Novel Super-elastic Materials for Advanced Bearing Applications. The use of a hard, resilient Ni-Ti alloy for corrosion-proof, shockproof bearing and gear applications is presented in this paper. Bearings made of the low modulus, hard, and super elastic 60NiTi material provide a viable solution to long-standing tribological challenges. The use of Ni-Ti alloys is a method for circumventing the limitations of traditional materials. Ni-Ti alloys have excellent aqueous corrosion resistance, high hardness, and a low elastic modulus, resulting in exceptional performance properties. Because more robust bearing materials, such as 60NiTi, are now available, the use of fewer and smaller bearings may be possible, reducing weight, power consumption, and potentially cost.

8) King Him Lo (2022): Presented paper on A Mechanism-Based General Theory for Friction of PTFE/PEEK Composite: Effects of PTFE Morphology and Composite Microstructure. To create a mechanism-based general friction theory for PTFE/PEEK composite, an inquiry that combines experimental and analytical methods is done in this study. An acceptable value of C of 0.2 may be determined by looking at the microstructure features of the PTFE/PEEK composites that were manufactured internally. The kind of tribotester, counter face material, and sliding speed used to conduct the friction test may also have an impact on the value of. The theoretical friction predictions agree favourably with the friction test results obtained for the entire range of PTFE and PEEK volume content (from 0% to 100%), even if a single value of C of 0.2 is employed.

9) Dongliang Liu (2018): Paper presented on Torsional Friction Behaviour of contact Interface Between PEEK and CoCrMo in Calf Serum. This study used a Leeds Prosim knee simulator to conduct torsional friction testing of PEEK against the CoCrMo alloy, imitating the contact mode between the prosthesis tibia and femur. The core region of PEEK is more susceptible to damage from minor loads, while the marginal region is more severely harmed by heavy loads. The severity of the damage to the PEEK surface increases with increasing torsional angle displacement. Under the various circumstances, PEEK demonstrated a low coefficient of friction. Whereas fatigue wear and abrasive wear mostly manifested in the marginal region, plastic deformation is the Main wear mechanism in the core region.

10) Ranjith-Kumar Sree Nilayam-Raveendran (2013): Paper presented on Comparative evaluation of metal and polymer ball bearings. This research compares how well metal and polymer perform when in rolling contact. PEEK bearings exhibit a lower level of vibration than dry metal bearings. Due to the decreased friction coefficient of the carbon transfer coating created during bearing operation, PTFE bearings showed more consistent operating speed after an initial running-in period when compared to PEEK bearings. It is anticipated that longer life and more stable operating levels will come from combining the excellent wear resistance capabilities of PEEK with the low coefficient of friction of the PTFE material. Only if there is less friction between the contacting surfaces would PEEK be preferable over PTFE.

11) Pixiang Lan (2017): Paper presented on Three-body abrasive wear by (silica) sand of advanced polymeric coatings for tilting pad bearings. The abrasive wear resistance of polyether ether ketone (PEEK) and ATSP-based coatings is examined in this work employing an accelerated wear experimental configuration with submerged lubrication and 2% weight of silica sand. Because of their elastic deformation and the development of a black tribo-layer on the surface, ATSP-based coatings offer excellent abrasive wear resistance and a very steady coefficient of friction (COF). As the silica sand was added, the wear rate of ATSP-based coatings increased, whereas the wear rate of PEEK-based coatings reduced. In the PEEK-based coating example, abrasive silica sand functioned as a solid lubricant that had a positive impact by reducing wear rate.

Results and discussions from the review:

Seung Yoon On (1) used carbon composites that offer poor or modest resistance to impacts and there were limitations in the design and the repairing of the carbon fiber composites is also difficult. Xingxin Liang (2) said about Rubber Supported Thrust Bearings (RWTBs) but they are having limited load capacity and are not suitable for the high load applications and they are susceptible to corrosion because these composites are made of rubber and metal and lubrication and cooling processes are also extraordinarily complex when compared to the traditional ways. Sri EndahSusilowati (3) used the Cu-Sn-Zn/ Gr metal matrix composites but the problems offered by them are reduced strength and wear resistance, machining it is exceedingly difficult due to its abrasive nature, and it cannot operate at elevated temperatures, and as it is a metal alloy it is also susceptible to corrosion thus reduces the performance and life span of the bearing.

A.V. Maksimkin (4) worked on the nanocomposites Ultra high molecular weight polyethylene (UHMWPE), this is also having an extremely limited temperature range irrespective of it, it is having low strength and stiffness, and highly flammable. Jisu Par (5), in his study, used Gas Foil Polymer Bearings (GFPBs), these bearings are having limited load capacity and rotational speed range, it is sensitive to temperature and contamination, are complex to operate, and produce noise and vibrations. PawełZmarzly (6) used AISI 52100 for his study as it is a type of steel it is affected by corrosion, is brittle in nature, limited welding ability and it is difficult to machine because of its high hardness and toughness. Christopher Della Corte (7) used super elastic material Ni-Ti alloy but it is brittle in nature, it experiences fatigue failure, and it is sensitive to heat treatment.

King Him Lo (8), Dongliang Liu (9), Ranjith-Kumar Sree Nilayam-Raveendran (10) and Pixiang Lan (11) used polymers for the construction of the bearing. They used diverse types of polymers like Poly Ether Ether Ketone (PEEK), Poly tetra Floro Ethylene (PTFE), Aromatic Thermosetting coPolyester (ATSP), etc... for the preparation of bearings, they offered particularly suitable properties like self-lubricating, reduced wear rate, effective resistance towards brittle behavior, corrosion and fatigue failure, and improved performance by reducing the losses due to friction.

Conclusion:

In this review, by going through all the papers we found that polymers are the most used materials in the bearing production industries in the recent years because of their exclusive properties like superior thermal resistance, mechanical resistance, wear resistance besides those these having corrosion resistance too. In the meanwhile, for the metal bearings we need to provide special lubrication arrangements because without lubrication the friction generation, wear and tear will be extremely high we will not get any such problems with polymers because polymers are self-lubricated. Analysis was done on different polymers but among them PEEK shows higher efficiencies with different collaborations that is with metals and polymer combinations. Remaining polymers get also exhibit good efficiencies when they are working with same type polymers but when we investigate collaborations with other materials their efficiencies are not that much effective when we compare with PEEK polymer. So, by this review we concluded that PEEK polymer is most suitable to produce bearings.

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