DEVELOPMENT OF NEW MODEL LOW FRICTION BEARING WITH OPTIMIZE GEOMETRY

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in fulfillment of the requirements for the degree of
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DECLARATION

I declare that this project entitled " Develop of new model low friction bearing with optimize geometry" is the result of my research except as cited in the references. Therefore, choosing an item has not been accepted for any degree and is not concurrently submitted in the candidature of any other degree.

Signature	:	
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APPROVAL

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering Technology (Maintenance Technology) with Honours.

Signature :

Supervisor Name : Dr. Muhammad Ilman Hakimi Chua Bin Abdullah

Date : 21 December 2022

DEDICATION

I dedicate this work to my beloved parents and supervisor Dr. Muhammad Ilman Hakimi Chua Bin Abdullah. They offered unconditional love and support and have always been there for me. Thank you so much for giving me the strength to finish my Final Year Project.

ABSTRACT

Bearings are among the most prevalent elements in civil-engineering buildings and mechanical machinery, and it have a wide range of uses. As a result, an improved bearing can significantly influence, potentially increasing reliability and efficiency. According to prior studies, rolling parts might minimise friction significantly compared to sliding action. Furthermore, contemporary manufacturing and material technologies enable the fabrication of an ideal structural bearing with a smoother and lower coefficient of friction surface. Different geometry models are designed using CatiaV5 software and manufactured utilising SLS 3D Printing in this study. Furthermore, all model designs are run through simulation using SIMSOLID software, and the prototypes is subjected to vibration analysis performance testing. The prototypes are put through surface validation, a scanning electron microscope (SEM), and a surface roughness tester are used to evaluate tribological behaviour. According to the overall findings, the majority of the optimized prototypes performed better. The force applied to the contact surface while a bearing is rotating is the main influencing factor. In contrast, when more force is applied, the SLS printed prototypes deform plastically and provide a smoother surface. Therefore, the smoother surface results in less machine vibration. The surface roughness results and SEM images provide a wealth of information to support the analysis. As a result, the optimized geomery bearing demonstrates the potential for use in upcoming applications.

ABSTRAK

Galas adalah antara elemen yang paling lazim dalam bangunan kejuruteraan awam dan jentera mekanikal, dan ia mempunyai pelbagai kegunaan. Akibatnya, galas yang lebih baik boleh mempunyai pengaruh yang ketara, yang berpotensi meningkatkan kebolehpercayaan dan kecekapan. Menurut kajian terdahulu, bahagian bergolek mungkin meminimumkan geseran dengan ketara jika dibandingkan dengan tindakan gelongsor. Tambahan pula, teknologi pembuatan dan bahan kontemporari membolehkan pembuatan galas struktur yang ideal dengan pekali permukaan geseran yang lebih licin dan lebih rendah. Model geometri yang berbeza direka bentuk menggunakan perisian CatiaV5 dan dihasilkan menggunakan Percetakan 3D SLS dalam kajian ini. Tambahan pula, semua reka bentuk model dijalankan melalui simulasi menggunakan perisian Simsolid, dan prototaip tertakluk kepada ujian prestasi analisis getaran. Prototaip dimasukkan melalui pengesahan permukaan, mikroskop elektron pengimbasan (SEM), dan penguji kekasaran permukaan digunakan untuk menilai tingkah laku tribologi. Menurut penemuan keseluruhan, sebahagian besar prototaip yang dioptimumkan menunjukkan prestasi yang lebih baik. Daya yang dikenakan pada permukaan sentuhan semasa galas berputar adalah faktor pengaruh utama. Sebaliknya, apabila lebih banyak daya digunakan, prototaip bercetak SLS berubah bentuk secara plastik dan memberikan permukaan yang lebih halus. Oleh itu, permukaan yang lebih halus menghasilkan getaran mesin yang lebih sedikit. Hasil kekasaran permukaan dan gambar SEM memberikan banyak maklumat untuk menyokong analisis. Hasilnya, galas geomeri yang dioptimumkan menunjukkan potensi penggunaan dalam aplikasi yang akan datang.

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ABS	-	Acrylonitrile butadiene styrene
CAD	-	Computer-aided design
CAE	-	Computer aided engineering
CAM	-	Computer- aided manufacturing
CFD	-	Computational fluid dynamics
COF	-	Coefficient of friction
DFT	-	discrete Fourier transform
DMLS	-	Direct Metal Laser Sintering
EBM	-	Electron-beam melting
EDX	-	Energy dispersive X-ray spectroscopy
FEA	-	Finite Element Analysis
FFT	-	fast Fourier transform
IDFT	-	Inverse discrete Fourier transform
LOM	-	Laminated object manufacturing
PLM	-	Product life cycle management
PPE	-	Personal protective equipment
PTFE	-	Polytetrafluoroethylene
RMS	-	Root mean square
SEM	-	Scanning electron microscope
SLM	-	Selective laser melting
SLS	-	Selective Laser Sintering
UAM	-	Ultrasonic Additive Manufacturing

CHAPTER 1

INTRODUCTION

1.1 Background

The first modern cylindrical roller bearing is invented by Dr.-lng. Josef Kirner in 1909 with crowned raceways to avoid damaging edge stresses at the roller ends. After evolution for more than 100 years, wide ranges of design, series, variants, and sizes are developed. They are distinguished by inner or outer ring flanges, cage design, number of roller rows and materials. In this research, the geometry of the cylindrical roller bearings is optimized. The cylindrical roller bearing is commonly used in stationary gearboxes, automotive motors, wind turbines, etc.

According to Cambridge Advanced Learner's Dictionary & Thesaurus, Optimized means to make something as good as possible (Cambridge Dictionary). The “Optimized geometry” in the research title is classified as topology optimisation in structural optimization. Topology optimization uses the algorithm to change the density of structure while controlling the stiffness contribution and make changes to the dimension of CAD model to obtain desired structural properties (Róbert and Peter, 2016). Optimization with a few simple structures where the film thickness takes a few distinct values can minimize the coefficient of friction torque in the new bearing geometries (Kalle Kalliorinne et al., 2020).

This research aims to create different geometry (circle, triangle, square, rectangular) holes on the outer ring to reduce the contact area between the roller bearing and the outer ring wall. The contact pressure on rolling elements is depends on the length of the contact surface; reduce the length of contact can increase the durability of the new geometry (Šteininger et al., 2020). Optimal texture patterns improve substantially the bearing load capacity in comparison to that of smooth sliders (Papadopoulos et al., 2011). Comparing to the solid pin, the different internal geometries of pins in sliding motion showed the lowest COF and wear rates at a high normal load, irrespective of their sliding speed. (Abdollah et al., 2020)

According to Wikipedia, CATIA is a multi-platform software suite for computer-aided design (CAD), computer-aided manufacturing (CAM), computer-aided engineering (CAE), 3D modelling and product lifecycle management (PLM), developed by the French company Dassault Systèmes. In manufacturing the prototypes, the software CatiaV5 is used to design and optimization of the CAD model. Additionally, the selective laser sintering (SLS) technology is used to print out the samples. SLS is an additive manufacturing technology; tiny particles of polymer powder are sintering into a solid structure with the help of a high-power laser. In material selection, Nylon PA12 is selected for the prototyping model; it could provide high-performance prototyping with great detail and great dimensional accuracy ideal for the bearing model. Moreover, it has design freedom, high productivity, and lower cost (formlabs).

Lastly, SIMSOLID is a structural simulation software programme that does statics, dynamics, and thermal analysis. Thus, simulate the performance of the improved design in SIMSOLID software to get forces and response pressure on various connections (contacted surfaces during operation). Meanwhile, the physical simulation is done using a turning shaft driven by a motor with accelerometer, surface roughness tester, and scanning electron microscope machine. Therefore, the vibration analysis, surface roughness, wear analysis, and chemical composition of prototypes are all documented.

Problem Statement

From the RESEARCH AND MARKETS report, the global market for the bearing is estimated at USD 113.1 Billion in 2020 and expected to be at USD 162.1 Billion in 2026. The market is forecast to grow at a compound annual growth rate, a CAGR of 6.3%. Roller bearings constitute the largest (77% of the global bearing market) and fastest-growing category. Additionally, there is an increase in demand for specialised or customised bearing to industry requirements (Bearing – Global Market Trajectory & Analytics, 2022). Nowadays, bearings work with heavy loads, high speed, different conditions (corrosive, humidity, temperature), etc. Thus, the performance of bearings is critical to accomplish the functional requirements. The common bearing failures are caused by the friction problems, such as wear and overheating.

Based on Wikipedia, the motion of solid surfaces, fluid layers and material elements sliding against each other will create friction. There are several types of friction: dry friction, fluid friction, lubricated friction, skin friction, and internal friction. The friction typically converts kinetic energy to thermal energy during the sliding motions (Wikipedia, 2022). Bearing friction is the rotational motion between rolling elements, raceways and cages. It is not constant and depends on the tribological phenomena in the lubricant film.

From the understanding of Amontons' Second Law of friction applied in dry friction, the force of friction is independent of the apparent area of contact (Wikipedia, 2022). Furthermore, one of the rules of rolling friction indicates that friction is caused by deformation of the contact surface. Therefore, to overcome the friction problems in bearing, it is crucial to investigate the contact area's effect during the rotational motion. Besides that, the material properties of the prototype (Nylon PA12) have a very low coefficient of friction, high environmental stability, strong resistance to chemicals with excellent impact and non-impact strength is suitable as the future material in manufacturing bearing. Moreover, Nylon 12 also has the characteristic of dampening noise and vibration. This is great in increasing the reliability of the equipment life and reducing the noises to protect operators' ears. Lastly, the technology of selective laser sintering (SLS) 3D printing also provides an alternative way to manufacture fully functional products with high precision and accuracy. High precision and accuracy with the delicate surface are perfect in reducing the friction in bearings.

Objectives

The objectives of this project are stated as below.

1. To fabricate a new bearing with optimize geometry
2. To run a test rig testing to validate the performance of new developed bearing compared to the existing model.
3. To analyse the tribological behaviour of the developed bearing.

Scope of Research

The scope of this research are as follows:

1. Fabricating a new bearing with optimised geometry using CAD/CAE analysis; A simulation is run by utilising SIMSOLID and a prototype bearing is printed by SLS method.
2. Run a test rig testing to validate the performance of newly developed bearing compared to the existing model using computerised vibration analyser (PT 500.04).
3. The tribological behaviour of the bearing is measured by profilometer (surface roughness tester- SJ401) and surface morphological analysis (SEM).