OPTIMIZATION OF BEARING SEAL INTERFERENCE

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ABSTRACT

This paper presents a comprehensive study on the optimization of bearing seal interference to improve bearing performance and efficiency. The research investigates various factors affecting seal interference and employs FEA method optimization techniques to find the optimal interference. The results demonstrate the potential benefits of optimized interference in reducing friction, enhancing sealing efficiency, and extending bearing life. In the FEA analysis, there are eight nodded shells of 281 elements were used to find the exact contact area so that interference could be optimized in a way. This analysis carried out by making a three-dimensional model of the assembled bearing with the seal was made by using Creo software and different interference models we chose so that we can have the optimised interference as already said these interference plays a major role in reducing the bearing torque and increases bearing life and this finite element was widely used to determine the contact area contact pressure and many more things like static structural simulation, thermal engineering analysis, model analysis etc, but we have used structural method to determine the contact area and contact pressure so the optimization was carried out. Creo is a good modelling tool which was widely used to make two-dimensional and three-dimensional models. This research we carried out because some customers were facing severe water ingress dusty environments were present and single-sealed bearing failures happened to overcome the situation sealed was carried out but there is a big challenge to optimize the seal interference as it will lead the early failure of the bearing.

Keywords: - bearing , torque, lip seals, gasket, Hydraulic system, Machine design

1. Introduction

Bearing seal interference refers to a situation where there is unwanted contact or friction between the sealing element (such as a lip seal or gasket) and the moving components of a bearing or a shaft. This interference can lead to increased friction, heat generation, and premature wear of the seal and bearing components. Proper installation and tolerance considerations are crucial to prevent bearing seal interference and ensure the reliable operation of machinery and equipment.

Bearing seals are essential components in many mechanical systems to prevent contamination and retain lubrication.

There are two primary types of bearing seals: contact seals and non-contact seals.

Contact Seals (lip seals) -The mechanical contact seal requires more power than the other seals, which is a deterrent to its use on lower power compressors. Contact seals, also known as lip seals or radial seals, physically touch the rotating shaft or inner ring of the bearing. The seal lip creates a physical barrier that prevents the ingress of contaminants (like dust, dirt, and water) into the bearing.

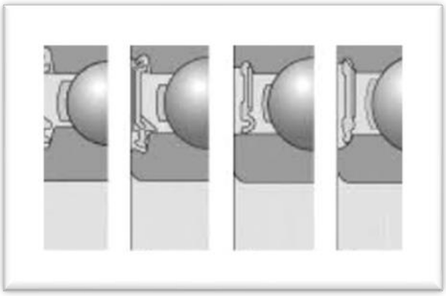


Figure no. 1 contact seal

Type of contact seal - they are three type

Single lip seals: A single lip seal is a type of seal which uses single lip contact and those contacts the shoulder of the inner race which is good for applications where less amount of contamination is there and it has a less amount of bearing torque as contact between lip and shoulder is less.

Figure no. 2 Single lip seals

Double lip seals: A double lip seal is a type of seal which uses double seal contact and the lip of the bearing contacts the shoulder of the inner races which is good for application where more contamination is there as the name suggests it contacts two areas then we can say the area is more but it can be modified to get the optimum result.

Figure no. 3 Double lip seals

High Pack seals: A high pack type of seal eliminates all the dirt content even water ingress and grease base oil purge, but these seals are more costly, and it is used for application where a high amount of contamination is there which can't be stopped by double lip and single lip seal as it is better than double and single lip seal.

Figure no. 4 High Pack seals

Contact seals provide excellent sealing performance but may generate some friction and heat due to their direct contact with the rotating components.

Non-Contact Seals: Non-contact seals are designed to seal without any physical contact between the rotating and stationary elements. In general, the benefits of non-contact seals include: no parasitic drag. No wear on the rotating element.

Figure no. 5 Non-Contact Seals

Non-contact seals, also known as labyrinth seals or shield seals, do not touch the rotating components directly. They rely on the geometry of their design to create a barrier against contaminants.

Common non-contact seal designs include:

Labyrinth seals: Intricate paths that impede the entry of particles and fluids.

Shield seals: Solid plates or rings that shield the bearing without touching the shaft.

The choice between contact and non-contact seals depends on the specific application's requirements. Contact seals offer better protection but may lead to slightly reduced efficiency due to friction. Non-contact seals are more efficient but may be less effective in harsh environments. Engineers select the appropriate seal type based on factors such as the application's operating conditions, maintenance requirements, and desired performance characteristics.

LITERATURE REVIEW-

(i) **Nanfei Wang Dongxiang Jiang (2016),** The paper presents a finite element model of dual-rotor system with pedestal looseness stemming from loosened bolts. Dynamic model including bearing pedestal looseness is established based on the dual-rotor test rig. Three-degree-of-freedom (DOF) planar rigid motion of loose bearing pedestal is fully considered and collision recovery coefficient is also introduced in the model. Based on the Timoshenko beam elements, using the finite element method, rigid body kinematics, and the Newmark- β algorithm for numerical simulation, dynamic characteristics of the inner and outer rotors and the bearing pedestal plane rigid body motion under bearing pedestal looseness condition are studied

(ii)**Zhiqiang Huang and Gang Li (2018),** To improve the performance of the cone bit bearing seal, experimental study and simulation analysis of seal failure were carried out, and optimization of the seal was conducted. Results show that damages are located on the shoulder of the rubber rings due to high shear stress caused by large compression ratio, and serious wear appears on the sealing face of the metal rings because of unreasonable contact pressure distribution. Optimization was conducted by finite element method on three aspects: the dip angles (3°–8°) of the sealing face, the widths (1.3–3.9 mm) of the sealing face, and the back support structure (10°–15°).

(iii) **Yi Zhou & Yi Zhou (2019),** A roller bit is a drilling tool widely used in oil and gas exploitation. The roller bit is applied to cutting the rock stratum, and its working life and rotational speed are important factors affecting the drilling efficiency. Moreover, a bearing sealing affects the working life and rotational speed of a bit. This paper proposes a helical sealing structure that addresses the problems of severe sealing wear and a short working life. This structure has been used in many engineering fields but was first applied to the roller bit. This paper investigates the sand removal mechanism of helical sealing through simulation and experiment. Additionally, helical sealing parameters were optimized. The optimum structural parameters of helical sealing in a high-speed roller bit were obtained. It was shown that the helical sealing structure can be applied to a roller bit with good effects of sealing and sand removal.

(iv) **Runliang Wang, Jianhua Liu, Feikai (2021),**The evaluation of sealing performance is important in the design stage and assembly process of sealing structures. To date, analyses of sealing structures have rarely quantitatively evaluated sealing performance: They tend to neglect microsurface topographic information or simplify rough surfaces. Herein, we propose a new and efficient simulation approach to analyse sealing performance based on a multiscale contact model. In this simulation approach, a new parameter, critical preload, is used as the index of sealing performance.

(v) **Junzhe Lin Yulai Zhao,(2021),** In the actual working process of rotating machinery, looseness is a common fault, which usually includes the looseness of rotating parts and the looseness of the foundation.(e looseness between bearing support and foundation is the most common fault in rotating machinery. Looseness fault may be caused by long-term severe vibration of the system due to low installation quality and faults such as oil-film instability. Once a looseness fault occurs, it is likely to cause a serious rub impact fault between the rotor and Stator.

Background and Application details-

In bearing applications such as propeller shafts conventional bearing design exhibits a contaminant issue as well as water ingress issue into the `bearing so to over these problems a double sealed deep groove ball bearing was introduced in the propeller shaft application.

These bearing has two no seals on one side so a total of 4 seals are these the inside is held on the outer ring and the outside seal is held by the help of the inner race.

These bearing does not allow base oil to come out and it helps to protest the water ingress inside the bearing so the issue of high contamination is resolved in these type of bearing the bearing torque will increase drastically so to overcome this optimization of seal interference is required so that life will increase when the same envelope size and mostly these bearing used in propeller shaft application where the load coming on the bearing is very less so load rating is not critical and it can be decreased and it is useful for the application so let us discuss the application as explained below.

A centre support bearing, also known as a carrier bearing, is commonly used in vehicles with a two-piece driveshaft, such as trucks and some rear-wheel-drive cars. Its primary function is to support the middle of the driveshaft and reduce vibrations and stress on the drive train. Here's a brief overview of its application and the types of propeller shafts:

Application:

Two-Piece Drive shaft: Centre support bearings are typically found in vehicles with a two-piece driveshaft. This design allows for flexibility and adjustment in the driveshaft's length, which can be beneficial for vehicles with longer wheelbases or rear-wheel drive.

Types of Propeller Shafts:

Propeller shafts, also known as drive shafts, are used to transmit power from the vehicle's transmission to the rear differential or front differential (in the case of four-wheel-drive vehicles). There are mainly two types of propeller shafts:

One-Piece Solid Shaft:

Construction: A one-piece solid shaft is a single, continuous steel shaft that extends from the transmission to the rear differential without any intermediate support. It is commonly used in smaller vehicles or those with shorter wheelbases.

Advantages: Simplicity and lower cost. It's well-suited for vehicles with shorter distances between the transmission and differential.

Two-Piece Shaft with Centre Support Bearing:

Construction: In this design, the propeller shaft is divided into two sections: a front section connected to the transmission and a rear section connected to the differential. The centre support bearing is positioned in the middle to support and stabilize the shaft.

Advantages: Allows for more flexibility in vehicle design, especially for longer wheelbases. It helps reduce vibrations and stress on the drivetrain components.

The centre support bearing itself typically consists of a bearing mounted in a housing that attaches to the vehicle's frame or chassis. It provides a pivot point for the driveshaft, allowing it to move slightly with the suspension while maintaining a connection between the transmission and differential.

The choice between a one-piece solid shaft and a two-piece shaft with a centre support bearing depends on the vehicle's design, length, and intended use. Longer wheelbases and rear-wheel-drive vehicles often benefit from the two-piece design with a centre support bearing to minimize drive train vibrations and accommodate variations in suspension movement.

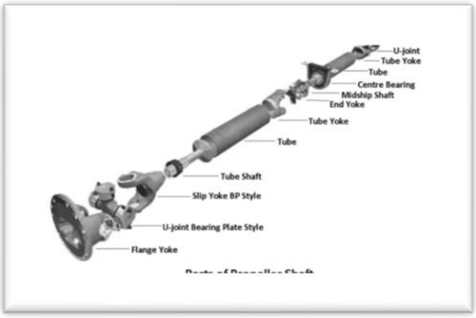


Fig 6 Parts of Propeller shaft (as per 6 no of reference.)

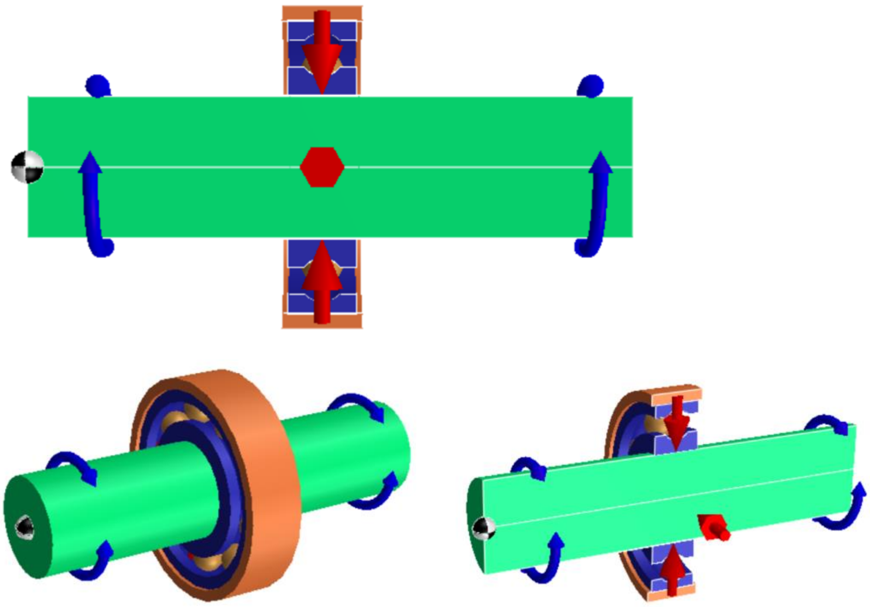


Figure no. 7

Propeller shaft 3 D model with load centre acting on the bearing centre with input power and output power.

Advantages & **disadvantage of bearing seal**

Sr. no.	ADVANTAGES	DISADVANTAGE
1	It handles a wide range of liquids including acids, salts and rough particles	It requires more space than outspread lip seals.
2	Long working life.	Mechanical Seals cannot normally deal with pivotal end play.
3	Mechanical seal handle marginally misaligned/non-concentric	High beginning expense.
4	The operation of does not bring about shaft wear.	Sealing countenances must be done smooth (0.08 to 0.4 micrometer) and can get effectively harmed.
5	Shaft condition is not basic	
6	Handle Bi-directional shaft revolution, huge weight, temperature and speed trips.	
7	A positive fixing for sustenance preparing,	

Results and discussion

The below are methods used for doing the analyses of bearing seal interference.

Geometry and Material Properties: Bearing modelling was done on Creo and bearing no is 6307 with 2 seals on each side.

Mesh Generation: Generated a finite element mesh for the entire assembly, ensuring that it accurately represents the geometry and captures critical details.

Boundary Conditions: Define boundary conditions such as constraints and loads on the chosen bearing.

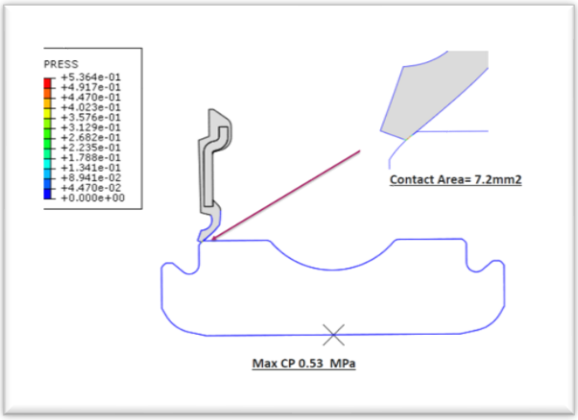
Contact Analysis: Set up contact interfaces between the bearing and seal, considering

Friction and interference. The interference defines how tightly the seal fits against the bearing.

Load Analysis: A self-generated load was generated, and interference and contact pressure were generated for these bearings.

Table no. 1

Design Trail	Contact Pressure (Mpa)	Contact Area (Mpa)	Contact force (N)
Design 1	0.53	7.2	3.816
Design 2	0.527	6.65	3.774
Design 3	5.02	1.47	3.84
Design 4	3.2	1.2	7.37
Design 5	4.85	2.74	13.29



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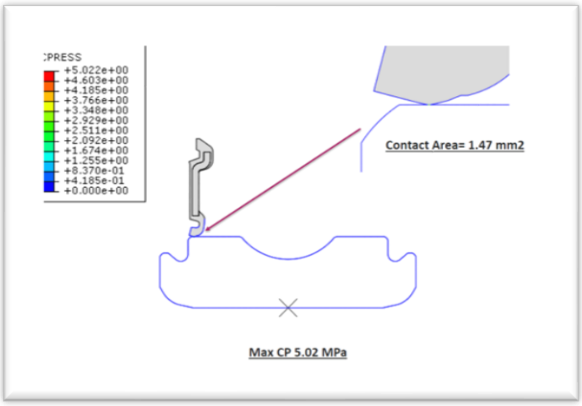

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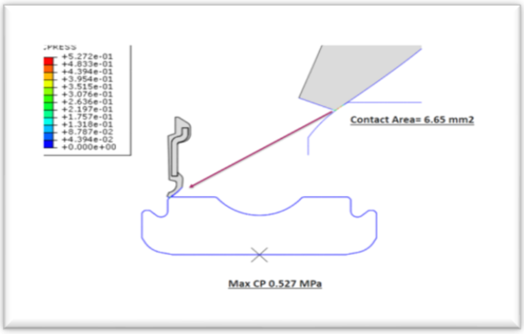

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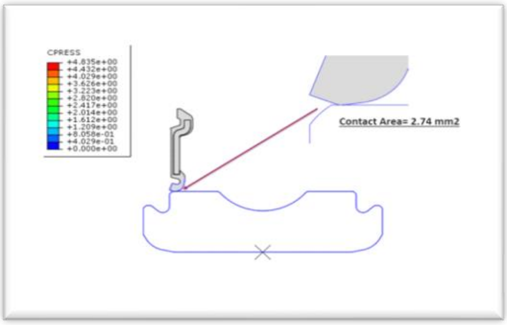

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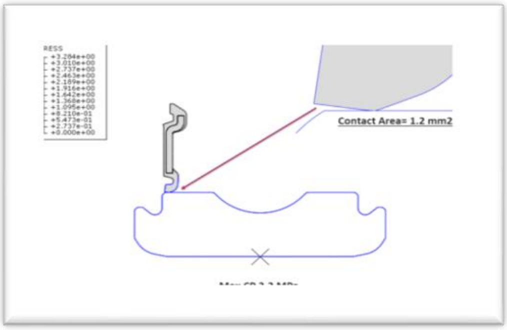

Figure No. 5

CONCLUSION:

We have got an optimized seal design made the samples and done the validation and the bearing is meeting the customer's required life.

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