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DESIGN AND ANALYSIS OF WATER PUMP INTEGRAL SHAFT BEARING WITH HERTZIAN CONTACT STRESS THEORY

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ABSTRACT

In this paper a integral shaft bearing is popular for higher specific load carrying capacity, preventing misalignment defects and eliminating the risk of undesirable distortion of the bearings, rather than Conventional one. Integral Shaft Bearing is used to reduce rotational friction and support radial and axial loads Friction in bearings which cause an increase of the temperature and Stresses inside the bearing. One also needs to address stress issues at the contact regions between any two elements; stress is induced when a load is applied to two elastic solids in contact. If not considered and addressed adequately serious flaws can occur within the mechanical design and the end product may fail to qualify. Stresses formed by the contact of two radii can cause extremely high stresses, the application and evaluation of Hertzian contact stress equations can estimate maximum stresses produced and ways to mitigate can be sought. Hertz developed a theory to calculate the contact area and pressure between the two surfaces and predict the resulting compression and stress induced in the objects. The roller bearing assembly is an example was the assembly undergoes fatigue failure due to contact stresses. This paper discusses the hertz contact theory validation using structural stress Analysis.

Keywords— Hertz Contact stress, contact stress analysis, Stresses within rollers, Roller contact analysis and Hertz contact stress calculations, ansys, catia.

1. INTRODUCTION

Bearings are machine elements that allow components to move with respect to each other. Bearings are used to support large skyscrapers to allow them to move during earthquakes, and bearings enable the finest of watches to tick away happily. Without bearings, everything would grind to a halt, including people, whose joints are comprised of sliding contact bearings! There are two types of bearings, contact and noncontact. Contact-type bearings have mechanical contact between elements, and they include sliding, rolling, and flexural bearings. Mechanical contact means that stiffness normal to the direction of motion can be very high, but wear or fatigue can limit their life.Non-contact bearings include externally pressurized and hydrodynamic fluid-film (liquid, air, mixed phase) and magnetic bearings. The lack of mechanical contact means that static friction can be eliminated, although viscous drag occurs when fluids are present; however, life can be virtually infinite if the external power units required to operate them do not fail. Ball bearings are commonly used machine elements. They are employed to permit rotary motions of, or about, shafts in simple commercial devices and also used in complex engineering mechanisms. Deep groove ball bearings are the most widely used bearings in industry and their market share is about 80% of industrial rolling element bearings. A deep groove ball bearing can support a thrust load of about 70% of its radial load.

1.1 Water pump bearings

Water pump bearings are double row bearings and, in contrast to conventional double row bearings, do not have an inner ring but raceways machined directly into the surface of the shaft. As a result, there is more space available for the rolling elements, giving a higher specific load carrying capacity than that of solutions with conventional single bearings. Furthermore, it is possible in this type of bearing to achieve economical combinations of ball and roller rows. In a small design envelope, this gives a broad range of load carrying capacities. The use of a common outer ring for two rows of rolling elements prevents misalignment defects, eliminating the risk of undesirable distortion of the bearings. In water pump bearings, the ends of the shaft normally extend beyond the outer ring on both sides

Application

Water pump bearings are mainly used in coolant pumps for road vehicles. Due to their versatile design, the ready-to-fit units are suitable for many other applications.

They can be used, for example, in:

■ fans

■ idler pulleys

■ vane pumps

■ angle grinders

HERTZIAN THEORY

Contact mechanics is the study of the deformation of solids that touch each other at one or more points. The physical and mathematical formulation of the subject is built upon the mechanics of materials and continuum mechanics and focuses on computations involving elastic, viscoelastic, and plastic bodies in static or dynamic contact. Central aspects in contact mechanics are the pressures and adhesion acting perpendicular to the contacting bodies' surfaces (known as the normal direction) and the frictional stresses acting tangentially between the surfaces. This page focuses mainly on the normal direction, i.e. on frictionless contact mechanics. Frictional contact mechanics is discussed separately.

Chapter-2

DESIGN AND MODELLING OF ENVIRONMENT TEST CHAMBER

CATIA offers a solution to shape design, styling, surfacing workflow and visualization to create, modify, and validate complex innovative shapes from industrial design to Class-A surfacing with the ICEM surfacing technologies. CATIA supports multiple stages of product design whether started from scratch or from 2D

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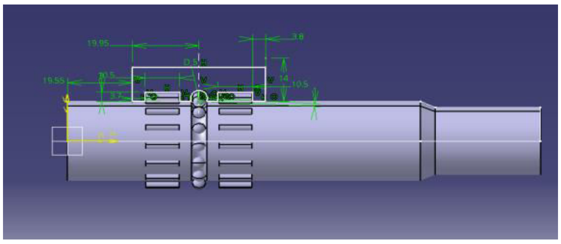
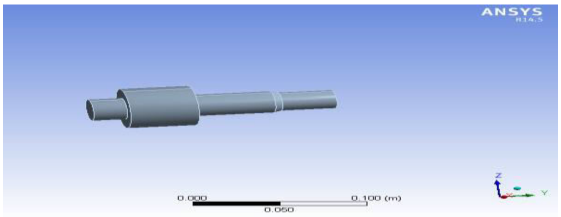
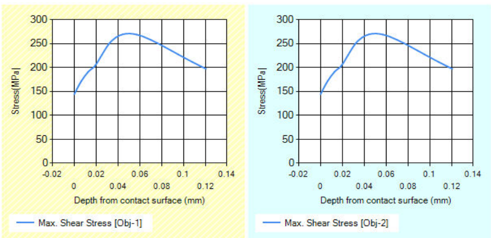
sketches. CATIA is able to read and produce STEP format files for reverse engineering and surface reuse





RESULTS				
Parameter	Symbol	Object-1	Object-2	Unit
Maximum Hertzian contact pressure	p_{max}	902		MPa
Max shear stress	τ_{max}	270.8	270.8	
Depth of max shear stress	z	0.05	0.05	mm
Rectangular contact area width	2b	0.127		

Note: Use dot "." as decimal separator.

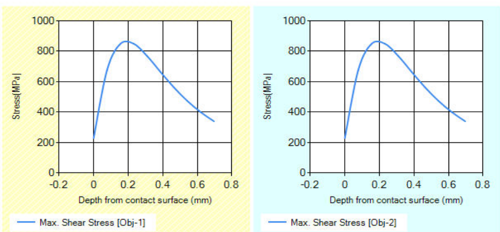


Object-1 Object-2

Spiracle:

RESULTS				
Parameter	Symbol	Object-1	Object-2	Unit
Maximum Hertzian contact pressure	p_{max}	2873.7		MPa
Max shear stress	τ_{max}	864.7	864.7	
Depth of max shear stress	z	0.191	0.191	mm
Circular contact area diameter	2a	0.773		

Note: Use dot "." as decimal separator.

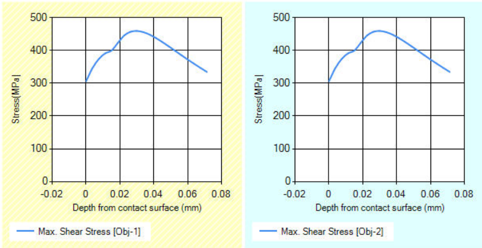


Object-1 Object-2

Alsi alloy 6500:

RESULTS				
Parameter	Symbol	Object-1	Object-2	Unit
Maximum Hertzian contact pressure	p_{max}	1529.2		MPa
Max shear stress	τ_{max}	459.2	459.2	
Depth of max shear stress	z	0.029	0.029	mm
Rectangular contact area width	2b	0.075		

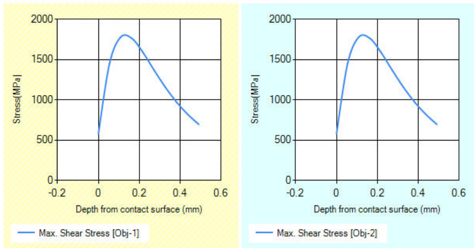
Note: Use dot "." as decimal separator.



Object-1 Object-2

RESULTS				
Parameter	Symbol	Object-1	Object-2	Unit
Maximum Hertzian contact pressure	p_{max}	5809.8		MPa
Max shear stress	τ_{max}	1801.1	1801.1	
Depth of max shear stress	z	0.131	0.131	mm
Circular contact area diameter	2a	0.544		

Note: Use dot "." as decimal separator.



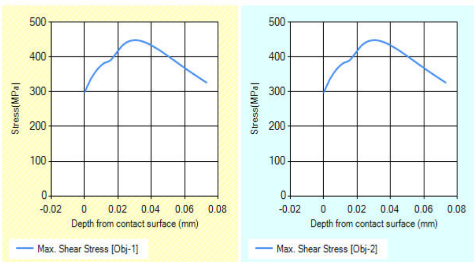
Object-1 Object-2

52100 Chrome Steel:

Cylindrical

RESULTS				
Parameter	Symbol	Object-1	Object-2	Unit
Maximum Hertzian contact pressure	p_{max}	1492.4		MPa
Max shear stress	τ_{max}	448.1	448.1	
Depth of max shear stress	z	0.03	0.03	mm
Rectangular contact area width	2b	0.077		

Note: Use dot "." as decimal separator.



Object-1 Object-2

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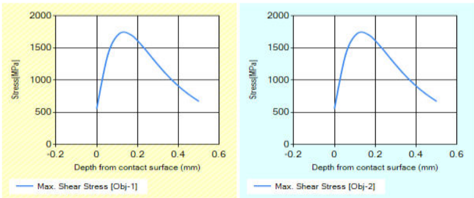
Spirical

Parameter	Symbol	Object-1	Object-2	Unit
Maximum Hertzian contact pressure	p_{max}	5623.8		MPa
Max shear stress	τ_{max}	1743.5	1743.5	
Depth of max shear stress	z	0.133	0.133	mm
Circular contact area diameter	2a	0.553		

Note: Use dot "." as decimal separator.

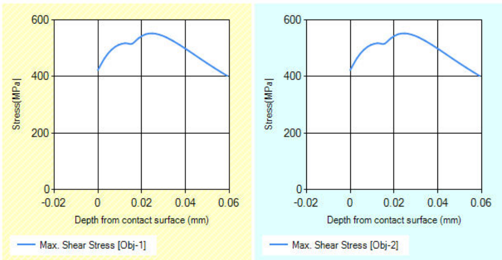


Object-1 Object-2

Silicon nitride:

Parameter	Symbol	Object-1	Object-2	Unit
Maximum Hertzian contact pressure	p_{max}	1840.8		MPa
Max shear stress	τ_{max}	552.8	552.8	
Depth of max shear stress	z	0.024	0.024	mm
Rectangular contact area width	2b	0.062		

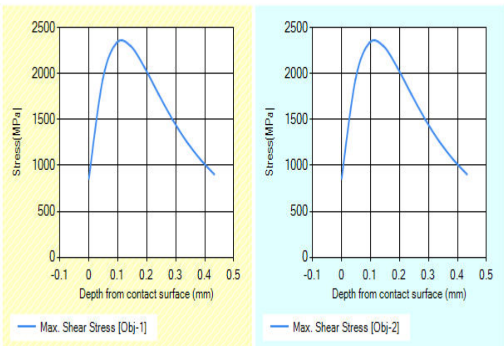
Note: Use dot "." as decimal separator.



Object-1 Object-2

Parameter	Symbol	Object-1	Object-2	Unit
Maximum Hertzian contact pressure	p_{max}	7439.3		MPa
Max shear stress	τ_{max}	2358.1	2358.1	
Depth of max shear stress	z	0.113	0.113	mm
Circular contact area diameter	2a	0.481		

Note: Use dot "." as decimal separator.



Object-1 Object-2

Chapter-4

ANALYSIS OF TEST CHAMBER

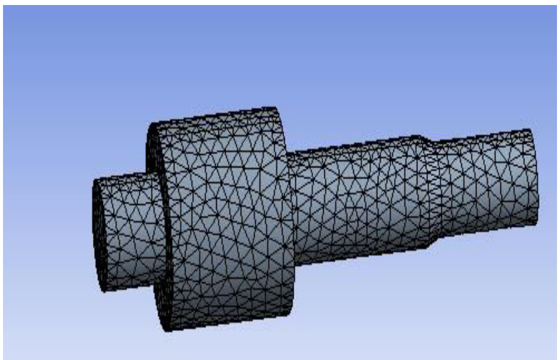
ANSYS is general-purpose finite element analysis software, which enables engineers to perform the following tasks:

- Build computer models or transfer CAD model of structures, products, components or systems
- Apply operating loads or other design performance conditions.
- Study the physical responses such as stress levels, temperatures distributions or the impact of electromagnetic fields.
- Optimize a design early in the development process to reduce production costs.
- A typical ANSYS analysis has three distinct steps.
- Pre Processor (Build the Model).

ANALYSIS OF RESULTS:

In this chapter, the results obtained for the analysis of enivarmental chamber system for the original profile and dynamic structural analysis are discussed. And also explained the graphs plotted by comparing those results.

Mesh:



Aluminium Alloy:

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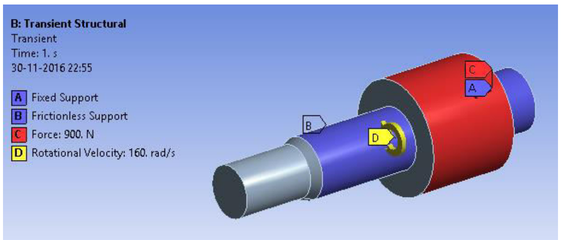
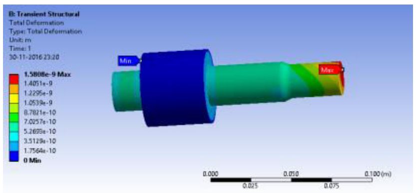
Transient dynamic analysis

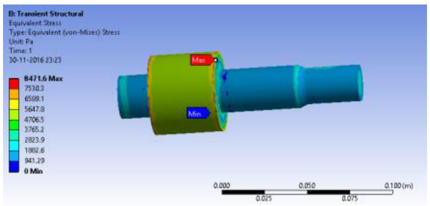


Solution:

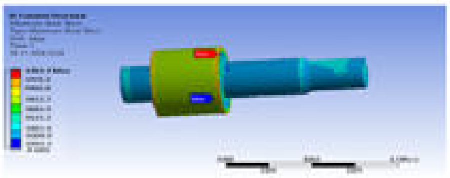
Total deformation



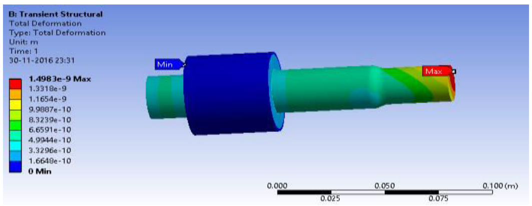
Equivalent stress

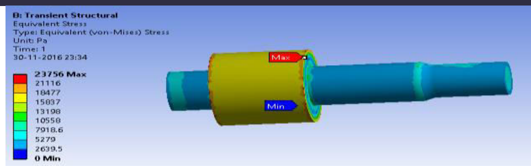


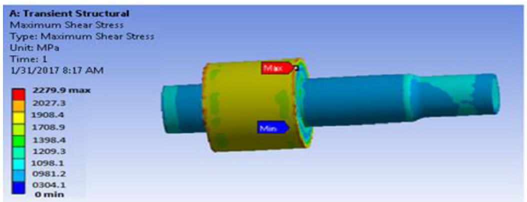
Shear stress



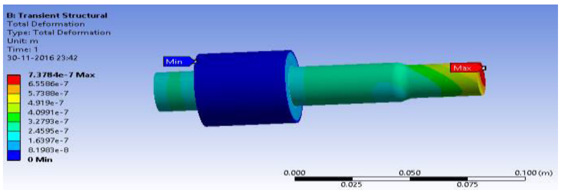
52100 chrome steel

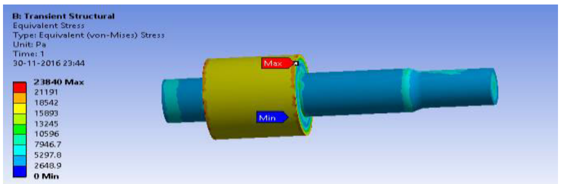


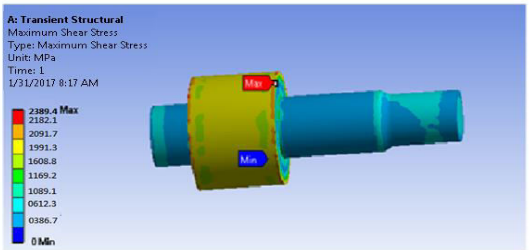




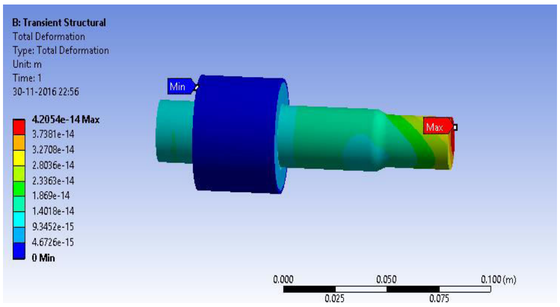
Aisi4140 alloy steel







Silicon nitride



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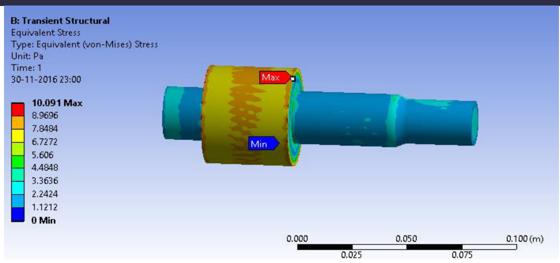

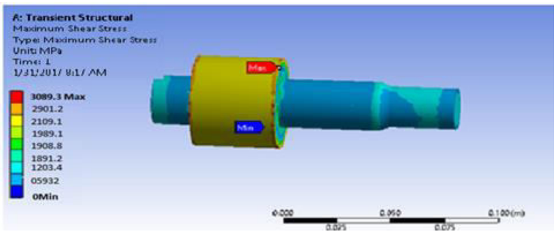

Result comparison between the theoretical and ansys software values:

Material name	Hertzen contact theory values Maximum Shear Stress	Anasys software values Maximum Shear Stress
Aluminum alloy	1135.5mpa	1263.7 MPa
Aisi4140 alloy steel	2260.3mpa	2389.4 MPa
52100 chrome steel	2191.6mpa	2279.9 MPa
Silicon nitride	2910.9mpa	3089.3 MPa

CONCLUSION

The comparison of manual analytical result, result obtained by Hertz stress calculator software and dynamic analysis results shows the dynamic analysis results are acceptable. As the difference in result is within 10% this difference is due to the approximation, In case of contact patch width finite analysis result shown in graph was plotted by selecting nodes at contact region the element size and node selection for plotting graph was the main criteria for result and the contact patch width is arrived manually from graph therefore this difference is acceptable. The value of contact stress is very important, as the stress value changes with contact area. The higher the contact area the stress generated will be less and for lesser contact area high stress will be generated. In various engineering applications line contact exists between bearing rollers, the contact stress are more critical and only point contact exists between ball bearing, ball screw etc finding the contact stresses are further critical therefore in order to capture accurate results proper care to be taken while meshing and assigning contacts depending on complexity of problem. The contact stress between rollers is important in order to ensure the stress generated is within elastic limits, this also helps predict accurately the fatigue life by plotting the value of stress in S-N curve (stress vs number of cycles) of the material. Based on required fatigue life the stress values can be optimized by modifying permissible load carrying capacity or by changing roller dimensions. The comparison of various results is shown below.From above analysis result obtained from ansys software so observing that result conclude the

1.Silicon nitride is low total deformation value is obtained means silicon nitride is better deformation withstand value comparing with other taken materials 2.Aisi4140 alloy steel is more von moiesses stress effects withstand value comparing with other and existed aluminum alloy material.

3.Aisi4140 alloy steel material is better stress withstand values comparing with other materials.So silicon nitride and Aisi4140 alloy steel materials are the better suitable materials for water pump integral shaft bearing system comparing other materials

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