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Design and Analysis of an Integral Shaft Bearing

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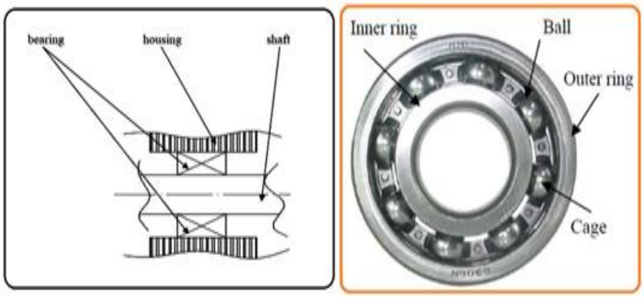
Abstract

An 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. If the heat produced cannot be adequately removed from the bearing, the temperature might exceed a certain limit, and as a result the bearing would fail. To analyze the heat flow, temperature distribution and stresses in a bearing system, a typical integral shaft bearing and its environment has been modeled and analyzed using the famous finite element tool ANSYS. In this study we investigate structural and thermal characteristics performance of integral shaft bearing to Analyze temperature distribution and thermal elongation due to friction also its effect on bearing clearances and vice-versa.

1-INTRODUCTION

The term "rolling bearing" includes all forms of roller and ball bearing which permit rotary motion of a shaft. Normally a whole unit of bearing is sold in the market, which includes inner ring, outer ring, rolling element (balls or rollers) and the cage which separates the rolling element from each other.



Rolling bearings are high precision, low cost but commonly used in all kinds of rotary machine. It takes long time for the human being to develop the bearing from the initial idea to the modern rolling bearing. The reason why bearing is used is that first it can transfer moment or force. Secondly and may be more important is that it can be interchanged easily and conveniently when it's broken. In the mechanical system shown in Figure-1, it is also possible to amount the shaft directly with housing. However, when this mechanism has some problem, the only possibility to recover the function of this system is to replace the housing or the shaft. From the mechanical engineer point of view, both of the mare not only very expensive but also time consuming to manufacture a new housing or shaft with the same parameters.

However when the bearings are used between them, the situation will be different. Normally there is no relative motion between shaft and inner ring or the outer ring with housing. So it has less possibility for

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the shaft or housing to be worn out. Usually the bearing first cracks and then the shaft or housing is broken. If the above situation happens it is really easy to figure it out: just buy a new bearing from the market with the same parameter and replace it. That's why bearings are so often used.

2-OBJECTIVEOFRESEARCH

The objective of theResearchProjectisto:
ToDesignofIntegralShaftBearingforWaterPump
Modeling & Assemblyofbearing componentsfrom2Ddrawingto3Dmodel.
Stress analysis andtemperaturedistributionforIntegralShaftBearing
ThermalelongationofcomponentsinIntegralShaftBearingatdifferenttemperature&itseffect onbearing clearances.

3-NEEDOFPROJECT

Theintegralshaftsealsprotectthebearingassemblyfrom bearingexposedtocoolantandabrasive contaminants.Ifprobable sealfailureisnotdetectedandbearingpresentinpumpisnotreplacedwill causesuddenfailure andpossiblyleadstocrisissuchassnappedbearingshaft.Sealleakageand bearingfailurecanoccursdue toexcessive thermal stressesbecauseofhightemperatureoperationof engine,vibrationdue tohighoperationalspeedetc.sodeterminationof bearingfailure shouldbe detected atdesignstageonly beforemanufacturing to reduceextracostand timetomarket. Optimizationofclearancebetweenrolling element andoutersleeve.

4-FEAANALYSISANDRESULTS

4-1-StressAnalysis

Finiteelementmethod(FEM)isanumericalmethod forsolvingadifferentialorintegral Equation.It hasbeenappliedtoanumberof physicalproblems,where thegoverningdifferentialequationsare available.Themethodessentiallyconsistsof assuming thepiecewise continuousfunctionforthe solutionandobtainingtheparametersofthefunctionsinamannerthatreducestheerrorinthe solution.Herewehave tofinemaximumstressesineachcomponentofbearing,and tosafe designof components materialMaximum Stress shouldbeless thanAllowablestress. Designallowable, Allowable stressσall=Yield StrengthorUltimate Strength* FactorofSafety,AssumeFactorof Safetyis1,AllowablestressesofMaterialsusedinassembly iscalculatedin followingtable

Table1-Material AllowableStress

Material	Components	Modulus Of Elasticity(GPa)	Yieldstrength MPa	Ultimate StrengthMPa	
SAE52100	Shaft,Balls, Rollers,Sleeve	210	260	460	460
Nylon66	Ball&RollerCage	36	80	NA	80
Aluminium Alloy	Housing	71	280	310	310

4.2. GeometricModel

IntegralShaftBearingproductdetails asshowninTable 4.2asperindustrialrequirements.Figure 4.2 showsthecomplete AssemblyofIntegralShaftbearing.

Table2.Integral Shaft BearingCharacteristic

Bearing	IntegralShaftBearing
Typeofrolling Element	Roller/Ball
No.ofRolling element	15
ComponentsDetailsforAssembly	Shaft,BallCage, Balls,RollerCage,Rollers,Sleeve
SleeveDiameter	30mm
ShaftDiameter	15.918mm

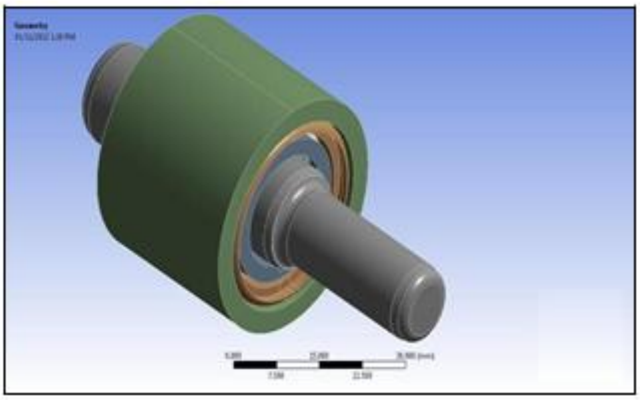

Fig3.Integral Shaft Bearing

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4-3-MeshGeneration

In thisanalysismeshgenerationisautomeshgenerationwithelementsizeis20.Thiselementsizeis usedforallthe bodyofIntegralShaftBearing.Hex-dominantmethodisusedforallthe partsof IntegralShaftBearing.

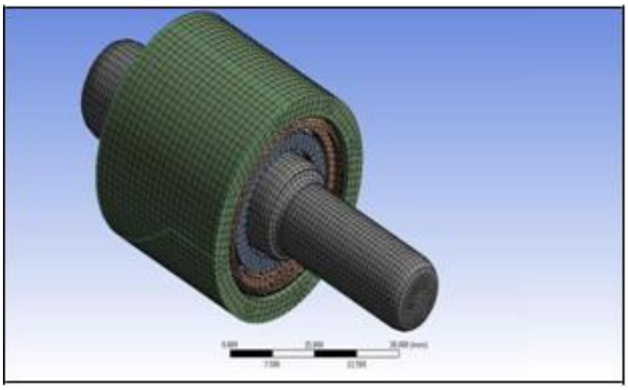

Fig4.Mesh Generation ofWholeAssembly

4-4-Loadingand BoundaryConditions

Loadingandboundaryconditionsbasicallyconsistoftwosteps firstissupport andsecondis applying loads.FollowingFigureShowstheSupports andForces

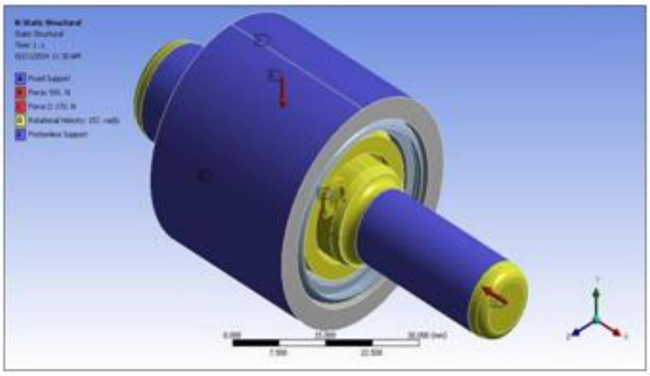

Fig5.LoadingandBoundaryConditions

Table3.Loadingandboundary conditions

speed (rpm)	Hub load (N)	% Use	Water Pump Temperature	Fit Conditions	Housing diameter	Sleeve OD	Radial clearance (Roller)	Radial clearance (Ball)
					Max. Interference		Minimumclearance	
1500	591	19.7	-30°C	Max. Interference condition	29.92	30	0.02	0.02

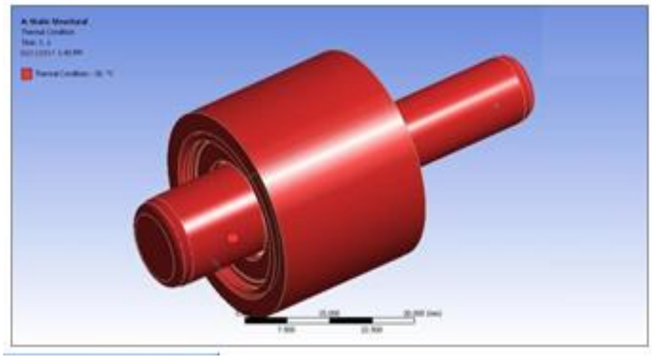

Fig6.Thermal Conditions

Afterrunningthe solutionofabovemodelwegetdifferentvaluesofsolutions suchas,Maximum principle stress, Equivalent Stress, Total deformation and equivalent strain. All theresults are describedbelow.

EquivalentStress:399.08Mpa(max)

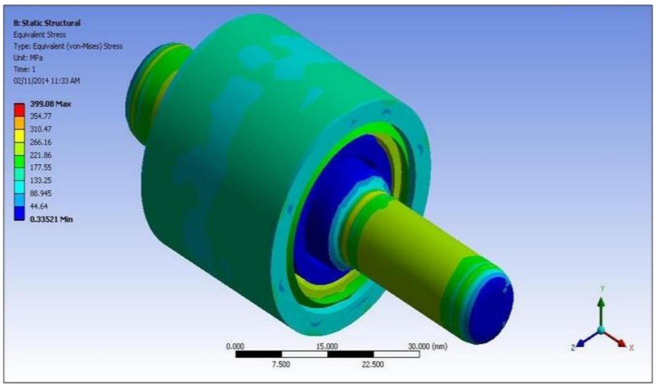

Fig7.EquivalentStress Plot

EquivalentStressforhousing:MaxStress252.25<310Mpa(Allowablestress)

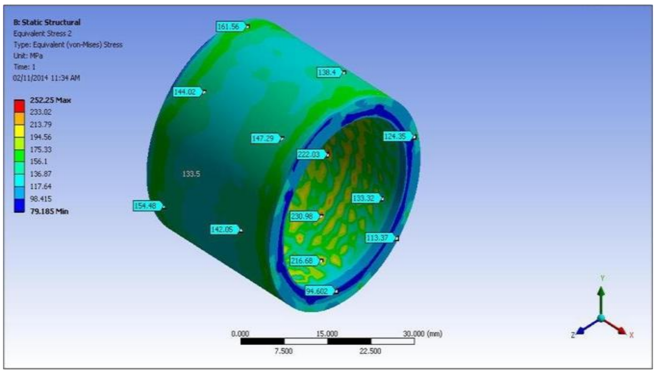

Fig8.EquivalentStressforhousing

Total Deformationsforhousing: 0.001194mm(Max)

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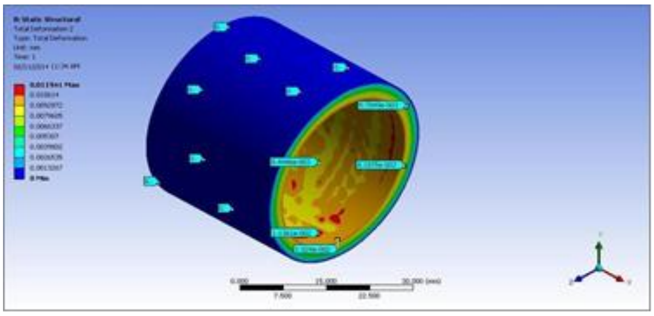

Fig9.TotalDeformation forhousin

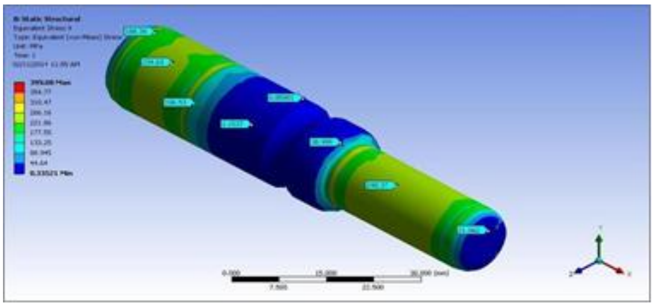

Fig10.EquivalentStressesforShaft

Directional Deformations for Shaft (Y-axis): Max. Deformation 0.00335mm

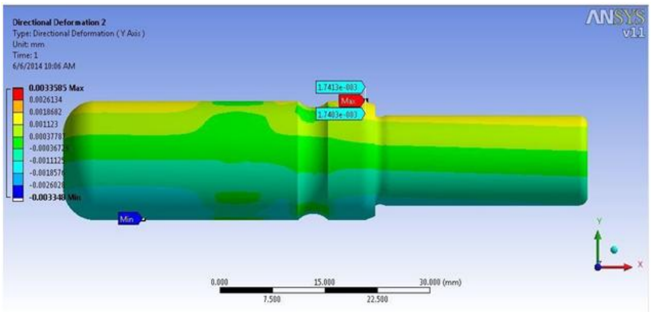

Fig11.DeformationsforShaft (Y-Direction)

EquivalentStressforRollers:MaxStress47.757<460Mpa (Allowablestress)

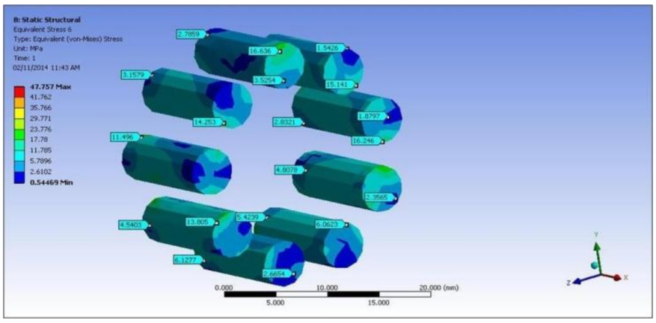

Fig12.EquivalentStressesforRollers

Directional Deformations for Rollers (Y-axis): Max. Deformation 0.003086mm

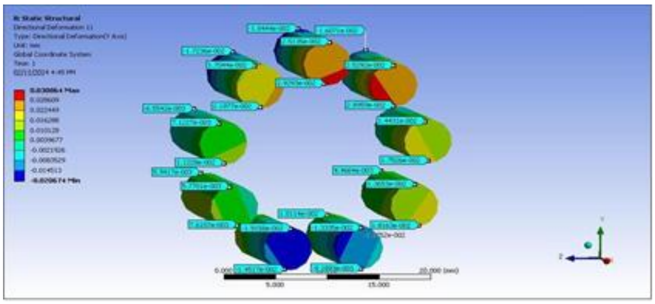

Fig13.DeformationPlot forRollers(Y-Direction)

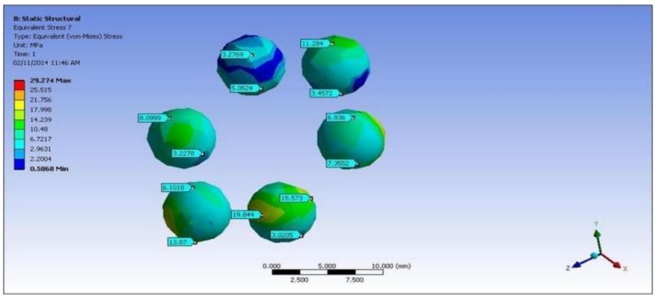

Fig14.EquivalentStressesforBall

DirectionalDeformationsforBall(Y-axis): Max. Deformation0.00939mm

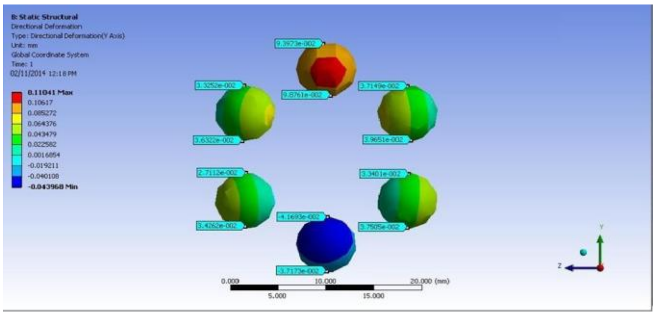

Fig15.DirectionalDeformationsforBalls(Y-axis)

EquivalentStressforSleeve: MaxStress329<460Mpa(Allowablestress)

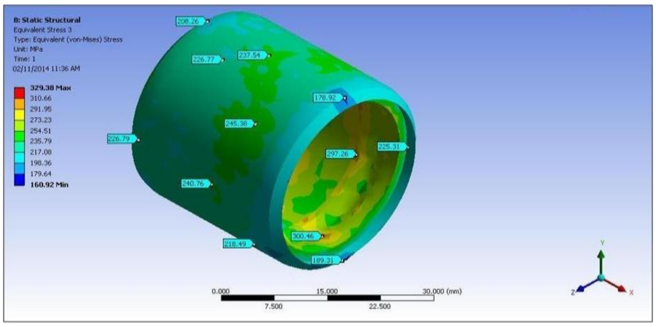

Fig16.EquivalentStressesforSleeve

EquivalentStresses atinnerareaofsleeve

5-ANALYTICALCALCULATIONS

5-1-Life ofBearings

Thelife of thebearingdecreaseswithanincreaseinthe load.

$$\frac{L_d}{L_c} = \left(\frac{C_d}{P_d}\right)^k$$

k=3forballbearings
=10/3forrollerbearings
Lc =lifefromthetable(manufacturerscatalog)
Cd=dynamic rating frommanufacturer
Pd=designload

The equationscanberewrittenasdependinguponthe variabletobecalculated.

$$C_d = P_d\left(\frac{L_d}{L_c}\right)^{1/k} \quad L_d = L_c\left(\frac{C_d}{P_d}\right)^k$$

5-2-EquivalentCombined Radial load

Forcombinedradialandthrustloads
P=equivalent radialload
R=actualradialload
Ft=actualthrustload
X= radialfactor(usually0.56) V=1.0 forinnerracerotating
=1.2 forouterracerotating

GivenData:
P=VXR+Y Ft
Dynamic Rating fromManufacturer:12800N
RadialLoadFr=591N
AxialLoadFa=170N
RadialFactor=0.56

Therefor,equivalent radialload,P =0.56*1.2*591+2*170
P =737.152N
5-4-BearingLife inHoursL10h
L10=

$$\left(\frac{C}{P}\right)^3$$

L10=5235.50millionrev

6-DISCUSSIONANDCOMPARISONOFRESULTS

Nowwehavetocomparetheresultsof Geometryafterdeformation.Forthecomparisonpurposewe havecalculatedstresses,deformation,andmostimportantlife of Bearing.

6-1-BearingClearancesEffects

Clearance betweenrollingelementlike rollers/ballsandsleeveismostcritical areaofIntegralShaft bearing.Frictionoccursbetweenrollingelementandsleeve there ischancesoffailureof bearing.Asper bearingdesignclearance is0.02mmwe havetocomparethis clearanceafterthermalexpansionof bearingcomponents.

Table4.DimensionsComparisonafterdeformationat Ball Side

Components	Diameter	Deformation	Diameterafterdeformation
Shaft	14.212	0.003086	14.21508
Balls	6.34	0.00939	6.34939
Sleev	26.924	0.00315	26.9271

Clearancebetweenballandsleeve afterdeformation:26.92715-[14.215086+ (6.34939*2)]
Clearance=0.013284mm<0.02mm

6.1.2.AtRollerSideClearance inY (Alldimensionsareinmm)

Before andafterthermalexpansioneffectondimensionsinY-DirectionofShaft,Rollersand Sleeve giveninTable5

Table5.DimensionsComparisonafterdeformationat RollerSide

Components	Diameter	Deformation	Diameterafterdeformation
Shaft	15.905	0.003086	15.9067
Rollers	4.763	0.003086	4.76608
Sleev	25.455	0.00315	25.4516

Clearancebetweenrollerandsleeveafterdeformation:25.45165-[15.9067+ (4.766086*2)]
Clearance=0.012778mm<0.02mm

Table5.1DimensionsComparisonafterdeformationat RollerSide

Components	Diameter	Deformation	Diameterafterdeformation
Shaft	15.905	0.003086	15.9067
Rollers	4.763	0.003086	4.76608
Sleev	25.455	0.00315	25.4516

Table5.2 DimensionsComparisonafterdeformationatRollerSide

Components	Diameter	Deformation	Diameterafterdeformation
Shaft	15.905	0.003086	15.9067
Rollers	4.763	0.003086	4.76608
Sleev	25.455	0.00315	25.4516

7-CONCLUSIONS

It is observed that Equivalent (Von-Mises) Stress Maximumat Shaft which is 189.1 Mpaand allowablestressofShaftmaterialis208MPa,alsoAfterDeformationBearingClearances areinlimit, fromthisweconcludethatdesignissafe.

CoupledanalysisofThermalandStructuralbothareequallyimportanttoanalyzetheStressand DeformationofIntegral ShaftBearing.

Byusingthe AnalyticalMethodBearingLife is58172.302hr, whichis alsosatisfiesthedesign.

FEManalysisisveryefficientmethodforachievingstressesatdifferentloadingconditionaccording toForces&temperatureappliedtothecomponentfrom thestaticanalysis.Theuseofnumerical methodsuchasFinite ElementMethodnowadaycommonlyusedtogivesdetailinformationabout structureorcomponent.

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