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Design and Development of Reliable Integral Shaft Bearing for Water Pump in Automotive Engine to Reduce Assemble Time and Increase Production

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Abstract

Background/Objectives: The prime objective of this work is modifying of water pump which is used for cooling the engine in automotives. **Methods/Statistical Analysis:** In the existing pump ball, bearing is used in which the assembly and maintenance is difficult. In order to overcome these problems integral bearing is proposed. So it is planned to modify the existing pump to accommodate integral bearing with the purpose of reduce the assembly time and increase production. **Findings:** The proposed integral shaft bearing has compact in size which is developed by eminence material and have one or two rows contains with balls as well as one row of roller. It has high reliability through a newly developed water resistant seal. This reliable bearing is three time better durability when comparing with existing ball bearing. It has high load durability, high resistant to heat load and water. **Application/Improvements:** The bearing with integral shaft has no inner rings, while having the raceway groove directly on the shaft.

Keywords: Automotive Engine, Cooling System, Integral Bearing, Productivity, Water Pump

1. Introduction

Bearings are now a day's extensively utilizing for use in house hold and engineering relevance. It reduces the friction between surface contacts of bodies to another relative concern in the rolling function aspect. It has admired for superior specific load moving ability, avoiding imperfection and reducing risk of unwanted deformation.

The structural as well as thermal personality in the function of integral shaft bearing is to examine high temperature sharing as well as thermal elongation by reason of friction[1]. The bearing structure has obtained steady state at high rotational speed but it didn't attain a critical temperature in any of the verified rotating speeds[2]. The modeling and Analyzing work have experienced with the aid of ANSIS software by means of finite element analysis. The bearing with shaft defects causes high damage in running conditions of the bearings[3]. The modeling and analyzing of integral bearing with considering the different parameters is essential to obtain the natural condition in the view of avoiding premature failure takes place[4].

The frictional mean effective pressure of the bearings depended with the speed and heavy weight at the points of the function. This phenomenon causes minimizing the viscosity of the lubricant as well as corresponding frictional victims[5]. In the sensible working environmental situation including extremely heavy dynamic load the bearing frictional power losses could be calculated with highly accurate[6]. Eccentric Shaft is widely appreciated for its features like corrosion resistant, long service, effective performance and reliability[7]. The shaft failed due to fatigue, which arises due to reasons in presence of cyclic over-loads, stress concentration and they may be due to production or operation causes[8]. Wavelet decomposition method classifies the bearing faults in an accurate manner and that, it classifies ball defect better than the frequency

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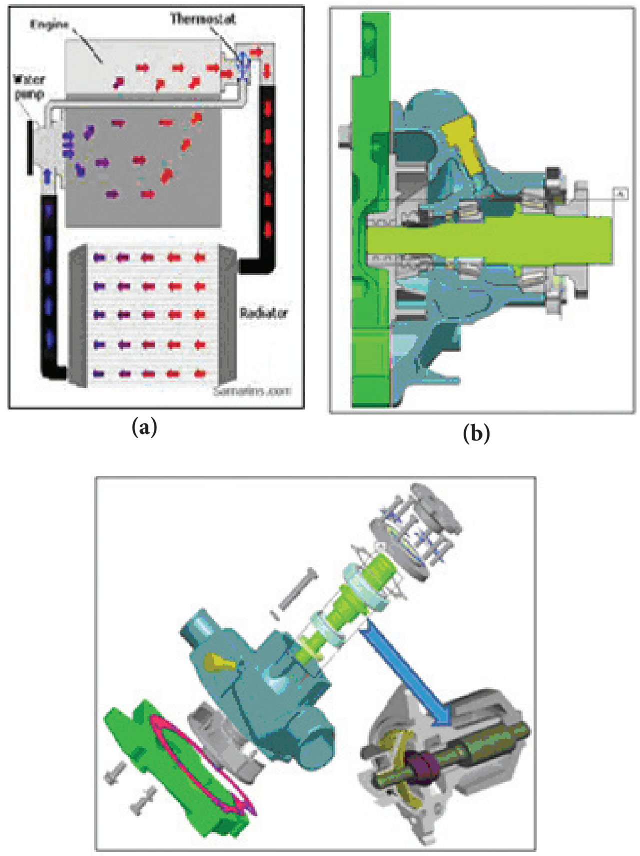
domain and time domain techniques considered individually[9]. The equivalent torque is at location near the gear because the induced shear stress will be a maximum at that section. Now the induced shear stress is equated to allowable shear stress and the minimum diameter calculated. The A.S.M.E. code defines the permissible or design shear stress[10]. The machined job through designed jig has high accuracy, surface finish, reduced cost of manufacturing, increasing company's productivity rate and quality[11]. The heavy coupling happens on radial track whereas the low coupling takes place axial as well as tilting track at the axis of rotation[12].

In our research work deals with modifying the existing pump to accommodate integral bearing with the purpose of reduce the assembly time and increase production. The proposed integral shaft bearing has compact in size which is developed by eminence material and have one or two rows contains with balls as well as one row of roller. It has high reliability through a newly developed water resistant seal.

2. Water Pump in Cooling System

Water pump is very much essential for circulating the coolant present in the system to entire engine circumference through water jackets with the desired pressure for dissipating heat. It is driven by crank shaft of the engine using belt which is connected with its pulley. Circuit diagram, cross sectional and exploded views of the water pump in cooling system are shown in Figures 1(a), (b) and (c) respectively.

Kinetic energy is transformed in to pressure energy due to the functions of water pump. Water pump have impeller as rotating pare and volute as stationary part. Impeller generates kinetic energy whereas volute converts it into pressure energy.



(c)

Figure 1. **(a)** Circuit diagram. **(b)** Cross sectional. **(c)** Exploded views of the existing water pump in cooling system.

2.1 Major Components of Water Pump

The major components of water pumps are shown in Figure 2. Figures 3(a), (b), (c) and (d) shows the different types of bearings such as ball, taper roller, angular contact and mechanical seal.

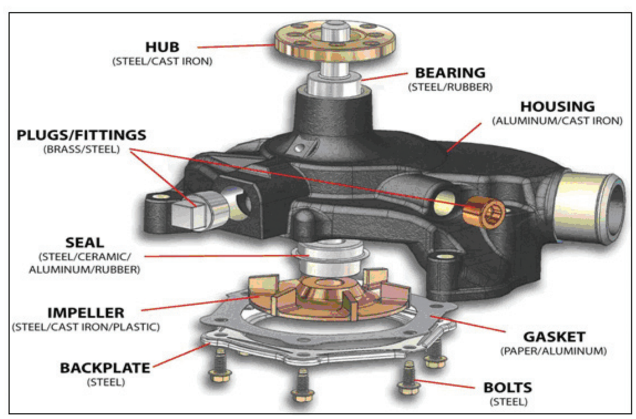


Figure 2. Major components of water pump.

2.1.1 Ball Bearing

A balls presents in between the two racers of bearing pass on weight. Also it decreases the friction, radial as well as axial weight.

2.1.2 Taper Roller Bearing

Taper roller bearing has inner ring called as cone as well as outer ring called as cup its cover rollers in the part of cage with providing required clearance.

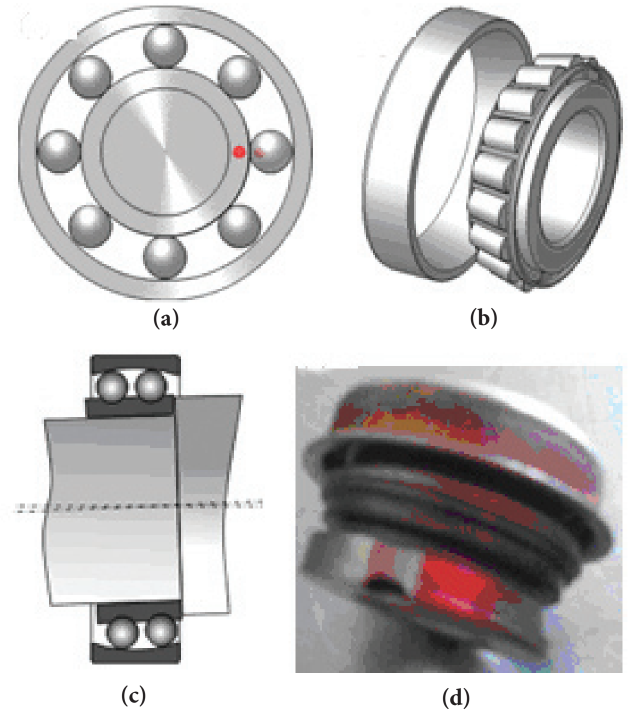


Figure 3. Images of. **(a)** Ball. **(b)** Taper roller. **(c)** Angular contact bearings. **(d)** Mechanical seal in water pump.

2.1.3 Angular Contact Bearing

Non-symmetrical racers form angular contact in ball bearings. In this bearing angle of contact between the inner and outer racers are same to facilitate the load carrying capacity through at an angle of path way to split load on racers axially.

2.1.4 Mechanical Seal

Mechanical seal is an appliance which prevents escaping of liquid or gases under pressure of the system as well as mechanism. The various parts of mechanical seal are stationary ring, rotary ring, secondary seal, spring and punched parts.

Figure 4 (a), (b) and (c) shows images of mechanical gasket, circlips and impeller are shown in respectively.

2.1.5 Mechanical Gasket

Mechanical gaskets are getting profile like torus. It seated in between two parts and acts as a sealing to it cross section.

2.1.6 Circlips

Circlips are in the form of circular clips which seated it grooved place to prevent the releasing of pins or shafts during functioning from its position.

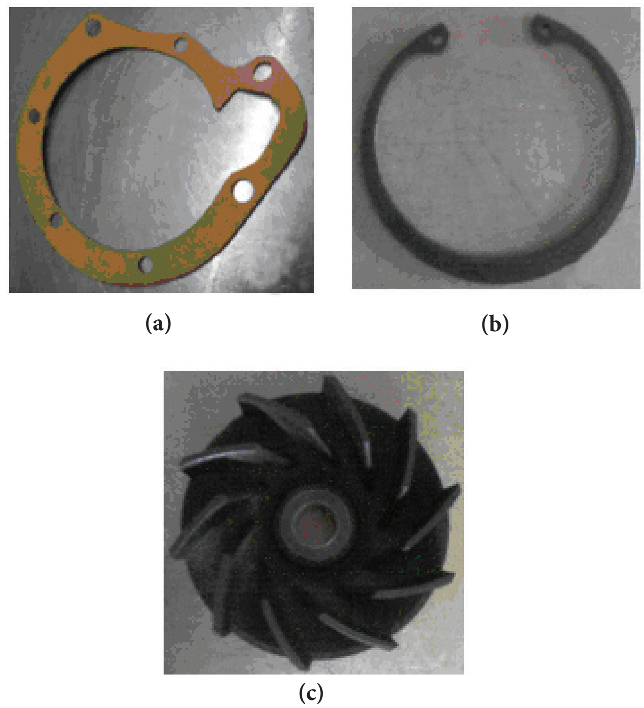


Figure 4. Images of. **(a)** Mechanical gasket. **(b)** Circlips. **(c)** Impeller in water pump.

2.1.7 Impeller

Impeller increases pressure energy for flowing coolant in the entire area of the cooling system. It takes drive from the engine by shaft attached it and it accommodated in the water pump casing.

Figures 5 (a), (b) and (c) shows images of pulley, oil seal and spacer in water pump are shown in

2.1.8 Pulley

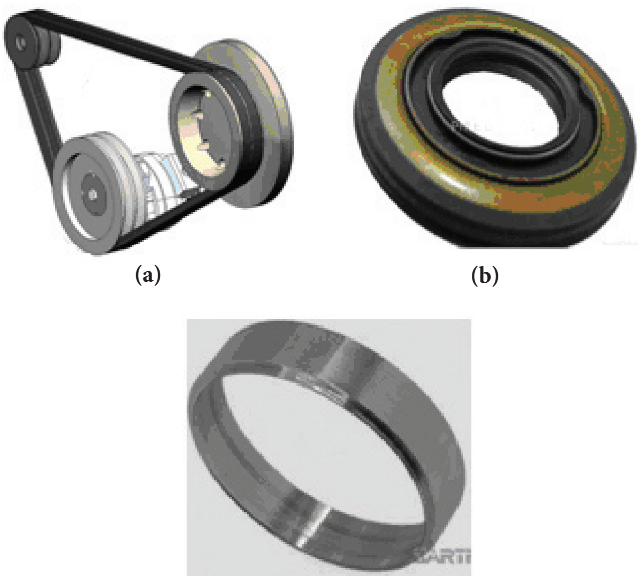
Pulley is a cooling system rotating power transmission member which is fitted at the end of the water pump shaft by means of key with slot. It is connected with engine crankshaft using v-belt.

2.1.9 Oil Seal

Oil seal covering the gap in between the water pump drive shaft and body of the pump to prevent the coolant leakages.

2.1.10 Spacer

Spacer is a component which is used to increase the space between two bearings. It is made up of stainless steel.



(a) (b)

(c)

Figure 5. Images of. **(a)** Pulley. **(b)** Oil seal. **(c)** Spacer in water pump.

3 Problem Statements in Existing Water Pump and Solution

3.1 Problem Statement in Existing Water Pump

Presence of many child parts makes the assembly complicated in ball bearing. Refilling of grease at regular intervals is necessary. As there is a problem of leakage, the life of bearing gets affected.

In the existing water pump, ball bearing is used. In general ball bearing can withstand radial load but in our case axial loads are negligible. The child parts ball bearings are inner race, outer race, spacer, circlips, distancer, oil seal and mechanical seal. Normally in water pump, grease cup are used to refill grease to lubricate the bearing. Number of child parts in taper roller bearing is more than the integral shaft bearings that were the cost of ball bearing is high. Assembly of existing water pump is tedious process.

3.2 Solutions to Overcome the Problems in Existing Water Pump

Our research work is proposed to integral shaft bearing to under solve that are problems. The integral shaft bearing is easily assemble to the cover of the body reduce the child parts water pump to weight also reduce it. Reduce machining time of the sitting place of the bearing part. When the machining time reduce to increase the production. The ball sitting groove has to directly load act on the shaft and ball so the inner race can't be damage so life of the pump is increase.

4. Proposed Integral Bearing and its Features

The bearing with integral shaft has no inner rings while having the raceway groove directly on the shaft. It gives high durability for powerful engines. It has high reliability through a newly developed water resistant seal. It allows sufficient lubrication. These reliable bearing has great stability three times better than tapper roller bearing. It also possesses high load durability, high resistant to heat load and water. The proposed integral bearing is shown in Figure 6.

The ball of the integral bearing could be designed with important consideration to offer superior angular load capacity for sustaining both fan and reasonable soaring counter balance of belt load.

5. Methodology of Designing

The design parameters and design process are described in this section.

5.1 Design Parameters

In the part of design important phenomenon of heat transfer such as conduction and convection as well as

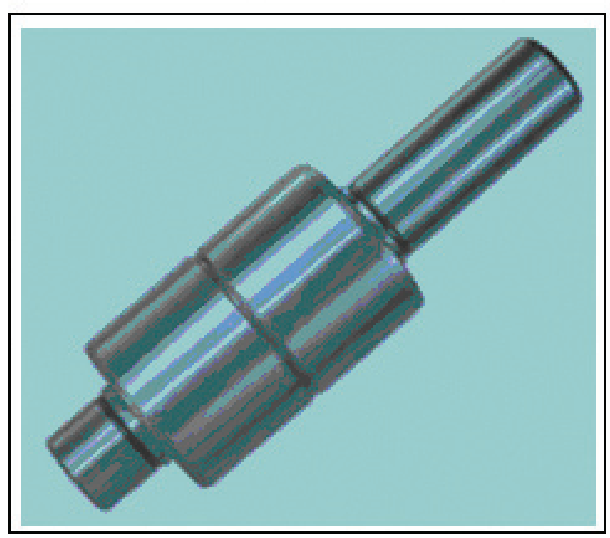


Figure 6. The image of the proposed integral bearing.

radiation and evaporation are considered in this work. Console factors of dry bulb temperature with relative humidity also taken while accounting of design.

5.2 Design Process

Dual perspective design method has been followed this process. Also in focal point of design the energy conservation utilized to get absolute form of the suitable component for automobile select with base material and its life compare with the vehicle. The utilization of design modeling components are auto CAD, 3D solid modeling, in-house prototype facilities, pro/mechanical stress analysis software, integrated design and production engineering.

6. Results and Discussion

In bearing different types of loads acting which are called radial and thrust. In radial loads are act at right angle to the shaft whereas in case of thrust loads be active at parallel to the shaft. Here multiple load calculation for bearing is needed because bearing could influence both type of load in multiple behavior. Japanese Industrial Standards system (JIS) methods are followed in this work while designing mathematical derives. In this method offer world level standard values for bearings as well as extensive diversity of industrial design activities which are necessitate accurate measuring.

Every one of ball bearing standard could be found through JIS B; here B is the classification regarding mechanical engineering, which is the classification the bearing falls.

The Dynamic Equivalent Radial Load Factor is distinct like "the moving directions as well as magnitude of bearings are able to get the similar life balance under the actual load and rotation conditions". Dynamic Equivalent Radial Load Factor (Pr) has been utilized to convert axial loads into radial loads as tabulated in Table 1.

Fundamental dynamic loads evaluation has been establish using JIS B1518 through endurance experiment with 1,000,000 revolutions.

$$Pr = XF_r + YF_a$$

The values of X as well as Y have been taken through Table 1

F_r is the radial load in Newton
F_a is the axial load in Newton

The values for X and Y that are not in the above Table 1 shall be calculated by linear Interpolation. Speed as 2530 rpm ~3000 rpm; Flange and pulley weight is 37.24N; Impellor weight is 9N; Pressure is 0.3bar and Diameter of the impellor is 95mm.

The values taking form line diagram for load acting at pulley Reaction force, R_1 as 1570N; Reaction force, R_2 is 271.6N; Reaction force, R_3 is 363.3N; and Axial load F_{ae} is 212.64N (F = P*A). The bearing ball and roller setting position on integral bearing is shown in Figure 7.

Taking moments at A;

$$RB \times 43.6 = 9 \times 94.8 + 363.3 \times 30.5 + 1570 \times 5 - 37.24 \times 24.2 - 271.6 \times 30 - 60 \times 109$$

$$\mathbf{RB = 96.07N = F_{r2}}$$

Taking moments at B;

$$RA \times 43.6 = 363.3 \times 13.1 + 1570 \times 38.6 + 37.24 \times 67.8 + 271.6 \times 73.6 + 152.6 \times 60 - 9 \times 51.2$$

$$\mathbf{RA = 2214.93N = F_{r1}}$$

Table 1. Dynamic Equivalent Radial Load Factor

Axial Load Ratio		$\frac{F_a}{F_r} \le e$		$\frac{F_a}{F_r} > e$		e
Units		X	Y	X	Y	
N	(kgf)					
$\frac{F_a}{IZDw}$						
0.172	{0.0175}				2.30	0.19
0.345	{0.0352}				1.99	0.22
0.689	{0.0703}				1.71	0.26
1.03	{0.105}				1.55	0.28
1.38	{0.143}	1	0	0.56	1.45	0.30
2.07	{0.211}				1.31	0.34
3.45	{0.352}				1.15	0.38
5.17	{0.527}				1.04	0.42
6.89	{0.703}				1.00	0.44

I: No. of rows, Z: No. of balls, Dw: Ball Diameter (mm)

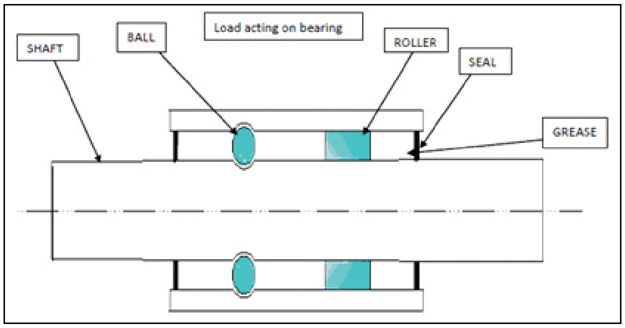


Figure 7. Bearing ball and roller setting position on integral bearing.

Table 2. Values taken by referring NSK bearing book

Bearings		Constant(e)	Load of axial Factor(Y1)	Basic Load Rating(Cr)
I	HR302/32	0.37	1.6	48500
I	HR30204J	0.35	1.7	27900

Load Calculation

$\mathbf{C_r = f_{cm}\ (i\ \cos\alpha\ )^{0.7}\ Z^{2/3}\ D_W^{\ 1.8}}$
$\mathbf{F_{ae} + 0.6 \times F_{r2}/Y_2 < 0.6 \times F_{r1}/Y_1}$

From NSK bearing book

$\mathbf{P_1 = F_{r1}}$
$\mathbf{P_2 = XF_{r2} + Y_2(0.6F_{r1} - F_{ae})}$
$\mathbf{F_{ae} + 0.6(F_{r2}) / Y_2}$
$= 212.64 + 0.6 \times 96.207/1.7$
$= 246.595 = F_a$
$\mathbf{0.6 \times F_{r1}/Y_1}$
$= 0.6 \times 2214.93/1.6$
$= 8.30.598$

Therefore

$\mathbf{F_{ae} + 0.6 \times F_{r2}/Y_2 < 0.6 \times F_{r1}/Y_1}$

From NSK Bearing Book

$\mathbf{P_1 = F_{r1}}$
$\mathbf{P_2 = XF_{r2} + Y_2(0.6F_{r1} - F_{ae})}$
$F_a/F_r = 246.595/96.207 >$ e .So, X = 0.4
$\mathbf{P_1 = 2214.93N}$
$P_2 = 0.4 \times 96.207 + 1.7\ (2214.93 \times 0.6 /1.6 - (212.64))$
$\mathbf{P_2 = 1089.0126N}$

Life of bearing 1:

Fatigue Life Factor
$f_h = f_n(C_{r1}/P_1)$
Using n = 3000, $f_n = 0.23$ (from NSK factor table)
$f_h = 0.23 \times 48500/2214.93$
$f_h = 5.036$
Rating fatigue life
$L_{h1} = 500 \times (f_h)\ 10/3$
$= 500 \times (5.036)10/3$
$= 109460.0753$ hours.

Life of bearing 2:

Fatigue Life Factor
$f_{h2} = f_n(C_{r2}/P_2)$
Using n = 3000, $f_n = 0.23$ (from NSK factor table)
$f_{h2} = 0.23 \times 27900/1089.0126$
$f_{h2} = 5.892$

Rating fatigue life
$L_{h2} = 500 \times (f_{h2})^{10/3}$
$= 500 \times (5.892)^{10/3}$
$= 184719.3811$ hours.

Estimated life of the bearings

Life of bearing 1 = 109460.0753 hrs
Life of bearing 2 = 184719.3811 hrs

The proposed integral shaft bearings are compact in size bearings and with either two rows ball or else single row ball in addition to single row roller are made-up using best quality material. It has high reliability through a newly developed water resistant seal. These reliable bearings have three times greater durability than ball bearings. It has high load durability, high resistant to heat load and water.

7. Conclusion

By change in the ball bearing into integral bearing into increase the life of bearing approximately 84,000 Hr's are increase the life time of the water pump.

The further development of the water pump in future is to reduce the weight of the component, increase mass flow rate and efficiency.

8. Acknowledgement

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