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Design Integration for Semi-Floating Axle Wheel Bearing

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***Abstract*—There has been a steady increase in the weight of typical family vehicles due to additional safety, luxury and performance features demanded by the driving public. This incremental weight increase has created a significant weight problem and challenged automakers ability to comply with fuel efficiency standards. There is also a potential for increasingly stringent carbon monoxide emissions regulations where weight once again constrains automakers ability to comply with any future legislation.**

The key point to reduce weight is the integration capability to meet the requirement such as space, performance, service, strength of component and so on. This paper describes integration methodology for rear wheel semi-floating axle for SUV. In addition, optimization of wheel bearing is performed to improve mass and strength bearing carrier by integrating bearing outer ring with bearing carrier. It is found from result of FE analysis and rig level testing that prototype of integrated wheel bearing meets vehicle performance and strength requirement.

Keywords*—Integrated Design; Semi-floating axle; Wheel Bearing;

I. INTRODUCTION

In current industrial scenario, bearings find a significant place in almost all mechanical applications that involves rotary motion of shaft. Different types of bearings are used for different applications. The shaft is supported by bearings having balls or rollers.

Deep groove ball bearings are commonly used in motors, transmission and wheel ends. Their designs can accommodate combined axial and radial load. The Deep Groove Ball Bearings are commonly used for moderate speed, heavy duty applications where durability is required. Common real world applications are in electrical motors, fan and machine equipment, axle system, gear box, engine motors and reducers. Deep groove bearings have inner and outer ring raceways between which balls are arranged.

For SUV rear axle wheel with ball-type axle bearings has the axle shaft and bearing held in place inside the axle housing by metal bearing retainer plate. The plate is bolted to the axle housing and is held in place on the axle shaft by a retaining ring, which is pressed onto the axle shaft. The operation of the ball-type bearing is designed to absorb radial load as well as the axle shaft end thrust. Because both loads are taken at the bearing, there is no axle shaft end thrust absorption or adjustment designed into the rear axle housing. To seal in the lubricant, an oil seal collar and oil seal is used. The oil seal collar is a machined sleeve or finished portion of the axle on which the lips of the seal ride. The oil seal retains the gear lubricant inside the axle housing. The axle seal prevents the lubricant from leaking into the brakes.

In this paper, integrated design of semi-floating axle wheel bearing on the rear axle for utility vehicle is investigated. In addition, optimization of the bearing carrier is performed to reduce mass and improve strength of the In-Wheel motor housing according to the test specification of weight transfer from the tire patch.

II. EXISTING LAYOUT

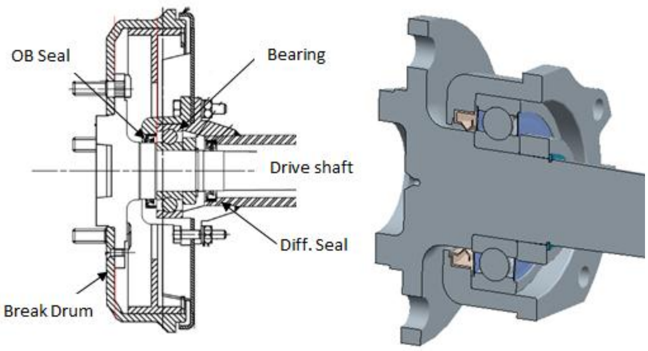

Fig 1. Rear Wheel Layout

Current layout is equipped with single row deep groove ball bearing with both side single lip seal. Bearing is pressed fit on drive shaft and having transition fit with cast iron housing. On drive shaft bearing is axially located by thrust collar which is press fit. Housing is carrying cassette seal (a robust three lip seal) on outboard side. Differential seal is preventing oil from differential gears. Given application is semi-floating axle with inner ring is rotating and outer ring is stationary.

Driving power is coming from differential gear and going to rear wheel-end. Function of bearing is to support drive shaft, carry rear axle weight and take radial as well as axial load during cornering.

Table 1
Existing design Vs. Proposed design

Sr. No	Components in Existing design	Components in Proposed Integrated design
1	Bearing Carrier	To be eliminated
2	Inboard side seal	To be eliminated
3	Outboard side Seal	To be eliminated
4	Standard Deep Groove Ball Bearing	Flanged deep groove ball bearing with robust seal design

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A. Proposed Solution for Integrated design for Wheel Bearing:

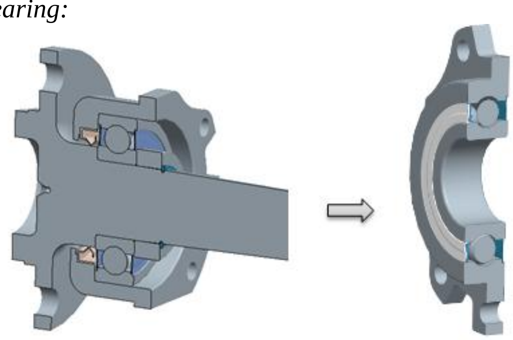

Fig.2 Integrated design for Semi-floating axle wheel-end bearing

In Integrated bearing design of semi floating axle bearing eliminates bearing carrier and integrates it with bearing outer ring. Proposed flanged outer ring design is as shown in fig. 3.4. In integrated design, inboard side seal i.e. differential seal is eliminated and it is replaced by robust seal which prevents oil leakage in bearing. Similarly for outboard side seal is replaced by two lip seal design to prevent environmental dust and contamination in bearing. Proposed integrated design provides unitized seal solution with integrated flange provides following benefits,

- Reduce assembly time of bearing pressing into bearing carrier
- Reduces assembly weight
- Eliminates inboard and outboard side seal assembly
- Reduces both seal cost
- Ease of maintenance and replacements

3.3 Input Data Sheet From Customer:

Vehicle data captured for technical evaluation of life and contact stress. Bearing feasibility study can be done based on vehicle geometry for various parameters. This parameter are axle weight, height of center of gravity, track width, wheel radius and load cycle specific segment of vehicle.

Table 2
Vehicle Data

Vehicle Data		
Sr. No	Description	Tentative requirement
1	Application	Scorpio Rear Wheel
2	Bearing Type	DGBB
3	Bearing Designation	6207
4	Bearing Application	Rear Wheel
5	Axle Type	Semi-Floating

Table 3 Wheel Data

	Vehicle Wheel Data	
1	Gross Vehicle Weight (kg)	2330 kg
2	Axle Weight (kg) FRT	930 kg
3	Axle Weight (kg) RR	1400 kg
4	Track Width	1443 mm
5	Wheel radius static/Dynamic	324/340 mm
6	Hight of center of Gravity	800 mm
7	Expected theoretical life as per M&M cycle	2,00,000 kms
8	Driven Wheel/Rim size	Rear /6J x15
9	Wheel Offset- Distance between wheel center & Rim	40 mm
10	Wheel Mounting PCD/Specification	120 mm, M14x1.5- 5Nos.
11	ABS/Non ABS, Brake type	Non ABS, DISC Brake @ Front

a. Bearing Selection

Bearing selection is depends on application requirement such as available space, axle weight, service life requirement, contact pressure at maximum lateral acceleration. It also based on requirement of system weight reduction, load carrying capacity and assembly method.

Table 4
Bearing Internal Geometry

	Parameter	Value (mm)
General	B	25.5
	P	65.5
Outer Ring	D	92
	Di	76.1
	Re	9.22
Ball	Dw	17.462
	No. of RE	7
Inner Ring	d	40
	d1	55.3
	Ri	8.925

III. THEOROTICAL ANALYSIS & VALIDATION

Based on bearing internal geometry and vehicle data available bearing life, contact pressure and truncation can calculated by using following expressions

Bearing life will be calculated by using ISO 281 expression
$L_{10}=a_1\ (C/P)^{\ P}$
On combined load application means axial load and radial load rolling elements have ability to ride on edge of raceway which causes to produce more stressed zone. Due to highly stressed zone bearing may get fail because of spalling on raceway. This phenomenon is called as Truncation

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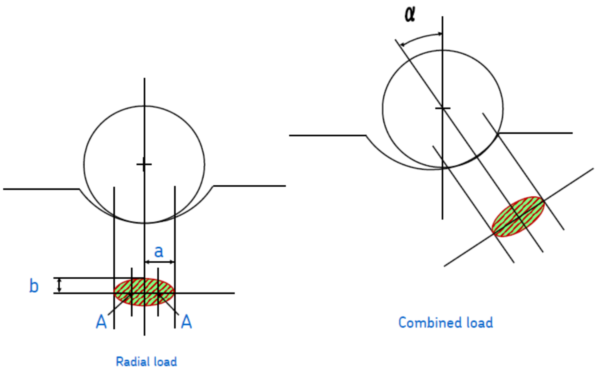

Fig.3 Load Distribution on raceway

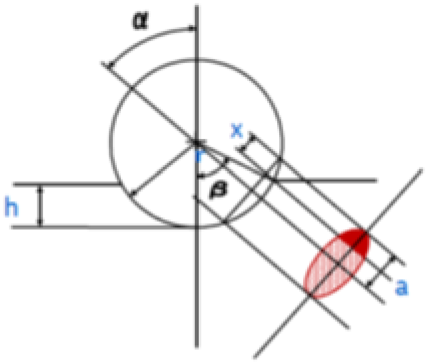

Fig.4 Truncation

Each bearing have minimum ability to take truncation. According to much field level test and benchmarking activity maximum truncation capacity of bearing is 30%. Beyond this value bearing may lead to failure.

$T = X/a = (a - r\sin(\beta-\alpha)/a)$

a. Bearing Heat Treatment

The most common steel for through hardening is a carbon chromium steel, containing approximately 1% carbon and 1,5% chromium, in accordance with ISO 683-17. Today, carbon-chromium steel is one of the oldest and most intensively investigated steels due to the continuously increasing demands for extended bearing service life. This steel normally undergoes a martensitic or bainitic heat treatment to obtain a hardness between 58 and 65 HRC.

Surface induction hardening offers the possibility to selectively harden a component's raceway, while leaving the remainder of the component unaffected by the hardening process. The steel grade and the manufacturing processes used prior to surface induction hardening indicate the properties in the unaffected areas, which means that a combination of properties can be achieved in one component.

Table 5
Hardness Specification

Inner Ring	Balls	Flanged Outer ring
Through Hardening	Through Hardening	Induction Hardening

Induction Hardening of outer ring

Based on performance resistance requirement, raceway and stress concentration area on flanged ring are heat treated by induction hardening process.

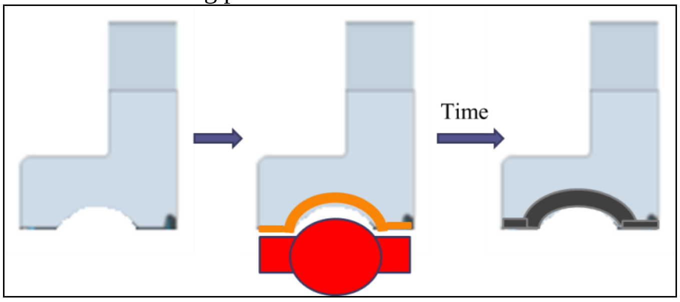

Fig. 5 Bearing outer ring induction hardening

For raceway of actual hardness profile Vs. Depth is calculated based on application data and maximum vehicle lateral acceleration capability.

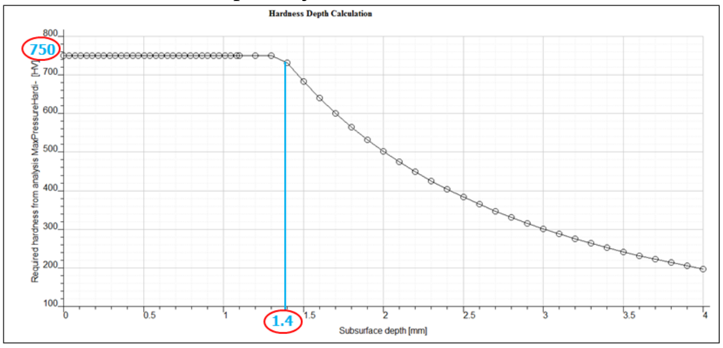

Fig. 6: Surface depth Vs. Hardness

The Permanent indentation of raceway due to static loading in an important aspect bearing. The evaluation of plastic indentation is not a trivial task. It relies on accurate measuring equipment and theoretical model that accounts for the subsurface stress. An early published model for estimation of plastic indentation in bearing was due to Plamgren.

$$\delta t = 1.3 * 10^{-7} \; [P^2/Dw \, (P_{I1} + P_{II1}) \, (P_{I2} + P_{II2})]$$

b. Outer ring Flange Thickness

Outer ring flange wall thickness is based on no. of threaded hole in flange design and their diameter. From von Mises theory theoretical calculated value is 9.5 mm. considering threaded hole diameter of 12 mm flange thickness considered as 10 mm.

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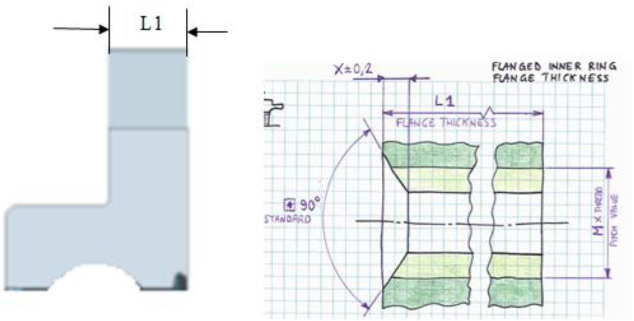

Fig. 7: Flange Thickness

Table 6
Calculation result Summary

Sr. No.	Design Parameter	Value
1	Bearing Life	18806 Hrs.
2	Truncation	13.2%
3	Bearing Internal clearance	0.01 µm
4	Maximum depth for Induction hardening for outer ring	1.34 mm
5	Outer ring flange thickness	10mm
6	Bearing seal	Low torque high integral seal

c. Strength and Endurance Test

In order to ensure the strength of bearing flange FEM analysis is performed according tothe test specification. The test condition of hub is defined as weight transfer traveling in 0.6g cornering.

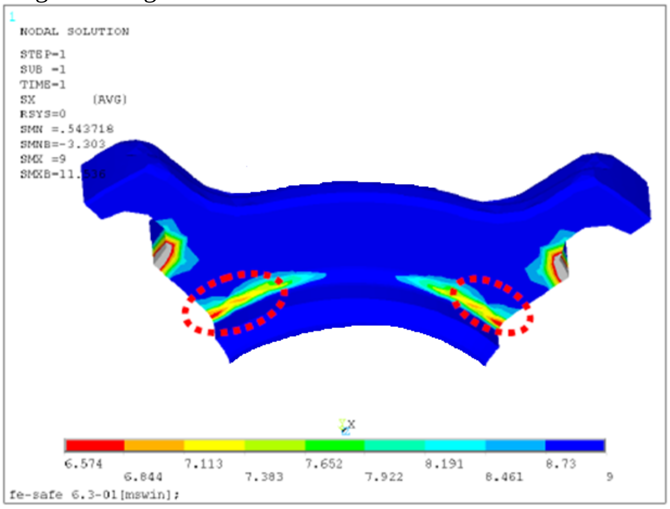

Fig 8: Static Stress by Tilting moment

To perform FE calculations it is considered that, outer ring flange and mounting holes have been constrained in all direction. Inner Ring mounted on drive shaft have been rigidly connected to tire patch via constraint equation (CE Element).

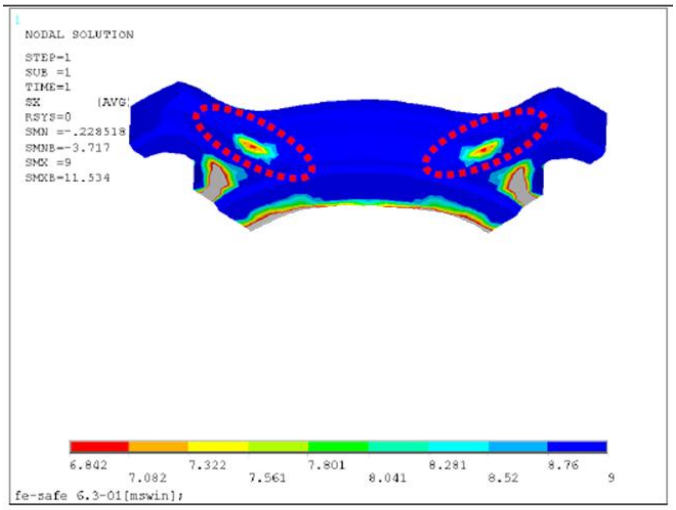

Fig 9: Boss Fillet results

d. Experimental Validation:

This test is designed to evaluate the raceway (rolling contact) fatigue life of the tested bearing unit under severe (but realistic) conditions. The conditions have been chosen to accelerate the test while ensuring a realistic failure mode. The test does not determine the L10 life of the test bearing unit since insufficient tests are performed for such an evaluation. An acceptance test strategy is used to give acceptable confidence both from the producers and customers viewpoint.

Fig 10: Experimental Setup

Test has been performed for 2 bearing samples to simulate actual condition of vehicle at lateral acceleration of 0.6g. With given load condition testing was done for 725 Hrs.

IV. CONCLUSIONS

Form this study it concluded from the work that, the unitized bearing with integrated flange can give complete solution to the current wheel end bearings problem. The effect of integrating flange to bearing outer ring reduces overall weight of assembly with benefit if ease of assembly than existing system layout Induction heat treatment to outer ring reduces time as well as cost of outer ring heat treatment than conventional heat treatment. By providing improved seal design to inboard and outboard side of bearing eliminates system level sealing, results in more improved sealing at bearing level itself.

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FUTURE SCOPE

This current project gives new exploration path in field of bearing integration with mating component. This application can be further extended transmission, final drive, steering, Gas turbine engines, Fuel pump and engine application. There can further exploring study for using different material such as Aluminums as flange material to improve strength and to lower weight.

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