Analysis and Design of Tractor Rear Axle using Finite Element Method- A review

Piyush.C.Chaudhari[1], Vimal.D.Sonara[2], Dr.Pravin.P.Rathod[3]

[1]*PG Scholar, Mechanical Engg. Department, Gov. Engg. college, Bhuj-370001, India,*
[2]*Assistant Professor, Mechanical Engg. Department, Gov. Engg. college, Bhuj-370001, India,*
[3]*Associate Professor, Mechanical Engg. Department,Gov. Engg.college, Bhuj-370001, India,*

Abstract: - *The world has immersed interest and investment in the automobile industry which affects their industries a great deal. Also, they are focusing on the development of vehicles with improve performance, increased stability, and enhanced driver pleasure. Due to their higher loading capacity, solid axles are typically used in the heavy commercial vehicles. A premature failure that occurs prior to the expected load cycles during life of rear axle shaft is studied. During the service life, dynamic forces caused by the road surface roughness produce dynamic stresses and these force lead to fatigue failure of axle shaft and its housing, which is the main load carrying part of the assembly.*

Tractor, An off-road vehicle is considered to be any type of vehicle which is capable of driving on and off paved or gravel surface. Off road condition includes uneven agricultural field surfaces and bumpy village roads on which the tractor has to operate. These ground irregularities leads to unexpected loads coming on the tractor components. Thus it is important to analyze rear axle of tractor so that we can solve problems regarding breakdowns and failures during field operations. In Present work finite element analysis approach is used to modify existing rear axle of tractor.

Keywords: Axle shaft; Stress concentrations; Fatigue failure; Finite element analysis, Life cycle.

I. INTRODUCTION

An Axle shaft is a rotating member usually of circular cross-section (solid or hollow), which is used to transmit power and rotational motion in machinery and mechanical equipment in various applications. An axle is a central shaft for a rotating wheel. The wheel may be fixed to the axle, with bearings or bushings provided at the mounting points where the axle is supported. The axles maintain the position of the wheels relative to each other and to the vehicle body. Dead axle does not transmit power like the front axle, in a rear wheel drives are dead axles. On the dead axle suspension system is mounted, so it's also called suspension axle. Generally axle shafts are generally subjected to torsional stress and bending stress due to self-weight or weights of components or possible misalignment between journal bearings.

Most shafts are subjected to fluctuating loads of combined bending and torsion with various degrees of stress concentration. For such shafts the problem is fundamentally fatigue loading. Eccentric Shaft is widely appreciated for its features like corrosion resistant, long service, effective performance and reliability.

II. MATERIALS & FAILURE ANALYSIS

Based on the literature review, the axle shaft is subjected to stresses in the axle shaft, corresponding to this loading pattern, have been calculated using ansys. The cyclic stress pattern is used to calculate the damage accumulation and fatigue life of the shaft using ansys workbench. Analysis reveals that the damage is occurring at root of spline of axle shaft, which was expected. Based on the particular load spectrum and the boundary conditions, the axle shaft is likely to break at 144233 km whereas the warranty is for about 150000 km.

Based on research work within rear axle and axle shaft using following materials are, SAE1040,SAE1020 ,SAE86B45, Al_2O_3, mild steel, gray cast iron, reinforce aluminium with fly ash and Al_2O_3 thus it is important to analyze rear axle of tractor so that we can solve problems regarding breakdowns and failures during field operations. In present work finite element analysis approach is used to modify existing rear axle of tractor.

III. TYPES OF REAR AXLES

In rear wheel drive vehicles, the rear wheels are the driving wheels, whereas in the vehicles with front wheels drive the front wheels are the driving wheels. Almost all the rear axles in the modern cars are live axles, which mean that these axles move with the wheels, or revolve with the wheels and are known as live axles. Dead Axles are those axles which remain stationary and do not move with the wheels.

A. Semi-float axles

The Semi float axle is used in light trucks and passenger vehicle / buses. In the vehicles equipped with Semi Float axle the shaft as well as the differential housing supports the weight of the vehicle. The wheel hub is directly connected to the axle shaft or is an extension of the same, the inner end of the axle shaft is spine and it is supported by the final drive unit

B. Three-quarter floating

This is a compromise between the more robust full float axle and the simplest semi float type of axle. In Semi Floating axle the bearing is located between the axle casing and the hub instead of being between the axle casing and the shaft as in case of semi float axle. Three quarter floating axles were much popular for cases and lighter commercial vehicles.

C. Fully floating Axle

Full Float Axle is considered as a robust one and is used for heavy vehicles / trucks meant to carry heavy loads. The axle shaft has flanges at the outer ends, which are connected to the flanged sleeve by means of bolts. There are two taper roller bearings supporting the axle casting in the hub, which take up any side load. Full Float axle is considered as the most heavy and costly axle.

- **Forces and torques on the rear axle**
1. Weight of the Body
2. Driving thrust
3. Torque Reaction
4. Side thrust

IV.REVIEW OF VARIOUS LITERATURES

Manish S Lande et al. [1] "comparative analysis of tractor's trolley axle by using FEA. (by considering change in materials existing shape and size)" Evaluate that the existing rear axle shaft used in tractor trolley shows that the existing axle has greater factor of safety so un-wontedly heavy axle is used for trolley in existing condition which increase the weight of axle as well as cost of axle. But the newly designed axle with different cross section and different material show that we can maximally reduces the 33.92% weight as compare to the existing axle. Also reduces the cost of trolley axle as the weight of the axle reduces. We reduce the cost of axle and the deformations as well as stresses developed in new designed axle are in within limits the minimum cost obtained for I cross section axle of SAE 1040 material, the deformation for that axle is 0.984 mm and stresses developed in that axle is 259.525 (N/mm^2) which are in within limit.

A.K. Acharya et al. [2] "Failure analysis of rear axle of a tractor with loaded trolley" This paper describes the failure analysis of the rear axle at the root of the spline of a tractor with a loaded trolley used for haulage.The front wheel lifting and the failure of the rear axle at the root of the spline though mainly due to the transfer of weight, not sufficient attention.

By reducing the hitching height and it was observed that by reducing the hitching height to 16.00 inches (which is normally taken as 19 to 20 inches) with reduction in the weight transfer factor by nearly 20%.

G.K. Nanaware et al.[3] "Failures of rear axle shafts of 575 DI tractors "Studied on Rear axle shafts of 575 DI tractors manufactured by Mahindra and Mahindra Ltd. Tractor failed before completion of warranty period. Most of the shaft failures (nearly 80–85%) occur during puddeling operations. Rear axle shafts fail in the spline portion. Cracks were found at the root of the splines. The causes of failure and remedies have been discussed in this paper.

The failure of rear axle shafts is due to inadequate spline root radius, which led to crack initiation and subsequent crack growth is by fatigue under the cyclic loading conditions of field operation. The present study clearly indicates that the optimum value of the spline root radius i.e. 1.5 mm (by FEA) should be used together with shot peening of the spline region and addition of boron to the material to increase fatigue strength.

Sanjay Aloni et al. [4] "Comparative evaluation of tractor trolley axle by using finite element analysis approach" Studied on Evaluation of Tractor Trolley Axle by Using Finite Element Analysis to modify existing rear axle of 6.0 ton tractor trolley. Fatigue failure of the rear axle finite element model was predicted after the dynamic load was imposed on it.

Spectrum analysis revealed that the failed axle shaft material is SAE 1020 steel. Fractographic features indicated that fatigue was the main cause of failure of the axle shaft. It was observed that the fatigue cracks originated from transition areas due to sharp corners. Modified axle produced with casting process with the use of ductile iron (65-45-12 or 450-12) strengthened.

Javad Tarighi et al.[5] "Static and dynamic analysis of front axle housing of tractor using finite element methods" Studied on MT250D Mitsubishi Tractor with 25hp power is used to do light agricultural operations.Finite element analysis results showed that the maximum stress of 238.84MPa is applied on the upper housing. According to Von-Misses theory, the value of maximum applied stress and allowable stress, the safety factor of 1.05 was obtained which is

less than the required value. The first four natural frequencies of housing were found as 678.54, 720.29, 908.78 and 1877 Hz, respectively. The obtained factor of safety is very low.

The present study clearly indicates that the front axle housing of MT250D Mitsubishi tractor is not strong enough to be mounted on a tractor.

Suggested modifications to increase strength and reliability are as follow:

1. Increase the thickness of upper box
2. Design a lightweight mechanical shovel with low
Capacity of bucket
3. Increasing the shell thickness in areas where stress
Concentration occurs

Siddarth dey et al. [6] "Structural Analysis of Front axle beam of a Light Commercial Vehicle (LCV)"Studied on front axle design by the noise and vibration analysis at static and dynamic loading conditions. The model selected is that of a light commercial vehicle (LCV) which has a gross vehicle load of around 5-10 tons. Stressed regions due to vehicle static load, braking torque, and during turning is established and the front axle beam is investigated to find out its factor of safety and maximum deformation under the mentioned conditions.

The results of the transient analysis showed that the maximum Von -Mises stress in the optimized front axle was 351 MPa.The value of maximum bending stress due to transient loading conditions was lower than the yield stress strength. Because the transient dynamic loads were applied on the axle suddenly, a permanent deformation could not take place. Therefore, it is concluded that the optimized front axle of combine has enough strength under transient loading conditions.The designed front axle is strong enough to be installed on the LCV and the optimized front axle has enough strength under static, harmonic and transient loading conditions.

M.M. Topaç et al. [7] "Fatigue failure prediction of a rear axle housing prototype by using finite element analysis." Premature fatigue failure of a truck rear axle housing prototype was investigated by using finite element analysis.In the analyses, stress concentrated regions were predicted at the banjo transition area. The regions in which the fatigue cracks originated were well-matched with the results of the analyses. Critical regions determined are subjected to a combined steady and cyclic tensile stress.

Analyses showed that premature fatigue failure can occur prior to the predicted 5×10^5 minimum cycles limit, if this load is applied in a cyclic manner. Give solution of the problem, **Redesigning** of the banjo transition area and increasing the **thickness** of the reinforcement ring may be a good alternative to obtain a longer fatigue life, which can satisfy minimum design criteria.

G.Rajesh Babu and N.Amar Nageswara Rao et al.[8] "Static and modal analysis of rear axle housing of a truck" carried out the static and dynamic analysis of banjo type rear axle housing by using FE method for two different materials like cast iron and mild steel. The induced deformation in cast iron housing is greater than mild steel housing and also the natural frequencies of the cast iron are lower than the mild steel. Also observed that the stress induced in the cast iron is lower than the mild steel and concluded that the cast iron is preferred for production of rear axle housing.

Osman Asi et al.[9] "Fatigue failure of a rear axle shaft of an automobile" This paper describes the failure analysis of a rear axle shaft used in an automobile which had been involved in an accident.The failure zones were examined with the help of a scanning electron microscope equipped with EDX facility. Spectrum analysis and micro-hardness measurement show that the failed axle shaft material was AISI 4140 steel as hardened and tempered condition. Fractographic features indicated that fatigue was the main cause of failure of the axle shaft. It was observed that the fatigue cracks originated from welded areas. Due to the **improper welding.**

So improper welding of hardened materials involves low ductility in the HAZ, stress concentration points, and inclusions in the structure that served as responsible for the fatigue cracks.

So that **preheat** treatment prior to welding and **post heat** treatment after welding of medium-carbon steels are necessary to control the hardness level in the HAZ and minimize residual stress.

Guruprasad.B.S I et al. [10] "Evaluating FOS for rear axle Housing using hybrid aluminium Composites." It is observed experimentally that the reinforced aluminum with Fly ash and Al2O3 enhances mechanical properties in comparison with monolithic metal. In present work with the use of finite element analysis factor of safety for rear axle housing is estimated for both hybrid composite and monolithic metal.

The fatigue factor of safety for composites is greater than the unreinforced alloy under dynamic loading conditions. The few results show that composite material have more safety factor for maximum loading when the load is applied statically.

Meng Qinghua et. al[11] "Fatigue failure fault prediction of truck rear axle housing excited by random road roughness "Show that a premature fatigue failure that occurred prior to the expected load cycles during the vertical fatigue tests of a

truck rear axle housing prototype. Analyzed for fatigue failure of truck rear axle housing excited by random load distribution from the uneven road profile. During operation of the truck the random load acts on the axle housing in vertical direction causes severe impact on the fatigue life of the components. By using random load distribution data the fatigue life of the truck is analyzed and also design optimization is proposed to increase the fatigue life of the components according to the simulation results and location of failure.

Mehmet Firat et. Al[12] "A computer simulation of four-point bending fatigue of a rear axle assembly" evaluated that the bending fatigue test of a rear axle assembly is simulated by using a FE-integrated fatigue analysis methodology. The fatigue test cycles and crack initiation locations are predicted using Smith-Watson-Topper and Fatemi-Socie fatigue damage parameters. Both damage parameters provided conservative test cycle estimates for the test conditions simulated. It is also observed that von Mises stress distributions cannot be used to predict fatigue crack initiation locations while Smith–Watson–Topper critical plane parameter estimated the cracking location suitably. Comparisons with the prototype tests showed the applicability of the proposed approach. It was also determined that von Mises stress distributions may not be an accurate measure for fatigue failure locations of rear axle in bending fatigue tests. The need of modeling the manufacturing effects in fatigue life analysis was also pointed out.

Khairul Akmal Shamsuddin[13] "Stress Distribution Analysis of Rear Axle Housing by using Finite Elements Analysis" A premature failure that occurred due to the higher loading capacity of the heavy vehicle is studied.. In this analysis, in which the stress are distribute, stress concentration from the load given to the axle housing make the axle housing failure.
 The reason failure occurs is because the axle housing no longer can prevent the load given onto it. From the several load given, the maximum load for the housing can stand was determined by using FE analysis. The result show that the maximum load can be carried by this rear axle housing is 4224.755 kg ≈ 42000 N. In this FE analysis, the axle material can stand up to 1×10^6 cycles before the crack initiated on the critical region. The factor of safety for the axle housing was determined from the analysis and manual calculation. The values from the analysis is n = 1.56 and from the calculation is 1.45 can be accepted because only has 7% of the error.
In order to increase the fatigue life of the housing, new design of rear axle model was developed with increasing the thickness of sheet metal to 7 mm used to make the housing can stand longer and increase the rigidity of the axle housing. But other consideration such as material changing and redesigning also can be used to improve the problem.

V. CONCLUSION

The failure of rear axle shafts is due to inadequate spline root radius, which led to crack initiation and subsequent crack growth is by fatigue under the cyclic loading conditions of field operation. The present study clearly indicates that the optimum value of the spline root radius i.e. 1.5 mm (by FEA) should be used together with shot peening of the spline region and addition of boron to the material to increase fatigue strength.
Spectrum analysis and micro-hardness measurement revealed that the failed axle shaft material was AISI 4140 steel as hardened and tempered condition. The composition, microstructure, hardness values of the base metal were found to be satisfactory and within the specification. Fractographic features indicated that fatigue was the main cause of failure of the axle shaft. It was observed that the fatigue cracks originated from welded areas. Results indicate that the axle shaft fractured in reversed bending fatigue as a result of improper welding.
Due to heavy load on rear axle specifically in tractor, its life is reduced. So it is important to analyze optimized design to increase its life run. We can optimize rear axle for increasing mechanical strength and easy manufacturability.
The objective of this paper is increasing working strength and increasing life cycle of rear axle shaft of tractor with using different material.

REFERENCE

[1]. Manish S Lande and Sunil J Rajpal, "Comparative analysis of tractor's trolley axle by using FEA. (By Considering change in materials existing shape and size)",International Journal of Mechanical Engineering and Robotics Research ISSN 2278 – 0149 Vol. 2, No. 3, July 2013.
[2]. A.K.Acharya, I. Panigrahi, P. C. Mishra, "Failure analysis of rear axle of a tractor with loaded trolley", international journal of innovative research & development Vol 2 Issue 10ISSN;2278-0211 oct-2013.
[3]. G K Nanaware, M J Pable, "Failures of rear axle shafts of 575 DI tractors", Engineering failure analysis 10 (2003) 719-724, ELSEVIER.
[4]. Sanjay Aloni and Sandip Khedkar "Comparative evaluation of tractor trolley axle by using Finite Element analysis approach", International Journal of Engineering Science and Technology.vol-4,ISSN:0975-5462,April-2012.
[5]. Javad Tarighi, Seyed Saeid Mohtasebi, Reza Alimardani, "Static and dynamic analysis of front axle housing of tractor using finite element methods", AJAE 2(2), 45-49, 2011.

[6]. Siddarth DeySri Rama Chandra Murthy. D, P.Baskar, "Structural Analysis of Front axle beam of a Light Commercial Vehicle (LCV)'', International Journal of Engineering Trends and Technology (IJETT)-Volume 11 Number 5 -pp 2231-5381 May 2014.

[7]. M M Topac, H Gunal, N S Kuralay, "Fatigue failure prediction of a rear axle housing prototype by using finite element analysis", Engineering failure analysis 16 (2009) 1474-1482, ELSEVIER.

[8]. G Rajesh Babu, N Amar Nageswara Rao, "Static and modal analysis of rear axle housing of a truck", International Journal of Mathematical sciences, Technology and Humanities 7 (2011) 69 -76.

[9]. Osman Asi, "Fatigue failure of a rear axle shaft of an automobile", Engineering Failure Analysis 13 (2006) ,pp 1293–1302.

[10]. Guruprasad.B.SArun.L.R, Mohan.K,"Evaluating, "fos for rear axle Housing using hybrid aluminium Composites",International Journal of Innovative Research in Science, Engineering and Technology Vol. 2, Issue 6, ISSN: 2319-8753 June 2013.

[11]. Meng Qinghua, Zheng Huifeng, LV Fengjun, "Fatigue failure fault prediction of truck rear axle housing excited by random road roughness", International Journal of the Physical sciences Vol. 6(7), pp 1563-1568, 2011.

[12]. Mehmet Firat."A computer simulation of four-point bending fatigue of a rear", axle assembly", Engineering Failure Analysis 18, 2137–2148(2011).

[13]. Khairul Akmal Shamsuddin , Mohd Syamil Tajuddin,Megat Mohd Amzari Megat Mohd Aris,Mohd Nurhidayat Zahelem,"Stress Distribution Analysis of Rear Axle Housing by using Finite Elements Analysis". The International Journal Of Engineering And Science (IJES), Volume-3, Issue- 10, Pages 53-61, ISSN (e): 2319 -1813 ISSN, (p): 2319-1805,2014.