Fatigue life evaluation of an Automobile Front axle

Prathapa.A.P [(1)], N. G.S. Udupa[(2)]

[1] M.Tech Student, Mechanical Engineering, Nagarjuna College of Engineering and Technology, Bangalore, India. e-mail: prathap.ap99@gmail.com

[2]Professor, Mechanical Engineering, Nagarjuna College of Engineering and Technology, Bangalore, India.

e-mail:ngsudupa@gmail.com

Abstract — This paper presents the axle apart from above loads is critically subjected to cyclic and shock loads. In case of four wheelers, Six wheelers and multi axle vehicles role of frontal axle is most important since it drives the rear axle .A robust design of frontal axle involves load calculations and load considerations for four wheeler and six wheeler, Followed by preliminary and detailed design considerations .

In the light, of the above an automobile truck frontal axle is considered for the topic of research to understand its behavior to the loads during service conditions and also at off design conditions for four wheeler and also for six wheeler. The study involves load calculations for various conditions namely four wheeler, six wheeler ,gyroscopic couple ,Fatigue, dead weight and so on .Further , the work is focused on structural evaluation of front axle using FEA approach with preliminary detailed design considerations which, includes Gross weight of the vehicle ,Inertial loads, dynamic loads and Rolling resistance. Commercial FE software (ANSYS) is used to determine the structural integrity of Frontal axle.

Keywords: Front axle, Static analysis, Campbell diagram, modal analysis, FEM

I INTRODUCTION

After years of study, predictable patterns change, the car industry is in its history of product changeover among the most intense. In order to achieve the need to design a medium cars, structural engineers will need to use Rich imaginative concepts. Increase in demand in the automotive designer, Rapid changes, one must first meet the new security requirements, later reduced weight [1]. In order, to meet fuel economy requirements. Experience cannot be extended to new size and performance data of the vehicle, which does not have new standards. Therefore, mathematical modeling is a logical way to explore. Recent, Finite element methods, computer-related digital technologies have opened up the new approaches to the car sets [2].

Figure.1.Dead Front Axle Mechanism of Commercial Truck

Front axle at both ends, an intermediate portion and a circular or elliptical cross-section or I section as shown in Fig 1. Special section (- I, circular, Square) portion of the axle so that it can withstand the bending loads due to weight of the vehicle and the braking torque applied [3].The dead weight of the vehicle is supporting the front portion of the vehicle, to facilitate the steering. Since, the assembly absorbs the impact transmitted to the irregularities of the road surface and also absorbs torque exerted thereon, due to the braking of the vehicle. Wheel is mounted on the minor axis. Front axle beam quality due to the bending load due to the presence of the vertical force under static conditions of the vehicle, while driving around a corner of the truck a plurality of power leads, e.g., the axial force or torsional force knuckle kingpin, between the pad spring Along the beam and asymmetric length of the interface due to the centrifugal effect of the vertical load. And turning the truck is braked to stop turning the torque pad and a sporty vehicle deceleration force on the surface of the pad caused the worst situation [5]. The project work on a comprehensive understanding of stress automobile front axle, the strain distribution and the different varieties of conditions to simulate the vibration frequency, and the theoretical basis of scientific designers to improve design quality and shorten the design cycle and reduce design costs [6].

II METHODOLOGY

First and foremost step for the design of the chassis is to find the boundary condition and the placing of the components. The Ergonomics is considered first and according to the ergonomics, the frontal part is constructed. The suspension pick up points are major consideration which can pull off or push off the chassis in the lateral direction during corner entry. A multi axle suspension reduces the sprung mass and hence a distribution of the forces in the unsprang mass. Chassis is to be decided based on the track width and wheelbase dimensions. But the relation between them are profoundly complicated, but few of them can be realized very easily, few of them are listed are below.

A long wheel base should have more stability during braking, and if it is polar moment of inertia is not so high, should produce more yaw moment in the corners entry. On the other hand, in slow corners it should have more “under steering tendency” asking for more steering angle and should be less agile.

A wide track will produce less weight transfer and so should give a higher cornering grip potential, but the vehicle will tend to follow wider lines on the track and to have, for example, bigger frontal area.

A wheel base of 3200mm and track width of 1700 is taken with the wheel base to track width ratio of 2. Stability doesn’t only depend on these two but also depends on the height of the vehicle. The total height of vehicle is should be designed for the golden ratio of 1.6 has to be achieved without which straight line stability cannot be achieved.

III.CAD AND FEM DESCRIPTION

THE 3D CAD MODEL OF THE FRONTAL DEAD AXLE OF A COMMERCIAL TRUCK IS MODELED USING CATIA V5 R17 SOFTWARE.

The design procedure may vary from Designer to designer. The procedure I followed are listed below.

The idea was to exploit the symmetry of the model, hence only half model is created by creating the base half I section. The end of the I section is modeled with the circular cross section to hold. A spline is created From the cylinder edge which follows the I section. The extended part is now fitted with the Cylinder for the holding; A rectangular pattern of hole is made to accommodate the drill in the model. Now the whole model is created by the symmetry in the y axis.

Figure.2. Solid Front Axle Beam

IV.MATERIAL PROPERTIES

The axle material is considered to be ANSI 4340 steel and its mechanical properties are as below:

Table 1: ANSI 4340 Steel mechanical properties for Axle.

Sl.No.	Specification	Value
1.	Density	7.7 - 8.03 gm/cc
2.	Poisson's ratio	0.27-0.30
3.	Elastic Modulus	190-210 Mpa
4.	Tensile Strength	744.6 Mpa
5.	Yield Strength	472.3 Mpa
6.	Elongation	22.0 %
7.	Reduction in Area	49.9 %

V BOUNDARY CONDITIONS

Analysis of Gyroscopic effect on the axle in six wheeler vehicle.

TPYE 1

Boundary conditions applied on the frontal axle when it has Gyroscopic effect, i.e; reaction forces as remote forces acting vertically downwards at king pin and fixed forces where the axle is connected to wheels.

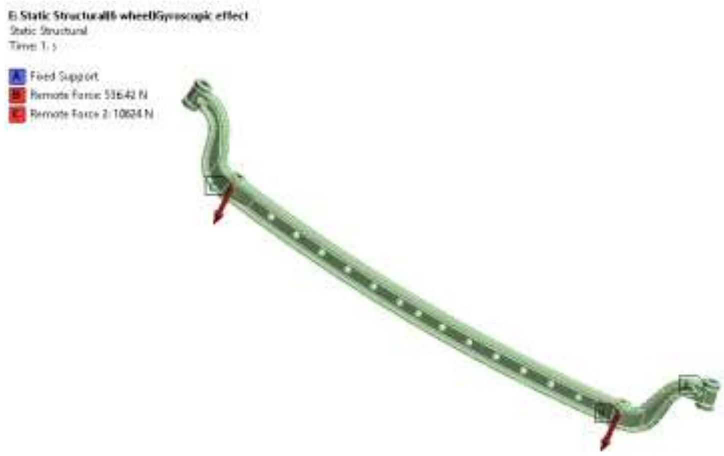

Figure.3. Boundary conditions due to gyroscopic effect

Analysis of Gyroscopic effect on the axle in four wheeler vehicle.

TYPE 2

Boundary conditions applied on the frontal axle when it has gyroscopic effect, i.e.; reaction forces as remote forces acting vertically downwards at king pin and fixed forces where the axle is connected to wheels. Analysis of Gyroscopic effect on the axle in four wheeler vehicle

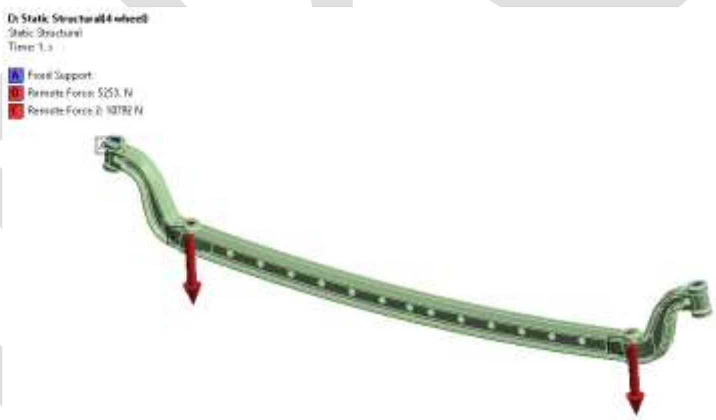

Figure.4. Boundary conditions due to gyroscopic effect

Mesh generation for 3D Model

The Model of the front axle is imported to ANSYS and ideal model is generated using Finite element modelling technique of ANSYS Software .The geometry imported is a 3D model which is meshed considering the SOLID 186 which is dominant ,Wherever 186 is not possible SOLID 187 is considered.

Figure.5.Finite element model of Front axle beam

It is very important to consider the type of element using in the analysis. It is seen that the stiffness matrix and interpolating function (Shape function) is different for different elements. The change in the stiffness matrix is due to the degree of freedom of the element, order of the polynomial used for the interpolation function and the type of load that the element can take.

VI. RESULTS AND DISCUSSION

Analysis results of entire axle in four wheeler truck

Von- Mises Stress distribution

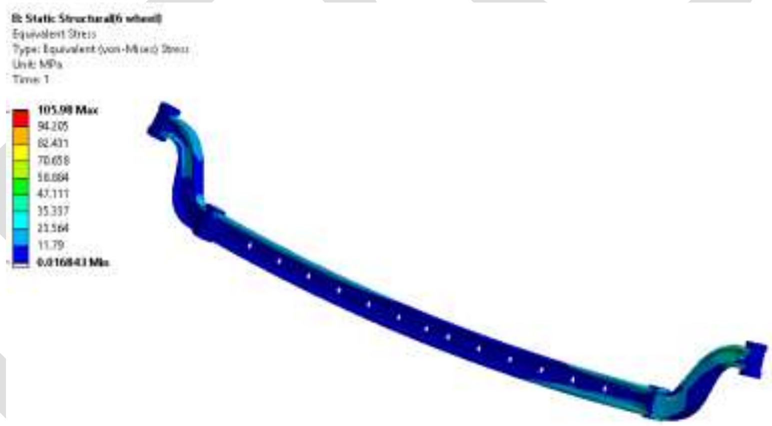

Figure.7. Von mises stress distribution for $W_1$and W_2

It is observed that maximum stress is 93.918MPanear the fillet area of the right wheel fixing end and it is less than Yield stress of the material.

Maximum Principal stress determination

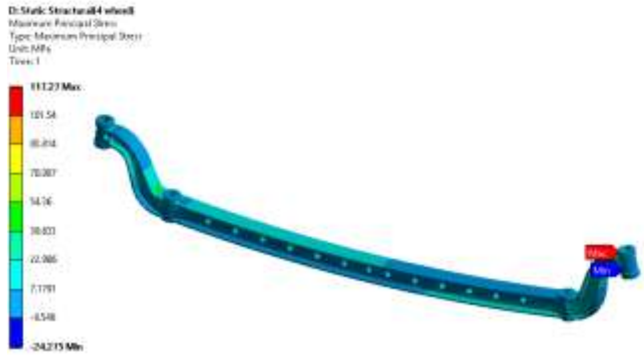

Figure.8. Maximum principal stress distribution for $W_1$and W_2

It is observed that maximum stress is 117.27Mpa near the top surface of the right wheel fixing end.

Minimum Principal Stress determination

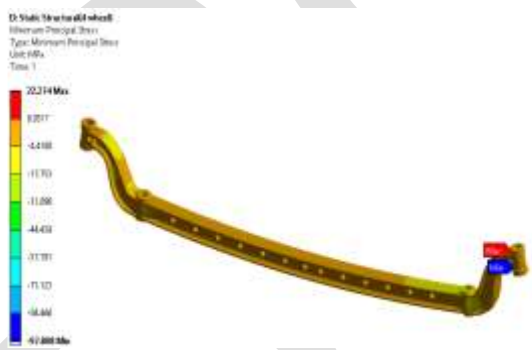

Figure.9. Minimum Principle stress

Maximum Principal Elastic Strain

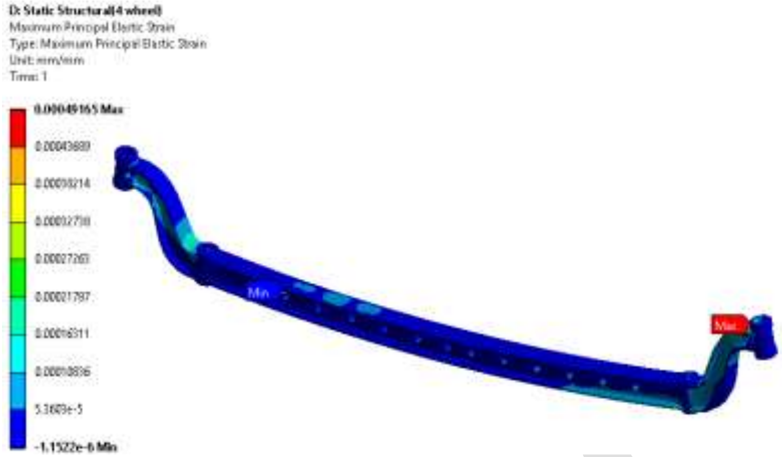

Figure.10.Maximum equivalent strain

Table: 1 Compilation of Results with Gyroscopic effect in 4 wheeler vehicle

Sl.No.	Parameter	Value (Max)
1.	Von Mises Stress	93.918MPa
2.	Maximum Principal stress	117.27MPa
3.	Minimum Principal stress	22.274MPa
4.	Maximum elastic strain	0.0004916

Analysis of Gyroscopic effect on the axle in six wheeler vehicle :

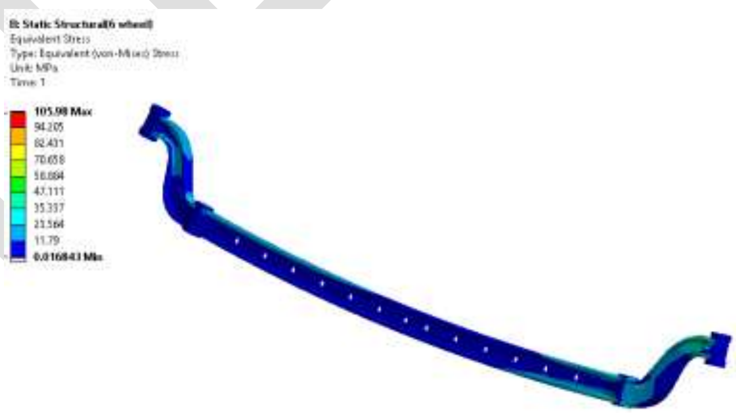

Figure.11. Von mises stress distribution for $W_1$and W_2

It is observed that maximum stress is 106.86Mpa near the fillet area of the left wheel fixing end and it is less than Yield stress of the material.

Maximum Principal stress determination

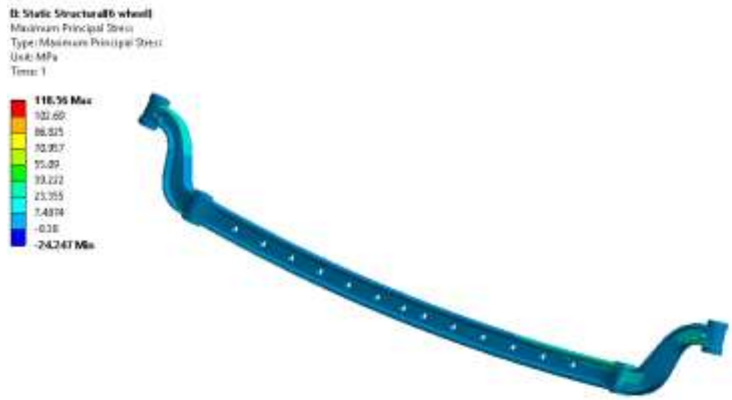

Figure.12. Maximum principal stress distribution for $W_1$and W_2

It is observed that maximum stress is 132.81Mpa near the top surface of the left wheel fixing end.

Minimum Principal stress determination.

International Journal of Engineering Research and General Science Volume 4, Issue 2, March-April, 2016
ISSN 2091-2730

Figure.13. Minimum Principle stress

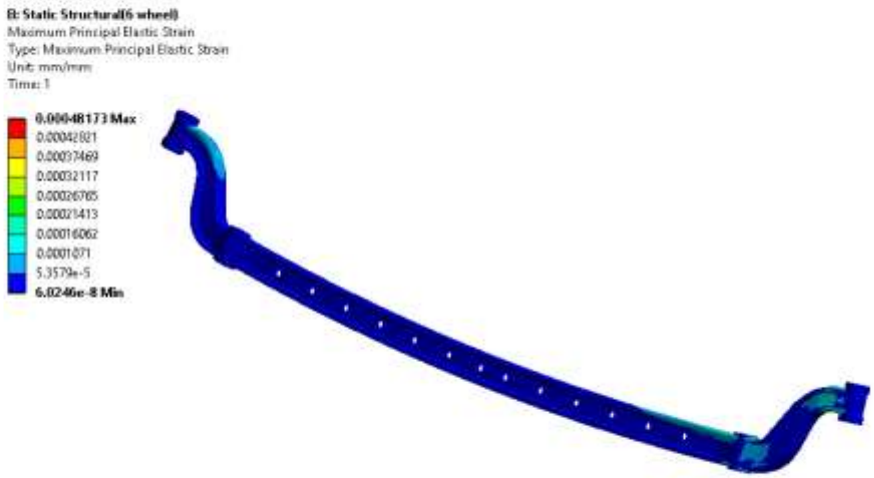

Figure.14. Maximum equivalent strain

Table 2: Compilation of Results with Gyroscopic effect

Sl.No.	Parameter	Value (Max)
1.	Von Mises Stress	105.98MPa
2.	Maximum Principal stress	118.56MPa
3.	Minimum Principal stress	27.724MPa
4.	Maximum elastic strain	0.000481

Fully reversed Cycle:

The cycle consists of the reversal of the load with the scale factor of 1. This fully reversed cycle is used for the analysis purpose.

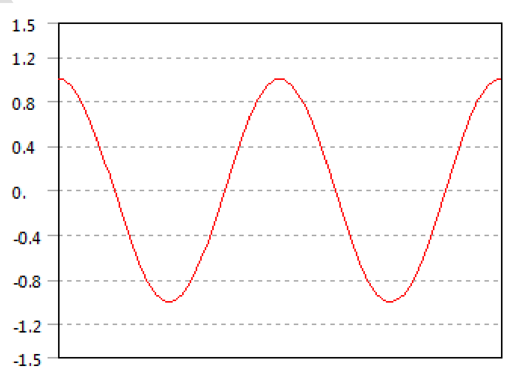

Figure.15. Fully reversed cycle

Life of the component:

Life of the components are always decided by the number of startup and shut down cycles required for the component to initiate crack. The start-up and shown down cycle is shown in the picture.

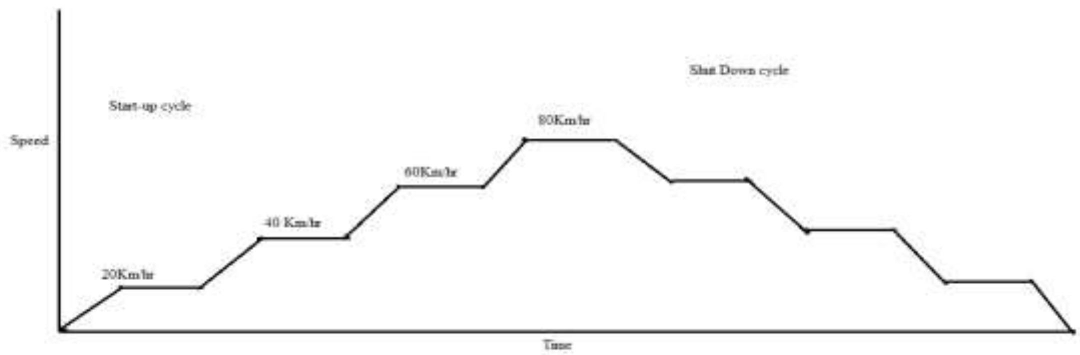

Figure.16. Start up and S`hut down cycle

CONCLUSION:

As the maximum principle stress increases beyond the yield limit, the crack initiation begin to happen as the maximum principle stress acts as tension in the material and shear stresses are completely absent in the material. Minimum principle stress always tends towards zero and doesn't create any serious deformations. Middle principle stress is compressive in nature; it tries to close the crack. If the middle principle is 68% of the yield, then the tensile force cannot open the crack up and the failure is 4 in million as per six sigma standard.

In this case equivalent stress plays a major role and acts as the decision maker. Equivalent stress is the deviatory stress of all the combined effect of stress derived from the strain energy theory is calculated and found to be well within the range.

REFERENCES:

[1] Kalpan Desai, et al., "Bending stress analysis of rear axle of Maruti-800car", International journal of engineering research and technology ISSN: 2278-0181, volume1, Issue6, August 2012.

[2] Anupam Singhal, et al., "Failure analysis of automotive FWD flexible driveshaft– A review", International journal of engineering research and applications, ISSN: 2248-9622, volume3, Issue1, Jan – Feb 2013, pp.577-580.

[3] C Kendall Clarke, et al., "Failure analysis of induction hardened automotive axles", ASM International, 16 May 2008.

[4] Ji-xin Wang, et al., "Static and dynamic strength analysis on rear axle of small payload off – highway dump trucks", Jilin University, Changchun130025, PR China, volume8, pp.79-86, 2012.

[5] Lawrence Kashar, "Effect of strain rate on the failure mode of a rear axle", ASM International, volume1, pp. 74-78, 1992.

[6] Mulani, et al., "FEA analysis of bullock cart axle under static and dynamic condition", International journal of engineering research and technology ISSN: 2321-5747, volume1, Issue2, 2013.

[7] JavadTarighi, et al., "Static and dynamic analysis of front axle housing of tractor using finite element Methods", Australian journal of agricultural engineering, volume2, pp.45-49, 2011.

[8] G Rajesh Babu, et al., "Static and modal analysis of rear axle housing of a truck", International journal of mathematical sciences, technology and humanities, volume7, pp.69-76, 2011.