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Fatigue life evaluation of an Automobile front axle

Chirag G[1], Kishor S[2]
*[1]Department of Mechanical Engineering, Nitte Meenakshi Institute of Technology, Bangalore, Karnataka, India
*[2]Department of Mechanical Engineering, Sir M. Visvesvaraya Institute of Technology, Bangalore, Karnataka, India

ABSTRACT

An axle is a central shaft for rotating wheel or gear. It is the important part of the vehicle. The axle maybe fixed to the wheels, rotating with them or fixed to its surrounding, with the wheels rotating around the axle. Basically there are two types of axles, front and rear. Frontal axle is important and critical part of the vehicle as it carries steering load, impact load, engine load and most of the vehicle curb weigh (60%). Hence it is important to study the design and structural integrity of front axle and how it will impact on the engine life and driver. The present work is to focus on structural analysis of front axle using FEA approach blended with the classical approach for preliminary design considerations and loading conditions. The approach of the problem is divided into two parts, primarily the design considerations of fatigue load condition and preliminary design of frontal axle. Secondly, finite element analysis and simulation of frontal axle is carried out to verify the preliminary design considerations at essential stage using FEA software.
Keywords: Front Axle, FEA, Static Analysis.

I. INTRODUCTION

An auto industry is one of the consequential and key sectors of the Indian economy. The auto industry includes of automobile sector, auto components sectors and includes commercial conveyances, passenger cars, multi-utility vehicles, two wheelers, three wheelers and cognate auto components. The ordinate dictations on the automobile designer incremented and altered rapidly, first to meet system safety needs and later to reduce weight so as to gratify fuel economy and conveyance performance requirements. Engine location paramount to provide more preponderant stability and safety at high speeds by lowering the centre of gravity of the road conveyances; the consummate centre portion of the axle is dropper. Front axles are subjected to both bending and shear stresses. In the static condition, the axle might be considered as beam fortified vertically upward at the terminuses (at the centres of the spring pads). Under the dynamic conditions, vertical bending moment is incremented due to road roughness. Thus it is very arduous to find the crack propagation in short time. So it is indispensable to incorporate finite element methodology. During the operation on conveyance, road surface irregularity causes cyclic fluctuation of accentuates on the axle, which is the main load carrying member. Ergo it is obligatory to ascertain whether or not the axle resists against the fatigue failure for a soothsaid

Accommodation life. Axle experiences thoroughly different loads in different direction, primarily bending load or vertical beaming due to curb weight and payload, torsion, due to drive torque, cornering load and braking load.

Front axle will experience a 3G load condition when the conveyance goes on the bump. Performing physical test for vertical beaming fatigue load is extravagant and time consuming. So there is an essentiality for building FE models which may virtually simulate these loads and can prognosticate the comportment. Albeit the FEA engender fairly precise results, solution precision heavily depends on precision of input conditions and overall modelling methodology used to represent the genuine physics of quandary. Consequently validation of FEA model is of utmost consequentiality. Typically FEA model is validated by correlating FEA results analytical design. Hence correct design of the front axle beam is very critical. The approach in this paper has been divided into two steps. In the first step analytical method used to design front axle. For this, the conveyance designations, its gross weight and payload capacity in order to ascertain the stresses and deflection within the beam has been utilized. In the second step front axle were modelled in catia. The cad model was solved in ANSYS software system. The FE results were compared with analytical design.

II. CONSTRUCTION AND OPERATION

A. Front axle

An axle is a central shaft utilized for rotating wheel. On wheeled conveyances, the axle could be mounted to the wheels, rotating with them, or located to its circumventions, with the wheels rotating around the axle. The axles achieve to transmit driving torque to the wheel. Adscititiously it can maintain the position of the wheels relative with each other and to the conveyance body. The axles must adscititiously bear the weight of the conveyance plus any cargo. The front axle beam is one of the main components of conveyance suspension system shown in figure 1. It houses the steering assembly as well. About thirty 30-40 percentage of the total conveyance weight is taken up by front axle. Front axle is composed of I-section in the middle portion and circular or elliptical section at the cessations.

Figure 1. Front axle beam

The special x-section of the axle makes it able to withstand bending loads due to weight of the conveyance and torque applied due to braking. It consists of main beam, stub axle, and swivel pin, etc. The wheels are mounted on stub axles. The front axles are generally dead axles, but are live axles in minuscule cars of compact designs and withal in case of four-wheel drive.

B. Stress Concentrations in Frontal Axle

Mathematical analysis and experimental quantifications show that the load Structural members, portions, adjacent to vary the stress distribution in which Peak stress does not reach a more preponderant degree than the average stress over Section. This increases the peak stress near the apertures, slots, notches, sharp Angle, cracks, and other transmutations in part are called stress concentration. That Section stress changes resulting concentrate is called stress raiser

In the life of the conveyance, the dynamic forces engendered dynamic stress this may lead to fatigue a positive axle is a paramount part of one failure with the conveyance used to carry the engine-driven system. Recent studies have shown, Static vigor conditions is met does not mean the mechanical components have illimitable fatigue life. Due to this, in a mechanical design process Element, it is crucial to assess the fatigue life to be taken in consideration. As long as it does not transmute the material and / or manufacturing process, the tensile vigor consequently, the fatigue vigor of the mechanical components cannot be transmuted. Cut back Critical area of stress concentrated on a mechanical element is a valid another way to get a longer fatigue life. On the other hand, the main one targets to the front axle of the conveyance is designed to meet the peak stress analysis which appeared in sundry sections of the body. .

In this work, we identify dead front axle of a commercial truck is a I-sectional member with all members of apertures distributed along its surface. In order to do analysis here, the sections of the sundry part to withstand the stress concentration in the conveyance kineticism is by utilizing commercial finite element software cerebrates of it as an aperture plate quandary. Light from the stress in the results obtained analysis was carried out in different components of the section is uniform stress the distribution of the stress will be verified for symmetric part of frontal axle.

C. Analytical and Mathematical Models of frontal Axle

for validation of the results

While designing and analyzing the structure with the help of the beam, it is very essential to know that the moment of inertia plays a very important role in the design. As the moment of inertia of the member is less, the bending stress will be more, as the moment of inertia of the member is more, less the bending.

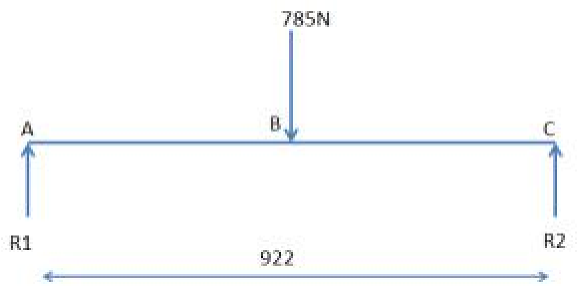
$$\sigma = \frac{M_b}{I} c$$

Where

M_b= bending moment

I= moment of inertia

C= Neutral axis distance from the farthest point.



$M_{b(Max)}$ = R1*l= 392.5* 461 = 180942 N-mm is always a constant for the any cross section.

D. Loading Conditions considered for analysis

Test load conditions:

Table 1

Sl.No.	Loading Value	Remarks
1	Dead weight =20000N	This load which is slightly higher than maximum weight of the vehicle is considered be acting to vertically downward on the center of the axle to perform Linear static analysis

E. Axle Material

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

Table 2

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 %
8	Hardness	217 HB

F. 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 2. Finite element model of Front axle beam

G. Analysis for 4 wheeled Vehicle: (Dead weight effect)

The analysis is carried out by loading the engine weight to the axle.

Boundary Conditions for 4 wheeled Axle:

Figure 3. Static loading condition

III. RESULTS AND DISCUSSION

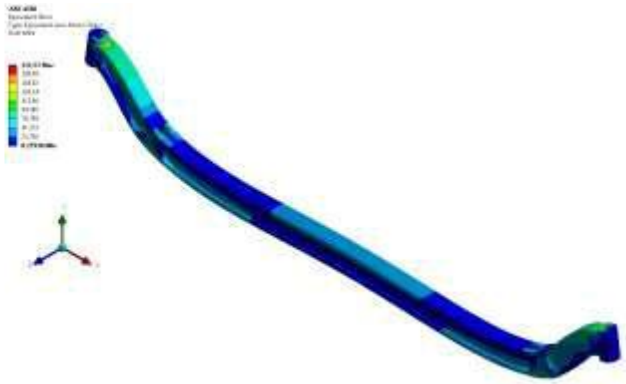


Figure 4: Equivalent stress conditions

Figure 5. Directional Deformation (X-axis) conditions

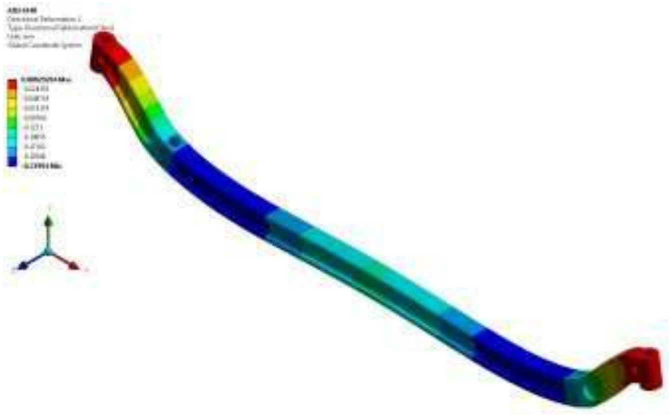


Figure 6. Directional Deformation (Y-axis) conditions

A. Compilation of Results for Dead weight (20KN)

Table 3

Sl.No.	Parameter	Value (Max)
1.	Von Mises Stress	211.57 MPa
2.	Directional Deformation (X-axis)	0.078076 mm
3.	Directional Deformation (Y-axis)	0.00020284 mm

It can be seen that the maximum equivalent stress are maximum at the right down part. But the maximum stress is well within the elastic limit and hence is safe for the further consideration.

B. Fatigue life estimation

In high-cycle fatigue conditions, materials performance is commonly characterized by an S-N curve, changes in material and geometry can easily be evaluated. Number of fatigue life cycles calculated by classical approach, considering 20 years of safe design and axle will sustain about 72000 cycles of fatigue loading (safe life design). But stress life approach does not account for notch root plasticity and Mean stress effects are often in error. Requires empirical Kf for good results.

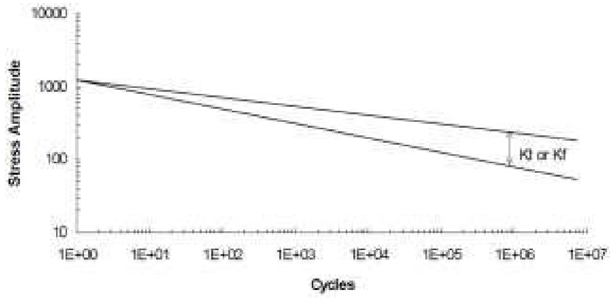


Figure 7. S-N CURVE

An ability of the material to sustain many cycles a component may experience in lifetime is the main objective of fatigue analysis.

IV. 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.

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