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Stress Analysis and Fatigue Analysis of Front Axle of Heavy-Duty Truck using ANSYS Ncode Design Life for Different Loading Cases

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ABSTRACT
Front axle of heavy duty truck is the important component of vehicle and needs good design under the various loading conditions of the complete vehicle. Aim of the project is to stress analysis and predict the life of front axle for vertical, and vertical and braking loading case. The fatigue life of front axle is generally estimated by stress life approach and strain life approach method. Front axle beam assembly was modeled in the NX cad software. Meshing and Stress analysis is performed by ANSYS workbench and fatigue analysis is performed by NCODE design life ANSYS tool under different loading cases. Fatigue life of axle obtained by FEA method is more than 2 x 10^5 cycles, which is considered as safe for vertical loading case. Similarly, Fatigue life of axle obtained is more than 4 x 10^3 cycles, which is considered as safe for vertical and braking loading case. The max stress region is below spring pad of axle for vertical loading and in the goose neck of axle for vertical and braking loading case.

Keywords: Front axle beam, Stress Analysis, Fatigue Life, NCODE ANSYS tool, Heavy Duty Truck

I. INTRODUCTION

In global economic scenario optimum vehicle design & life prediction of different parts of vehicle like front axle, steering knuckle, crankshaft etc. is of major concern and at the same time improve a product quality. Present off-highway vehicle market demands low cost, light weight & long life components to meet the need of cost effective vehicle. Due to which, more effective use of materials and relevant surface treatments are required to increase the fatigue life components of vehicle.

Fatigue failure often occurs from cracks initiated below spring pad and at notches of front axle beam. It is generally described in sequential process consisting of three main stages, i.e. crack initiation, crack propagation and fracture [1]. Therefore, it is the need to develop durable products which are safe against fatigue failure.

Front axle beam takes about 30-35 % of total vehicle weight. The main three reasons of failure of mechanical components are Corrosion, wear and fatigue [2]. Main reason for failure of front axle beam is the fatigue damage due to continuous fluctuating loads which acts from irregular road surface. Therefore, the research on the fatigue life of different vehicle parts has important value.

Front axle is subjected to different loads in different direction under the dynamic condition of vehicle. Bending occurs in axle, when vehicle takes turn and torsion due to braking load.

II. LITERATURE SURVEY

Min Jhang, Lijun Li (2015) analyzed stress and fatigue life of front axle beam by finite element analysis and experimental method. Also, investigate the effect of crack parameters like length and depth on fatigue life [1]. Topac (2008) evaluated the fatigue failure prediction and fatigue life of a rear axle housing prototype by using Finite element analysis of heavy duty truck. The expected load cycles required to fail during the vertical fatigue tests of a rear axle housing prototype is studied and mechanical properties were determined of housing material [3].

Various experiments and numerical methods were adopted by Leon et al. (2000) to obtain the stress analysis of a frontal truck axle beam and improved the quality of product by reducing the development time [4].

2.1 Closer Review

In this project our aim is to stress analysis and estimate fatigue life of front axle beam of heavy duty truck under different loading condition using Ansys NCODE Design Life software.

III. COMPONENTS OF FRONT AXLE BEAM

The Front axle is fitted with wheels at its ends using steering knuckle and king pin as shown in Fig. 1. The king pin inclination is desirable for alignment of wheels. The part of vehicle weight is transmitted through the wheels through this axle. Front axle beam supports the weight of front parts of the vehicle. It absorbs shocks which are transmitted due to road surface irregularities and gives the cushioning effect and also when brakes are provided at the front wheels, it withstands bending and torsional stresses.

All standard front axles have an ‘I’ Cross section between the left spring pad to right spring pad and rectangular or circular cross sections at the ends. An axle is usually a forged component for which a higher strength to weight ratio is desirable. The ‘I’ cross section has higher Section modulus and hence gives better performance with lower weight [5]. This type of construction produces an Axle which is lightweight and has good strength.

When the vehicle goes into motion, the axle receives the torsional stresses of driving and braking. When the brakes are applied suddenly, the axle twists against the springs and actually twists about normal upright position [3]. In addition to twisting during braking, the front axle moves up and down as the wheels move on rough surfaces roads and also cornering force applied as vehicle takes turn.

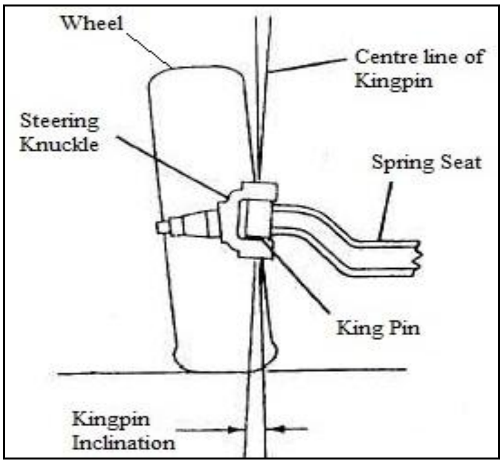

Fig. 1 Components of Front axle beam

IV. DETAILS OF FRONT AXLE BEAM

4.1 Axle Details

- Type: Front Non-Drive Steer Axle (Heavy Duty Truck)
- Axle rating: 15000lbs (6803.88 kg)
- Material: AISI 1045

Table 1.Material Properties

Material property	
Yield Strength (Syt)	884 MPa
Ultimate Strength (Sut)	991 MPa
Poisson ratio (μ)	0.3
Modulus of Elasticity (E)	2.1e5 MPa
Hardness (BHN)	170 HB

Table 2.Chemical Composition

Sr. No.	Element	Weight Ratio
1.	Carbon, C	0.43-0.50 %
2.	Manganese, Mn	0.60-0.90 %
3.	Phosphorous, P	$\leq$0.040%
4.	Sulfur, S	$\leq$ 0.050 %

4.2 Vehicle Nomenclature

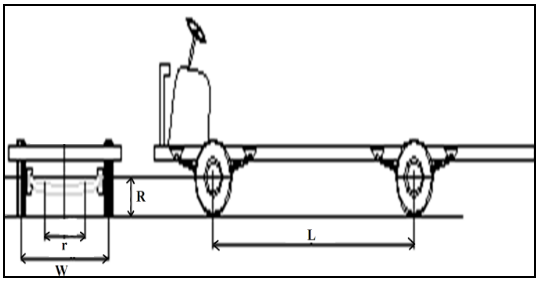

Fig. 2 Vehicle Nomenclature [6]

1. Total weight of vehicle including carrying load = 60206.95 kg
2. Gross Axle weight = 6803.88 kg
   Various dimensions are as shown in Fig. 2,
3. Dist between tire centers (W) = 2135 mm
4. Pad to Pad distance (r) = 820 mm
5. Radius of wheel(R)= 535 mm
6. Wheel base (L) = 4400 mm

4.3 Loading Condition

In actual working conditions the axle is subjected to dynamic forces so while doing analysis of front axle, equivalent dynamic condition for two loading cases are considered as follows.

Table 3. Loads for FAB Analysis [6]

Load Case	Vertical(Fv)	Braking(Fb)
Vertical	3g = 200.25	-
Vertical + Braking	2.8g = 189.9	2g = 133.5

Where, 1g = 1 x 9.81 x Axle Rating
= 1 x 9.81 x 6803.88
1g = 66.75 KN

V. FINITE ELEMENT MODEL

5.1 Preprocessing

The FE model of the complete beam axle assembly is created using UNIGRAPHICS modeling software as shown in Fig.3

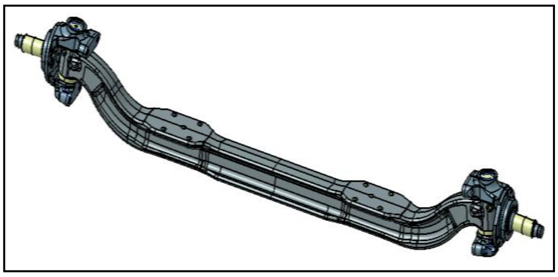

Fig. 3 Assembly of FAB

5.1.1 Meshing

In the total assembly of front axle beam, steering knuckle and kingpin are meshed with grid size 8mm because the steering knuckle and master pin are still retained and front axle meshed with grid size as a 5mm. Tetrahedral element type is used for whole assembly. In advanced sizing function proximity and curvature is ON.

The finite element model is obtained, as shown in Fig. 4

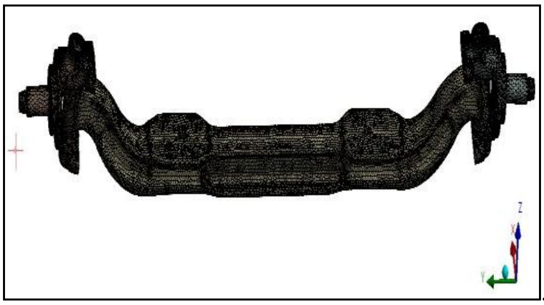

Fig. 4 Finite Element Model of Front Axle

5.1.2 Boundary and Loading Condition

Movement constraints of *X*, *Y*, *Z* directions are applied on the left support knuckle and movement constraints of *Y*, *Z* directions are applied on the right support knuckle, as shown in Fig. 5 for vertical loading case. Force applied on both pad is 100.125 KN for vertical Loading case.

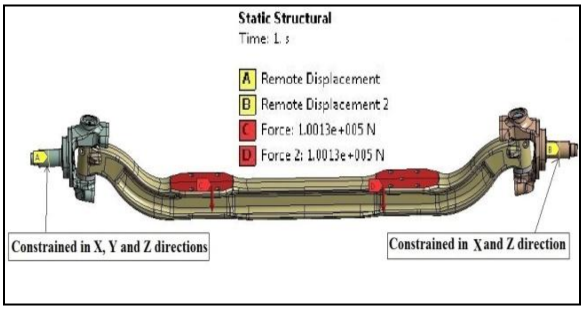

Fig. 5 Boundary and Load Condition for Vertical Case

Similarly, Movement constraints of *X*, *Y*, *Z* directions are applied on the left spring pad and movement constraints of *Y*, *Z* directions are applied on the right spring pad, as shown in Fig.6 for vertical + Braking loading case.

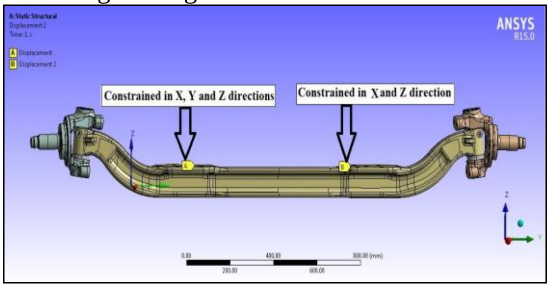

Fig. 6 Boundary Condition for Vertical + Braking Case

Vertical force applied on both left and right knuckle is 94.950 KN and Braking force applied on both knuckle is 66.750 KN which is shown in the Fig.7.

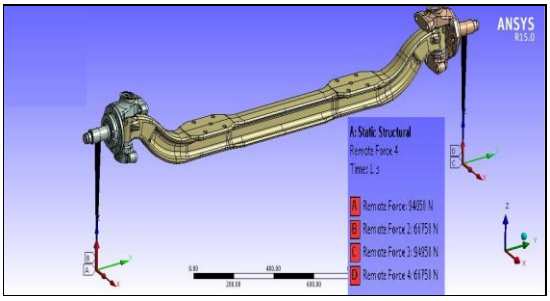

Fig. 7 Loading Condition for vertical + Braking Case

5.2 Processing

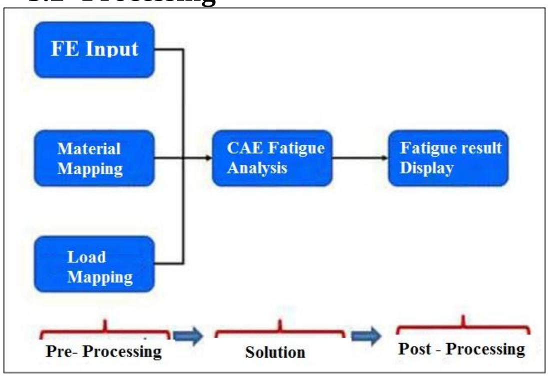

Fig.8 Basic workflow of Ncode

In this box tree, the three left boxes define the FE Input, Material Mapping, and Load Mapping as a pre-processing activity, the center box define the CAE Fatigue Analysis for solving actions, and the box on the right side define the Fatigue Results Display as a post-processing activities as shown in Fig.8.

5.3 Post Processing

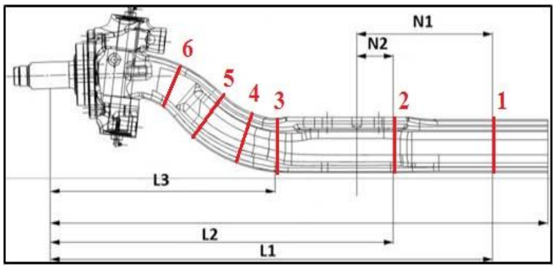

Fig. 9 Sections of FAB

For vertical loading case, section 1, 2 and 3 are considered which are shown in Fig.9.Because, high stress regions are below spring pad or middle of axle for vertical case using BMD. Similarly, section 3, 4, 5 and 6 are considered for vertical and braking loading case.

For vertical case loading, max stress region is below spring pad which is verified by FEA results as shown in the Fig.10. Life of axle is evaluated by NCODE, which is shown in Fig.11.

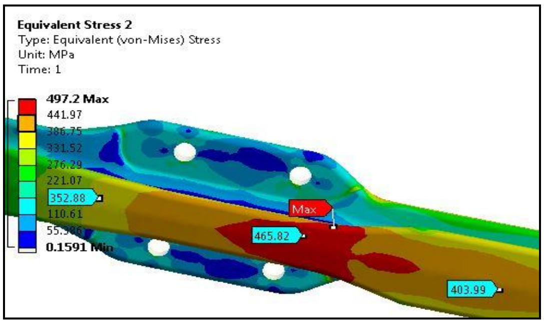

Fig. 10 Vertical Case Stress Analysis

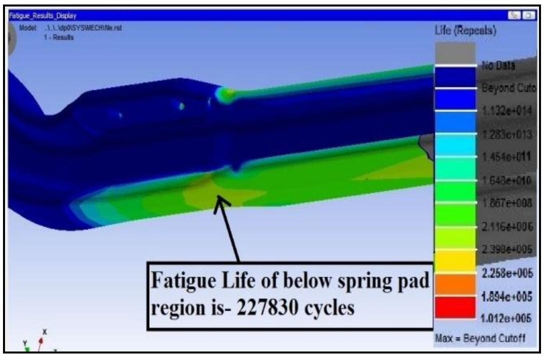

Fig. 11 Life of FAB for Vertical Case

For vertical and braking loading case, max stress region is in the goose neck of axle which is verified by FEA results as shown in the Fig.12. Life of axle is evaluated by NCODE, which is shown in Fig.13.

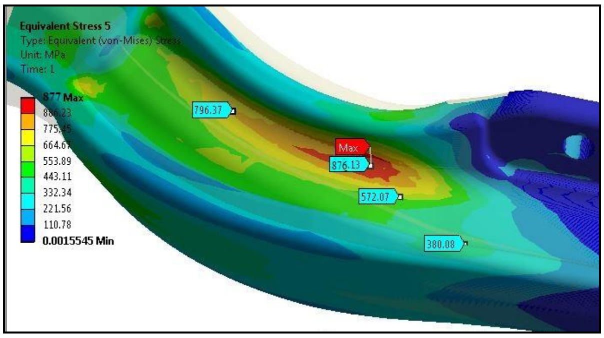

Fig.12 Vertical + Braking Case Stress Analysis

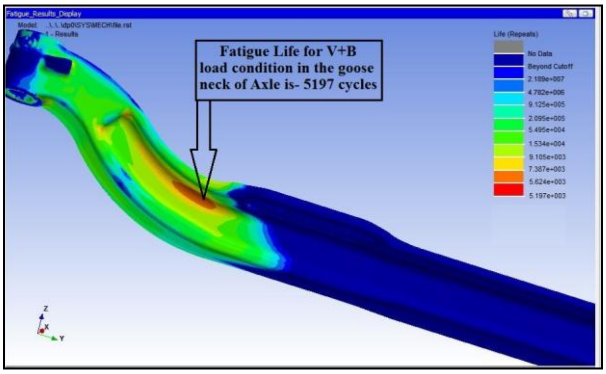

Fig.13 Life of FAB for Vertical + Braking Case

VI. RESULTS

5.1 Vertical Loading Case Results

The FEA results of vertical loading case are shown below in the Table 4.

Table 4.FEA result for Vertical Case

c/s	Vertical Fv (KN)	Von Mises Stress σ(N/mm^2)	Life (No. of Cycles)
1	100.12	403.99	227830
2		497.20	
3		352.88	

5.2 Vertical and Braking Loading Case Results

The FEA results of vertical and braking loading case are shown below in the Table 5.

Table 5.FEA result for Vertical Case

C/S	Fv(KN)	Fb (KN)	□ (N/mm^2)	LIFE (No. of Cycles)
3	94.95	66.75	380.08	5197
4			572.07	
5			877.13	
6			796.37	

VII. CONCLUSION

1) The fatigue life is more than 2 x 10^5 cycles, which is the general requirement of vertical loading case. By FEA solution method, we got fatigue life as more than 2 x 10^5 cycles, which shows design is safe (Table 4).
2) Fatigue life of axle obtained is more than 4 x 10^3 cycles, which is considered as safe for vertical and braking loading case (Table 5).
3) Under vertical loading case, maximum stress is below spring pad region. So, the life is minimum of below pad region and maximum stress region is in the goose neck of axle for vertical and braking case.

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