INVESTIGATION OF STRESSES IN REAR HALF AXLE OF AN AUTOMOBILE

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Abstract - There are many causes of half axle failure. Among them the twisting and bending stresses induced in the rear half axle under the action of rising of angular velocity and the vertical load is acting on the axle. For investigation purpose the model is considered as rear axle of bus. For analysis different cases are considered like increasing angular velocity, inclination of axle, load acting on the axle etc. As angular velocity increases the FE stresses goes on increasing because of torque is increasing. At constant speed the axle is inclined the FE stresses increases rapidly in a certain degree after that it will in the same nature. The extra load is act at the end of wheel side, the stresses goes on increasing and defection also increasing. The inclination of axle is permit below 1° to avoid chances of failure and deflection on axle is predominant. When comparing FE stresses with analytical, it is found that the good agreement is obtained at higher angular velocity. The maximum stresses are obtained at the junction of axle and gear.

Key Word: Rear axle, Gear, FEM

1. Introduction

The stresses analysis is the complete and comprehensive study of stress distribution in specimen and under study. To improve the quality of product and in order to have safe and reliable design, it is necessary to investigate the stresses induced in the component during working condition. 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.

This paper deals with the FE analysis of rear axle of an automobile .the stress analysis of rear axle is carried out under different cases such as (1) varying angular velocity under no load (2) changing the inclination of axle with geared hub. (3) Applying additional force for constant angular velocity (4)applying the constant force for various inclination of axle (5)variable angular velocity under constant force. FE analysis is carried out using ANSYS. The result of FE analysis are verified by analytical calculations.

2. Goemetrical dimensions and material properties of rear axle.

It is intended to use the same geometrical model of rear axle under identical loading condition for FE analysis and analytical estimation of stresses. The major dimensions of rear axle considered for present analysis are as followers

Diameter of shaft of axle (d) = 0.047m
Radius of gear (r_g) = 0.675m
Area of shaft (As) = 1.73x10-3 m2
Mass of shaft (ms) = 13.619 kg
Thickness of gear (t) = 0.02m
Length of shaft if axle (L) = 0.98m
Area of gear (A_g) = $7.089 x 10^{-3}$ m^2
Mass of gear (mg) = 1.113 kg
length of spline (l) = 0.07m

The material properties considered for the rear axle with the above geometric dimensions are given table 1.

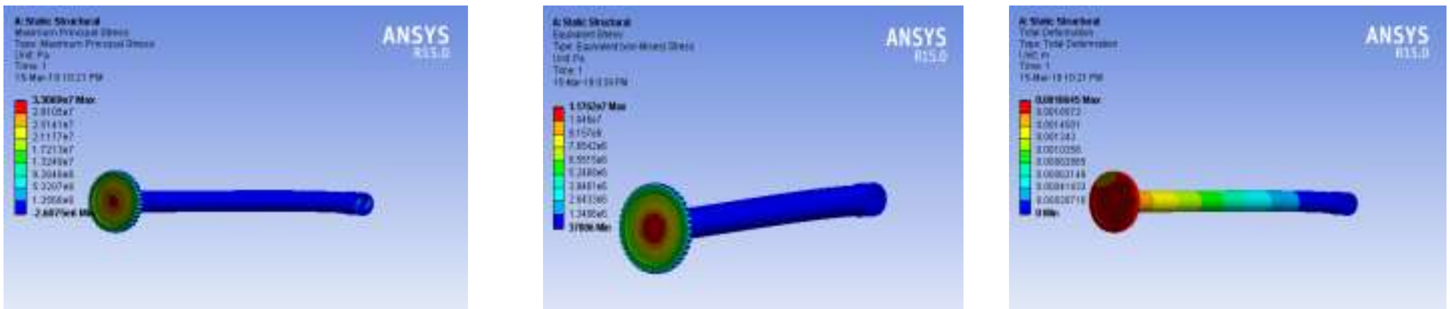
Material	Mild Steel
Ultimate strength	S_{ut} = 440 MPa S_{ys} = 370 MPa
Modulus of elasticity & Modulus of rigidity	E = 250 GPa G = 80 GPa
Density	ρ = 7850 Kg/m^3
Poisson's Ratio	μ = 0.3

3. Finite Element Analysis of Rear Axle

For FE analysis the FE model of rear half axle of bus is considered. A SOLID 72 element and tetrahedral meshing is use for FE analysis. The various cases considered for analysis are given in forth coming section.

3.1 Analysis by considering varying angular velocity under no load

The table 2 shows the comparison between analytical stresses and FE stresses. The stress variation is shown in



(a) Maximum principal (b) von-mises stress (c) Maximum deflection

Fig 3.1.1 FE stresses by varying angular velocity

Table 2 shows Von-mises stresses and Maximum principal stress for variable angular velocity

Load (ω)	Maximum Principle stress (N/m²)	Maximum shear stress (N/m²)	Von-mises stress (N/m²)	Analytical stress (N/m²)
31.41	1.3055×10^{7}	6.3474×10^{6}	1.1762×10^{7}	2.11×10^{7}
35	1.6204×10^{7}	7.8782×10^{6}	1.4599×10^{7}	2.42×10^{7}
40	2.1164×10^{7}	1.029×10^{7}	1.9069×10^{7}	2.902×10^{7}
45	2.6786×10^{7}	1.3023×10^{7}	2.4134×10^{7}	3.44×10^{7}
50	3.3069×10^{7}	1.6078×10^{7}	2.9795×10^{7}	4.059×10^{7}

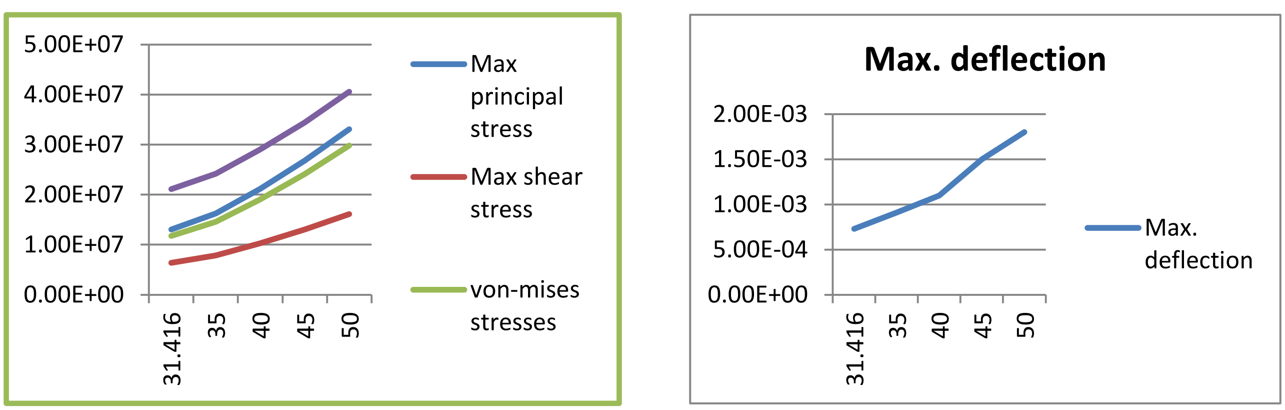


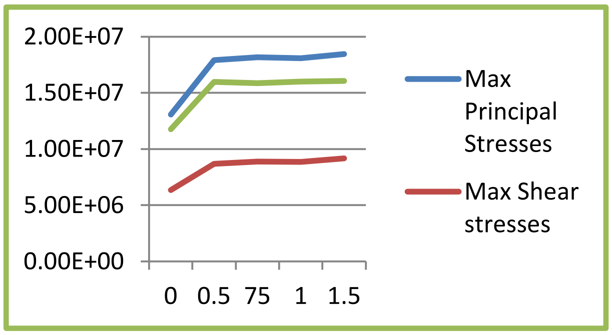
Fig 3.1.2 Variation in stresses and deflection w.r.t. angular velocity

3.2 Analysis by changing the inclination of axle with geared hub

The table 3 shows the varying inclination of axle at constant angular velocity (31.41rad/sec) & the variation in stress are as shown in figure. 3.2

Table 3 Von-mises stress and maximum principal stress for constant angular velocity of rear axle

Inclination of Axle (θ)	Maximum Principle stress (N/m^2)	Maximum shear stress (N/m^2)	Von-mises stress (N/m^2)
0	1.3055×10^7	6.3474×10^6	1.1762×10^7
0.5	1.7912×10^7	8.6732×10^6	1.5973×10^7
0.75	1.8155×10^7	8.8928×10^6	1.5868×10^7
1.0	1.8076×10^7	8.8496×10^6	1.6012×10^7
1.5	1.846×10^7	9.1678×10^6	1.6047×10^7



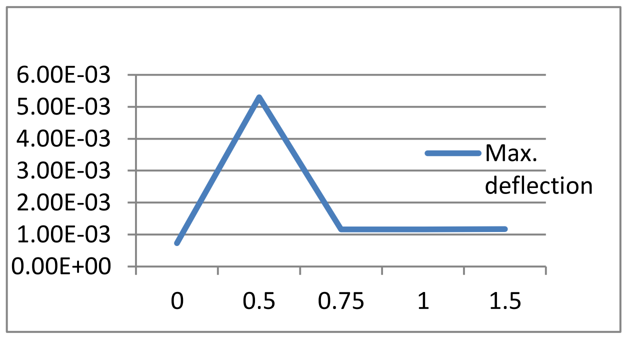


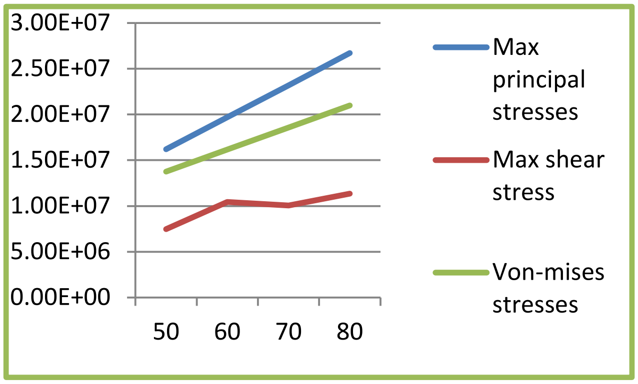
Fig. 3.2 Variation in stresses and deflection w.r.t. inclination

3.3 Analysis by applying additional force for constant angular velocity

The table 4 shows the variation of FE stresses on axle by varying the point load act on the end of the axle (at wheel end) & the variation in stresses in as shown in figure 3.3

Table 3 Von-mises stress and maximum principal stress for constant angular velocity of rear axle

Load (KN)	Maximum Principle stress (N/m^2)	Maximum shear stress (N/m^2)	Von-mises stress (N/m^2)
50	1.6199×10^7	7.455×10^6	1.3764×10^7
60	1.97×10^7	8.7542×10^6	1.6767×10^7
70	2.3203×10^7	1.0054×10^7	1.8571×10^7
80	2.6706×10^7	1.1354×10^7	2.0975×10^7



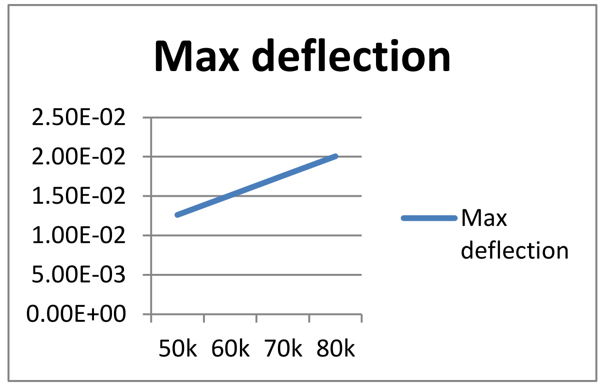


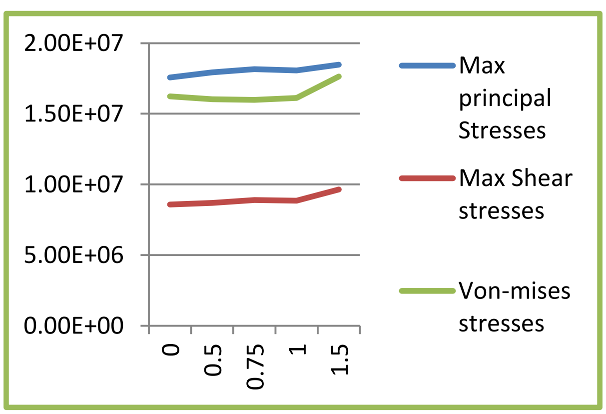
Fig3.3.Variation in stresses and deflection w.r.t. load

3.4 Analysis by applying the constant force for various inclination of axle

The table 5 shows the variation of FE stresses by varying inclination at constant point load (50KN) and angular velocity (31.41rad/sec) & the variation in stresses in as shown in figure. 3.4

Table 5 shows Von-mises stresses, Maximum deflection, Maximum Shear stress and Maximum principal stress for variable forces

Inclination of Axle (θ)	Maximum Principle stress (N/m^2)	Maximum shear stress (N/m^2)	Von-mises stress (N/m^2)
0	1.6199×10^7	7.455×10^6	1.3764×10^7
0.5	1.794×10^7	8.6869×10^6	1.6028×10^7
0.75	1.8152×10^7	8.8908×10^6	1.5972×10^7
1.0	1.8072×10^7	8.848×10^6	1.6116×10^7
1.5	1.8462×10^7	9.6464×10^6	1.7635×10^7



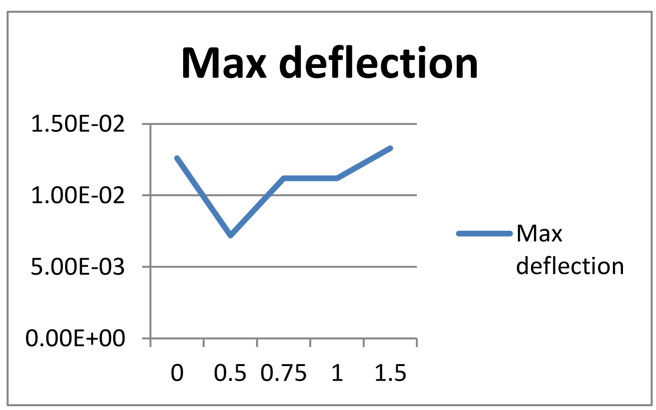


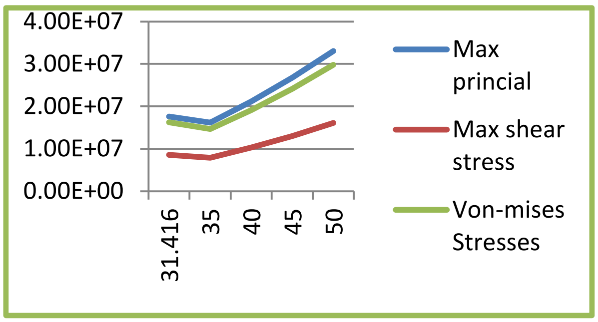
Fig. 3.4 Variation in stresses and deflection w.r.t. inclination

3.5 Analysis by variable angular velocity under constant force

The table 5.5 shows the variation of FE stresses by varying angular velocity at constant point load (50KN) & the variation in stresses in as shown in figure.

Table 6 shows Von-mises stresses and maximum principal stress for variable forces

Load (ω)	Maximum Principle stress (N/m²)	Maximum shear stress (N/m²)	Von-mises stress (N/m²)
31.41	1.6199×10^{7}	7.455×10^{6}	1.3764×10^{7}
35	1.6166×10^{7}	7.859×10^{6}	1.463×10^{7}
40	2.1126×10^{7}	1.0271×10^{7}	1.9099×10^{7}
45	2.6748×10^{7}	1.3004×10^{7}	2.4164×10^{7}
50	3.3031×10^{7}	1.6059×10^{7}	2.9895×10^{7}



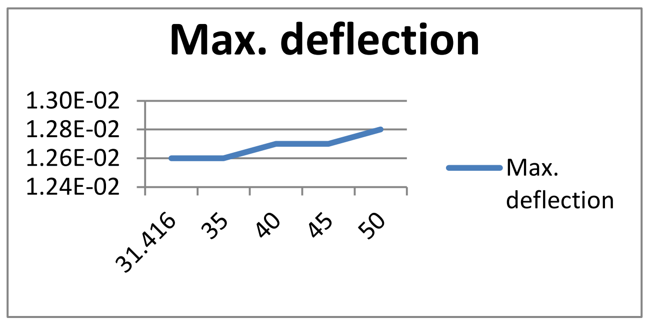


Fig 3.5 Variation in stresses and deflection w.r.t. angular velocity

4. Analytical estimation of stresses in rear axle

An effort is made to estimate the stresses in rear axle of vehicle using analytical approach as follows:
Diameter of shaft of axle (d) = 0.047m
Length of shaft if axle (L) = 0.98m
Radius of gear (r_g) = 0.675m
Area of gear (A_g) = $7.089\text{x}10^{-3}$ m²
Area of shaft (As) = 1.73x10-3 m2
Mass of gear (mg) = 1.113 kg
Mass of shaft (ms) = 13.619 kg
Fatigue bending factor (Kb) = 1
Fatigue torsion factor (Kt) = 1
Omega (ω) = 31.416 rad/s

Calculations
Maximum principal Stress for 31.41 rad/s

P_1=3035.09 W N_1=300rpm

$P_1=2\pi N_1 T_1/60$

$3035.09=2\times\pi\times300\times T_1/60$

T_1=96.61 N.m

Maximum principal stress

$M+\sqrt{M^2+T^2}=\frac{\pi}{32}\times\sigma b\times d^3$

$86.07+\sqrt{(86.07)^2 + (96.61)^2} = \frac{\pi}{32} \times \sigma b \times (0.047)^3$

σb= 2.11×10^7 N/m^2

Maximum principle stress for 35 rad/s

P_2=4745.57 W N_2=334.22rpm

$P_2=2\pi N_2 T_2/60$

$4745.57=2\times\pi\times334.22\times T_2/60$

T_2=135.59 N.m

Maximum principal stress

$M+\sqrt{M^2 + T^2}=\frac{\pi}{32}\times\sigma b\times d^3$

$86.07+\sqrt{(86.07)^2 + (135.59)^2} = \frac{\pi}{32} \times \sigma b \times (0.047)^3$

$\sigma b=2.42\times10^7$ N/m²

Maximum principal Stress for 31.41 rad/s

P_3=7651.56 W N_3=381.97rpm

$P_3=2\pi N_3 T_3/60$

$7651.56=2\times\pi\times381.97\times T_3/60$

T_3=191.29 N.m

Maximum principal stress

$M+\sqrt{M^2 + T^2}=\frac{\pi}{32}\times\sigma b\times d^3$

$86.07+\sqrt{(86.07)^2 + (191.29)^2} = \frac{\pi}{32} \times \sigma b \times (0.047)^3$

$\sigma b=2.902\times10^7$ N/m²

Maximum principal Stress for 31.41 rad/s

P_4=11300 W N_4=429.71rpm

$P_4=2\pi N_4 T_4/60$

$11300=2\times\pi\times429.71\times T_4/60$

T_4=251.14 N.m

Maximum principal stress

$M+\sqrt{M^2 + T^2}=\frac{\pi}{32}\times\sigma b\times d^3$

$86.07+\sqrt{(86.07)^2 + (251.14)^2} = \frac{\pi}{32} \times \sigma b \times (0.047)^3$

$\sigma b=3.44\times10^7$ N/m²

Maximum principal Stress for 31.41 rad/s

P_5=15810 W N_5=477.46rpm

$P_5=2\pi N_5 T_5/60$

$15810=2\times\pi\times477.46\times T_5/60$

T_5=316.25 N.m

Maximum principal stress

$M+\sqrt{M^2 + T^2}=\frac{\pi}{32}\times\sigma b\times d^3$

$86.07+\sqrt{(86.07)^2 + (96.61)^2} = \frac{\pi}{32} \times \sigma b \times (0.047)^3$

$\sigma b=4.059\times10^7$ N/m²

5. Discussion & Conclusion

It is observed from table 2 that FE stresses are maximum at the junction of gear and axle. It is compared with analytical calculations, the stresses are nearer to FE stresses while observing the maximum principal stresses & von-mises stresses. It is also seen that when the angular speed increases, the stresses are goes on increasing because torque is varying on axle.

From table 3, considering the varying inclination of axle at constant speed, it is observed that inclinations are increasing from 0^o to 1.5^o, the FE stresses are increases rapidly from $0^o$to 0.5^o then the stresses are obtain similar in nature from 0.75^o to 1.5^o, the maximum stresses is obtained at the junction of gear and axle. Similar nature of deflection of an axle is obtained. This type of the case is seen while vehicle is running.

When the vehicle is running, some extra load is act on the rear axle & this is to be considered in this case as shown in table 4. The load is increases at end of axle, it is observed the FE stresses goes on increasing while the load increases at constant speed & axle is straight.

From table 5 the inclination is varied from 0^o to 1.5^o & load is constant at the end axle (wheel end). It is observed that, for 0^o to 0.5^o the stresses are suddenly raised and it will be constant at 0.5^o to 1^o after it will be again rise at 1.5^o. The deflection of an axle from 0^o to 0.5^o it will decrease, and then suddenly rise from 0.5^o to 0.75^o then it will be constant at 0.75^o to 1^o after that it will be rise at 1.5^o from graph 3.4, the inclination of the shaft is to be permit only at 0^o to 1^o because deflection is suddenly raised after that. It is best suitable; the axle inclination is permit below 1^o to avoid chances of failure.

From table 6, when angular velocity is increasing, the stresses is also increasing on the axle, the stresses are linear from 31.416 to 50 rad/sec. the deflection is similar in nature.

From table 1 & 6, 2 & 4, the FE stresses are similar in nature and negligible variation is occurred on the axle but deflection is varying.

It is to be found that when load rises on the axle at the end (wheel) , then the deflection of axle and FE stresses increases. Also the angular velocity are increases, the FE stresses are also increases. When we compare the results of FE stresses with analytical, it is found that good agreement of higher angular speed.

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