

ANALYSIS ON THE REAR AXLE HOUSING OF HEAVY TRUCK USING ANSYS

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Abstract - An axle is a central shaft for rotating wheel. It is the important part of the vehicle. The axle may be 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. The rear drive axle is one of the most important and critical part since it bears the majority of the vehicle weight as well as houses the entire transmission components. The service life of the axle depends overall on the axle housing, shafts, drive heads, other minor and major components. Failure of these axle housing leads to breakdown of vehicles and also damage to human life. In the present work geometry of rear axle housing is created in UG NX software as per the drawing. Then the model is imported to ANSYS work bench 14 for analysis through IGES format. The purpose of these work is static structural, modal and fatigue analysis to predict the stress, natural frequency and life of rear axle housing. Result of the static structural analysis to understand the maximum and minimum loads. When rear axle housing subjected to repeated loads it leads to fatigue failure. The fatigue life axle housing should resist $5e+05$ cycles. In order to achieve the required fatigue life number of iteration has been performed. Final iterated value of fatigue life was $5.14e+05$ cycles which is greater than $5e+05$ cycles. Modal analysis has been performed for optimized rear axle housing.

Key Words: Rear axle housing, Static Structural Analysis, Fatigue analysis, Modal analysis

1. INTRODUCTION

The modes of transportation in nowadays international are via street, railways, air, water, cable, pipeline and space. Among these transportations, the road transportation is mainly used by many people. Delivery performs a vital position in financial increase and globalization. The road delivery gives entire freedom to the street users to transfer the motors from one lane to any other lane and from one avenue to another avenue in step with their want and handy. This type of flexibility of modifications in place, course, speed, and timings of journey isn't always viable to any other modes of transport. Handiest through avenue transportation, it is possible to offer door to door carrier. Motors afford extra flexibility with low potential but require higher strength and greater utilization region. The transport may regard the intermediate exchange of car, within or throughout modes, together with a bus or railway station.

2. OBJECTIVES

The main objective of this work is to analysis the automobile rear axle housing. This is achieved through the following set of objectives:

- Modeling of axle housing using UG NX 11 and use of ANSYS workbench 14 for analysis.
- To study of static structural analysis of the rear axle housing to understand the maximum and minimum loads.
- To study on fatigue analysis of the rear axle housing to find the fatigue life.
- Necessary design changes will be adopted to attain the required fatigue life ($>5e+05$ cycles) of the rear axle housing.
- Modal analysis to find out the natural frequency of the optimized rear axle housing.

3. METHODOLOGY

1. Creating 3D model of rear axle housing using UG NX 11.
2. Model is imported to ANSYS workbench 14 for the analysis.
3. Mesh and applying boundary conditions
4. Static structural analysis to understand maximum and minimum loads
5. Fatigue analysis for optimizing the model by increasing the thickness to attain the required life ($>5e+05$ cycles)
6. Modal analysis for optimized rear axle housing.

4. MATERIAL PROPERTIES

TABLE 1: Properties of material

Material type	Structural steel
Poisson's ratio(μ)	0.3
Young's modulus(E)	200 GPa
Density(ρ)	7850 kg/m ³
Yield strength(σ_y)	497.5 MPa
Ultimate strength(σ_{ut})	629.9 MPa
Allowable stress	170 MPa

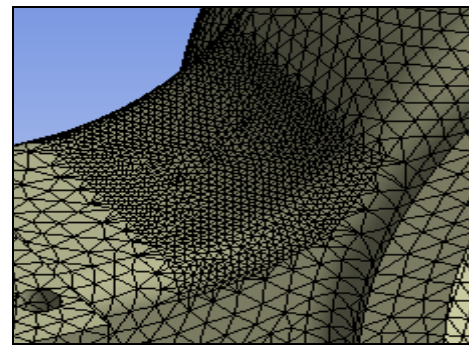


Figure 3: Detailed view of meshing

The above figure shows the meshing detailed views, in the analysis the axel housing is meshed with tetrahedral. Fine mesh has been created at high stress region as shown in the figure 3. The element size is 6 mm. Number of elements are 139122 and the Number of nodes is 245084.

5. MODEL OF REAR AXLE HOUSING

The 3D model of the rear axle of a heavy truck is modeled using UG NX 11. Figure shows 1.

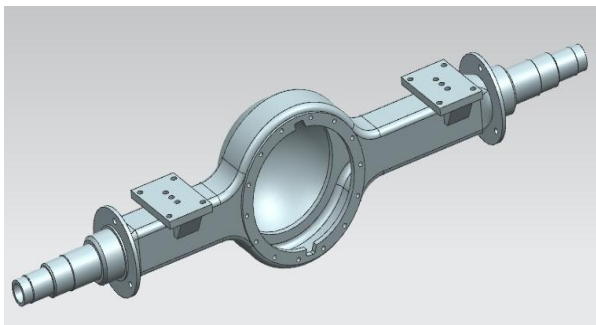


Figure 1: 3D Model of rear axle housing

5.1 MESH GENERATION FOR 3D MODEL

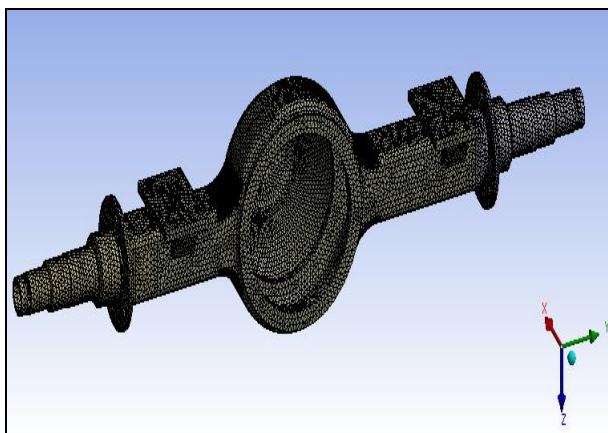


Figure 2: Meshed model

5.2 BOUNDARY CONDITIONS

The two ends are fixed completely. The load is applied on the either end of the spring seat and in $-XC$ direction as shown in figure 4. Boundary conditions are applied with the two different load cases. Total load acting on the rear axle which is divided in to two half and then applied on the either ends of the spring seat.

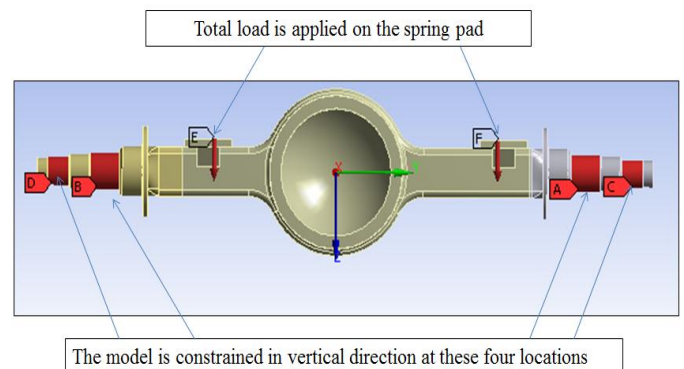


Figure 4: Applied boundary conditions

6. RESULT AND DISCUSSION

- **Case 1- Maximum load case:** The total weight coming on axle housing is 30 kN when the truck is fully loaded to capacity and this load is considered for the analysis. Static structural, modal and fatigue life has been performed.
- **Case 2- Minimum load case:** The minimum weight is 20 kN due to own body weight of the truck. Again here, the load is considered for the analysis. The analysis is carried for this minimum load condition to find minimum stress in the axle.

Case 1:

6.1 static structural analysis: The structural analysis is carried out by considering the two cases that is maximum loading conditions and minimum loading conditions as followed below,

- **Equivalent stress (von-mises):**

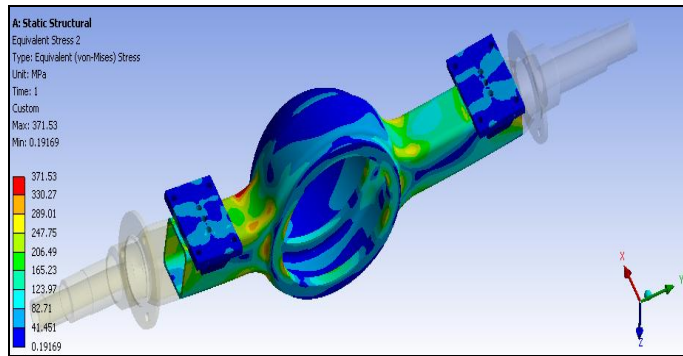


Figure 5: Equivalent stress

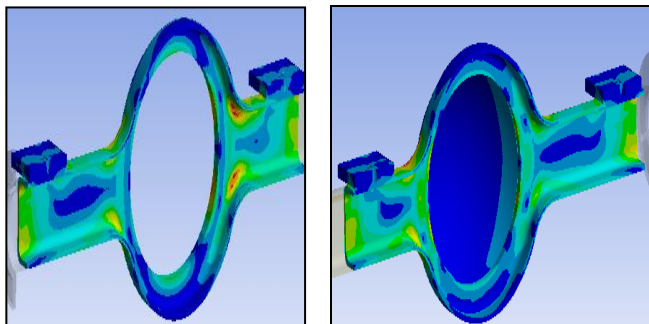


Figure 6: Stress distribution inside the axle housing

- **Maximum principal stress**

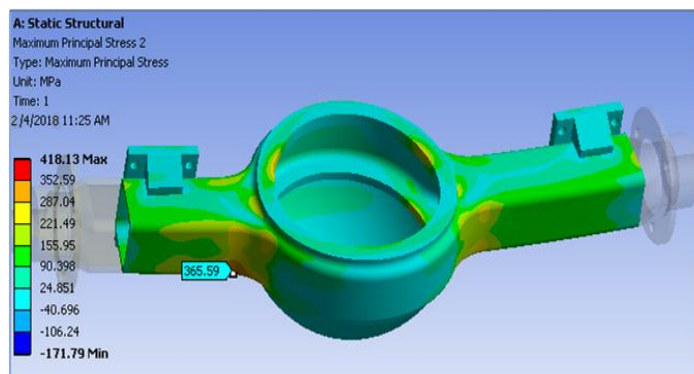


Figure 7: Maximum principal stress

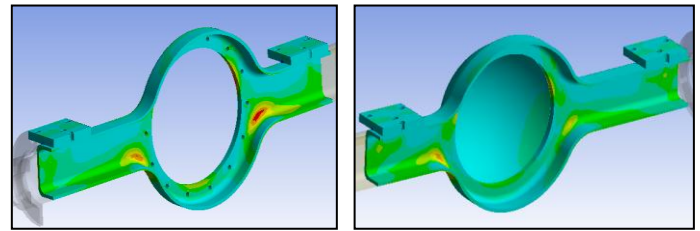


Figure 8: Stress distribution inside the axle housing

Minimum principal stress

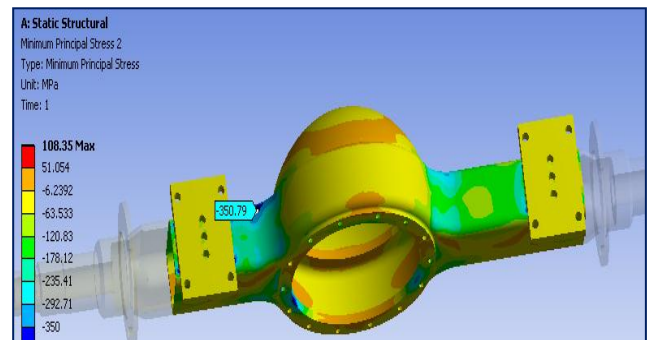


Figure 9: Minimum principal stress

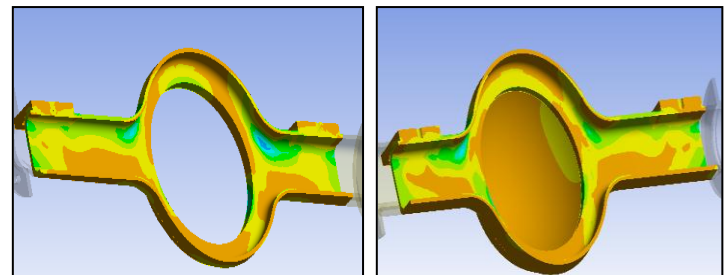


Figure 10: Stress distribution inside the axle housing

Case 2:

- **Equivalent stress (von-mises):**

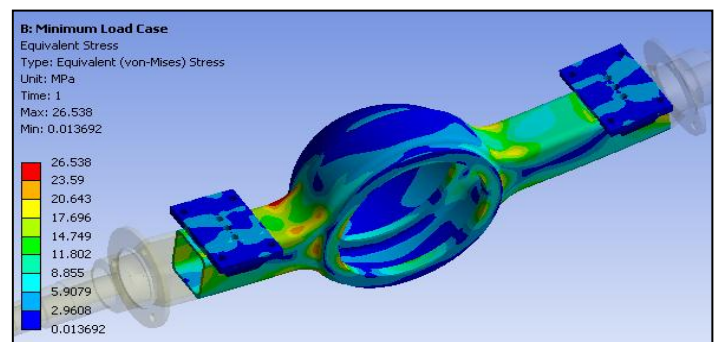


Figure 11: Equivalent stress

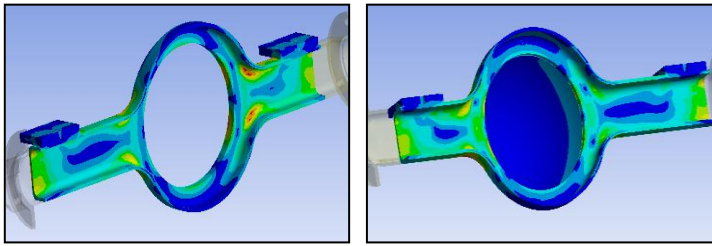


Figure 12: Stress distribution inside the axle housing

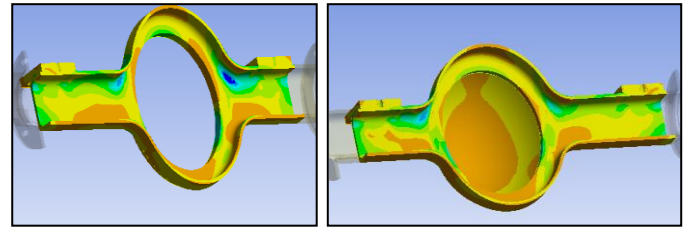


Figure 16: Stress distribution inside the axle housing

• Maximum principal stress

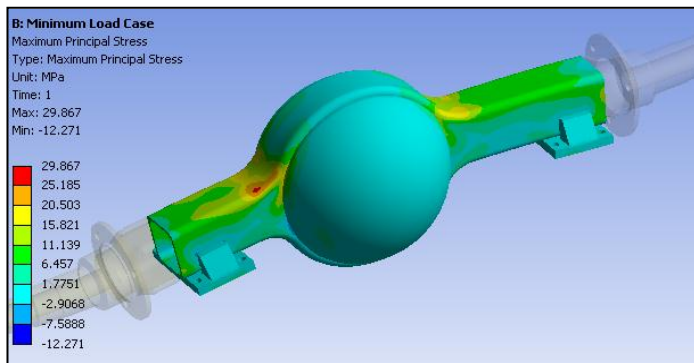


Figure 13: Maximum principal stress

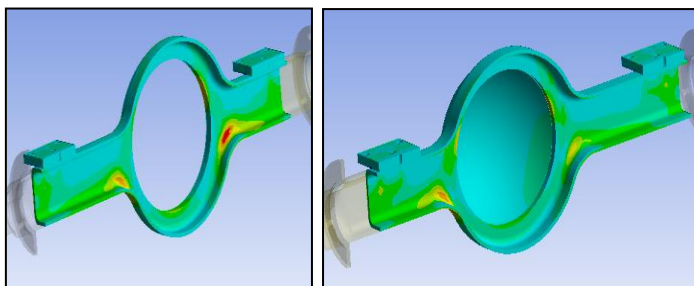


Figure 14: Stress distribution inside the axle housing

• Minimum principal stress

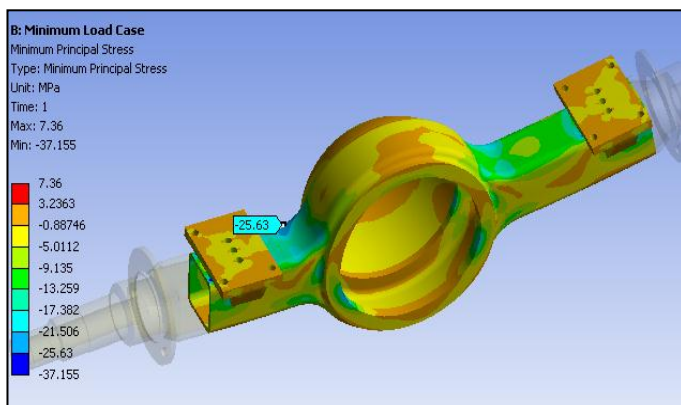


Figure 15: Minimum principal stress

6.2 Fatigue life for maximum load case

The fatigue analysis is performed by using a fatigue tool. Initially the type of approach for the analysis is selected, i.e., stress-life approach. The boundary conditions are applied. i.e., type of loading – zero based stress, Mean stress theory – Goodman’s approach is selected, and the equivalent stress is considered as the stress component. Then the model is solved and results are noted. The result shows the fatigue life in number of cycles.

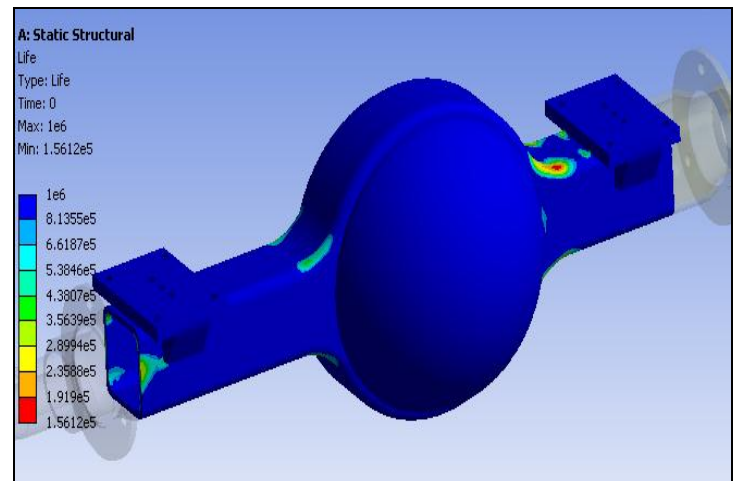


Figure 17: Fatigue life

- The number of cycles to failure at high stress region is 156120 cycles. The cycles to failure obtained is less than the design fatigue cycle of 5e+05 cycles.
- The blue region shows the infinite number of cycles.
- The design changes are required to achieve fatigue cycles.

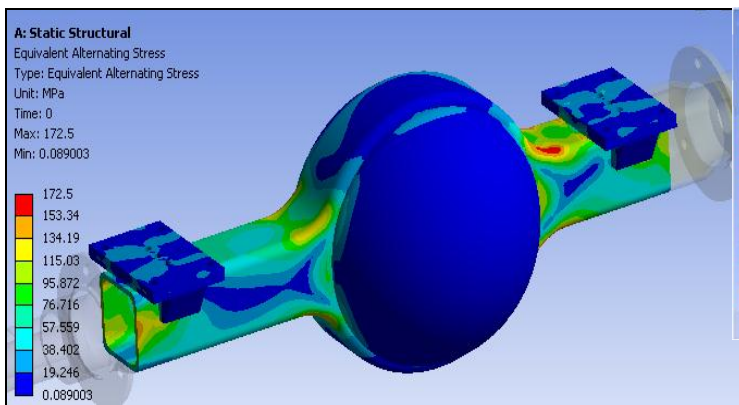


Figure 18: Equivalent alternating stress

6.3 Design Optimization for maximum load case

From the static structural analysis it is observed that von-mises stress of 371.53 MPa was observed between dome and rectangular section. The fatigue life for this design is 1.56×10^5 cycles at high stress region but the fatigue life is less than the required life (5×10^5 cycles). So the design iteration has been carrying to achieve the required life by increasing the thickness. Figure 19 shows that thickness is added at high stress region (between the dome and the rectangular section).

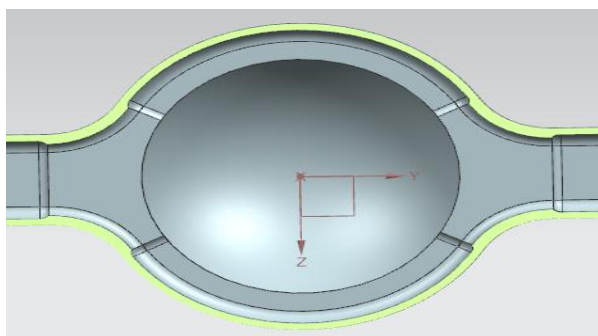


Figure 19: Thickness added

a) Baseline design

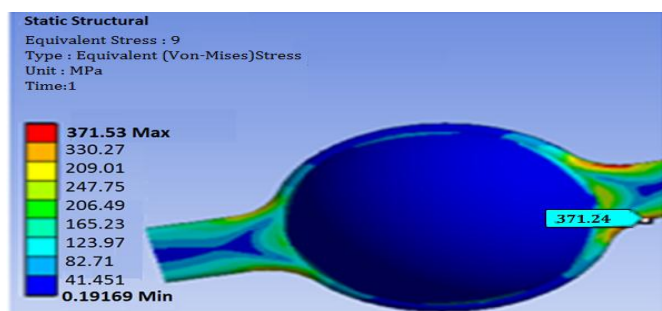


Figure 20: 10mm thickness of von mises stress

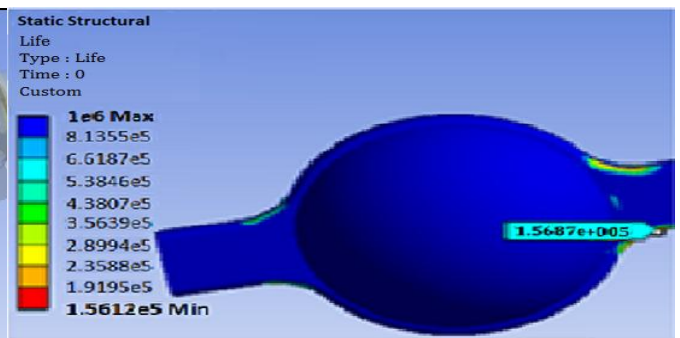


Figure 21: 10 mm thickness of fatigue life

The initial design of rear axle housing was having 10mm thickness. The von-mises stress of 371.53MPa was observed between dome and rectangular section. The fatigue life for this design is 1.56×10^5 cycles at high stress region. The von-mises stress was less than yield stress (497.5MPa) but the fatigue life is less than the required life (5×10^5 cycles). The design iteration was carried out to achieve required cycles.

b) Design Iteration 1

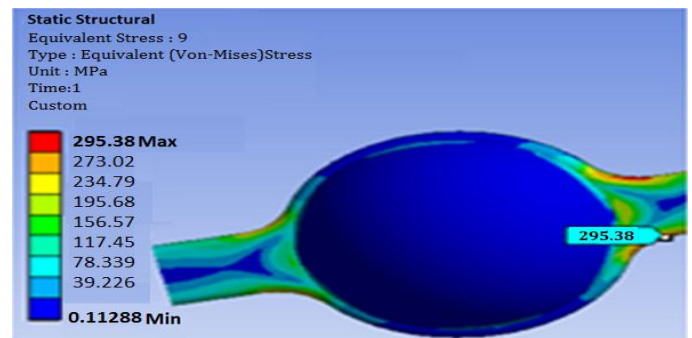


Figure 22: 12mm thickness of von mises stress

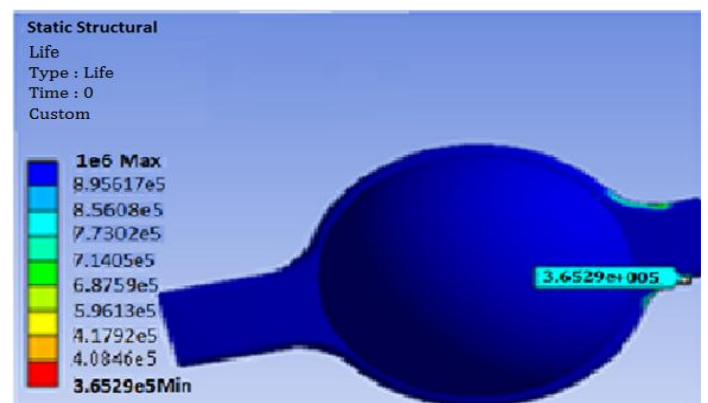


Figure 23: 12 mm thickness of fatigue life

In this iteration, 2mm thickness was added at the high stress region. The obtained von-mises stress is 295.38MPa and fatigue life is 3.65×10^5 cycles which are still less than the required life.

c) Design Iteration 2

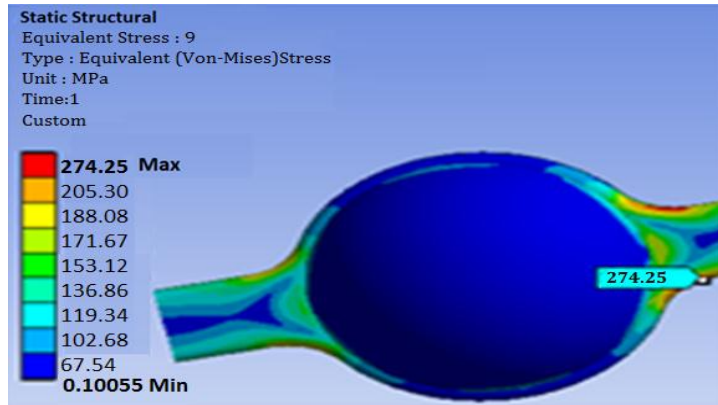


Figure 24: 15mm thickness of von mises stress

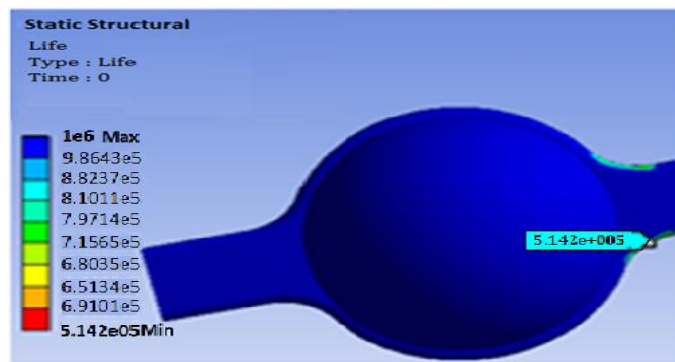


Figure 25: 15 mm thickness of fatigue life

The thickness was increased to 5mm. In this design the required number of fatigue life was achieved. The von-mises stress observed is 274.25MPa and fatigue life was 5.14e+05 cycles.

6.4 Modal analysis

Modal analysis has been performed for optimized and safe design as shown in the figure

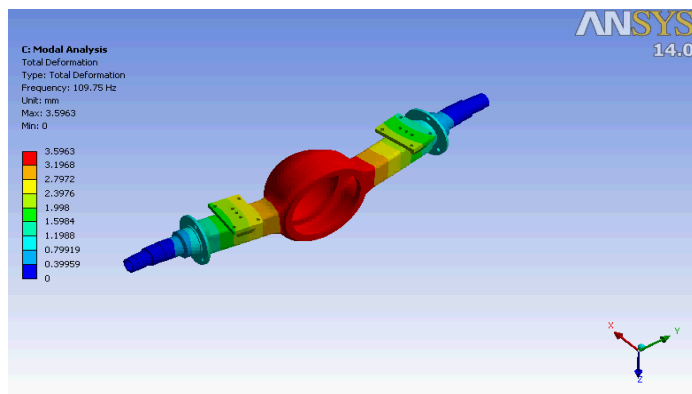


Figure 26: First mode shape

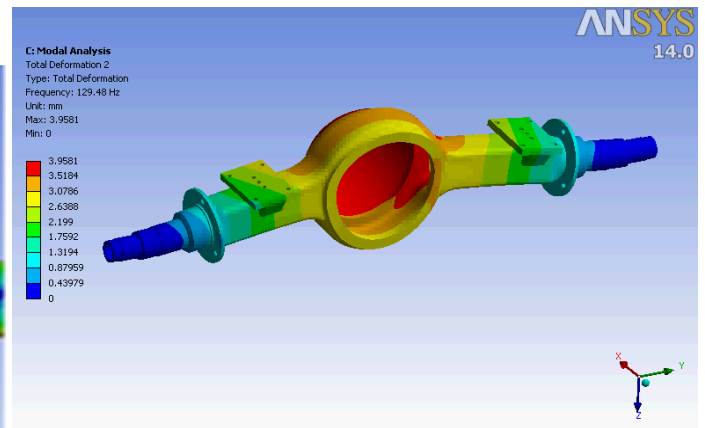


Figure 27: Second mode shape

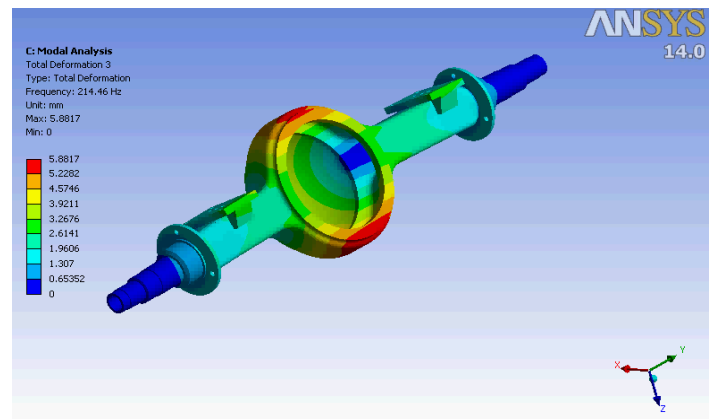
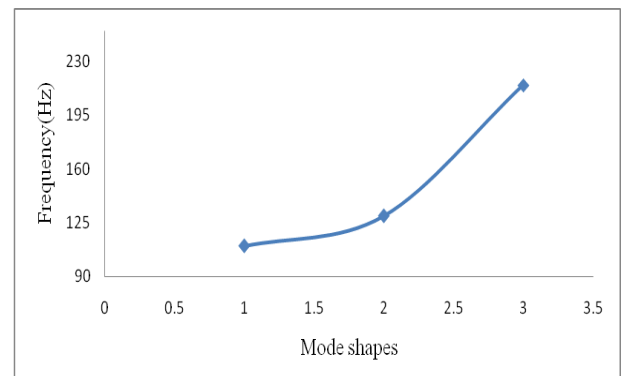


Figure 27: Third mode shape

Table 2: Mode shape and frequency of rear axle housing

Modes	Frequency(Hz)
1	109.75
2	129.48
3	214.46



Graph 1: Mode shapes v/s frequency

7. CONCLUSIONS

- In the baseline design, the static stress observed for maximum load case is 371.24 MPa which is less than the yield strength of 497.5 MPa. The fatigue life should be greater than $5e+05$ cycles, but the obtained life is $1.58e+05$ cycles which is less than the required fatigue life. The design iterations were carried out to increase the fatigue life.
- In the first design iteration, 2mm thickness was added at the high stress region. The maximum von misses stress observed is 295.38MPa and the fatigue life at this region is $3.65e+05$ which are still less than the required life.
- The fatigue life at the high stress region obtained is $5.14e+05$ after increasing the thickness to 5mm. The maximum von misses stress for this design iteration is 274.25MPa.
- Modal analysis will be carried out to find the natural frequency of the optimized rear axle housing which is well above the exciting frequency. Hence there is no chance resonance.

7.1 Scope for the future work

As extension of present work, the following studies may be carried out in future:

- The study can be extended for the evaluation of rear axle lives by experiment investigation.
- Harmonic and transient dynamic analysis can be extended.

All these options are presenting to the designer to enable him to make a decision based on manufacturing on other constraints. Although solution seen to be a good result.

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