Design Optimization of Automobile Rear Axle Housing for Fatigue Loads using Finite Element Analysis

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Abstract— Rear axle housing takes the load of chassis through leaf spring arrangement. Also houses the differential and rear axle drives. The housing is subjected to various structural loads during movement of automobiles. Now-a-days design optimization is becoming important in the analysis as the cost plays an important role in the overall cost of the structure along with higher dynamic effects with heavier structures. Fatigue is the failure of the structures under repeated loads. Due to road conditions, the rear axle housing is subjected to flexuating loads continuously. In the present work, a Rear axle housing used for a truck system will be initially analysed for static loads. This check allows the problem for minimum static structural strength. Later the housing will be analysed for fatigue loads. The weak regions of the rear housing will be identified and suggestions will be done to improve the structure. Final iterated value of 79Mpa is close to the allowable limit of 86.3Mpa of the given material. All the results are represented with necessary graphical plots.

Key words: Rear axle housing, static and modal analysis, Fatigue failure, finite element analysis

I. INTRODUCTION

The rear axle and the differential are completely encompassed in the axle housing. This housing shields rear axle and differential from water dust etc. and also acts as a vessel for lubricant for lubrication purpose. An example for axle housing is shown in the figure1.1 below. It supports the inner bearings and springs and parts of the brake assembly. On top of the rear axle housing there is a spring seat. A filter and drain plug is provided for filling and removing the gear oil. A variety of materials is used for making the axle housing and those materials would be pressed steel, cast steel, malleable iron, cast aluminium or forging steel.

A live axle is a shaft or a kind of beam axle suspension system that connects laterally the two wheels of the vehicle rotated along with the axle. If the vehicle is a front wheel drive vehicle then rear axle will be considered as a dead axle. The dead axle used in most of the trucks and trailers is mainly for the load bearing purpose.

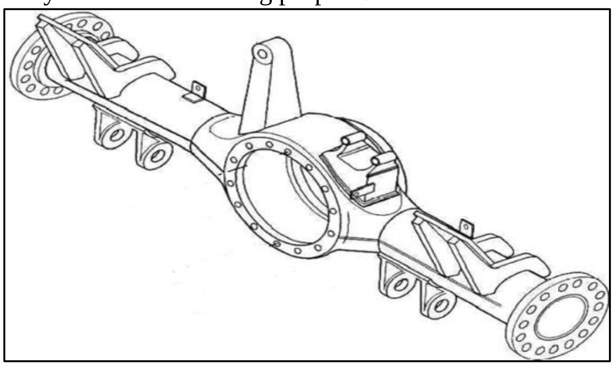

Fig. 1: Axle Housing

A. Different Types of the Axle Housing

1) Spilt Type

In split type of axle housing two halves are used to make axle casing and then they are assembled together by bolts. The major disadvantage of this type is that in case of any fault, the rear axle as a whole need to be detached as a single unit and then disassembled. This type of axle housing is no more in use. A split type of axle housing is shown in figure below.

2) Banjo Type or Separate Carrier Type

As the name indicates it is Banjo shaped. It is one-piece type of axle housing. Axle casing and differential are separated. A separate carrier is used for differential and this is bolted to the axle casing. The two halves shafts are positioned from the sides. The advantage of this type is that in case of repair, only the damaged half shaft can be detached from side directly without disturbing other side and also differential assembly can be opened only by opening the bolts.

3) Salisbury or Integral Carrier Type

This type of axle housing is similar to the Banjo type of axle housing in construction. The only difference is that it differs in the carrier. The permanent housing tubes pressed and welded in sides is seen in the differential housing.

II. 3D MODEL OF REAR AXLE HOUSING

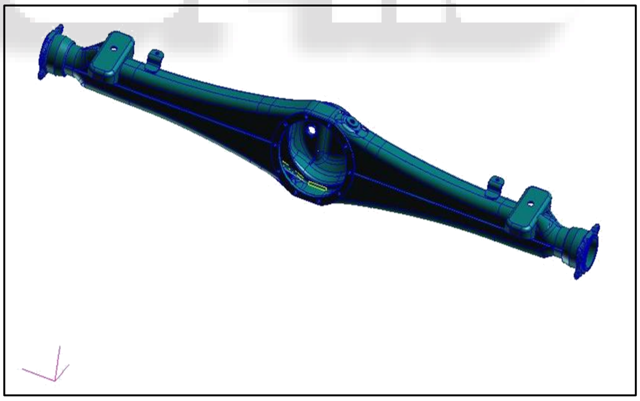

Fig. 2: CAD model of the Rear Axle Housing

The figure 2.1 shows three dimensional modeling of the problems. The geometry is built using Catia software using sketcher, part model and assembly options.

III. MATERIAL PROPERTIES

Properties	Structural Steel
Young's Modulus	200Gpa
Poison's ratio	0.3
Yield Stress	420Mpa
Density	7850kg/m3
Allowable Stress	170Mpa
Operational Frequency	40 Hz

Table 1: Material Properties

IV. FINITE ELEMENT MODEL OF THE REAR AXLE HOUSING

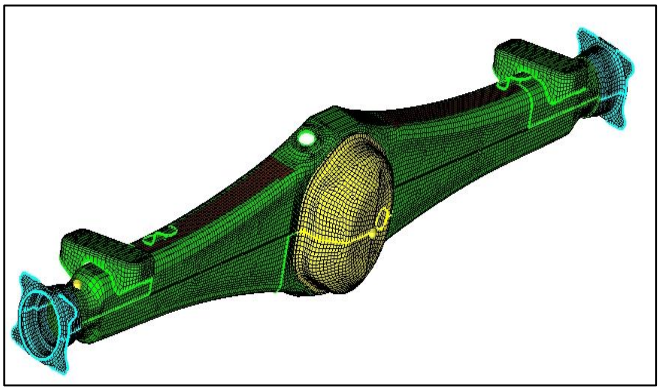

Fig. 3: Meshed Model of the Rear Axle Housing

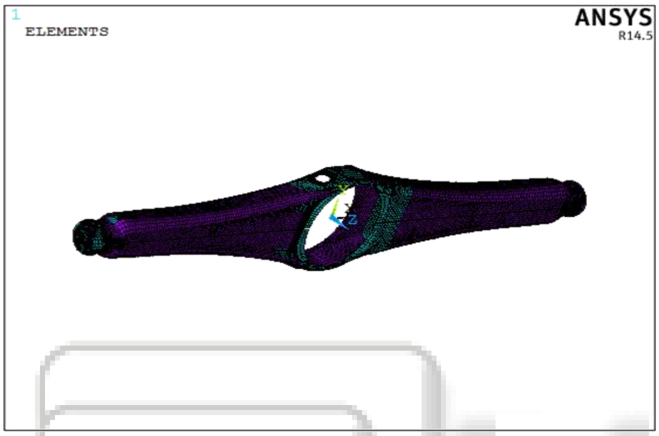

Fig. 4: Shell Region

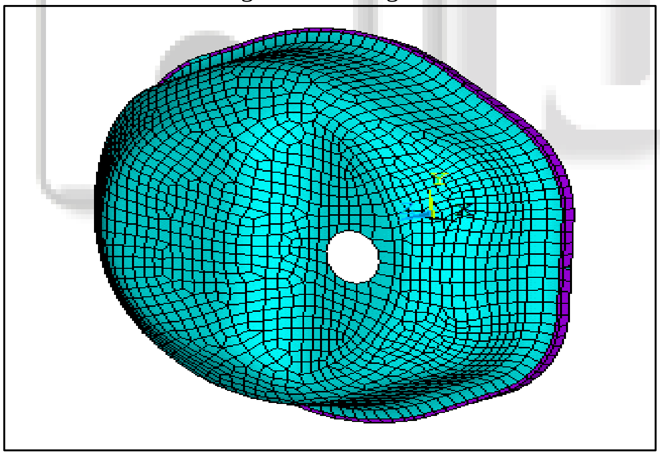

Fig. 5: Closed up view of Dome

The rear axle housing is meshed with two dimensional shell elements. Initially the geometry is imported to Hypermesh in step file format and later mid surfaces are extracted. The mid surface is split to form 4 node quad elements. 4 node quad elements have better accuracy compared to the three node elements. The elements are grouped based on their size of the structure. The different components are created to find the region of stress concentrations and variations. Total 22942 of elements and 24349 nodes are used for meshing. Generally, accuracy depends on the type of mesh of the problem.

V. NUMERICAL ANALYSIS

Analysis for rear axle housing has been carried out in 2 stages. Initially the meshed structure is imported to Ansys for further analysis in 'inp' file format. The following cases of analysis are carried out.

- Self-weight analysis of the rear axle housing.
- Fatigue analysis for the problem.

The results are represented for displacements and stresses for structural safety. Generally, a structure safety is decided by the amount of displacement and stress and so the stress and deformation results are presented to decide safety of the problem

A. Case 1: Self Weight Analysis

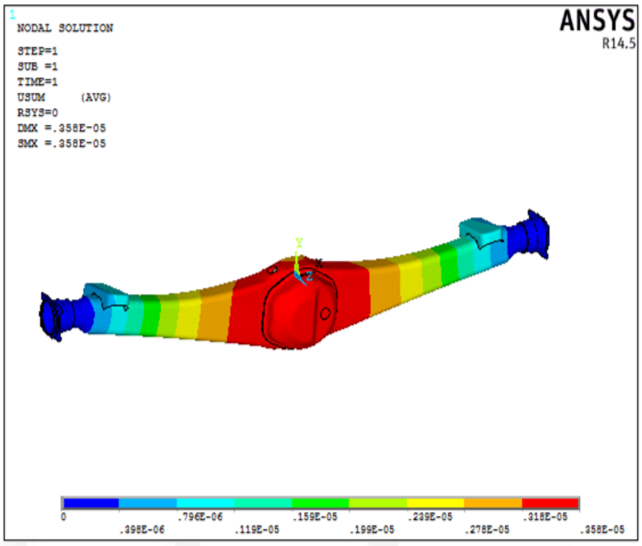

Fig. 6: Deflection due to self-weight of Rear Axle Housing (0.00358mm)

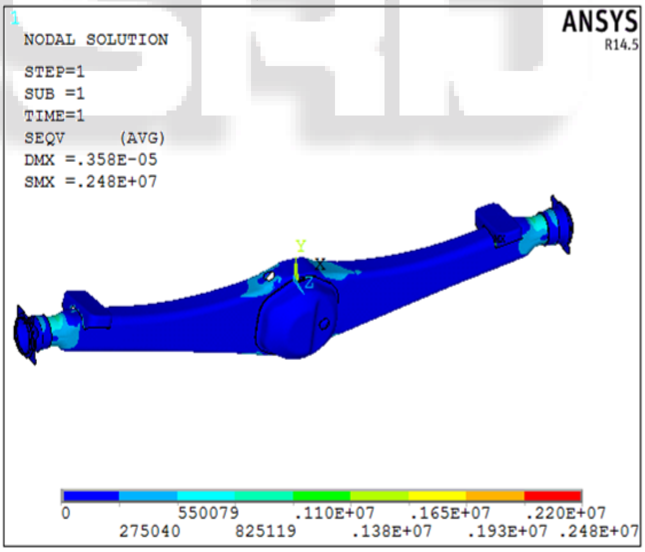

Fig. 7: Vonmises stress due to self- weight of Rear Axle Housing (2.48Mpa)

B. Case2: Fatique Analysis

The figure 5.3 shows vonmises stress developed for the minimum load. The maximum stress is around 54.9 Mpa as shown in the figure. The vonmises stress can be defined as the stress corresponding to the stored strain energy and also it is called as equivalent stress and is the main criteria for failure prediction of engineering components.

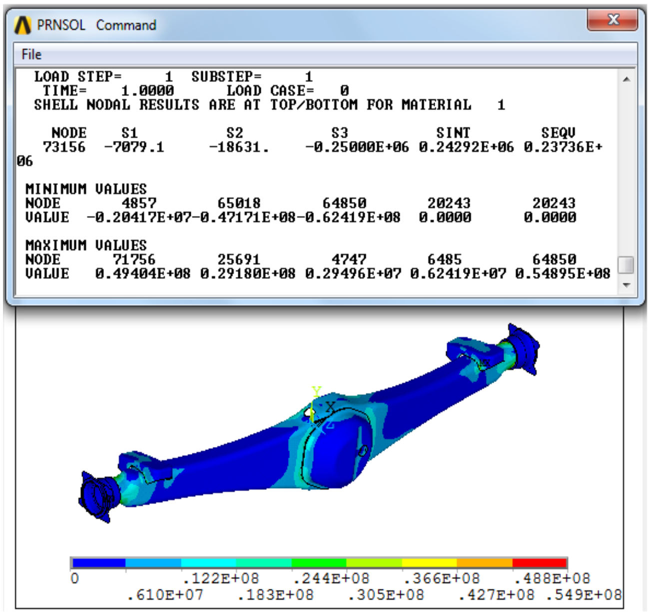

Fig. 8: Vonmises Stress for minimum Load

C. Case2.1: Fatigue Data for S-N Curve

For fatigue analysis, SN curve data is very important to find the life of the members subjected to cyclic loads. And S-N curve for the given material is as follows.

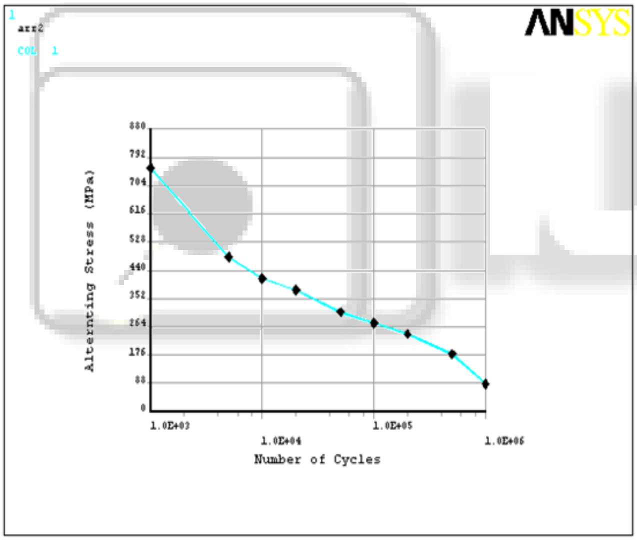

Fig. 9: S-N curve for the Material

Figure 5.4 represents the S-N curve for the material which shows that as the number of cycles increases allowable fatigue stress reduced, 86.2 N/mm^2 is the fatigue limit equivalent to one million or 10 lakh cycles.

D. Case2.2: Design Optimisation and Alternating Stresses

Iteration	Dome	Shell	Wheel Housing	Bracket	Weight	Alternating Stress
1	4	14	16	20	356	4.13
2	3.5	12	12	15	290	21
3	3	10	11	12	252	38
4	3	9	9.5	11	225	56
5	3	8.5	9	10	215	62
6	3	8	8.5	9.5	211	78

Table 2: Design Optimisation and Alternating Stresses

E. Case2.3: Final Set Results for Optimization

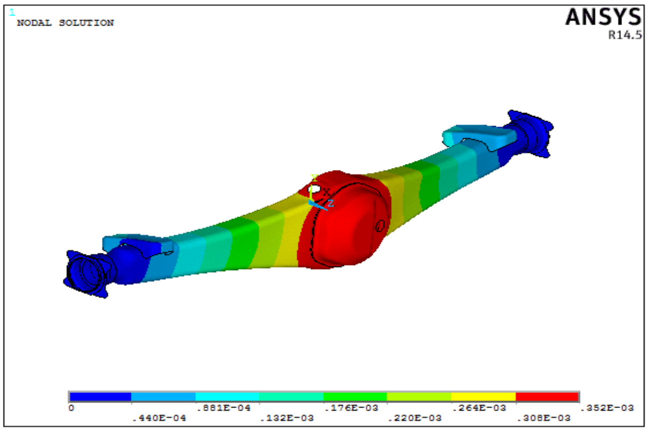

Fig. 10: Deformation in the Rear axle housing for maximum load after Design Optimization

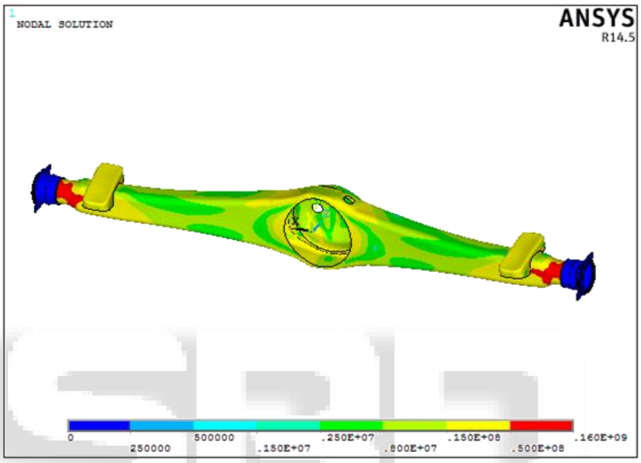

Fig. 11: Vonmises Stress for the Maximum Load (Maximum stress: 160Mpa) after Design Optimization

VI. RESULTS

Parameters	Without optimisation due to self-weight	With optimisation due to self-weight
Vonmises stress(Mpa)	2.48	160
Deformation(mm)	0.00358	0.352

Table 3: Overall Comparison of the Parameters

VII. CONCLUSIONS

Rear axle housing is modeled and analysed for fatigue optimization. The analysis summary is as follows.

- Self-weight analysis is carried out to determine deformation and stress.
- The fatigue evaluation tool has given fatigue value of 4 Mpa which is less compared to the allowable fatigue limit.
- So design optimization is carried out by grouping the different components like, shell, dome, brackets and wheel housing. All the results are represented in the table form.

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