

Structural Design and Stress Analysis of a Front Axle for A 4gnr Heavy Commercial Vehicle

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Abstract—Front axle carries the weight of front part of the Automobile, as well as facilitates steering and absorbs shocks due to road surface variations. The front axle is designed to transmit the weight of the Automobile front the spring to the front wheels, turning right and left as required. So proper design of front axle beam is extremely crucial. The paper deals with design and analysis of front axle. The same analysis with help of FE results were compared with analytical design. For which paper has been divided in to two steps. In the first step front axle was design by analytical method. For this vehicle specification – its gross weight, payload capacity, braking torque used for subject to matter to find the principle stresses & deflection in the beam has been used. In the second step front axle were modelled in CAD software & analysis in ANSYS software

Index Terms—Front Axle Design, Heavy Commercial Vehicle (HCV), Structural Analysis, Finite Element Analysis (FEA), Stress Distribution, Static and Dynamic Loading, Vehicle Suspension System, Fatigue Life Estimation

I. INTRODUCTION

An auto industry is one of the important and key sectors of the Indian economy. The auto industry includes of automobile sector, auto components sectors and includes commercial vehicles, passenger cars, multi-utility vehicles, two wheelers, three wheelers and related auto parts. The demands on the automobile designer increased and altered rapidly, first to meet system safety needs and later to reduce weight so as to satisfy fuel economy and vehicle performance requirements. Engine location important to provide greater stability and safety at high speeds by lowering the center of gravity of the road vehicles; the complete center 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 supported vertically upward at the ends (at the centers of the spring pads).

Under the dynamic conditions, vertical bending moment is increased due to road roughness. Thus it is very difficult to find the crack propagation in short time. So it is necessary to incorporate finite element methodology. During the operation on vehicle, road surface irregularity causes cyclic fluctuation of stresses on the axle, which is the main load carrying member. Therefore it is necessary to make sure whether or not the axle resists against the fatigue failure for a predicted service life. Axle experiences completely 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 vehicle goes on the bump. Performing physical test for vertical beaming fatigue load is expensive and time consuming. So there is a necessity for building FE models which may virtually simulate these loads and can predict the behavior. Even though the FEA produce fairly accurate results, solution accuracy heavily depends on accuracy of input conditions and overall modeling methodology used to represent the actual physics of problem. Therefore validation of FEA model is of utmost importance. 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 vehicle specifications, its gross weight and payload capacity in order to find out the stresses and deflection within the beam has been used. In the second step front axle were modelled in Pro-e. The cad model was solved in ANSYS software system. The FE results were

compared with analytical design

II. PROBLEM IDENTIFICATIONS

1. High Structural Loads in Commercial Vehicles

The front axle in heavy commercial vehicles like the 4GNR is subjected to high loads due to curb weight, payload, braking, cornering forces, and road irregularities. Improper design can lead to structural failure or reduced service life.

2. Complex Stress Distribution

The axle experiences complex stress combinations, including bending, torsion, and shear. An inaccurate understanding of stress distribution may result in over- or under-designed components, affecting performance or safety.

3. Fatigue Failure Risk

Continuous exposure to dynamic and cyclic loads can cause fatigue failure over time. Detecting fatigue-prone areas early in the design process is essential for ensuring long-term reliability.

4. Limitations of Traditional Design Methods

Analytical methods, while helpful, are often insufficient for predicting real-world behavior under complex loading. They may not capture detailed stress concentrations or localized effects.

5. Cost and Time Constraints of Physical Testing

Physical testing of axles under various loading scenarios is expensive and time-consuming, making it impractical to iterate multiple design alternatives.

6. Need for Accurate Simulation and Validation

Finite Element Analysis (FEA) is a powerful tool, but its accuracy heavily depends on correct input parameters, boundary conditions, and validation against real-world or analytical data.

7. Material Selection Challenges

Choosing the right material that balances strength, weight, cost, and manufacturability is a challenge, especially under varying environmental and load conditions.

8. Safety and Regulatory Compliance

The axle must meet stringent safety standards and regulations, making accurate stress analysis and design validation critical.

9. Service Life Prediction

A lack of precise data or simulation models may lead to incorrect predictions about axle service life, increasing the risk of in-service failures

III. METHODOLOGY

The research methodology outlines the systematic approach adopted to design and analyze the front axle of a 4GNR heavy commercial vehicle. It includes a combination of theoretical, computational, and comparative methods to ensure accuracy, reliability, and applicability of the design.

Analytical Design Approach

- Apply fundamental engineering equations to:
- Calculate bending moment, shear force, and stress
- Determine deflection under load
- Use these results as a baseline for validating the FEA model.

CAD Modeling

- Develop a detailed 3D model of the front axle using CAD software (e.g., Creo, SolidWorks).
- Ensure dimensional accuracy based on analytical design and vehicle integration requirements.

Finite Element Analysis (FEA)

- Import CAD model into ANSYS or similar simulation software.
- Define:
 - Material properties
 - Boundary conditions
 - Loading scenarios (e.g., vertical load, bump load, torsion)
- Mesh the model with appropriate element size and refinement in high-stress zones.

Tools & Software Used

- CAD Software: Creo / SolidWorks
- FEA Software: ANSYS Workbench

IV. LITERATURE REVIEW

[1] Pathan et al. (IJARST, 2020) carried out both analytical and FEA-based design for a front axle. They compared different materials (AISI 4130, AISI 4140, AISI 1020, 27C15, Gray Cast Iron) and checked geometrical variations. Their study also compared stresses and deflections from analytical calculations with those from finite element models.

[2] Maddewad, Jadhav et al. (IRJET, 2017) optimized front axle design via analytical formulas and FEA. The focus was on ensuring sufficient strength under loads while trying to reduce weight.

[3] Khan, Ganorkar & Dehankar (IJSART, 2017) performed FEA on a front axle beam under static

vertical loading and also inertial loads (acceleration/deceleration) to find stress, strain, and displacement. They compared modified designs vs existing ones.

V. CONCLUSION

The structural design and stress analysis of the front axle for a 4GNR heavy commercial vehicle demonstrate the critical role of engineering precision in ensuring vehicle safety, durability, and performance. Through careful material selection, geometric optimization, and comprehensive stress analysis, the front axle can withstand the demanding loads and dynamic forces encountered during operation. Finite element analysis (FEA) and other simulation techniques help identify stress concentrations and potential failure points, allowing for design improvements that enhance reliability and longevity. Ultimately, a well-designed front axle contributes to the overall stability, handling, and load-carrying capacity of heavy commercial vehicles, supporting efficient and safe transportation under heavy-duty conditions.

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