

# Design and Analysis of Locomotive Wheel Axle

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**Abstract:** *A non-spinning machine element called an axle is used to support rotating parts such as wheels and pulleys. The axle is one of the train's most important components, and it is connected to the wheel via an interference fit. Since the beginning of railway history, derailment due to axle failure has been one of the most devastating sources of devastation. The goal is to use Computer-Aided Build software to design a railway wheel axle with specific dimensions, then model it using simulation software with the required loading conditions and constraints. This paper used Unigraphics NX-12 to model the train wheel axle and then imported it into Hypermesh software to simulate it.*

**Keywords:** derailment; wheel axle, simulation, Unigraphics NX-12, CAD

## 1. INTRODUCTION

The axle can be attached to the wheels and revolve on wheeled vehicles. The later axle type, especially on bicycles, is frequently referred to as a spindle. Straight axles are used for the rear axles of commercial trucks and heavy-duty off-road vehicles.

Split axles allow for a differential even when the suspension is not independent. The wheel on each side of a split-axle arrangement is linked to a separate shaft. This allows the left and right wheels to be independently suspended, resulting in a smoother ride. SAE 41xx steel is more resistant to bending and breaking, and welding is complicated.

Dedmon et al. [1] presented the results of stress analysis estimations for various North American freight train axle configurations. Axle stress analysis approaches were compared and contrasted, and loading criteria appropriate for various axle designs were utilized. The authors recommend that the North American freight railway industry use a standard axle stress analysis approach when designing new axles, especially for axles operated at higher gross rail loads (GRL).

Ooi et al. [2] utilized the finite element method to simulate the modal analysis of a portal axle (FEM). Modal analysis of gear train system combinations often utilized in portal axles is one of the critical areas of research being investigated by researchers at the University of Bristol. The gear teeth bending stress and contact stress behavior of three gear trains are also investigated using FEM static stress analysis at different angular locations from 0° to 18°.

A new methodology for analyzing gear train designs and investigating gear stress behavior in gear trains has been developed by the Royal Institution of Chartered Surveyors (RAS) at the University of Manchester. It considers the impact of single and double pair gear teeth and the different stresses experienced by different types of the gear train.

Nielsen et al. [3] employed a 3-level full factorial (3LFF) DOE on the web and a constrained layer damping (CLD) treatment to improve the wheel design's performance. An increase in wheel mass of 14 kg results in an A-weighted rolling noise reduction of 11 decibels when compared to a reference wheel design without CLD for a certain load condition (dB). A combination of wheel design and damping optimization along with superior damping optimization can lower a vehicle's noise output by up to 50%.

Remennikov et al. [4] conducted a literature study to evaluate the most common characteristics of loading conditions for railway track installations, particularly impact loads induced by wheel/rail interaction. The most typical dynamic impact loadings caused by wheel/rail contact and anomalies are covered in this article. The effects of rail corrugation, wheel flats, shells, worn wheel and rail profiles, inadequate welds or joints, and track faults on typical impact loads are discussed, with an emphasis on the usual patterns of impact load waveforms found on railway tracks.

Chih-Hsien et al. [5] investigated the design of a power train for a two-axle four-wheel-drive (4WD) electric vehicle (EV) to increase energy efficiency and drive stability for a 500cc internal combustion engine Utility Vehicle (UV). Two 5kw brushless DC motors with motor drivers, an automated manual gearbox (AMT), and a 288V16AH Lithium-ion battery pack will power the vehicle.

A sliding mode technique was used to create the power-split method for the 4WD EV, and numerical simulation revealed that each wheel's slip ratio could be regulated within an optimal value under the eCE40 driving pattern.

## 2. DESIGN AND SIMULATION

The simulation was performed on normal circumstances, such as necessary boundary conditions, material, and load because the goal is to model the railway carriageway. Hyper Works (HyperMesh) is the software tool used to simulate the wheel axle. The Unigraphics NX-12 CAD program was utilized solely to create the railway wheel axle.

**2.1 Material properties:** 30 NiCrMoV12 steel was used to the Rail wheel axle, with the following properties.

- $E = 180\text{GPa}$  Young's Modulus
- Density =  $8900\text{Kg/mm}^3$
- Yield Strength =  $490\text{MPa}$
- Poisson's Ratio = 0.3

*Structural Analysis:* The most extensively used numerical approach for tackling engineering issues is finite component modelling (FEM). The generality of FEM allows it to address the analysis needs of today's complex engineering systems and designs. Because the designer will undertake constant quantity design, recognising many circumstances and picking the optimal style, it is a cost-effective design method.

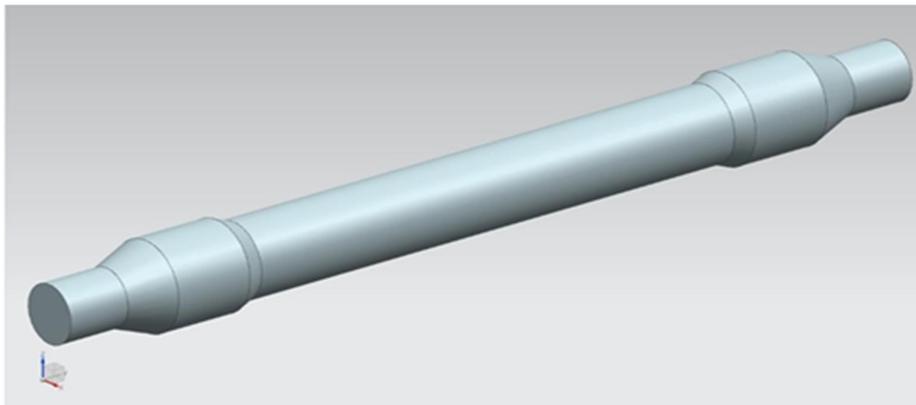


Fig. 1 Isometric view of the Rail wheel axle

## 2.2 Boundary conditions:

- The shaft was in remission, all told DOF at the first ending of the shaft mounted with the wheel.
- The allowable axial load of 587N has been applied at the second ending of the shaft mounted with the wheel.

**2.3 Meshing:** Meshing is the process of dividing an object's continuous geometric space into thousands or more forms in order to fully characterise its physical shape. The more complex a mesh is, the more accurate the 3D CAD model will be, allowing for more realistic simulations.

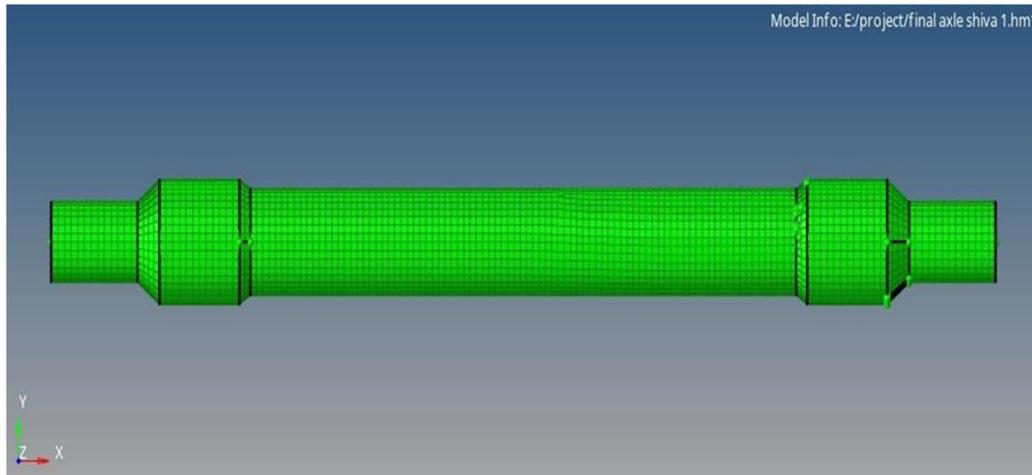


Fig. 2 Geometry mesh

## 3. RESULT AND DISCUSSION

Unigraphics NX-12 CAD software was used to develop the train wheel axle. Hyper Works (HyperMesh) software is used to run the simulation. To obtain the results, the requisite boundary conditions were applied. Figures 3 and 4 depict the outcomes. Table 1 shows the simulated deformation and stress.



Fig 3. Railway wheel axle displacement contour.

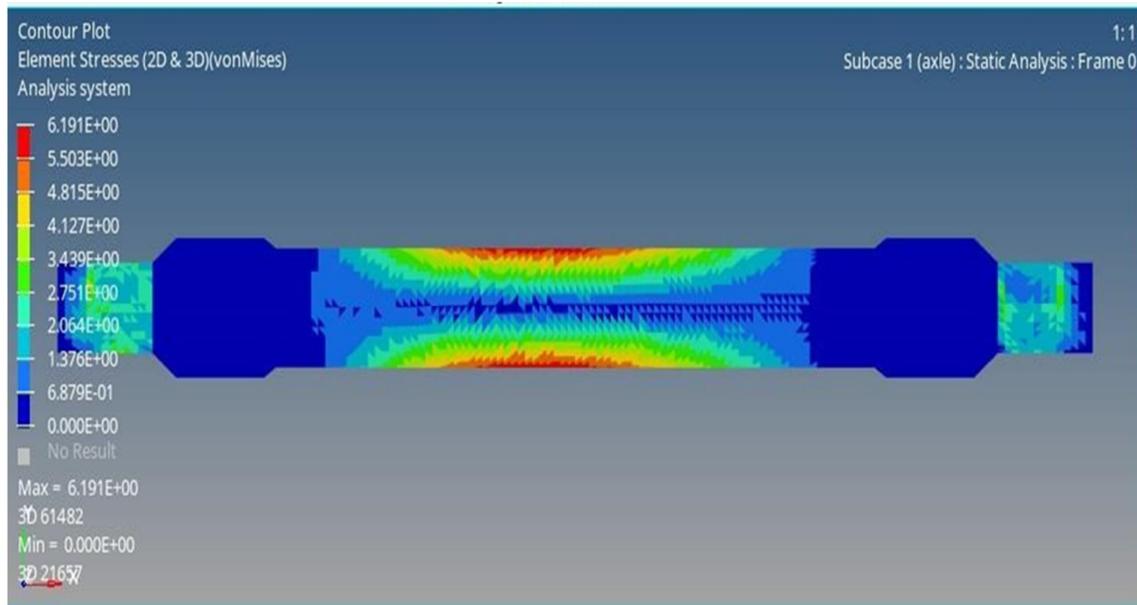


Fig. 4 Railway wheel axle stress contour.

Axle Model	Total deformation (mm)		Equivalent (Von Mises) Stress (MPa)	
	Minimum	Maximum	Minimum	Maximum
Stepped	0	0.014884	0.6879	6.191

#### 4. CONCLUSION

In Solid Works, an NX-CAD model of the wheel axle is created, and this model is then imported into ANSYS for processing. The track is attached after a 587N axial force is applied to the circumference of the steering wheel shaft.

Following are the conclusions from the results obtained:

- ANSYS' maximum stress is less than the material's yield stress.
- Ultimate strength is less than Von-Mises stresses.
- Because the Von-Mises stresses are smaller than the ultimate strength when deflections are taken into account, 30 NiCrMoV12 steel is recommended for the specified Rail wheel axle.
- A dynamic model with six degrees of freedom is created to get the forces operating on the shaft.
- After that, a thorough examination of dynamic forces acting on the shaft is provided.
- According to the initial findings, the critical frequencies 468Hz and 469Hz have the stress of 336MPa and 333MPa, respectively. The material (stainless steel) utilized for gear has a yield strength of 490 MPa.
- The Von-Mises stress at frequencies of 468Hz and 469Hz has stressed the material more than the yield strength. As a result, the Rail wheel axle's design is safe for the aforementioned operational loading circumstances.

## REFERENCES

- [1] Dedmon, S. L., Pilch, J. M., & Lonsdale, C. P. (2001). A comparison of railroad axle stress results using different design sizes, loading criteria and analysis methods. In ASME International Mechanical Engineering Congress and Exposition (Vol. 35821, pp. 197-200). American Society of Mechanical Engineers.
- [2] Ooi, J., Wang, X., Tan, C., Ho, J. H., & Lim, Y. P. (2012). Modal and stress analysis of gear train design in portal axle using finite element modeling and simulation. *Journal of Mechanical Science and Technology*, 26(2), 575-589.
- [3] Nielsen, J. C., & Fredö, C. R. (2006). Multi-disciplinary optimization of railway wheels. *Journal of Sound and Vibration*, 293(3-5), 510-521.
- [4] Remennikov, A. M., & Kaewunruen, S. (2008). A review of loading conditions for railway track structures due to train and track vertical interaction. *Structural Control and Health Monitoring: The Official Journal of the International Association for Structural Control and Monitoring and of the European Association for the Control of Structures*, 15(2), 207-234.
- [5] Chih-Hsien, Y., Chyuan-Yow, T., & Chih-Ming, C. (2012). Study on power train of two axles four wheel drive electric vehicle. *Energy Procedia*, 14, 1528-1535.