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A Stress Analysis on Railway Axle With Fatigue Crack Growth

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Abstract

This paper present the analytical method of a railway axle using three different load at a constant speed. Very rare case is may be possible, Train is running condition then suddenly apply the break and one wheel is stationary condition and second wheel is rotating in some angle (angle of twist). To estimate maximum shear stresses, 3D models are generated by modeling software CATIA V5 and simulation is done by finite element software package ANSYS 14.0.What the effects on axle in ANSYS and find out the maximum shear stress. Material used for Axle is high carbon steel..Analytical method of calculating maximum shear stress uses general theory in shear stress in shaft.

NOMENCLATURE:

z	:	Torsional Shear Stress	θ	:	Angle Of Twist
R	:	Radius Of The Shaft	T	:	Twisting Moment
J	:	Polar Moment Of Inertia	C	:	Modulus Of Rigidity
L	:	Length Of The Axle	P	:	Force
N	:	No of Speed	T	:	Torque
d	:	Diameter Of The Shaft			

Keywords: Railway Axle, Shear Stress, Shear Stress Theory, CATIA V5, ANSYS 14.

Introduction

An axle is one of the most important components of rail vehicle which transmits the weight of the vehicle to the wheels, meets the vertical and horizontal loads formed during static and dynamic moving, and carries driving moment and braking moment. Railway axles are safety relevant components usually designed for up to 30 years of service.

Axle:- An axle is a central shaft for a rotating wheel or gear. On wheeled vehicles, the axle may be fixed to the wheels, rotating with them, or fixed to its surroundings, with the wheels rotating around the axle. In the former case, bearings or bushings are provided at the mounting points where the axle is supported. In the latter case, a bearing or bushing sits inside the hole in the wheel to allow the wheel or gear to rotate around the axle. Sometimes, especially on bicycles, the latter type is referred to as a spindle.

There are three different kinds in vehicles axle:

- Straight,
- Split And
- Tandem.

Straight:- In a straight axle, there is one shaft connecting the two parallel wheels. The wheels are both secured in place onto the axle. The rotation rate and direction is fixed by the axle. The benefits of this type are the ability to keep the wheel position consistent and distribute the weight of heavy loads evenly.

Split:- In a split-axle design, each wheel is attached to a separate shaft. The purpose of this split is to provide a fixed position for the wheel, but also to allow each wheel to move independently of the other. This type is used on passenger cars. With a tandem axle, there are multiple axles located in relatively close proximity to each other. The purpose of this

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design is to increase the weight capacity of the vehicle and is most commonly used on large trucks.

Tandem:- A tandem axle is a group of two or more axles situated close together. Truck designs will use such a configuration to provide a greater weight capacity than a single axle. Semi trailers usually have a tandem axle at the rear.

Car axle:-**There are three different kinds in vehicles axle**:

- A front-wheel,
- A rear-wheel-drive,
- Four-by-four vehicles.

A front-wheel-drive car has an car axle that connects the front wheels to the drivetrain and motor. This configuration is unique to front-wheel-drive vehicles. The front-wheel-drive system connects the motor and transmission directly to the differential gears on the axle of the front wheels.

A rear-wheel-drive has a standard car axle that connects the rear gears to the transmission and driveshaft. As the driveshaft turns, it causes the gears in the rear end to turn the wheels of the vehicle. This uses gear drive technology, which makes use of specific gear ratios to turn the wheels on the axle.

Four-by-four vehicles have a gear drive on both the front and rear axle of the vehicle. This makes both the front and rear wheels turn with the acceleration of the motor. This complex design makes the four-by-four axle one of the most expensive axles to fix.

Rail axle:-An axle is a straight shaft that is fixed in location and is used to mount rotating wheels or gears. The wheel or gear can be attached to it with a built in bearing or bushing. A bearing or bushing fits inside the center of the wheel and allows it to rotate without affecting the axle itself. The purpose of an axle is to secure the wheels or gears to specific locations relative to other wheels or gears. Railway axles are commonly operated over a service life of 30 years or more which refers to a very high number of loading cycles in the order of 109. Fatigue failure of axle has been a source of difficulty for engineers since the railway service started in the early part of the 19th century. Railway axle designed for a long term of operation. Railway axles are, however, one of the most important components in railway systems since a fail-safe design is not available. In order to maintain the safety of the high-speed railway system, a large number of investigations and experiments have been carried out by outstanding research ever since, and many improvements have been made in the material, manufacturing, heat treatment and design method. Axles in service are regularly checked by ultrasonic testing and magnetic particle inspection.

The benefit of high axle loads:

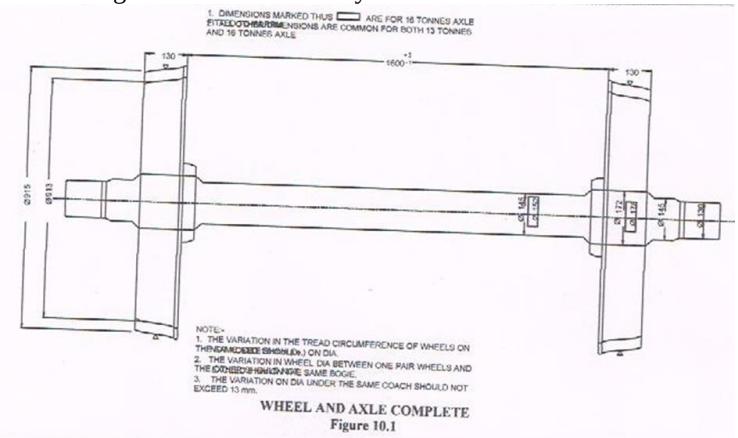
- Fewer wagons will be needed to haul the same load, leading to lower capital cost

and possible reduction in wagon maintenance cost, fewer locomotives,

- lower fuel consumption per net tonne,
- reduction in train wagon kilometre operated,

fewer crew deployment entailing savings in wages.

2D drawing of wheel set assembly



WHEEL AND AXLE COMPLETE
Figure 10.1

Shear Stress In Shafts

When a shaft fixed at one end is subjected to a torque (or twisting moment) at the other end, then every cross- section of the shaft will be subjected to shear stresses. It may be noted that the shear stress is zero at the centroidal axis of the shaft and maximum at the outer surface. The maximum shear stress at the outer surface of the shaft may be obtained by the following equation, known as torsion equation.

$$z/R = T/J = C.\ \theta/L$$

Where :-

z= Shear stress induced at the outer surface of the shaft or maximum shear stress.

R = Radius of the shaft,

T= Torque or twisting moment,

J = polar moment of inertia. It is the second moment of of area of the section about its polar axis= I_x+I_y

C = Modulus of rigidity for the shaft material,

L = Length of the shaft, and

Θ = Angle of twist in radian on a length

Problem Formulation

A shaft is required to transmit 1MW power at 240 rpm. The shaft must not twist more than 1˚ on a length of 15 dia. If the modulus of rigidity for

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material of the shaft is 840 GPA. Find the dia. of the shaft and shear stress induced.

Indian Railway Axle Dimensions

Modelling of the Axle is done by CATIA V5, and analysis done by ANSYS 14. For analysis static structural solver is used in ANSYS 14.

Dimensions of Railway Axle

Total Length of axle= 2263mm

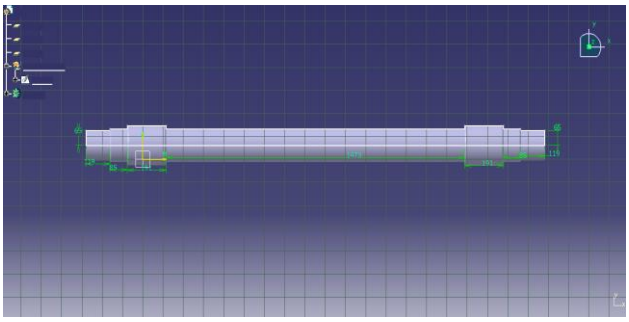

Figure1. DIMENSIONS OF RAILWAY AXLE

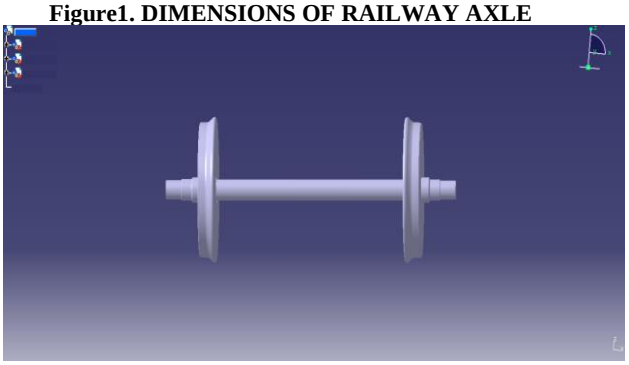

Figure2 wheel set assembly
Cross section of wheel set assembly

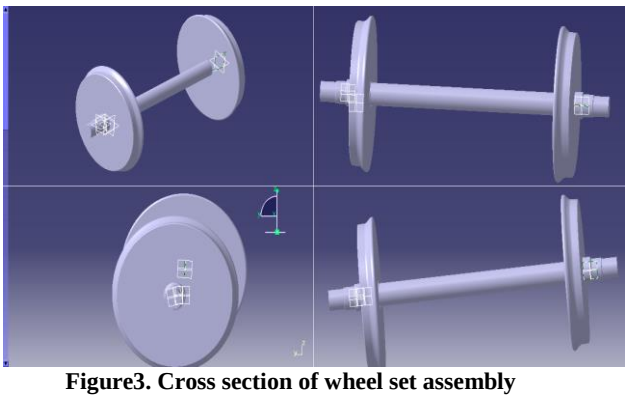

Figure3. Cross section of wheel set assembly

Meshing

During analysis default meshing is taken in wheel set assembly in ANSYS 14.Then meshing of model has been done using default meshing type. Meshing is an important part of Finite Element modeling which has a strong influence on the reliability and accuracy of results as well as the model efficiency. Refined mesh usually provides more accurate results than coarse mesh. However the refined mesh increases the computational cost significantly. Hence, some meshing strategies are employed to set up a reliable Finite Element model with reasonable cost. For the parts which undergo high level loading or stress, refined mesh is necessary. On the other hand, for the parts which are away from the severe loading or stress condition, coarse mesh is suitable to reduce the model size.

Meshed of the Model

During analysis default meshing is taken in

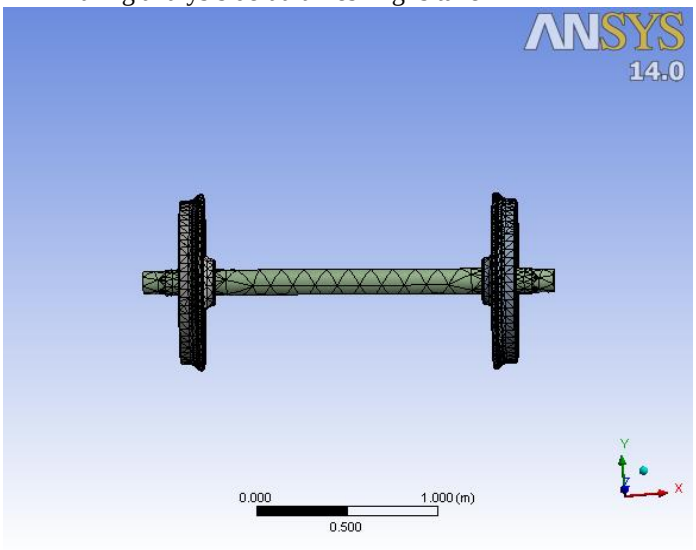

Figure4. MESHED OF THE MODEL

Boundary Conditions and Material Properties (FEM Modelling)

A three dimensional CAD model of wheel set assembly is imported to static structural workbench of ANSYS, various loading and boundary conditions are applied on it. Material properties of Carbon Steel are considered. For finding maximum shear Stresses by varying UDL loads of 22.82t,25t and 30t is applied to the centre. During analysis two boundary conditions has been considered which on railway axle are as follows:

1. Fixed support at the one side wheel and other side wheel apply the Angle Of Twist.
2. Force acted at the centre in the UDL form and and also apply the moment and which is calculated from Maximum Shear Stress Theory at different load 22.82t to 25t and 30t.

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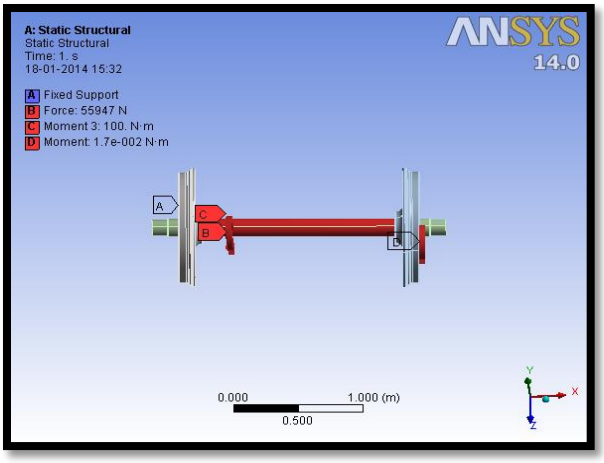


Figure5. BOUNDARY CONDITIONS

Material used for Axle is high carbon steel whose properties is in ANSYS 14 are shown in table.

Showing Rail Axle Along With Their Chemical Compositions

C%	Si %	Su %	P%	Ni/Cu%	Mo/V%	N%
0.37-1.2	0.15	0.04	0.04	0.30	0.05	0.007

Mechanical Property Of Materials

The design parameters are shown below in table-

Parameter	Value SUP9
Modulus of rigidity G	84GPa
Poisson's Ratio(υ)	0.28
Ultimate Tensile strength	550-650N/mm^2
Tensile strength Yield	320N/mm^2
Density(ρ)	0.00000785 Kg/mm^3

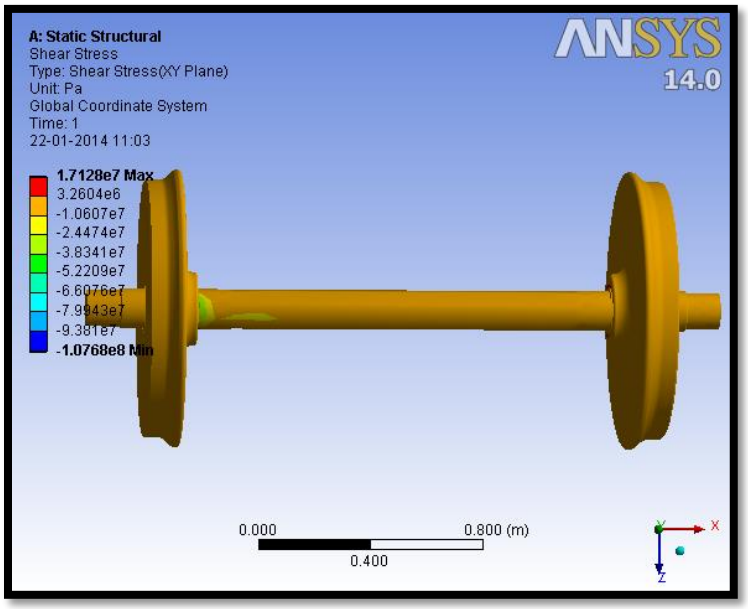
Results And Comparsion Table

The structural stress analysis of the railway axle model is carry out using the FEA in ANSYS 14. The load applied at the centre of the axle by applying the analysis over the axle which is facing the load we get the stress distribution in the numeric as well as in the form of the color scheme.We are using a three different load with a constant speed and find out the maximum shear stress with the help of ANSYS. Results of theoretical, and ANSYS are closer, therefore the design are accepted.

- Theoretical results (from shear stress in shaft theory)
- ANSYS results.

To get the result for 22.82ton

Force = 55947N where speed 100km/h, then the shear stress and total deformation on axle are shown in figure 6(a)(b)



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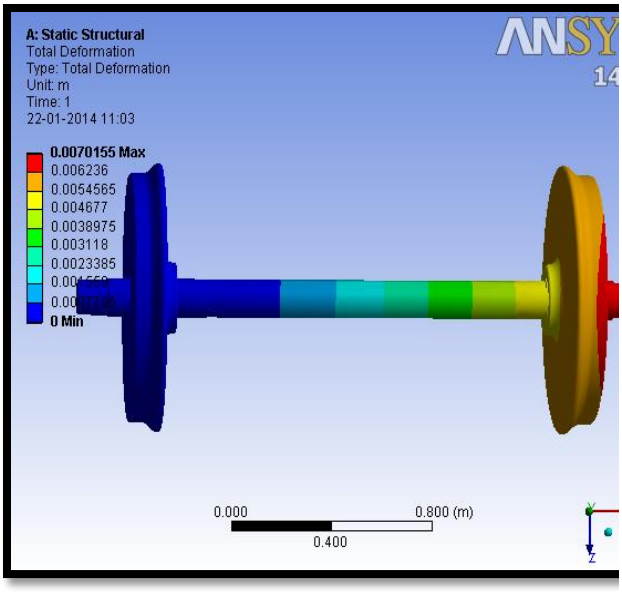
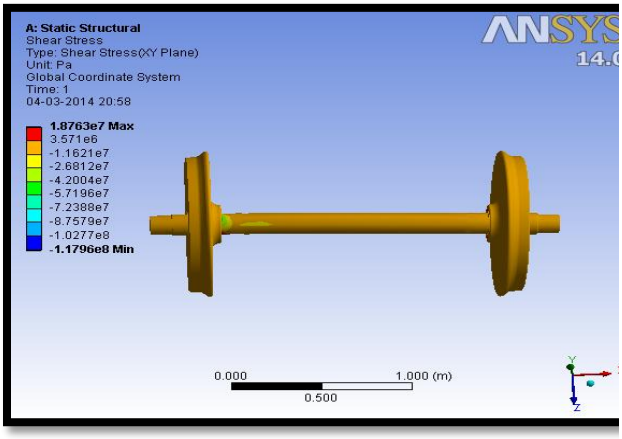
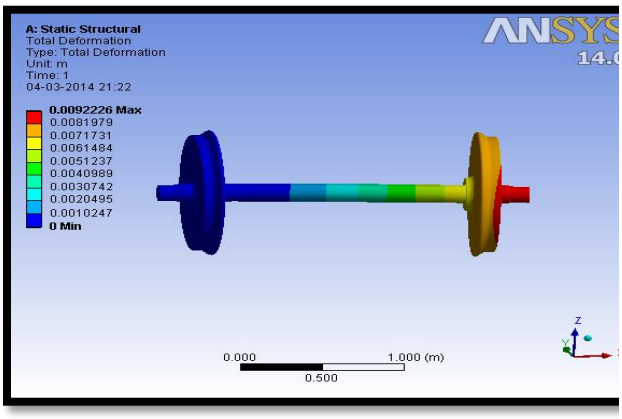


B. To get the result for 25 ton

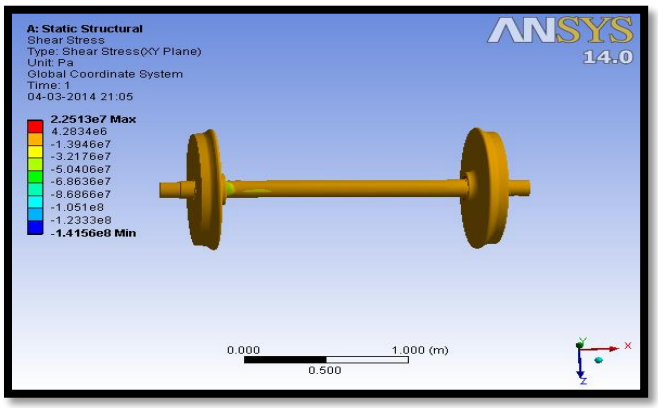
Force = 61291N where speed 100km/h, then the shear stress and total deformation on axle are shown in figure 7(a)(b)

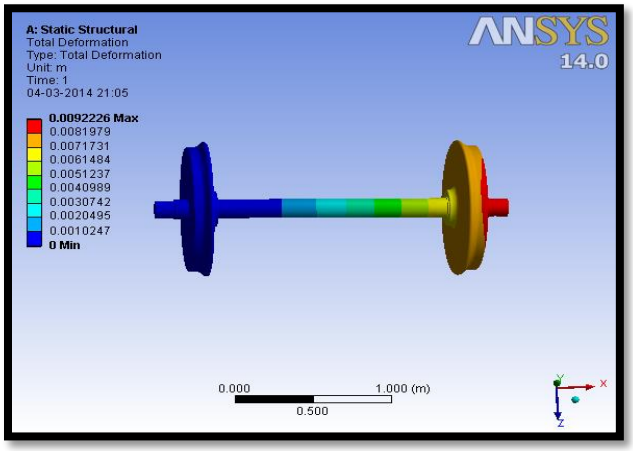




C. To get the result for 30ton

Force = 73549N where speed 100km/h, then the shear stress and total deformation on axle are shown in figure 8(a)(b)





Comparing the results of software analysis by mathematical approaches

load	Shear stress	
	Software analysis	Mathematical approaches
22.82t	$1.7128e^7$	$1.553e^7$
25t	$1.8763e^7$	$1.6311e^7$
30t	$2.2513e^7$	$1.9550e^7$

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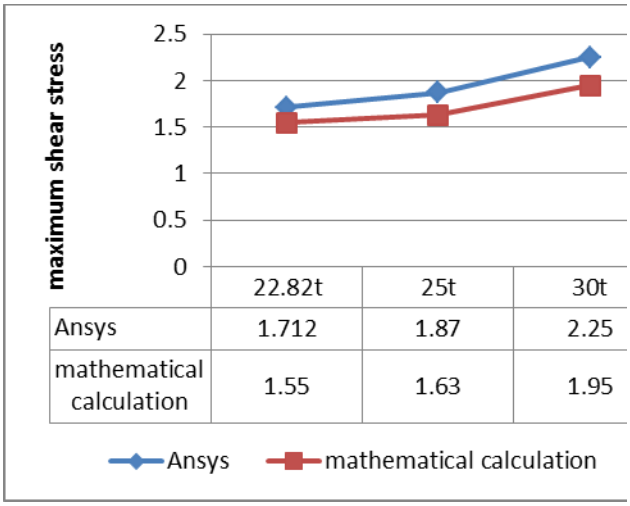

Conclusion

Analytical method of shear stress in shaft theory of assumptions and simplifications and it is intended to determine the maximum shear stress values. In this paper, numerical approach has used for predicting the static contact and shear stresses of axle. it is shown that the effective method to estimate the shear stress using three dimensional model of a railway axle and to verify the accuracy of this method the results with three different loads are compared with theoretical formulas.Results of theoretical and ANSYS are closed, and also calculate the angle of twist are very closed to found the general theory of shear stress in shaft. Therefore the design are accepted.

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