

STRESS ANALYSIS OF TRACTOR REAR AXLE COMPOSITE SHAFT USING ANSYS

Arvind Kumar¹, Dr. L. P. Singh²

PG Scholar of Master of Technology¹, Assistant Professor²

Department of Mechanical Engineering Sam Higginbottom University of Agriculture, Technology and Sciences, Allahabad, 211007

ABSTRACT

Tractor is an off road vehicle which is considered to be any type of vehicle which is capable of driving on and off paved or gravel surface. Off road condition includes uneven agricultural field surfaces and bumpy village roads on which the tractor has to operate. Thus it is important to analyze rear axle shaft of tractor so that we can solve problems regarding breakdowns and failures during field operations. In this project, the material of the rear axle shaft is to be modified with composite materials and its corresponding mechanical properties were to determine using ANSYS Software.

Keywords—Rear axle shaft, Composite material, Agriculture field

1. INTRODUCTION

An Axle shaft is a rotating member usually of circular cross-section (solid or hollow), which is used to transmit power and rotational motion in machinery and mechanical equipment in various applications. An axle is a central shaft for a rotating wheel. The wheel may be fixed to the axle, with bearings or bushings provided at the mounting points where the axle is supported. The axles maintain the position of the wheels relative to each other and to the vehicle body. Dead axle does not transmit power like the front axle, in a rear wheel drives are dead axles. On the dead axle suspension system is mounted, so it's also called suspension axle. Generally axle shafts are generally subjected to tensional stress and bending stress due to self-weight or weights of components or possible misalignment between journal bearings. Most shafts are subjected to fluctuating loads of combined bending and torsion with various degrees of stress concentration. For such shafts the problem is fundamentally fatigue loading. Eccentric Shaft is widely appreciated for its features like corrosion resistant, long service, effective performance and reliability. The primary purpose of Axle shaft is to act as power transmitting member from final drive to wheels. This is made possible by taking engine power through final drive component bull gear or planetary carrier according to type of final drive and then giving the same further through spline to axle shaft and to wheel through rim which is mounted on axle flange.

1.2. Problem Definition & Present Work

The present work includes the simulation (stress and deformation analysis) of rear axle shaft subjected to moment, equal to 130 N-M. The stress and deformation analysis was carried out using static structural tool i.e. ANSYS. The analysis was done for one cross sections.

- This analysis helps in the replacement of conventional rear axle shaft with change of material for better corrosion resistant, long service, effective performance and reliability.
- To achieve substantial stress reduction in the shaft by replacing it with these materials.

LITERATURE REVIEW

Guruprasad *et al.* department of Mechanical Engineering, The Oxford College of Engineering, Bangalore has observed experimentally that the reinforced aluminum with Fly ash enhances mechanical properties in comparison with monolithic metal. The fatigue factor of safety is calculated for constant amplitude load varied from 1820 N to 91000 N. The fatigue factor of safety is calculated for fatigue strength corresponds to $8e5$ cycles. (Evaluating For Rear Axle Housing Using Hybrid Aluminum Composites)

Chaudhari *et al.* PG Scholar, Mechanical Engg. Department, Gov. Engg. college, Bhuj-370001, India, Presented paper on Analysis and Design of Tractor Rear Axle using Finite Element Method The axle shaft is likely to break at 144233 km whereas the warranty is for about 150000 km. Fractographic features indicated that fatigue was the main cause of failure of the axle shaft. It was observed that the fatigue cracks originated from welded areas. (Analysis and Design of Tractor Rear Axle Shaft Using Finite Element Method)

Acharya *et al.* failure analysis of rear axle of a tractor with loaded trolley” This paper describes the failure analysis of the rear axle at the root of the spline of a tractor with a loaded trolley used for haulage .The front wheel lifting and the failure of the rear axle at the root of the spline though mainly due to the transfer of weight, not sufficient attention. By reducing the hitching height and it was observed that by reducing the hitching height to 16.00 inches with reduction in the weight transfer factor by nearly 20%. G.K. Nanaware et al. Failures of rear axle shafts of 575 DI tractors “Studied on Rear axle shafts of 575 DI tractors manufactured by Mahindra and Mahindra Ltd” (Failure Analysis for Rear Axle of Tractor with Loaded Trolley)

2. Material and Methodology

In this concept, we are adding the three materials to be involved. They are

- Ductile cast iron
- Carbon fiber
- E-glass

3. SOFTWARE DESIGN

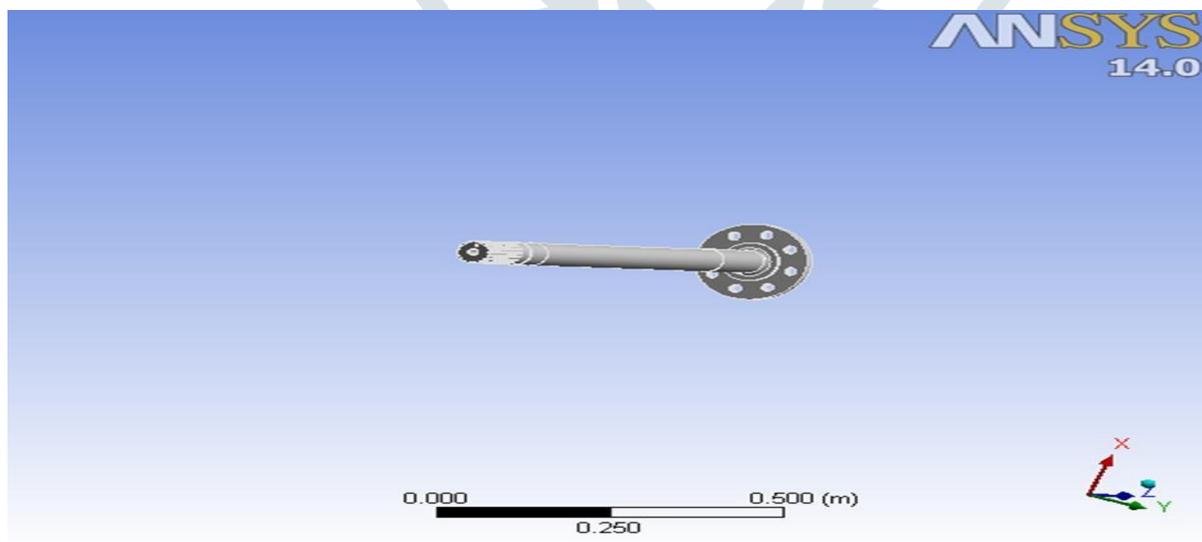


Fig.1 3D Design of Rear Axle Shaft for Circular Section

4. CALCULATIONS:

4.1. Engine Torque Calculation:

Maximum speed of a tractor = 29.61 km/h

Length of the propeller shaft = 0.75m

Rotational Speed $n = 1900$ rpm

Maximum Horsepower $P = 30\text{HP}$ i.e., 23.8kW

Torque $T = P / 2 \pi n$

$= (23.8 \text{ kW}) (1000 \text{ W/kW}) / 2 \pi (1900 \text{ rev/min}) / (60 \text{ sec/min})$

$= 119.5 \text{ Nm}$

MAX Force on Differential Unit is

Force = Torque / Length

$= 11 / 0.75$

$= .159 \text{ KN}$

4.2. Stress Calculations for Circular Shaft:

Weight on each Rear Tyre (F): 2000 N

Length of Axle shaft: 0.750m

Diameter of the Shaft: 0.05m

Stress:

$\sigma = F/A$

Area of the Shaft (A) = $2\pi rh + 2\pi Rh$

$= 2 * 3.14 * (0.05) * 0.75 + 2 * 3.14 * (0.19) * 0.025$

$= 0.26533 \text{ Sq m}$

Therefore, Stress $\sigma = 2000 / 0.26533$

$= 7537.7 \text{ Pa}$

5. BASICS OF FEM

The finite element method has become a powerful tool for the numerical solution of a wide range of engineering problems. Applications range from deformation and stress analysis of automotive, aircraft, building, and bridge structures to field analysis of heat flux, fluid flow, magnetic flux, seepage, and other flow problems. With the advances in computer technology and CAD systems, complex problems can be modeled with relative ease. An approximate solution for the partial difference equation can be developed for each of discretized elements. The finite element method is endowed with three basic features that account for its superiority over other competing methods: Geometrically complex domain of the problem is represented as a function of geometrically simple sub domains called “finite elements”. Over each finite element the approximation, functions are derived using the basic idea that any continuous function can be represented by a linear combination of algebraic polynomials. Algebraic relations among the undetermined coefficients (i.e. nodal values) are obtained by satisfying the governing equation often in a weighted integral sense over each element. A three dimensional body occupying a volume „V” and having a surface “S” is shown in Fig 1. Points in the body are located by x, y, z co- ordinates. The boundary is constrained on some region where displacement is specified. On part of the boundary, distributed force per unit area T, also called traction is applied. Under the force, body deforms .The deformation of a point

$X = [x, y, z]^T$ is given by three components of its displacements: $U = [u, v, w]^T$

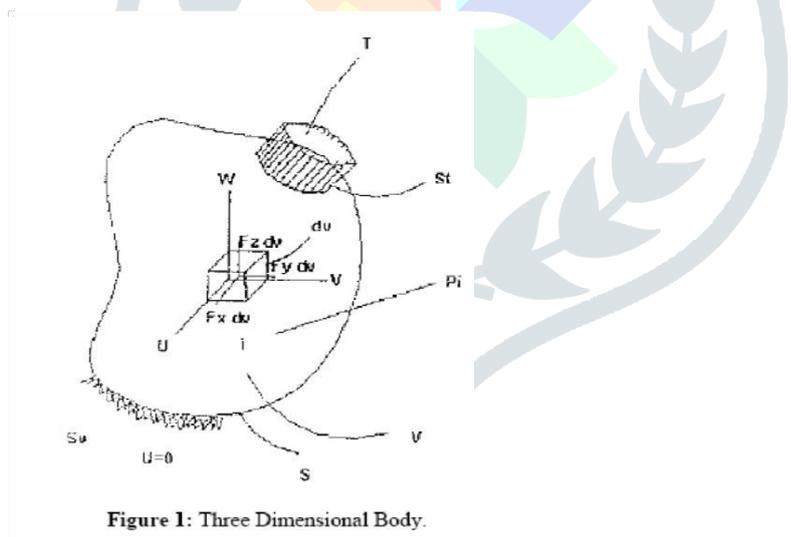
Where

u = displacement in x-

Direction v = displacement in y-
direction

w = displacement in z- direction

In the same manner i.e. in terms of the transpose of the matrix formed by the components of respective physical quantity other physical quantities can be written. Now if we consider equilibrium of this body then



$\Sigma F_x = 0, \Sigma F_y = 0$ and $\Sigma F_z = 0$. Also $dV = dx \cdot dy \cdot dz$

Therefore, we get the equilibrium equations

$$\frac{\partial \sigma_x}{\partial x} + \frac{\partial \tau_{xy}}{\partial y} + \frac{\partial \tau_{xz}}{\partial z} + f_x = 0$$

$$\frac{\partial \sigma_y}{\partial y} + \frac{\partial \tau_{xy}}{\partial x} + \frac{\partial \tau_{yz}}{\partial z} + f_y = 0$$

$$\frac{\partial \sigma_z}{\partial z} + \frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} + f_z = 0$$

The stresses are related to strain, which, in turn, are related to displacements. This leads to requiring solution of second-order partial differential equations.

6. Modelling and Meshing

The geometry is drafted based on the dimensions of geometric design parameters. The axle is 3 dimensionally modeled then meshed properly to divide it into elements and nodes.

Finite element model was generated using free meshed 4 nodes quadratic tetrahedral element due to their flexibility in curved and complex shapes, which has three degrees of freedom per node i.e. translation in x, y, z directions were used. Quality checks and mesh optimization for elements were also performed taking into consideration of aspect ratio, distortion, stretch. Geometric models of rear axle shaft were developed in one sections. The digital images of models are given below;

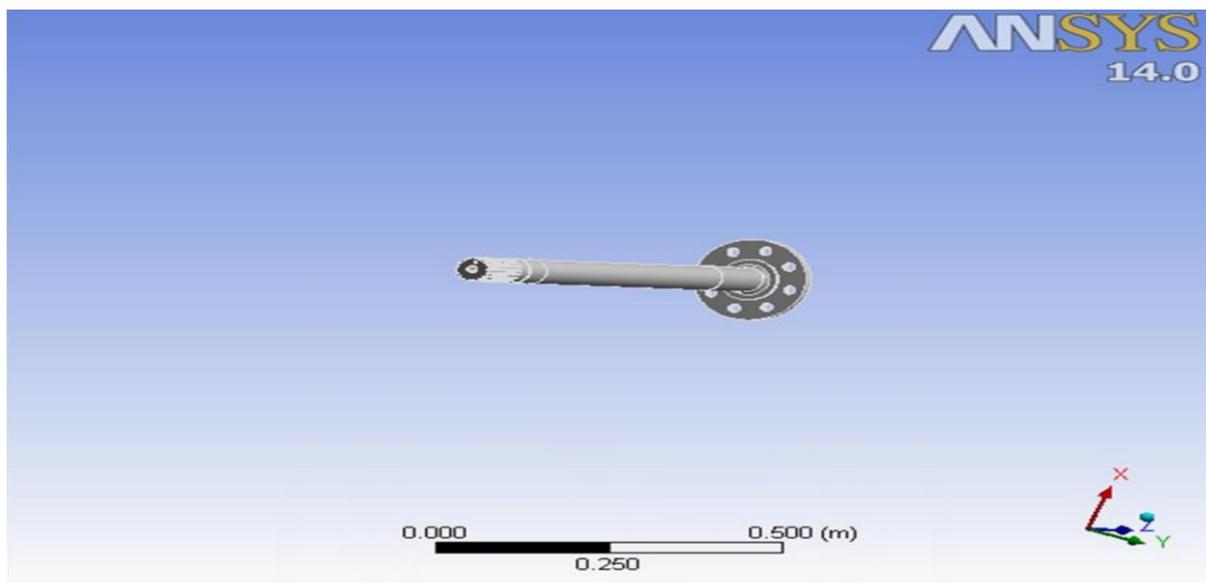


Fig.1 3D Design of Rear Axle Shaft for Circular Section (ANSYS)

7. ANALYSIS AND TEST RESULT

7.1. Ductile Cast Iron

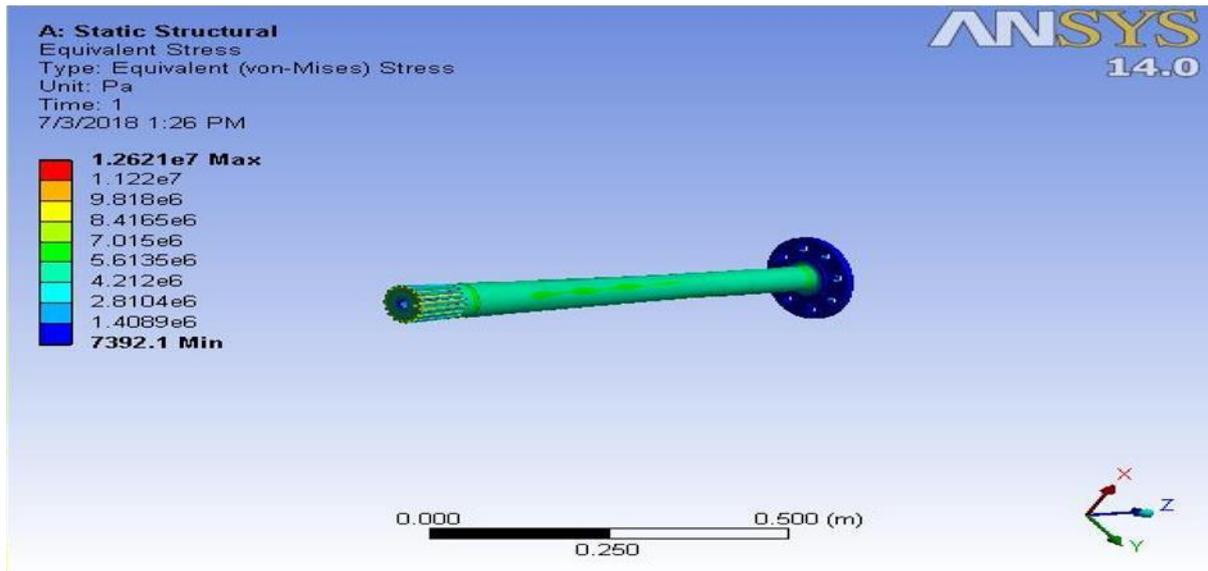


Fig.3 Stress Analysis Image in ANSYS (For Ductile Cast Iron)

7.2. For Carbon Fiber

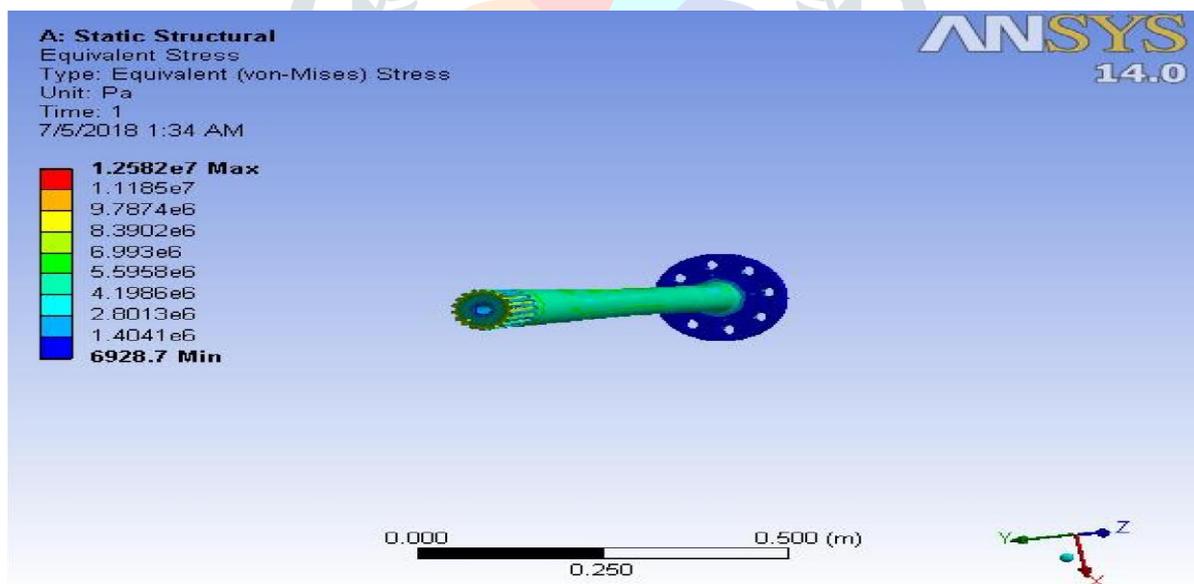


Fig: Stress Analysis image in ANSYS (For Carbon Fiber)

7.3. For E-Glass

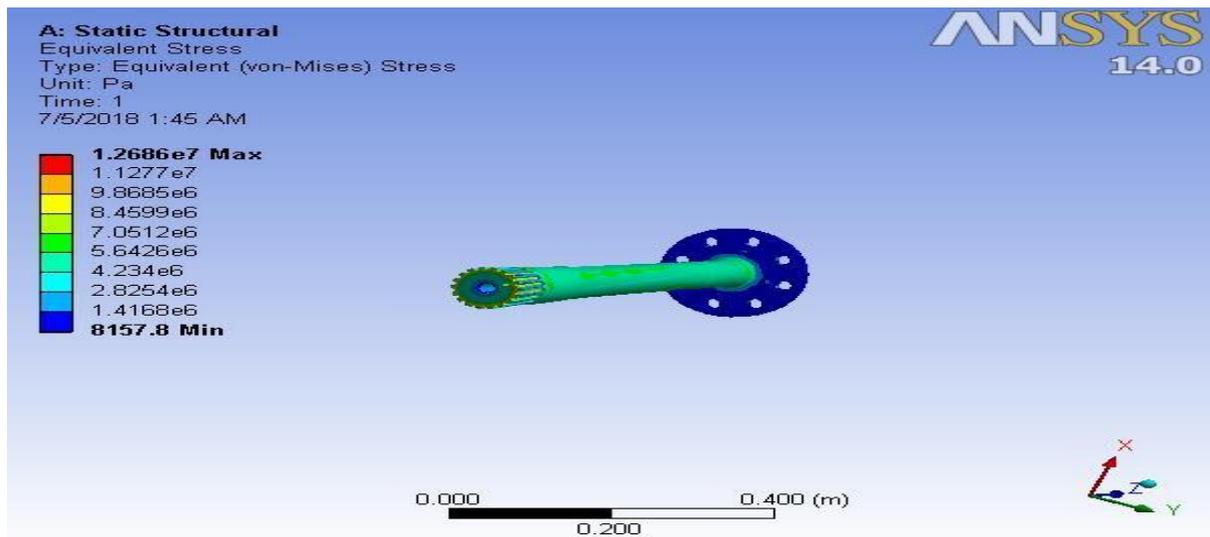


Fig: Stress Analysis Image in ANSYS (For E-Glass)

7.4. For Composite Material

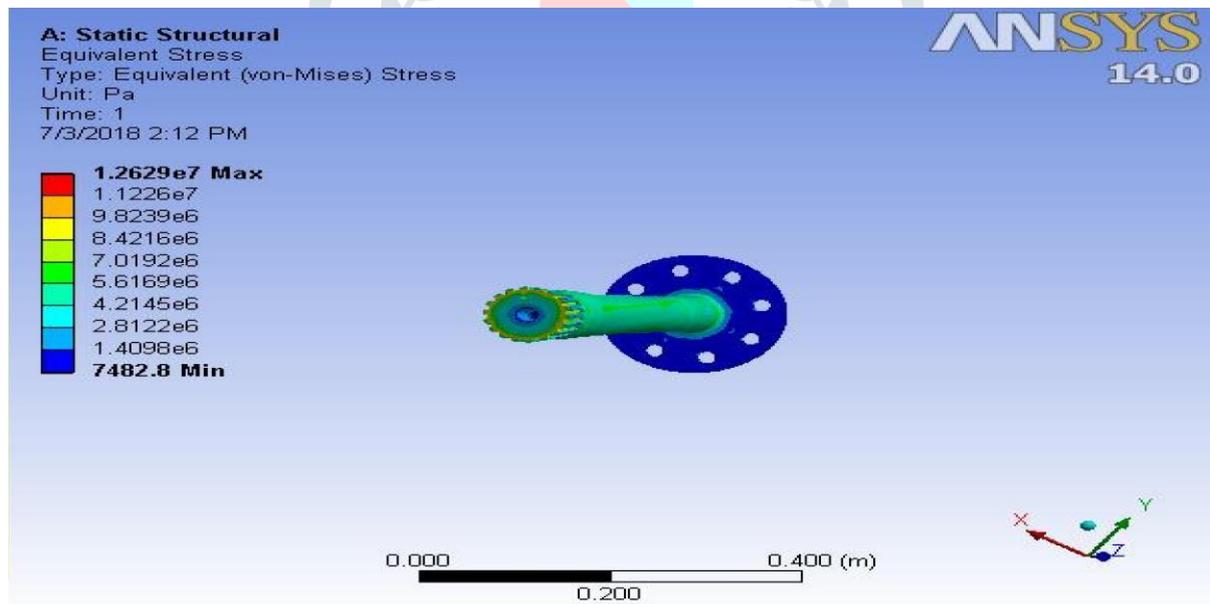
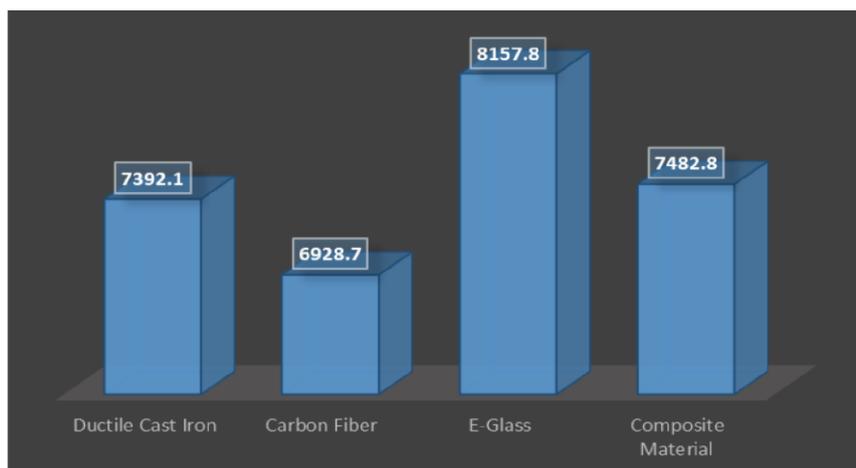


Fig: Stress Analysis Image in ANSYS (For Composite Material)

8. CONCLUSION

Rear Axle shaft function and location in transmission layout discussed. Imperial approach for estimation of load case were possible established along within causing variation in final usage. These composite can be used for both static and dynamic applications like connecting rod, suspension arms, springs, rear axle housing

etc. Thus we can optimize the rear axle shaft for increasing mechanical strength and easy manufacturability and change of material for better corrosion resistant, long service, effective performance and reliability. Hence to achieve the substantial stress reduction in shaft by replacing these materials.



From the bar chart it is clear that the stress produced is minimum in carbon fiber and maximum in e-glass. Ductile cast iron and composite material have 7392.1 and 7482.8 Pascal stress respectively.

From the bar chart it is clear that the value of the stress produced into the composite material is less than that of stress calculated, thus the composite material is safer than that of the structural steel.

So, we can use this composite material for making the rear axle shaft which has more stress handling capacity than the structural steel.

Property of the composite material

Tensile Strength	1157 Mpa
Yield Strength	833 Mpa
Elastic modulus	190-210 Gpa
Bulk modulus	140 Gpa
Shear Modulus	80 Gpa
Poisson ratio	0.27
Rockwell hardness value	80

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