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STATIC ANALYSIS OF FRONT AXLE AND ITS OPTIMIZATION USING COMPOSITE MATERIALS

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ABSTRACT

Automotive axle is a static load carrying structural member. This paper deals with static structural analysis of front axle and its weight and cost optimization using composite material. Front axle of light duty truck has been selected for the case along with suitable static loading conditions. Carbon Epoxy composite and E-glass Epoxy composite were considered initially as replacement of existing AISI 4140 steel material. 3D modeling of front axle design was done in SolidWorks2015 and ANSYS 15.0 was used for FEA and simulation. Results of analysis suggest, Carbon Epoxy composite material as best suitable replacement for existing steel. Carbon Epoxy composite axle design with reduced weight and lower material cost are the focal outcomes of work.

Key words : AISI- (American Iron and Steel Institute), ANSYS 15.0, Composite materials, SolidWorks2015.

1. INTRODUCTION

An automotive axle is a central shaft for rotating wheel or gear. On wheeled vehicles, the axle may be fixed to the wheels rotating with them or fixed to the vehicle with wheels rotating around axle. Front axle, rear axle and stub axle are the major types of axles used in vehicle. Front axles are further classified as dead axle and live axle. Dead axles do not rotate and have sufficient rigidity and strength to carry vehicle weight, whereas live axles transmit power from gear box to the wheels. Load distribution on each axle depends on position of axle and number of axles used in vehicle.[3]

Their structural strength, stability etc, are hardly evaluated resulting in reduced passenger safety, fuel efficiency etc. with increased possibility of maintenance, damages etc. Hence there is a need to ease of optimization etc with very low levels of cost implications [8]. Today companies requires product design quick, accurate and optimum. This work aims to optimize the axle design for weight and cost criteria. Composites being the high strength low density cheaper materials, Carbon Epoxy composite and E-Glass Epoxy composite have been considered for the analysis in consideration with existing AISI 4140 steel axle performance. The work has been carried out on front axle of double axel four wheeler light duty truck having maximum gross vehicle weight of 12 tonnes. Failures of axles have frequently raised question on its strength and load carrying capacity.

2. AXLE SELECTION AND LOADING CONDITIONS

Front axle of double axel four wheeler truck has been selected for the case. It is dead axle having 'I' cross-sectional beam. Maximum loading condition of 12 tonnes has been considered. The analysis has been carried out for maximum loading condition of 12 tonnes which is equally distributed on both axles. Geometry of front axle was studied to get loading points. 6 tonnes of gross vehicle weight acting on front axle supported by leaf spring and self-weight of axle are the major concerns of front axle loading as shown in Fig 1.

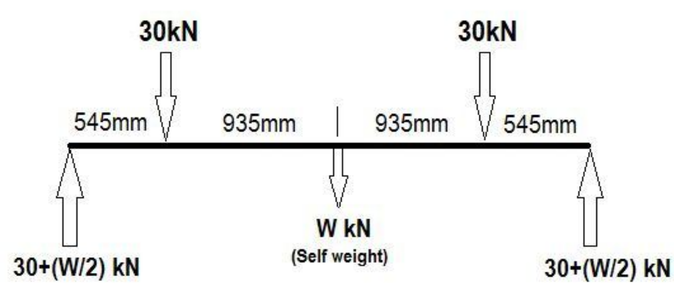

Fig 1: Static loading on front axle beam

3. MATERIAL CONSIDERATION

Existing front axle is made up of low alloy low carbon steel having grade AISI 4030. It is high strength steel material. Initially two composite materials viz. Carbon Epoxy Composite and E-Glass Epoxy composite were taken into consideration for the replacement of existing steel. These Composite materials have good strength by weight ratio which is required to reduce the weight of the automobile. The Properties of materials are given in Table 1.

Table 1 Material properties [12]

Material	Yield strength (MPa)	Poisson's ratio	Density (g/cm3)	Young's modulus (GPa)
AISI 4140	415	0.29	7.85	200
Carbon epoxy composite	1080	0.31	1.6	70
E-Glass fiber composite	2800	0.23	2.6	83

4. GEOMETRY AND 3D MODELING

Front Axle Geometry of light duty truck was considered. It is 'I' section beam in the middle and having provision for stub axles to fit at the both ends. 3D model of front axle was built in SolidWorks 2015 by measuring actual physical dimensions of front axle. Figure 2 shows the 3D cad model of front axle. The envelope dimensions of axle are as presented in Table 2.

Table 2 Overall front axle dimensions

X(mm)	Y(mm)	Z(mm)
2960	179	300

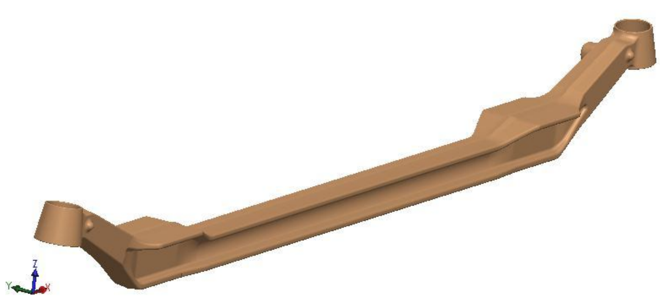

Fig 2: 3D CAD model of front axle

5. STATIC STRUCTURAL ANALYSIS OF FRONT AXLE

Based on the loading conditions and material database generated, FEA was carried out using ANSYS Workbench 15.0 to obtain the Maximum deflection and Maximum induced stress. The analysis was done for all the three materials for same geometry. Maximum induced stress and total deformation values for the existing AISI 4140 steel axle were taken as reference to check composite materials' allowable stress and deformation.

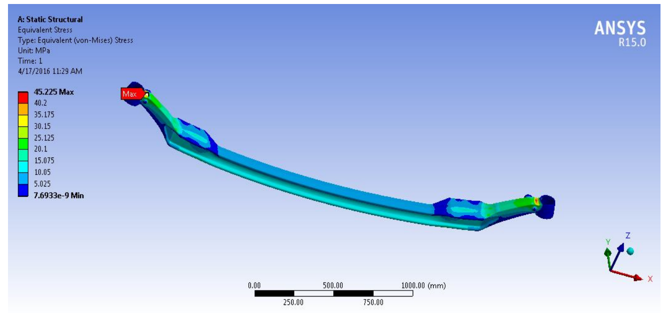

Fig 3 Von-Mises stress in AISI 4140 steel

Figure 3 shows the Von-Mises stress in AISI 4140 Steel material front axle. Whereas fig. 3 shows the total deformation the axle undergoes with the same material.

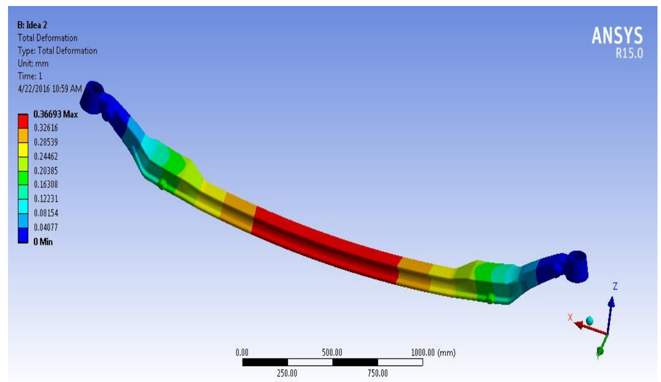

Fig 3 Total Deformation in AISI 4140 steel

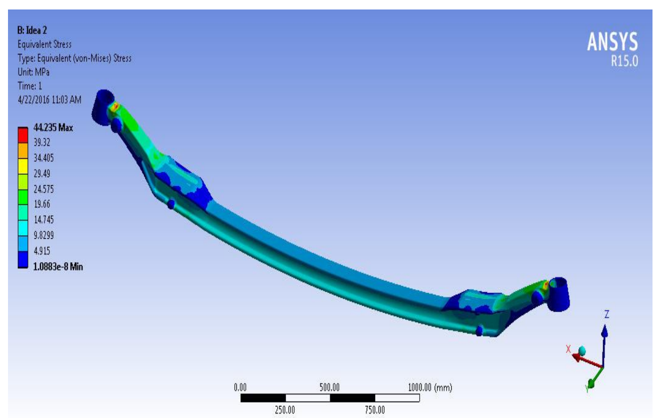

Fig 4 Von-Mises stress in Carbon Epoxy composite axle

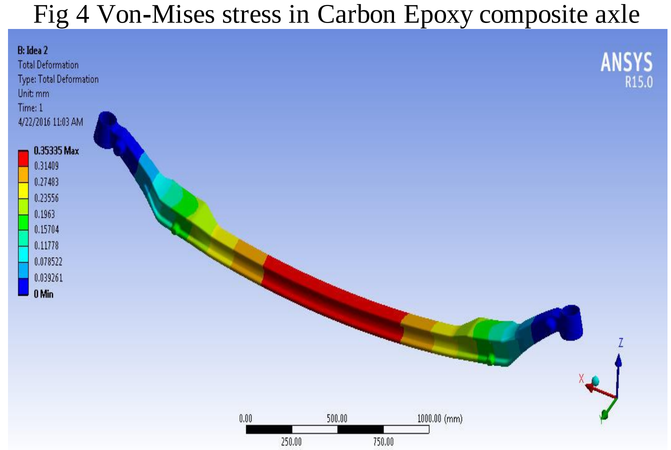

Fig 5 Total Deformation in Carbon Epoxy composite axle

Similarly fig 4 shows the stresses induced in the same axle when loaded with same boundary conditions but with Carbon epoxy composite as material. Whereas figure 5 shows the total deformation of carbon epoxy composite axle.

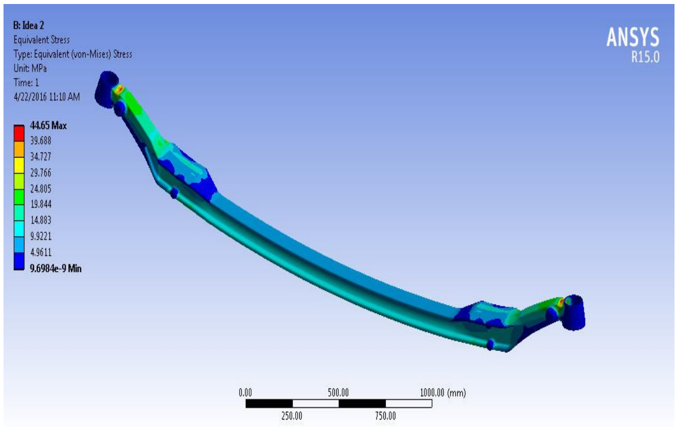

Fig 6 Von-Mises stress in E-Glass Epoxy composite axle

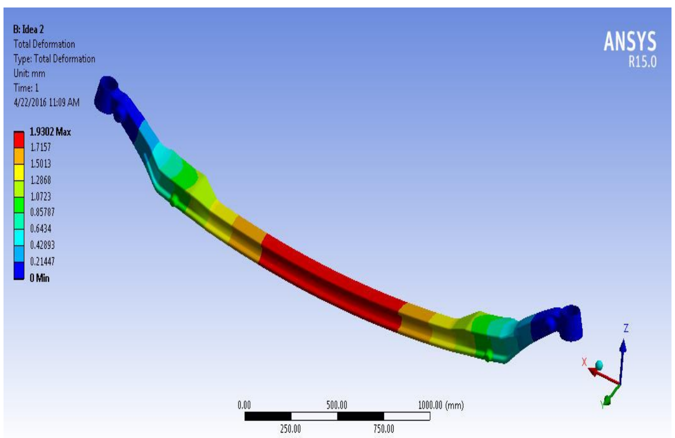

Fig 7 Total Deformation in E-Glass Epoxy composite axle

Figure 6 and figure 7 shows Von-Mises Stress and total deformation of axle with E- Glass as material.

6. Results & Conclusions

Table 3 Results Comparison

Material	Yield Strength (MPa)	Max. Induced Stress (MPa)	Total Deformation (mm)
AISI 4140 Steel	415	45.225	0.3796
Carbon Epoxy composite	1080	45.082	0.3533
E-Glass Epoxy composite	2800	45.674	1.9302

Table 3 shows the tabulated results of the three tests conducted on same axle but with different materials it gives Max induced stress and deformations.

ANSYS results for static structural loading condition shows that Maximum induced stress is approximately same in Axle made of steel as well as composite Materials. For all materials considered, maximum induced stress is lesser than its yield strength. In reference with AISI 4140 steel, Carbon Epoxy composite deforms around 4% lesser but E-Glass Epoxy composite deforms five times more than that of steel.

Optimization of axle

Thus Carbon Epoxy composite material is the best suitable composite material than E-Glass Epoxy composite, and selected as replacement for existing AISI 4140 steel. The existing axle design will be of approximately 80% lighter in weight. Table 4 shows the optimization of axle in weight reduction.

Table 4. Optimization of AXLE

Material	Weight (kg)	% reduction
AISI 4140 steel	147.5	Reference
Carbon epoxy	30.55	79.28

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