International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No.03, April 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

Weight optimization and buckling analysis of tie rod using CFRC material

Laxman Shinde[1], Dr.S.S.Gawade[2]

[1] *PG Student,* [2] *Professor*

Department of Mechanical Engineering,

Rajarambapu Institute of Technology, Rajaramnagar, MS(India)

ABSTRACT

Design of suspension components in an automotive is very critical as they are constantly under varying loads. The tie rod is an important part of suspension system. It connects the steering to the suspension in order to transform the motion. Buckling of tie rod is typically occurring failure mode. Tie rod are generally made up of steel or alloy steel. Current material of tie rod is replaced with carbon/epoxy composite material as strength to weight ratio of steel and alloy steel are less as compared with carbon fiber reinforced composites. Properties of carbon/epoxy composite material are calculated. Volume ratio of reinforcing material to matrix material is taken as 70:30.The tie rod is modeled by using CATIA. Critical buckling load results and total deformation results are obtained using ANSYS.

Keywords—Carbon fiber, CFRC, Critical buckling load, FEA, Tie rod

I. INTRODUCTION

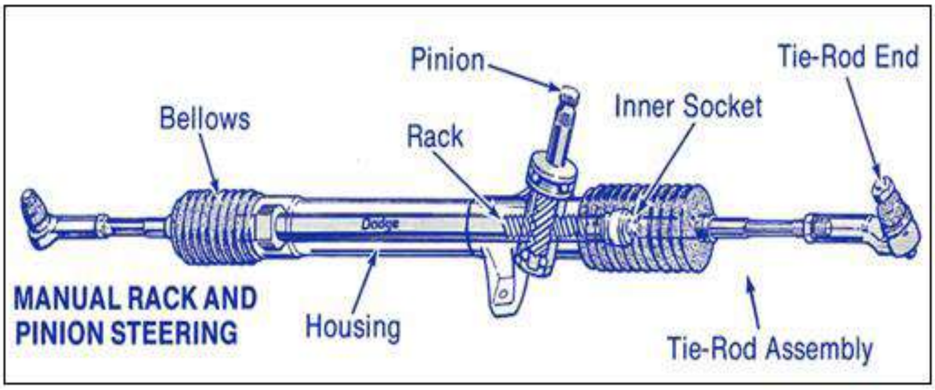

Fig.1 tie rod assembly

The tie rod connects the steering to the suspension in order to transform the motion as shown in figure 1. A tie rod consists of an inner and an outer end. Tie rods are attached on both ends of the steering rack and as the pinion rolls over the slotted rack, they help push and pull the front tires as the steering wheel is turned. Tie rod may additionally get fail because of fluctuating forces during steering and bumping of vehicle. Failure of tie rod may also reason instability of vehicle and ends in an accident. Also the indications given by using the tie rod earlier than failure are very much less. Bad tie rods can negatively have an effect on a vehicle's front and end alignment which may bring about uneven wear of the internal and outer edge of a vehicle tire. [1,2,5]

Hence a tie rod should be designed in such a way that it should not get fail under any circumstances. Effort has been taken for improving performance of tie rod. But these efforts either lead to increase in material cost, manufacturing cost of component and weight of component.

Strength of tie rod can be improved by using metal alloy. Young's modulus of nickel and titanium based alloys is high but titanium and nickel alloys are difficult to use as material for tie rod because they are too expensive. Aluminum alloys are light in weight but the strength and other mechanical properties offered by aluminum are comparatively poor than steel and alloy steel.

The composite materials have better mechanical properties. Composites are light in weight, compared metals. Their lightness is important in automobiles. The service life of composite material is much higher than metals. Strength of composite material can be designed in specific direction [3, 4].

II. SELECTION OF MATERIAL

The study of existing tie rod materials and alternative materials were carried out. The properties of materials are studied in detail. The Critical buckling load depends on Young's modulus, effective length and moment of inertia. Euler equation for critical buckling load is given by following equation:

(1)

The material having high value of Young's modulus offer higher value of critical buckling load.

Table I. Material properties

Fiber of wire	Density (ρ) Kg/	Young'smodulus E(GPa)	E/ρ Ratio GPa- /Kg
Steel	7600	207	0.027
Aluminum	2680	73	0.027
E- glass	2548	72	0.033
S- glass	2487	86	0.033
Carbon	1810	242	0.1337

From above table carbon fiber has maximum specific modulus, where specific modulus is ratio of Young's modulus with density. Hence carbon fiber is selected as reinforcement material. Epoxy is taken as matrix material.

III. PROPERITIES OF CABRNON/EPOXY COMPOSTITE

The properties of composite are calculated by micromechanical analysis.

a. Volume fraction of carbon fiber – 0.7 (70%)

b. Volume fraction of epoxy – 0.3 (30%)

Properties of carbon fiber are shown in table II

Table II Properties of carbon fiber

Parameter	SI unit
Young's modulus( )	242 Gpa
Density ( )	1810 Kg/
Poisson's ratio ( )	0.3

Properties of epoxy are shown in table III

Table III Properties of epoxy

Parameter	SI unit
Young's modulus( )	3 Gpa
Density( )	945 Kg/
Poisson's ratio( )	0.3

The density of composite material is,

(2)

Young's Modulus of composite material is:

(3)

Poisson's ratio of composite material is:

(4)

The properties of carbon fiber composite are given in table IV.

Table IV Properties of composite material

Parameter	**SI unit**
Young's modulus( )	170 Gpa
Density(	1550 Kg/
Poisson's ratio(	0.3

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IV. MODELLING OF TIE ROD

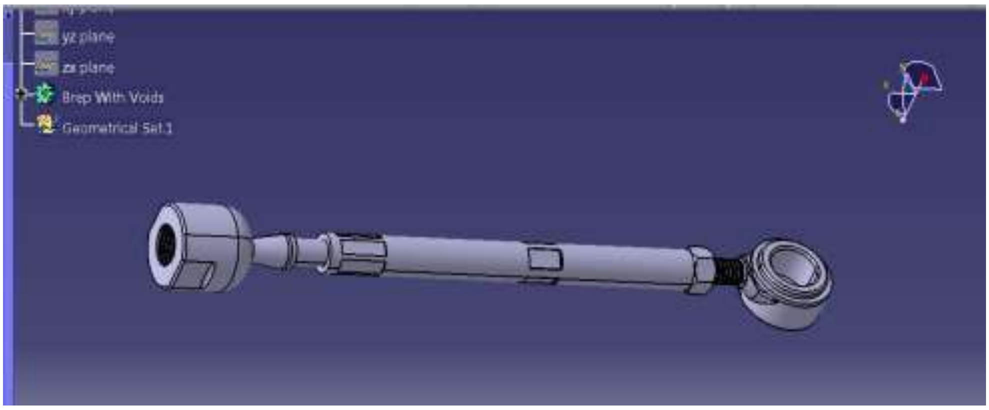

Fig. 2. 3D model of tie rod

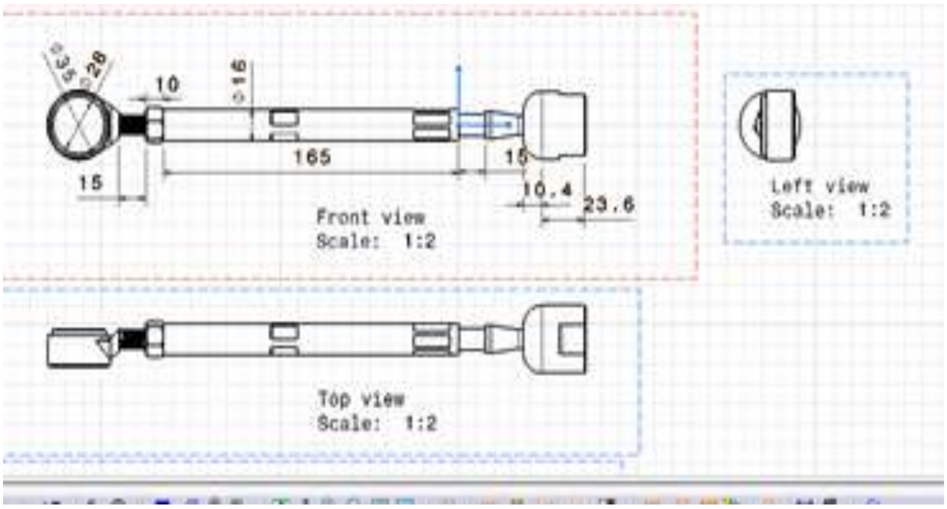

Fig. 3. 2D drafting of model

The model of tie rod is created in catiaV5. Fig 2 shows the 3dimentional model of tie rod. Fig 3 shows the 2D drafting of the tie rod.

V. ANALYSIS OF TIE ROD

The model was meshed in ANSYS. Fig 4 shows meshed model of tie rod.

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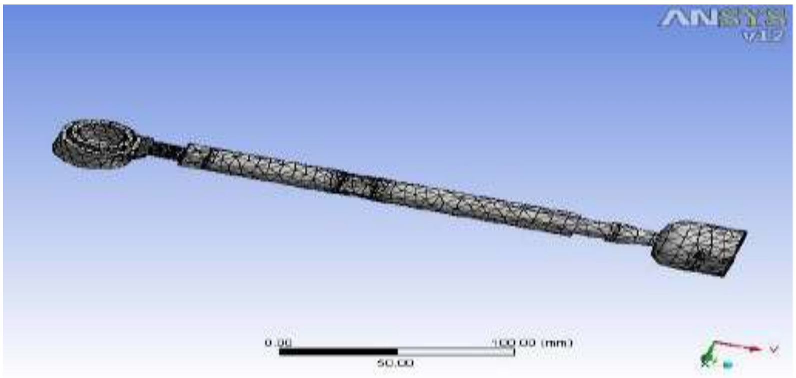

Fig. 4 meshing of tie rod

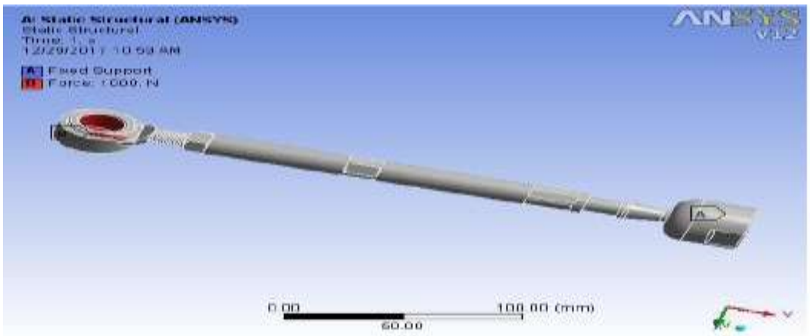

Fig. 5. Application of support and load for steel tie rod

One end of steel tie rod was fixed while at other end compressive load of 100N magnitude was applied as shown in fig 5. The Total deformation results are shown in fig 6 and Critical buckling load results are shown in fig 7.

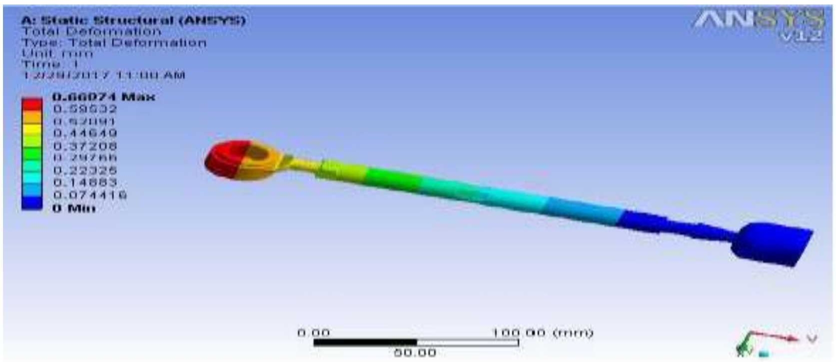

Fig 6. Static structural analysis result for steel tie rod

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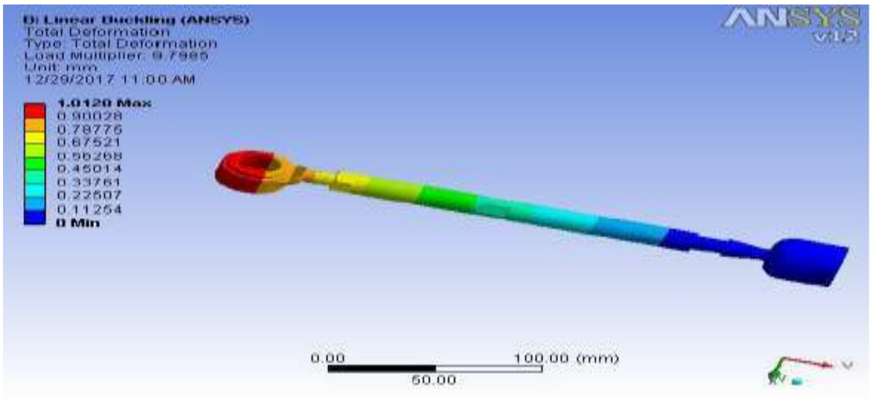

Fig 7 Linear buckling result for steel tie rod

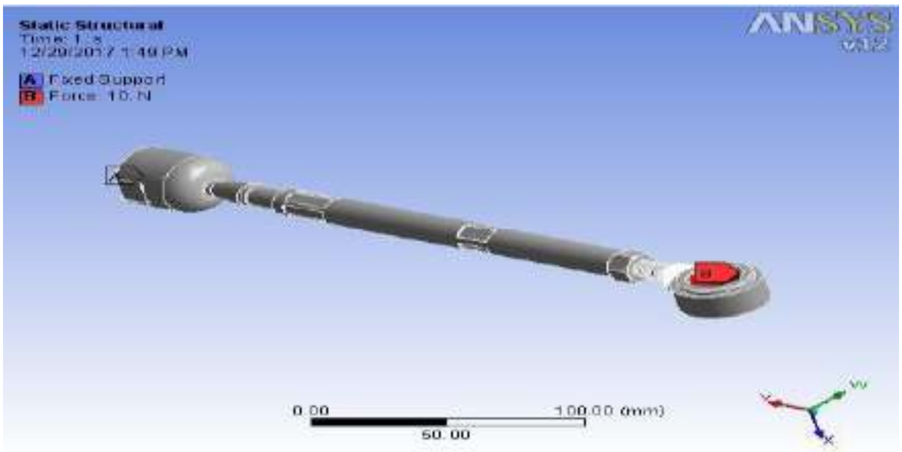

Fig 8 Application of load and support for carbon/epoxy tie rod

One end of carbon/epoxy tie rod was fixed while at other end compressive load of 10N magnitude was applied as shown in fig 8. The Total deformation results are shown in fig 9 and Critical buckling load results are shown in fig 10.

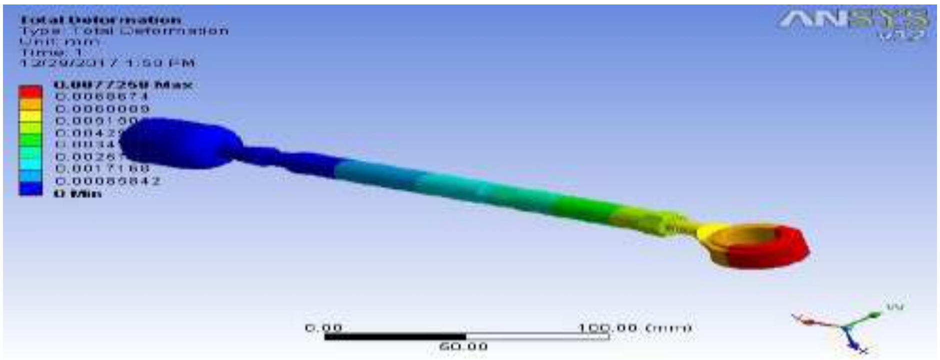

Fig. 9 Static structural result for carbon/epoxy tie rod

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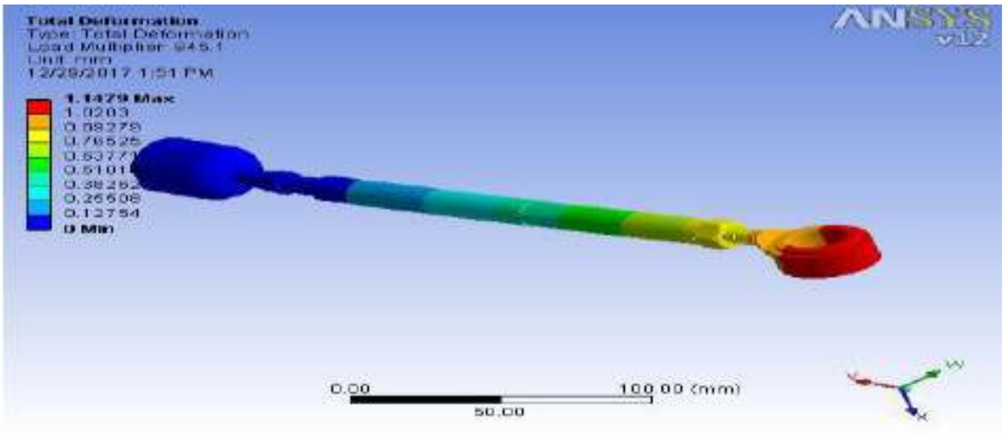

Fig 10 Linear buckling result for carbon/epoxy tie rod

VI. WEIGHT OF TIE ROD

The mass of two rack end inner tie rod of steel material can be calculated as:

M = (5)

= 0.626 Kg

Where the density of steel is 7800 Kg/

Length of inner tie rod is 200mm and diameter is 16mm.

The mass of two rack end inner tie rod of steel material can be calculated as:

M =

= 0.125 Kg

Where the density of carbon/epoxy composite is 1550 Kg/

Length of inner tie rod is 200mm and diameter is 16mm.

VII. RESULT AND DISCUSSION

For steel material the force of 1000N was applied the maximum. Total deformation obtained in linear buckling analysis was 1.0128mm. The load multiplier obtained in linear buckling analysis was 9.7985. Hence the critical buckling load for steel material is 9798.5N.

For carbon/epoxy composite material the force of 10N was applied. Maximum total deformation obtained linear buckling analysis was 1.1479mm. The load multiplier obtained in linear buckling analysis was 845.1N. Hence the critical buckling load for carbon/epoxy material is 8451N.

The mass of steel tie rod is 0.626 Kg while that of carbon/epoxy composite material was 0.125Kg which is approximately five times lighter than that of steel material.

Table V. Values of critical buckling load for steel and carbon/epoxy composite and corresponding weight of rod.

Sr.No.	Material	Critical buckling load (N)	Mass of rod
1	Steel	9738.5	626
2	Carbon/epoxy	8451	125

VIII. CONCLUSION

- The properties of carbon/epoxy composite material were found theoretically. The ratio of reinforcement to matrix is taken as 70:30.
- From analysis critical buckling load for steel and carbon/epoxy composite are obtained. The critical buckling load for both steel and carbon/epoxy composite were nearly equal.
- Weight of carbon/epoxy composite tie rod is found to be approximately five times lighter than steel.
- The current material of tie rod is steel and alloy steel which can be replaced by carbon composite material without compromising required strength.
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ACKNOWLEDGMENT

I would like to express my deep sense of gratitude to my supervisor Dr. S. S. Gawade for his inspiring and valuable suggestions. I am deeply indebted to him for giving me a chance to study this subject and providing constant guidance throughout this work. I acknowledge with thanks, the assistance provided by the Department staff, central library, staff and computer faculty. Finally, I would like to thanks to my colleagues and friends for directly and indirectly helping me for the same.

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