Failures and Rectification of Heavy Vehicle Chassis Due to Different Load Conditions

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Abstract— The automobile is divided into two parts body and chassis. The chassis is basic structure of a vehicle. It contains all the engine parts and power systems but the frame is the main portion of chassis which do not contain any other assemblies like engine parts. Its principle function is to safely carry the maximum load for all designed operating conditions. Composite material is a material composed of two or more distinct phases (matrix phase and dispersed phase) and having bulk properties significantly different from those of any of the constituents. Different types of composite material are available and one of it is Polymer matrix composite. It is very popular due to their low cost and simple fabrication methods. It has the benefits of high tensile strength, high stiffness and good corrosion resistance etc. At present this polymer matrix composite materials are used in aerospace, automobile industries due to it high strength to low weight ratio. In the present work, the dimensions of an existing heavy vehicle chassis of a TATA SE1613 TURBO TRUCK vehicle is taken for modelling and analysis. The vehicle frame is initially modelled by considering 'C' section and then with 'H' section, 'I' section in PRO-E Wild Fire 5.0 Software. After that imported to SOLID WORKS 2012. The analysis is done with Cast Iron, Steel, composite material Eglass/Epoxy, subjected to the same pressure as that of a steel frame. The design constraints are stresses and deformations. The results are then compared to finalize the best among all the three frames.

Key words: Chassis Made of Cast Iron, Stainless Steel, Epoxy and Sections of C, H, I

I. Introduction

Automotive chassis is a French word that was initially used to represent the basic structure. It is a skeletal frame on which various mechanical parts like engine, tyres, axle assemblies, brakes, steering etc. are bolted. It gives strength and stability to the vehicle under different conditions. At the time of manufacturing, the body of a vehicle is flexibly molded according to the structure of chassis. It provides strength needed for supporting vehicular components and payload placed upon it. Automotive chassis helps keep an automobile rigid, stiff. It ensures low levels of noise, vibrations and harshness throughout the automobile.

The chassis is considered to be the most significant component of an automobile. It is the most crucial element that gives strength and stability to the vehicle under different conditions. Automobile frames provide strength and flexibility to the automobile. The backbone of any automobile, it is the supporting frame to which the body of an engine, axle assemblies are affixed. Tie bars, that are essential parts of automotive frames, are fasteners that bind different auto parts together. Automotive frames are basically manufactured of steel. Aluminum is another raw material that has increasingly become popular for manufacturing these auto frames. In an automobile, front frame is a set of metal parts that forms the framework which also supports the front wheels. It provides strength needed for supporting vehicular components and payload placed upon it.

II. Chassis Materials

Traditionally, the most common material for manufacturing vehicle chassis has been steel, in various forms. Over time, other materials have come into use, the majority of which have been covered here.

- Cast Iron
- Stainless Steel
- Composite Materials

Cast iron is a group of iron-carbon alloys with a carbon content greater than 2%. Its usefulness derives from its relatively low melting temperature.

A. *Properties of Cast Iron*

Properties	Cast iron
Young's Modulus(GPa)	82 to 140 GPa
Poission's Ratio	0.26
Density(g/cm^3)	7.2 g/cm^3
Yeild strength(MPa)	98 to 280 MPa

Table 1: Properties of cast iron

1) *Composition of Cast Iron*

Iron Type	Percent (%)				
	Carbon	Silicon	Manganese	Sulfur	Phosphorus
Gray	2.5 - 4.0	1.0 – 3.0	0.2 – 1.0	0.02 – 0.25	0.02 – 1.0
Ductile	3.0 - 4.0	1.8 – 2.8	0.1 – 1.0	0.01 – 0.03	0.01 – 0.1
Compacted Graphite	2.5 – 4.0	1.0 – 3.0	0.2 – 1.0	0.01 – 0.03	0.01 – 0.1
Malleable (Cast White)	2.0 – 2.9	0.9 – 1.9	0.15 – 1.2	0.02 – 0.2	0.02 – 0.2
White	1.8 – 3.6	0.5 – 1.9	0.25 – 0.8	0.06 – 0.2	0.06 – 0.2

Table 2: Composition of cast iron

B. *Stainless Steel*

Stainless steel, also known as inox steel or inox from French inoxydable, is a steel alloy with a minimum of 10.5% chromium content by mass. Stainless steel is notable for its corrosion resistance, and it is widely used for food handling and cutlery among many other applications. Stainless steel's resistance to corrosion and staining, low maintenance, and familiar lustre make it an ideal material for many applications.

1) *Properties of Stainless Steel*

Properties	Stainless steel
Young's Modulus(GPa)	210 GPa
Poission's Ratio	0.305
Density(g/cm3)	7.83 g/cm^3
Yeild strength(MPa)	42.4 - 250 MPa

Table 3: Properties of stainless steel

2) *Composition of Stainless Steel*

ELEMENT	CONCENTRATION
IRON	67.0% - 69.0%
CHROMIUM	16.0% - 18.0%
NICKEL	10.0% - 14.0%
MOLYBDENUM	2.0% - 3.0%
MANGANESE	2.0% maximum
SILICON	1.0% maximum
PHOSPHORUS	0.04% maximum
SULFUR	0.03% maximum
CARBON	0.03% maximum

Table 4: Composition of stainless steel

C. Composite Materials

A composite material is defined as a material composed of two or more materials combined on a macroscopic scale by mechanical and chemical bonds. Unique characteristic of many fiber reinforced composites is their high internal damping capacity. This leads to better vibration energy absorption within the material and results in reduced noise transmission to neighbouring structures.

D. E-Glass/ Epoxy

An individual structural glass fiber is both stiff and strong in tension and compression that is, along its axis. Although it might be assumed that the fiber is weak in compression, it is actually only the long aspect ratio of the fiber which makes it seem so i.e., because a typical fiber is long and narrow, it buckles easily. On the other hand, the glass fiber is weak in shear that is, across its axis. Therefore if a collection of fibers can be arranged permanently in a preferred direction within a material, and if the fibers can be prevented from buckling in compression, then that material will become preferentially strong in that direction. E-Glass / Epoxy Resin Composites are extremely strong materials used in roofing, pipes and automobiles.

Composition: 54% SiO_2 - 15% Al_2O_3 - 12% CaO

1) *Properties of E-Glass/ Epoxy*

Properties	Cast iron
Young's Modulus(GPa)	80 GPa
Poission's Ratio	0.23
Density(g/cm3)	1.9 g/cm^3
Yeild strength(MPa)	4750 MPa

Table 5: Properties of E-Glass/ Epoxy

III. CALCULATIONS

A. Basic Calculation for Chassis

Basic Calculation for Chassis: Model No. = SE1613 Turbo Truck (TATA)

Specification of chassis as per the IS 9435 for the wheel base 4565mm as mentioned as under

- Front track = 1933mm
- Rear track = 1809mm
- Overall length = 7720mm
- Front Overhang = 1185mm

Weight of the chassis as per the IS 9211 for the wheel base 4565mm as mentioned as under:

Tolerance of the chassis is maintained according to the Inter Europe StVZO.

- Complete chassis weight = 4235 Kg.
- Bare chassis weight with cowl = 4045 Kg.
- Max. Permissible gross vehicle weight = 16200 Kg.
- Weight of the Engine = 413 Kg.
- Total weight acted on the chassis = 16200 Kg.
- Capacity of Truck = 16.20 ton =16200 kg = 158922 N
- Capacity of Truck with 1.25% = 158922 x 1.25 N = 198652.5 N
- Total Load acting on the Chassis =198652.5 N
- Each Truck chassis has two beams.
- So load acting on each beam is half of the Total load acting on the chassis.
- Load acting on the Chassis = Total load acting on the chassis /2 = 198652.50 / 2 = 99326.25 N / Beam

B. Calculation for Pressure

Beam is simply clamp with Shock Absorber and Leaf Spring. So Beam is a Simply Supported Beam with uniformly distributed load. Load acting on Entire span of the beam is 99326.25 N.

- Pressure acting on top surface of chassis structure = load/area
- (For C-Section) Uniformly Distributed Load/area = 99326.25 /615598 = 0.1613 N / mm^2.
- (For H-Section) Uniformly Distributed Load/area = 99326.25 /545848 = 0.18196 N / mm^2.
- (For I-Section) Uniformly Distributed Load/area = 99326.25 /615598 = 0.1613 N / mm^2.

C. Mass of Frame

The mass of an object is a fundamental property of the object, a numerical measure of its inertia, a fundamental measure of the amount of matter in the object.

Mathematical equation for mass is

Mass = Volume × Density

- For Steel: We know, Density of steel = 7830kg/m3

Volume of frame = 4.9104×10-2 m^3

Total mass of frame = 7830 × 0.049104 = 384.48kg

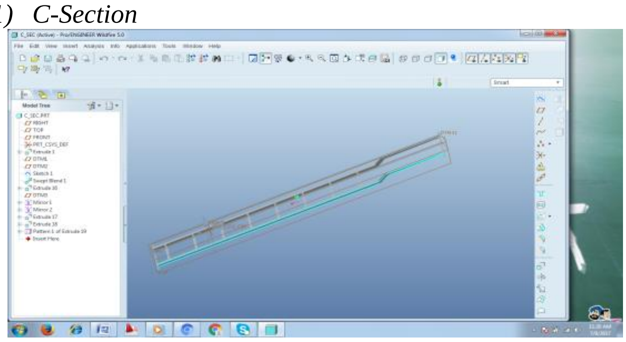
- For Cast-Iron: We know Density of Cast-iron = 4200 kg/m$_3$
  - Volume of Frame = 4.9104×10-2 m^3
  - Total mass of Frame = 4200 × 0.049104 = 206.23 kg
- For E-Glass Epoxy: We know Density of E-glass/Epoxy = 2600 kg/m$_3$
  - Volume of Frame = 4.9104×10-2 m^3
  - Total mass of Frame = 2600 × 0.049104 = 127.67 kg

IV. MODELLING OF CHASSIS

The modelling of various sections like C,H,I of chassis done in pro-e wildfire 5.0 by using cast iron, stainless steel and epoxy/e-glass. Different sections of chassis were below which includes drafting also.

A. Images in Pro.Engineer Software

1) *C-Section*



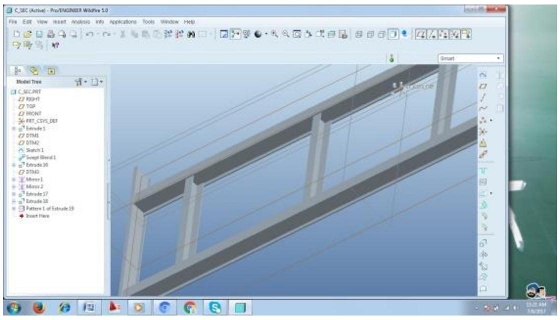


Fig. 1: C-Section

2) *I-Section*

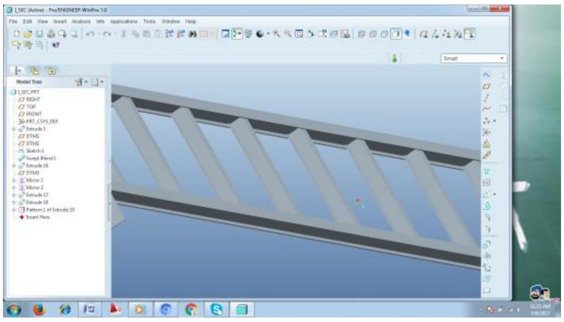


Fig. 2: I-Section

3) *H-Section*

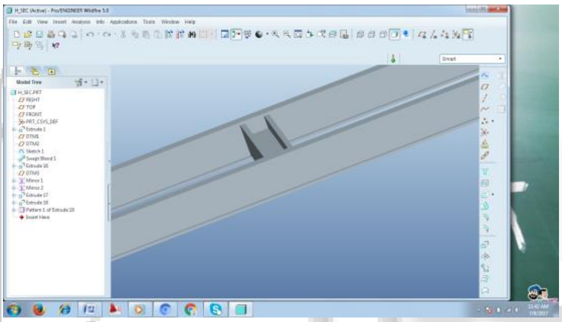


Fig. 3: H-Section

B. *Drafting Images in Pro E*

1) *C-Section*

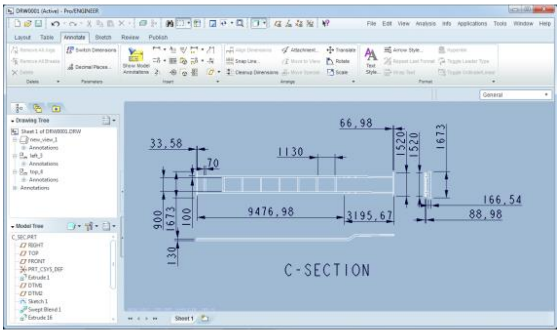


Fig. 4: C-Section

2) *I Section*

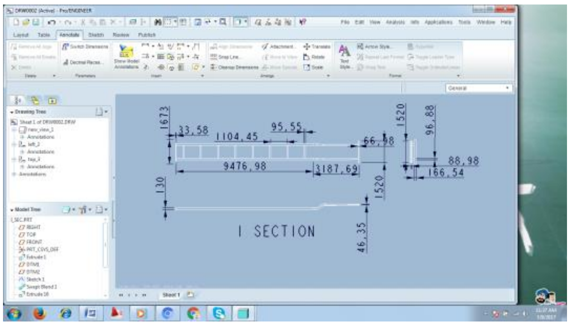


Fig. 5: I-Section

3) *H-Section*

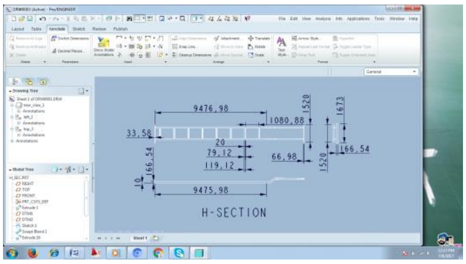


Fig. 6: H-Section

V. Analysis of Chassis Using COSMOS Software:

FEA consists of a computer model of a material or design that is stressed and analyzed for specific results. It is used in new product design, and existing product refinement.

COSMOS Works is a design analysis automation application fully integrated with Solid Works. This software uses the Finite Element Method (FEM) to simulate the working conditions of your designs and predict their behaviour. FEM requires the solution of large systems of equations. Powered by fast solvers, COSMOS Works makes it possible for designers to quickly check the integrity of their designs and search for the optimum solution.

COSMOS Works is a design analysis system fully integrated with solid works. COSMOS Works provides one screen solution for stress, frequency, buckling, thermal and optimization analysis.

A. *Types of Analysis*

– Static Analysis: This was the analysis done when the vehicle is stationary. Here the input we are applying pressure on the chassis. We will get the outputs like stress, displacement, strain etc.
– Modal Analysis/Dynamic Analysis: This was the analysis done on chassis applying forces when the vehicle is in motion. The pressure is applied on the chassis and we get how much frequency displacement taken place.
– Fatigue Analysis: This is the analysis done on chassis to find the damage percentage and life of the chassis. Here we will show the graph between stress and number of cycles(S-N curve).
– Impact Analysis: This is the analysis done to chassis and find the impact when there occurs an accident. And at various speeds how the stress, strain, displacement varies for a given pressure.

B. *Sample Analysis Images*

1) *Structural Analysis*

– C - Section

a) Stainless Steel

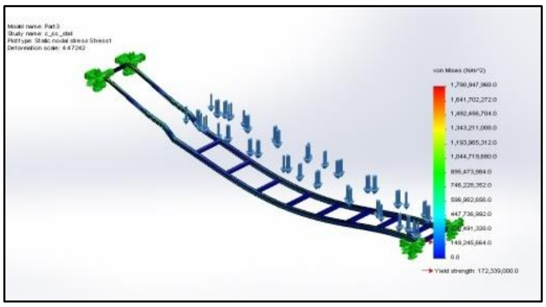


Fig. 7: Stress

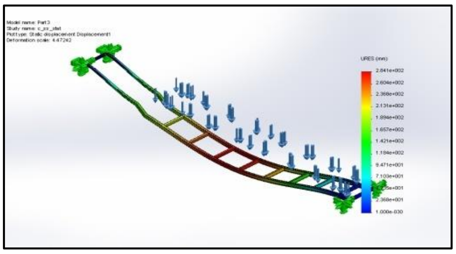


Fig. 8: Displacement

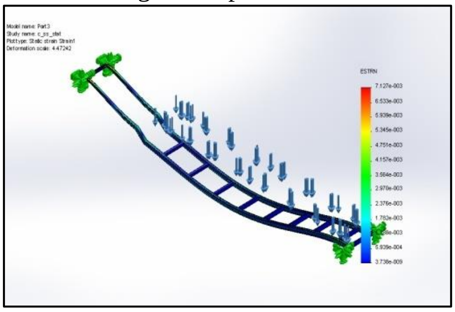


Fig. 9: Strain

C. Modal Analysis

– H-SEC

a) Cast Iron

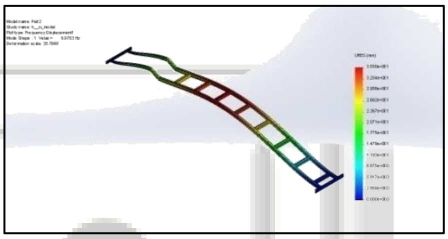


Fig. 10: Mode-1

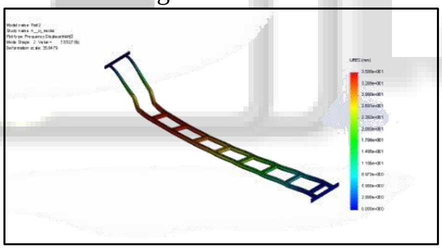


Fig. 11: Mode-2

2) Fatigue Analysis

a) Analysis Images

– C-Section

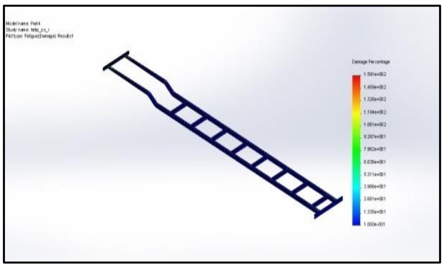


Fig. 12: Damage plot

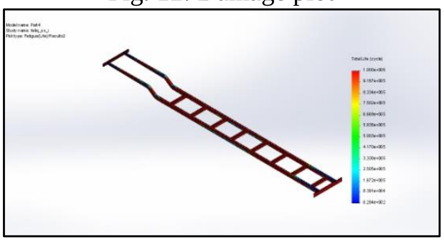


Fig. 13: Life plot

3) Impact Analysis

Impact Analysis

– I-SECTION,
– E-Glass,
– 60 KMPH

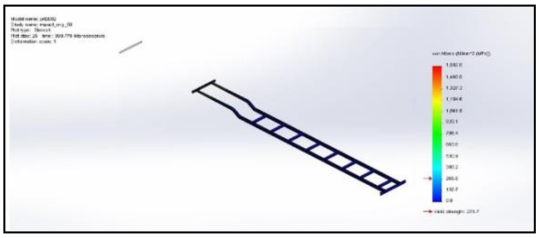


Fig. 14: Stress

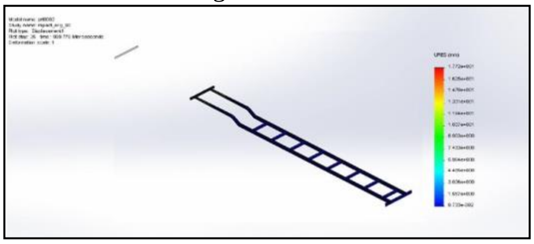


Fig. 15: Displacement

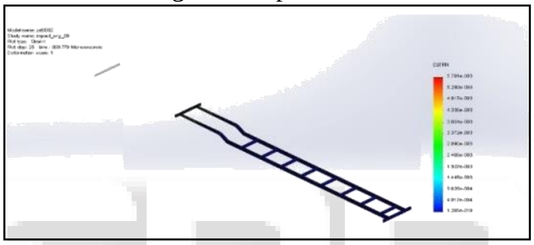


Fig. 7: Strain

VI. RESULTS

A. Structural Analysis

1) C-Section

Material	Stress	Displacement	Strain
Cast iron	1792.51	299.12	0.0074522
E-Glass	892.074	260.373	0.00856325
Steel	1790.95	284.123	0.00712713

Table 6: C - Section

2) H-Section

Material	Stress	Displacement	Strain
Cast iron	1887.95	305.654	0.00074644
E-Glass	922.538	263.243	0.008442345
Steel	1893.8	290.317	0.00714428

Table 7: H - Section

3) I-Section

Material	Stress	Displacement	Strain
Cast iron	1799.94	309.937	0.00748423
E-Glass	892.709	267.13	0.00856514
Steel	1798.08	294.399	0.0071566

Table 8: I - Section

B. Modal Analysis

1) C-Section

Material	Displacement-1	Displacement-2	Displacement-3	Displacement-4	Displacement-5
Cast iron	39.2374	39.1451	43.4624	40.1129	42.873

E-Glass	65.0332	65.5987	72.9073	67.0429	71.6661
Steel	37.9785	37.8705	42.0501	38.8189	41.4805

Table 9: I – Section

2) *I-Section*

Material	Displacement-1	Displacement-2	Displacement-3	Displacement-4	Displacement-5
Cast iron	36.9963	38.2404	43.2401	39.0299	41.3183
E-Glass	63.7688	63.7689	74.4216	65.1524	67.4747
Steel	35.7806	37.6007	41.8507	37.7941	40.018

Table 10: I – Section

3) *H-Section*

Material	Displacement-1	Displacement-2	Displacement-3	Displacement-4	Displacement-5
Cast iron	35.4991	35.8791	42.4622	38.86	44.7781
E-Glass	59.2182	57.4547	70.5644	63.0794	71.3332
Steel	34.3485	34.8721	41.0782	37.647	43.5672

Table 11: H - Section

C. *Fatigue Analysis*

1) *I-Section*

Material	Damage	Cycles
Cast iron	199.914	1E+006
E-Glass	145.298	1E+006
Steel	159.131	1E+006

Table 12: I - Section

2) *H-Section*

Material	Damage	Cycles
Cast iron	161.783	1E+006
E-Glass	125.625	1E+006
Steel	135.185	1E+006

Table 13: H - Section

3) *C-Section*

Material	Damage	Cycles
Cast iron	149.711	1E+006
E-Glass	118.745	1E+006
Steel	127	1E+006

Table 14: C - Section

D. *Impact Analysis*

1) *C-Section*

Material	Stress	Displacement	Strain	KMPH
Cast iron	1374.96	5.23085	0.00463953	60
	2593.7	8.72247	0.00775642	100
E-Glass	606.484	5.17535	0.0046683	60
	1008.16	8.62891	0.00777688	100
Steel	1443.15	5.22941	0.00466199	60
	2735.39	8.71972	0.00779054	100

Table 15: C - Section

2) *H-Section*

Material	Stress	Displacement	Strain	KMPH
Cast iron	1381.78	5.21319	0.004543	60
	24477.41	8.69157	0.00759734	100
Steel	1460.92	5.21132	0.0045689	60
	2544.66	8.68596	0.0076449	100
E-Glass	1008.2	8.632	0.00757	60
	987.312	8.53988	0.00795364	100

Table 16: H - Section

3) *I-Section*

Material	Stress	Displacement	Strain	KMPH
Cast iron	1592.76	17.718	0.00578071	60
	2686.68	29.5201	0.009740617	100
Steel	1776.93	17.5174	0.00563719	60
	3011	29.1789	0.00953432	100
E-Glass	585.125	17.4299	0.00531427	60
	990.803	29.0311	0.00907594	100

Table 17: I - Section

VII. CONCLUSIONS

Presently steel, aluminum & cast iron are used in manufacturing of chassis. In this project first step we have done the analysis on the present design. By seeing structural analysis results we have observed that the stress value's for E-Glass Epoxy are less than their respectively allowable stress values as compared to steel and cast-iron of any section. We have done structural analysis for the three materials of different section. We observed that the stress results obtained are almost reduced to half when compared with present design.

Also we have seen Modal analysis results for three materials. We have observed that less vibration are produced for Steel and Grey cast iron compared to other materials by changing C-Section to I-Section and H-Section.

We have done Fatigue analysis on the three sections using the three materials for same cycles the damage plot is less for E-Glass comparatively with other materials.

For Impact analysis the E-Glass epoxy stress and Displacement values are low comparatively other materials of different sections.

The main conclusion of the project in case of changing sections from C-Section to I and H Sections the Modal, Structural and Fatigue analysis we are getting better result. For impact analysis I-section is giving better result and the material E-Glass is better for manufacturing in recent loads conditions.

So, we conclude that by using composite material E-Glass epoxy (127.7 kg) instead of Steel(384.4 kg) & Cast-iron(206.23 kg) the weight of the chassis reduces three times compared with steel and almost twice compared with cast-iron because density of Steel & Cast-iron is more compared to E-Glass Epoxy.

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