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Virtual Analysis of E-glass Based Fibre Composite

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Abstract: The work here started with manufacturing a glass fibre composite with E-glass fibre and epoxy resin using hand layup process. The fibre was placed in an eight layered structure and compressed to form the composite. Thus formed campsites basic parameters such as density young's modulus and poisons ratio are calculated. These values are feeded in as the material properties of the sample designed for testing in an analysis software. On this sample tensile and bending tests are conducted virtually and the results of these test are compared with the results of other materials. Based on the comparison of these results the differences in the composites and other materials is established.

Keywords: E-glass fibre, Epoxy, Composite, Analysis, Tensile, Bending

1. Introduction

There is always a search for the replacement of metals for the applications at various occasions, at first there came the concept of alloys where two metals were taken and blended into one to achieve a combined property of both the metals. These are still used at a large scale in the present day, but fail to achieve optimum efficiency at some critical conditions. To overcome this problem composites became an easy solution because of their ease of manufacture and sustaining qualities at extreme conditions.

Composites can be made from many different combinations of materials, these can be stated as fibres, adhesives and additional chemicals. The fibres can be of natural or synthetic, adhesives are single compounds or the mixture of different combinations and the additional chemicals are for the adding required qualities into the composite.

In the fallowing paper a composite is manufactured and it's virtually analysed using computer software to compare its strength with comparison to the metals. This complete process will illustrate the main areas were the major differences are being a raised in the case of composites and metals during stress/bending force application.

2. Fibre for Composite Material

The composite material here is made using the synthetic glass fibre for achieving high strengths as the natural fibres are weak in comparison to the synthetic fibres. Synthetic fibres have various categorisation based on their properties, these properties are like they nature resist alkaline, resist conduction to electricity, have more strength and so on. Based on these features the fibres are named as E, S, AR, M, D, C among all these we have chosen E glass fibre for the preparation of sample.

On a large scale to produce the E-fibreglass, boron oxide is applied to silica, lime, alumina and magnesia while alkaline oxides are excluded. This composition is then heated, and the molten paste begins to obtain a viscous consistency at around 800 ° C. This is almost homogeneous at 1400 ° C but the last bubbles and impurities only vanish at 1500 ° C from the bottle. The molten mass, when refined, is perfectly transparent when it leaves the furnace and the mass is passed through dies to produce a thread of glass. This thread is then made to scale, wrapped and dry.

Products made of e-glass fibres are particularly resistant to abrasion and vibration and have excellent flexibility. The glass thread has a higher specific resistance than that of alloys. This capability enables the development of glass threads that reinforce high-performance composites. The excellent electrical insulating properties, even at low thicknesses, combined with its mechanical strength and behaviour at various temperatures, formed the basis for the first glass thread applications. The thermal conductivity of e-glass fibres is low. The fibre is non - flammable and can withstand temperatures above 600 ° C.

3. Preparation of Testing Sample

The sample prepared here will be a composite E-glass fibre and Bisphenol-A epoxy resin and no other additive chemicals are added into the composite this will be a combination of purely resin, hardener and the fibre. The preparation will fallow hand layup process and compression by loading.

3.1 Fibre Preparation

The E-glass Fibre is an electrically resistive fibre and the E in the name stands for this property. The chemical composition of the E-glass fibre is a combination of fallowing as written in respect of their weight percentage (55% of silicon dioxide) + (14% of aluminium oxide) + (0.2% of titanium dioxide) + (7% of boron trioxide) + (22% of Calcium oxide) + (1% of Magnesium oxide) + (0.5% of Sodium oxide) + (0.3% of Potassium oxide). The E- glass fibre also provides tensile strength of 3.44 Gpa and young's modulus of 72.3 Gpa.

Fig.1 E-glass Fibre Strips

In the preparation process the fibre sheet is taken and strips of fibre are cut out to a dimension of breadth 20mm and length of 200mm, thickness of each strip is 0.3mm. With these dimensions eight strips are cut out in the view of making eight layered composite.

3.2 Adhesive Component

The adhesive component used here is a combination of bisphenol resin and an amine based hardener, these are mixed in a volume ratio of 1:1. The resin and the hardener had a pot life of 20min, after that the exothermic reaction of the mixture begins. The total settling time for the mixture is 48hr after that the composite will be ready for physical modifications.

Fig.2 Resin Hardener Mixture

3.3 Preparation

The first step in the sample preparation is making mould of desired shape. Here a rubber mould is made of rectangle shape and it could accommodate a volume of 8ml, with the dimensions of 2mmx20mmx200mm. Then the next step fallows the mixing of resin and the hardener in the mixing jar with a 1:1 volume ratio, so resin of 3ml and hardener of 3ml are mixed by steady stirring in the in mixing jar. After the mixing the resin hardener thoroughly first layer of the mix is applied to the base of the mould and the fibre strip readied before is placed into the mould. This way alternative layers of fibre and the resin are added into the mould till it reaches a total of eight fibre layers.

Fig.3 Fibre Layer in the Mould

After each fibre layer application it is made sure that there are no air gaps trapped in between, when the layup is completed the upper surface is covered by a thin film to avoid any dust accumulation. Now onto the whole mould weights are loaded to compress the fibres layers together and it is noted that over loading of the weights leads to the leakage of the resin hardener mixture. The whole setup will be left alone away any disturbances and moist for a minimum time period of 48hr, after which the samples will be ready for physical modifications.

4. Testing

The testing procedure will involve on analysing the material in different loading conditions in a virtual mode. The results obtained will be compared to that of different other materials, all of this analysis will be done in abaqus software. The properties of the materials used are stated in the following table.

Table.1: Properties of samples Used

	Density-gm/cm^3	Young's Modulus-GPa	Poisson's Ratio
Mild Steel	7.85	205	0.29
Cast Iron	7.3	210	0.35
Aluminium	2.7	69	0.334
Copper	8.96	117	0.355
Composite	1.5955	0.028	0.225

4.1 Tensile Test

The testing is done by creating a dog bone shaped testing sample and creating a tensile force in one direction and restricting the growth in other directions. The force applied is a pressure of 10.976K.Pa on the sample, in comparison to the composite the different materials are taken are Mild Steel, Cast Iron, Aluminium and Copper. In this test a random set of 28 nodes were selected from different points and variation of the direct stress at those points are plotted on a graph.

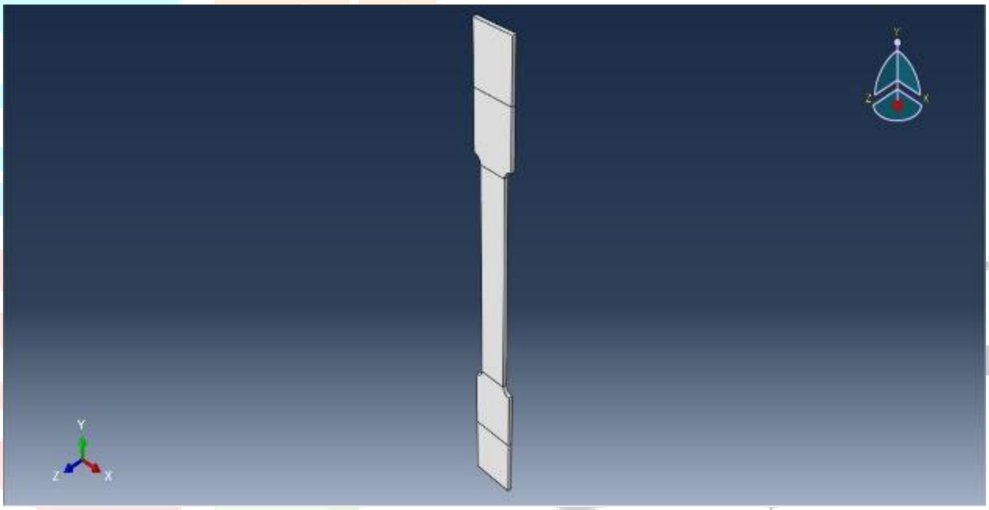

Fig.4 Tensile Testing Sample

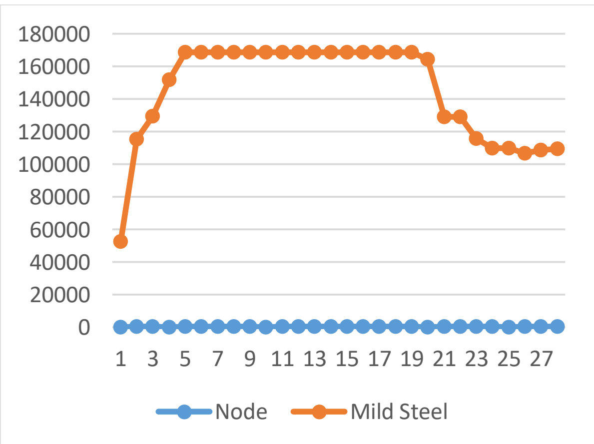

Fig.5 Tensile Test of Mild Steel

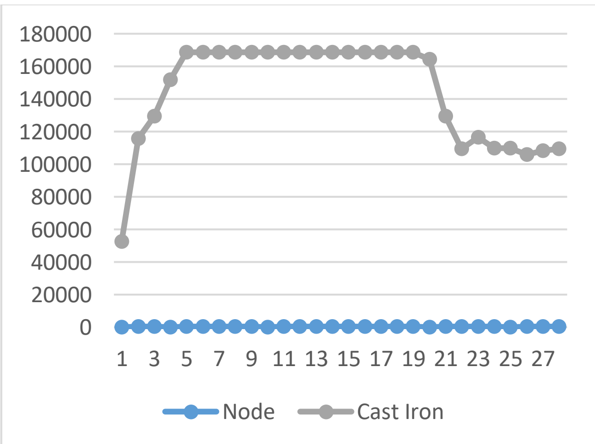

Fig.6 Tensile Test of Cast Iron

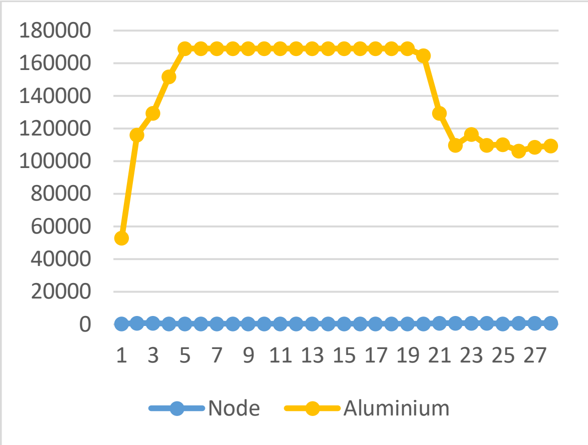

Fig.7 Tensile Test of Aluminium

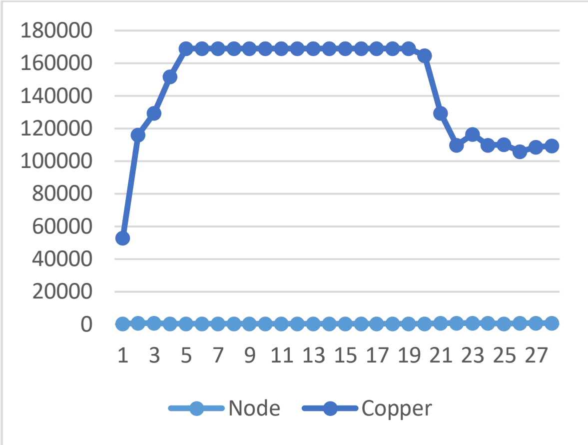

Fig.8 Tensile Test of Copper

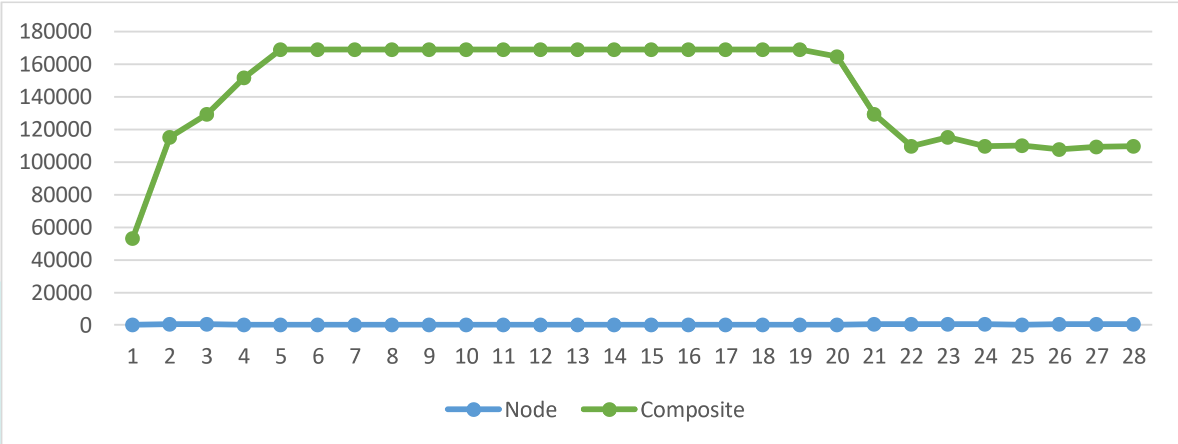

Fig.9 Tensile Test of Composite

After the comparison it is observed that the maximum direct stress in the samples is observed to be 16.88kPa and this happened between the nodes 5 to 19. But the major difference is observed when the drop was seen in stress developed, this was different in each sample.

Table.2: Tensile Test Output

	Max Stress(kPa)	Dropped Down(kPa)	Difference(kPa)
Mild Steel	16.88	12.92	3.96
Cast Iron	16.88	10.94	5.94
Aluminium	16.88	10.94	5.94
Copper	16.88	10.94	5.94
Composite	16.88	10.95	5.93

It is observed that all this variation had happened at the nodes 21 and 22 of the samples. The stresses developed at the different parts can be seen the following figure which depicts the different stress regions with distinctive colours.

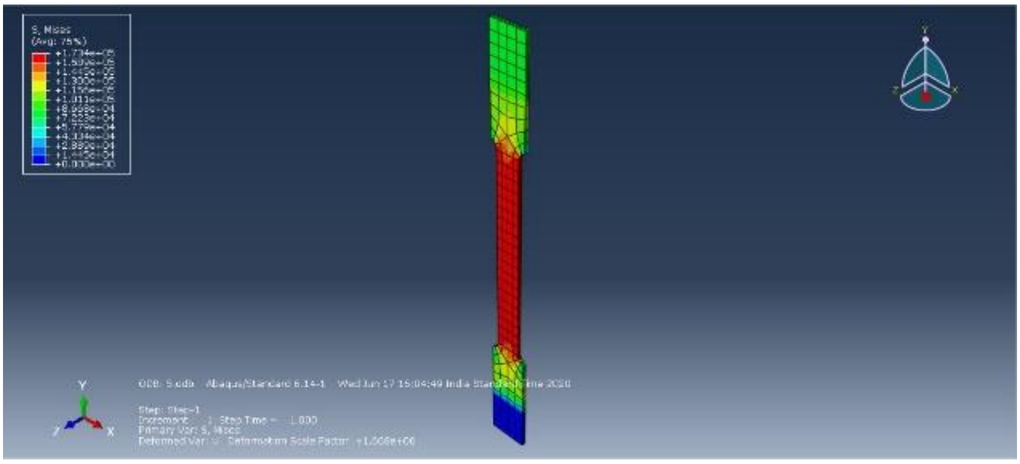

Fig.10 Deformed Tensile test Sample

4.2 Bending Test

The bending test is performed on a flat bar design then a total of 40 elements are considered all the body and yield stresses are plotted to graph, force applied on the body will be of 687N and this is a concentrated force unlike the pressure applied in the tensile test. In this test the sample is arrested for its movement in all the directions except for y-axis where the loading is done. The sample is arrested by fixing its ends and force applied at the mid-section.

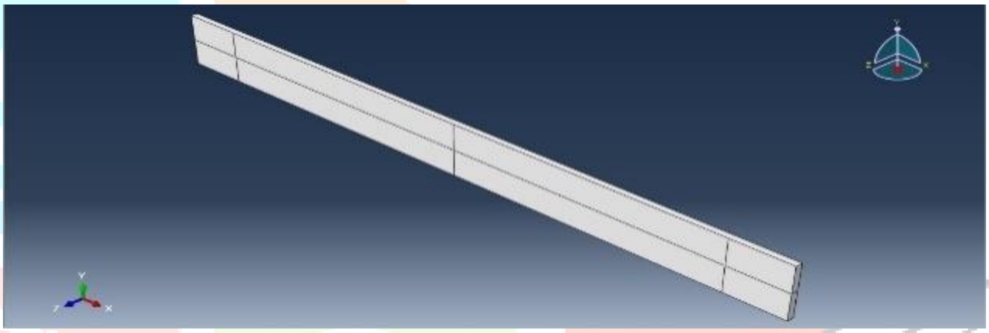

Fig.11 Bending Test Sample

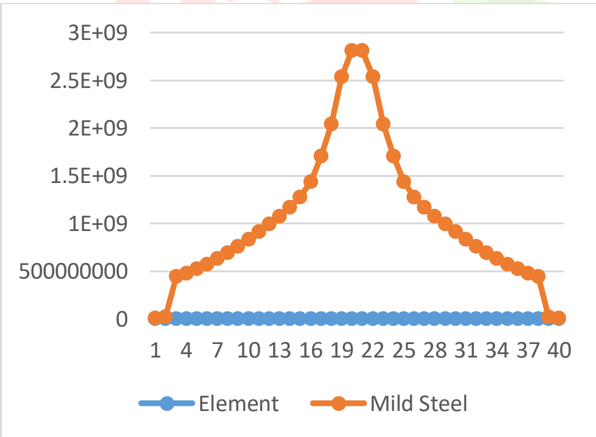

Fig.12 Bending Test of Mild Steel

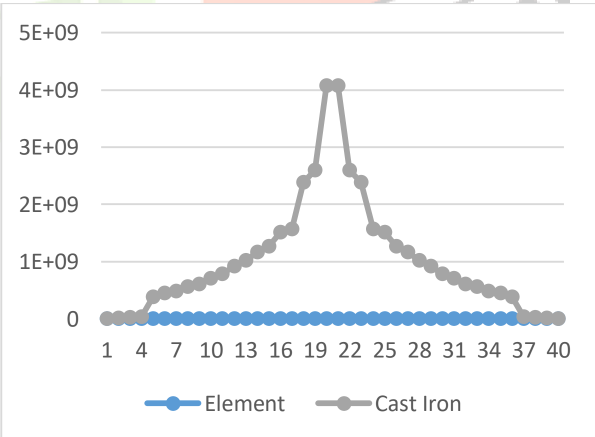

Fig.13 Bending Test of Cast Iron

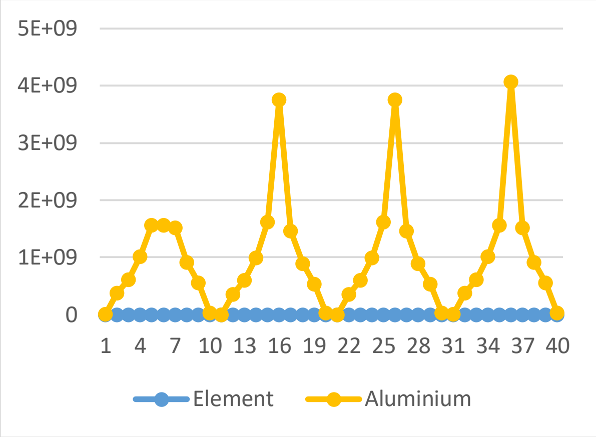

Fig.14 Bending Test of Aluminium

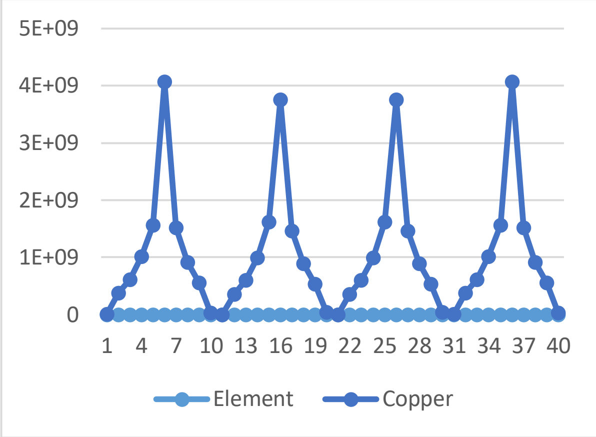

Fig.15 Bending Test of Copper

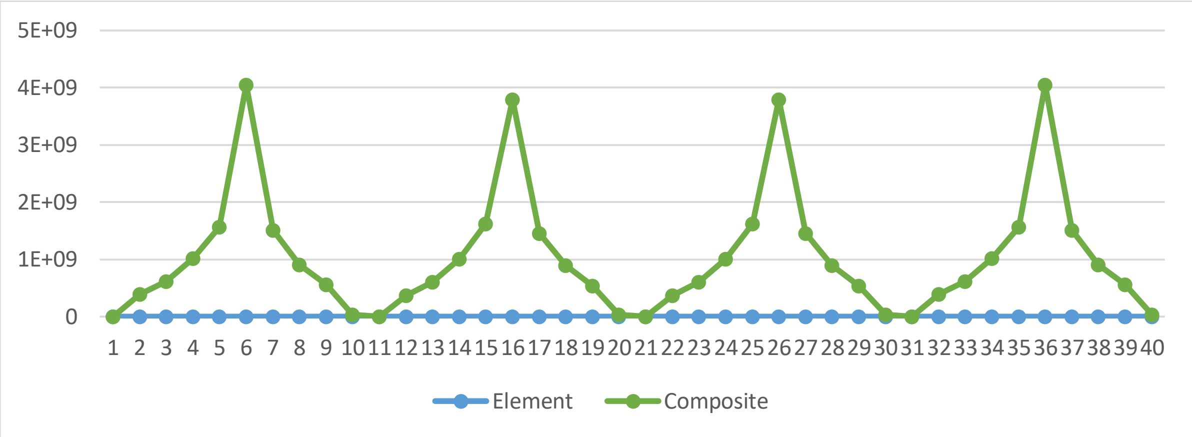

Fig.16 Bending Test of Composite

It is observed that the mild steel and cast iron yielded out at one instance, whereas the rest of the samples had multiple yielding points. The yielding stress achieved in the different samples can be stated as fallows.

Table.3: Bending Test Output

	Max Yield Stress(kPa)	No of Yielding Points
Mild Steel	281000	1
Cast Iron	407000	1
Aluminium	407000	4
Copper	407000	4
Composite	405000	4

Among all the material samples which had four yielding points it is observed that the aluminium had 3 yield points at with a yield stress of 407000kPa and on one point with a yield stress of 157000kPa. The deformation of the sample after the testing can be seen in the picture below with the different areas of deformation each depicted with distinct colours.

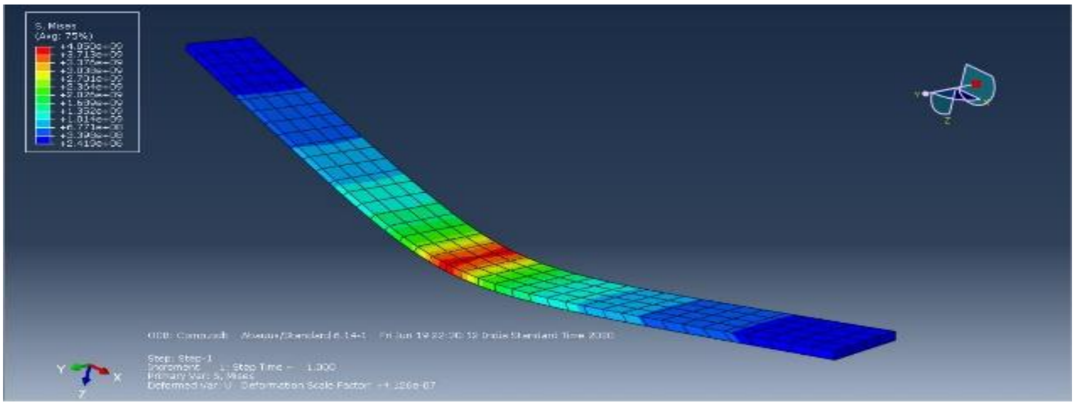

Fig.17 Deformed Bending Test Sample

5. Results

The testing process showed the stress output and the yield regions in the specimens and the composite had same deformation regions when compared to other material samples. The values of direct stress developed is 16.88kPa and the yield stress developed in the composite is 405000kPa. This has placed composite in a position to replace copper and aluminium but still not in place to replace mild steel and cast iron. The mild steel and cast iron still have better usable characteristics when compared to the composite.

6. Conclusion

The virtual analysis showed the exact difference between the different samples at each selected node, this gave the accurate variation between the samples under the various loading conditions of tensile and bending nature. The composite compared was capable to achieve output similar to that of aluminium and copper but failed in comparison to mild steel and cast iron, this can overcome in future by adding additives to the composite to increase its tensile strength and rigidity. The additives can be thought of as calcium carbonated, silica, graphite and many others, these not only improve the strength of the composite but also induce additional qualities based on the chemical nature.

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