

COMPARISON OF STRUCTURAL ANALYSIS OF CARBON FIBRE, ALUMINIUM MADE CONNECTING ROD

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ABSTRACT

Connecting rods that function in internal combustion engines are subjected to high cyclic loads comprised of dynamic tensile and compressive loads. The model of the connecting rod parts are designed using composite materials and analysed using FEM. Further study can also be carried out on dynamic loading working conditions for longer life cycle against failure.

Keywords: *composites, connecting rod, fabrication, analysis, thermal, structural.*

INTRODUCTION

Connecting rods that function in internal combustion engines are subjected to high cyclic loads comprised of dynamic tensile and compressive loads. They must be capable of transmitting axial tension and compression loads, as well as sustain bending stresses caused by the thrust and pull on the piston and by the centrifugal force of the rotating crankshaft.

Generally connecting rods are being made up of stainless steel and aluminium alloy through the forging process, as this method provides high productivity and that too with a lower production cost. Forces generated on the connected rod are generally by weight and combustion of fuel inside cylinder acts upon piston and then on the connecting rod, which results in both the bending and axial stresses. Therefore it order to study the strain intensity, stress concentration and deformation in the crank end of the connection rod, firstly based on the working parameter and the vehicle chosen the design parameter or dimensions of the connecting rod is calculated, then the model of the connecting rod parts is prepared and finally it is analyzed using Finite Element Method and results thus achieved will provide us the required outcome of the work done here .Also further study can also be carried out later on for the dynamic loading working conditions of the connecting rod and also improvement in design can also be made for operation condition and longer life cycle against failure.

SHAPES OF CONNECTING ROD

The two basic styles of connecting rods are I-Beam and H-Beam. Some rod suppliers only make I-Beams, others only make H-Beams, and some offer both types or variants of the I-Beam design. The I-Beam design is used for most stock connecting rods because it provides a good combination of light weight and strength.

- I - beam rod:
- H -beam rod:



Fig-1 Types of connecting rod

Whether I-Beams, H-Beams or something else, the alloy used in a set of rods and the subsequent heat treatment the metal undergoes during the manufacturing process are extremely important for both strength and reliability.

All connecting rods for automotive use need to be lightweight but strong enough to withstand and transmit the thrust from the pistons to an engine's crankshaft. Holes on both ends of a connecting rod are machined to perfectly connect to pistons and the crankshaft. Connecting rods are available in a variety of sizes and materials ideal for certain situations.

STRESS AND FAILURE

The connecting rod is under tremendous stress from the reciprocating load represented by the piston, actually stretching and being compressed with every rotation, and the load increases as the square of the engine speed increase. Failure of a connecting rod, usually called **throwing a rod**, is one of the most common causes of catastrophic engine failure in cars, frequently putting the broken rod through the side of the crankcase and thereby rendering the engine irreparable; it can result from fatigue near a physical defect in the rod, lubrication failure in a bearing due to faulty maintenance, or from failure of the rod bolts from a defect, improper tightening or over-revving of the engine.

MATERIALS USED FOR CONNECTING ROD

1. Steel:

Steel is an alloy of iron and other elements, primarily carbon, widely used in construction and other applications because of its high tensile strength and low cost. Carbon, other elements, and inclusions

within iron act as hardening agents that prevent the movement of dislocations that otherwise occur in the crystal lattices of iron atoms.



Fig-2 Connecting rod made of aluminium

2. Aluminium:

Aluminium is a good material for connecting rods because of its lightweight. Reducing the weight of the rods reduces the mass of the rotating and reciprocating parts and allows the engine to rev faster and rev higher. In addition to good throttle response, Aluminium is lighter weight can reduce vibration and stress on the crankshaft. Lighter rods also allow the use of heavier, stronger pistons.

3. Carbon fibre:

The properties of carbon fibre, such as high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion, make them very popular in aerospace, civil engineering, military, and motorsports, along with other competition sports. However, they are relatively expensive when compared with similar fibre, such as glass fibre or plastic fibre.

Carbon fibre is usually combined with other materials to form a composite. When combined with a plastic resin and wound or moulded it forms carbon-fibre-reinforced polymer (often referred to as carbon fibre) which has a very high strength-to-weight ratio, and is extremely rigid although somewhat brittle. However, carbon fibre are also composited with other materials, such as with graphite to form carbon-carbon composites, which have a very high heat tolerance.

Structure and properties:

Carbon fibre is frequently supplied in the form of a continuous tow wound onto a reel. The tow is a bundle of thousands of continuous individual carbon filaments held together and protected by an organic coating, or size, such as polyethylene oxide (PEO) or polyvinyl alcohol (PVA). The tow can be conveniently unwound from the reel for use. Each carbon filament in the tow is a continuous cylinder with a diameter of 5–10 micrometers and consists almost exclusively of carbon. The earliest generation (e.g. T300, HTA and AS4) had diameters of 16–22micrometers. Later fibre (e.g. IM6 or IM600) have diameters that are approximately 5 micrometers.

The atomic structure of carbon fibre is similar to that of graphite, consisting of sheets of carbon atoms arranged in a regular hexagonal pattern (grapheme sheets), the difference being in the way these sheets interlock. Graphite is a crystalline material in which the sheets are stacked parallel to

one another in regular fashion. The intermolecular forces between the sheets are relatively weak Van der Waals forces, giving graphite its soft and brittle characteristics.



Fig-3 Carbon fibre

4. EPOXY RESIN:

Epoxy resins are low molecular weight pre-polymers or higher molecular weight polymers which normally contain at least two epoxide groups. The epoxide group is also sometimes referred to as a glycidyl or oxirane group.

A wide range of epoxy resins are produced industrially. The raw materials for epoxy resin production are today largely petroleum derived, although some plant derived sources are now becoming commercially available (e.g. plant derived glycerol used to make epichloro hydrin).

Epoxy resins are polymeric or semi-polymeric materials, and as such rarely exist as pure substances, since variable chain length results from the polymerisation reaction used to produce them. High purity grades can be produced for certain applications, e.g. using a distillation purification process. One downside of high purity liquid grades is their tendency to form crystalline solids due to their highly regular structure, which require melting to enable processing.

An important criterion for epoxy resins is the epoxide content. This is commonly expressed as the **epoxide number**, which is the number of epoxide equivalents in 1 kg of resin (Eq./kg), or as the **equivalent weight**, which is the weight in grams of resin containing 1 mole equivalent of epoxide (g/mol). One measure may be simply converted to another:

$$\text{Equivalent weight (g/mol)} = 1000 / \text{epoxide number (Eq./kg)}$$

Why only Epoxy with Carbon Fiber?

CARBON FIBER-REINFORCED EPOXY composites exhibit high specific strength, high specific stiffness and good fatigue tolerance. Furthermore, the fabrication of components and structures from composites allows for the integration of design principles and manufacturing processes, resulting in optimally tailored mechanical and physical characteristics.

Epoxy resins are typically about three times stronger than the next strongest resin type. Epoxy adheres to Carbon Fibre, Fibre glass, and Aramid (Kevlar), very well and forms a virtually leak-proof barrier.

The epoxy can undergo plasticization and hydrolysis, which cause reversible and irreversible changes in the polymer structure. Due to these processes both the modulus and glass transition temperature are lowered

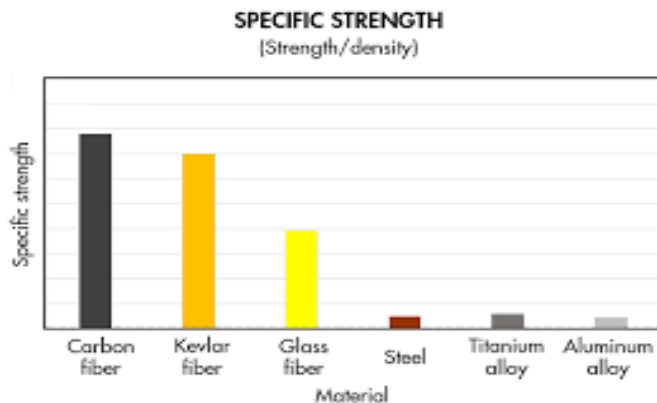


Fig-4 Comparison of specific strength of materials

Designing connecting rod

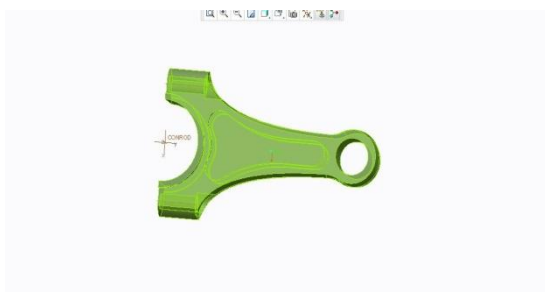


Fig-5 Design of Connecting Rod



Fig-6 Assembly of Connecting Rod

Structural properties	steel	Al-Alloy 4032 T6
YOUNGS MODULES (Pa)	2e11	7.7e10
POISON RATIO	0.29	0.33
DENSITY (kg/m^3)	7850	2690
YEILD STRENGTH (Pa)	2.5e8	3.3e8

Table 1: structural properties of Steel and Al alloy

CARBON FIBRE EPOXY

CARBON FIBRE EPOXY	
YOUNGS MODULES(Mpa) E_{xx}	91820
YOUNGS MODULES(Mpa) E_{yy}	91820
YOUNGS MODULES(Mpa) E_{zz}	9000
POISON RATIO _{xy}	0.05
POISON RATIO _{yz}	0.3
POISON RATIO _{zx}	0.3
DENSITY (kg/m³)	1480
YEILD STRENGTH (Pa)	3.35e8

Table 2: Properties of carbon fibre epoxy

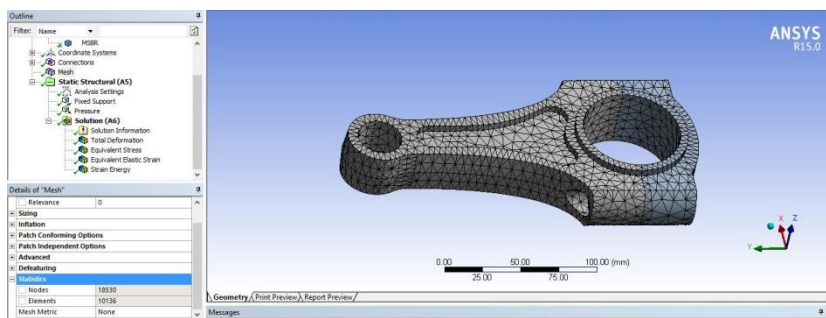


Fig-7 Finite Element Model of Connecting Rod

RESULTS FOR EXSISTING MATERIAL (STEEL)

We apply same boundary conditions (10mpa) for all materials and results shown in below.

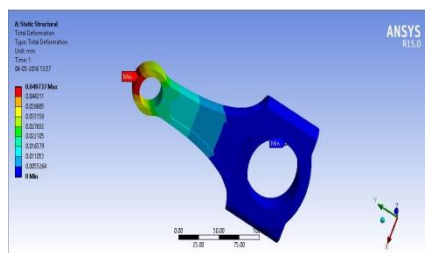


Fig -8 Deformation

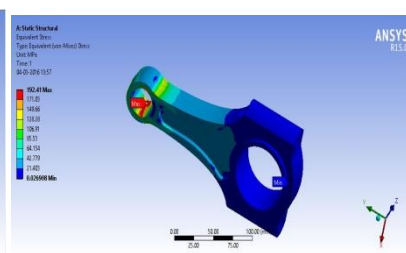


Fig-9 Stress

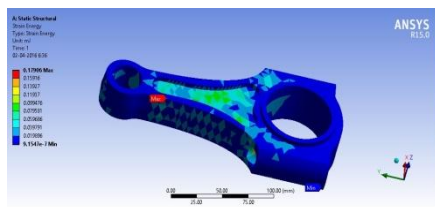


Fig -10 Strain

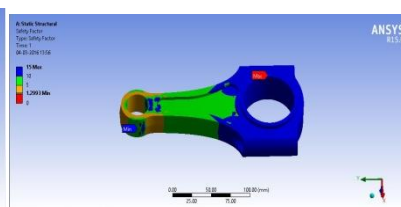


Fig 11: Factor Of Safety

RESULTS FOR AL-ALLOY 4032-T6

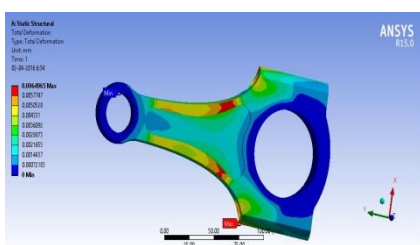


Fig- 12 Deformation

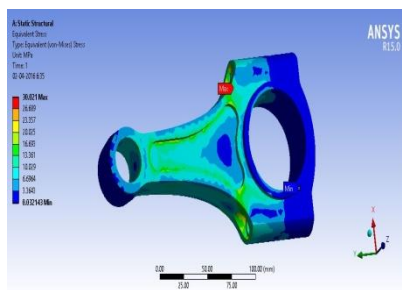


Fig -13 Stress

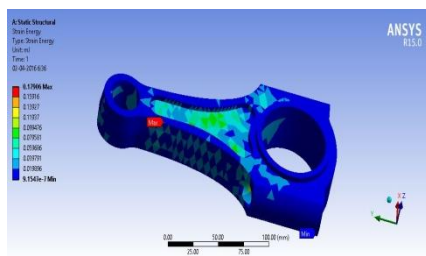


Fig-14 Strain

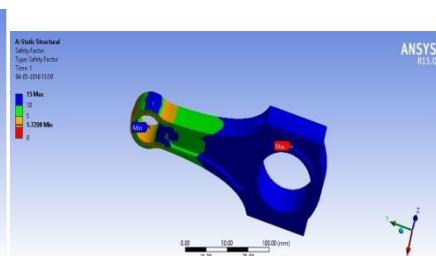


Fig-15 Factor Of Safety (Fos)

RESULTS FOR CARBON FIBRE EPOXY

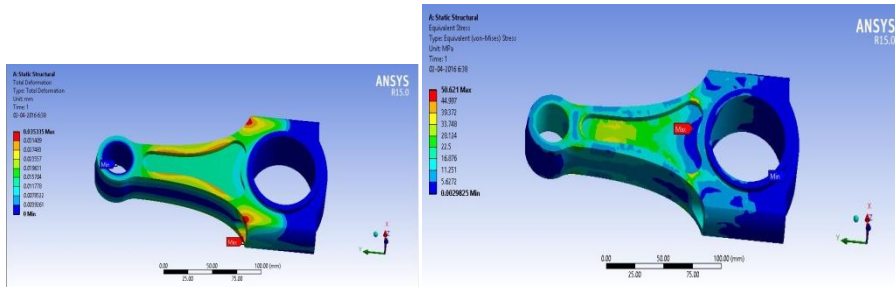


Fig-16 Deformation Fig-17 Stress

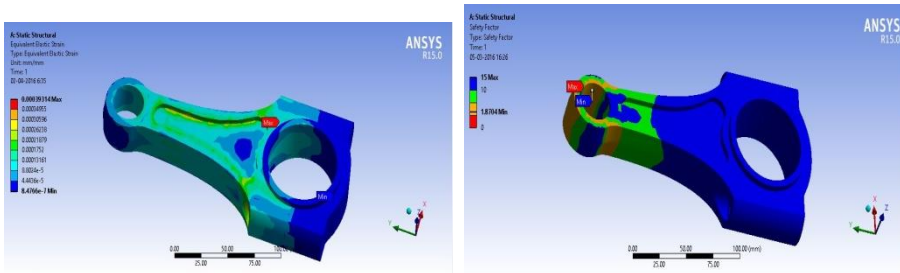
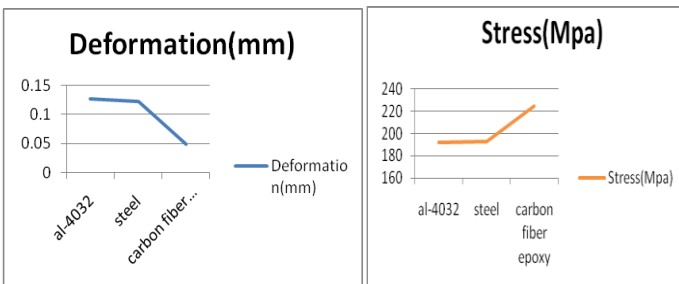


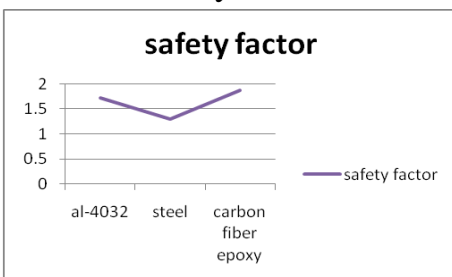
Fig-18 Strain Fig-19 Factor Of Safety (Fos)

GRAPHS REPRESENTING THE COMPARISON OF THE RESULTS



Graph-1 Graph-2

Factor of safety



Graph-3

From the above results al-4032 having high deformation values and carbon fibre having less deformation compare to other two materials, and next for stress carbon fibre epoxy having high stress and al-4032 have less stress compare to other materials and also all three materials under yield strength limits

so our object is safe at this boundary condition, and finally safety factor values are high for carbon fibre and then al-4032 and then steel materials respectively.

THERMAL ANALYSIS

RESULTS FOR EXISTING MATERIAL (STEEL)

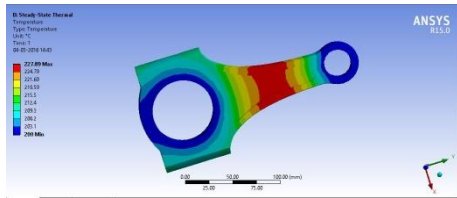


Fig-20 Temperature

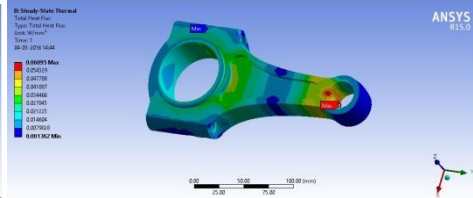


Fig-21 Total heat flux

RESULT FOR AL-ALLOY 4032

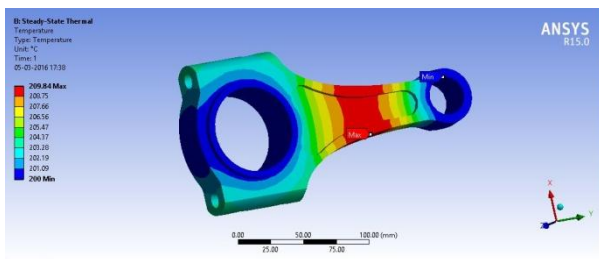


Fig-22 Temperature

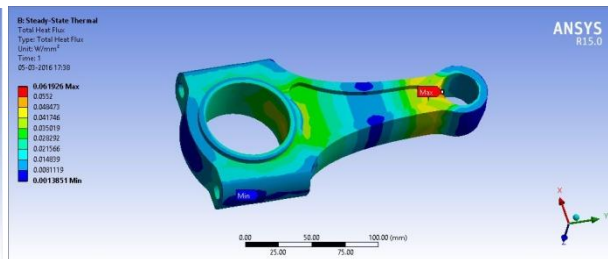


Fig-23 Total heat flux

RESULT FOR CARBON FIBRE EPOXY

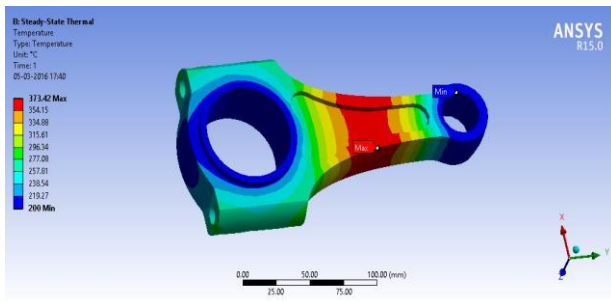


Fig-24 Temperature

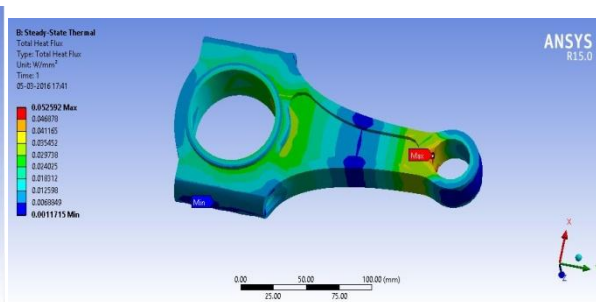
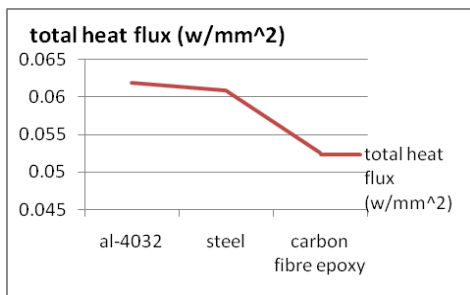
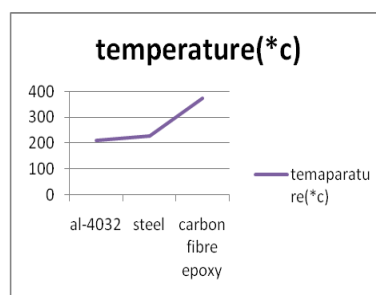


Fig-25 Total heat flux

THERMAL GRAPHS



Graph-7



Graph-8

FABRICATION OF DIE:

Raw material for Die:

The carbon fibre connecting rod was produced using hand-layer method.

Designing of Die:

The die is made in to three layers name as upper layer, middle layer and bottom layer. The middle which has hallow shape of cutting rod as shown in figure below will be the main die were material is changed in to desired shape with the help of epoxy resin. Other two layers are for covering the middle layer for not the air to pass and keep the resin at given higher temperature.

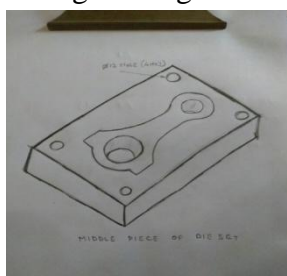


Fig-26 Middle plate of wooden piece

Die: The shape is cut at the given thickness of connecting rod with sharp and accurate shape in hollow form in the wooden part. This hollow form is formed for having a connecting rod in a definite form by filling the carbon fibre inside the hollow part of the wooden piece. After obtaining the shape of hollow part of connecting rod, the wooden piece is placed on the lower part by placing a polythene sheet in between the lower part and middle part.

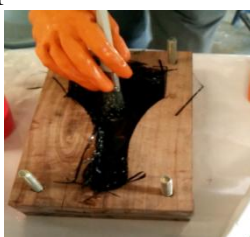


Fig-27

Now after placing proper carbon fiber sheet with required epoxy resin the middle layer is covered with another polythene sheet and then top wooden layer of the die is placed on the top and fixed firmly with nut and bolts in such a way that there is no passage of air in between the layer.

These total preparation is kept for 24 hours to get the desired shape connecting rod and should see that there is no loosening in nuts.



Fig-28

PRECAUTIONS

- See that there is no leakage of epoxy from the passage of the die.
- Use clean brushes while applying epoxy in to the die.
- Use gloves for applying epoxy in to the die.
- See that epoxy is not touched with bare hands.

After completing 24 hrs we see that total die was fixed with each other and to remove that we took help of hammer and chisel. After removing the upper and lower layer of the die polythene sheet is removed this was fixed on the surface of the middle layer.

As epoxy is highly adhesive the middle layer had to be broken to get the formed connecting of given thickness and shape. To do these we take help of hammer and hacksaw to make the wood into pieces. We use finishing tool to do finishing on the rod.

Finally we get the correct shaped connecting rod which is not having holes at both the ends to make these we use further process shown in next stage.

CONCLUSION

- From the results of structural analysis we can say that connecting rod made with carbon fiber material shows good mechanical properties theoretically as compared to the presently used materials i.e. aluminum and steel.
- By thermal analysis we can say that carbon fiber withstands higher temperature as compared to other two and it has low heat flux. Theoretical values may vary.
- We would like to conclude that composite like carbon fibre has good strength and can be suitable for connecting rod but with high quality epoxy since carbon fiber is very light in weight and has good elastic property which can give more efficiency to engine.

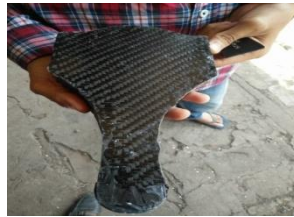


Fig-29

FUTURE SCOPE IN THIS PROJECT

1. The uses of carbon fibre composites is expected to increase significantly during the next few years.
2. There are requirements In EU's end of Life Vehicles Directive (ELV) for the automotive industry to maintain a low ash content of residual products which can be achieved by replacing fibre glass with carbon fibre in composites. It can replace Aluminium in manufacturing of connecting rods for racing bikes as they can be replaced easily. Now a days most of the automobile companies are using carbon fibre for making only body parts.
3. By critically analyzing (manual testing) the project thermally, FUNCTIONALLY GRADED MATERIALS can be introduced and fabricated for testing.

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