



# EXPERIMENTAL ANALYSIS OF QUASI-STATIC IMPACT OF SANDWICH COMPOSITE LAMINATES

Syed Azmath, VISHVANATH, RAJESHWAR SANGU

Department of Mechanical Engineering  
Ellenki College of Engineering And Technology,  
Patelguda, Hyderabad.

## ABSTRACT

The fatigue response of sandwich composite panels with an improved structure and different orientations to increase their fatigue resistance is investigated herein. In order to compare the fatigue performance of sandwich structures, a specific and instrumented ball drop tester was designed and developed. Different sandwich structures are analyzed. Composite materials here compose of E-Glass fibre matrix composite skin and a foam core. Usually the foam core is Polyurethane (P.U) and Polyphenolic. The latter structure is specially designed to improve crashworthiness for transport applications, aeronautical and space structures.

The main results of this study are evaluation of the absorbing energy performance of the sandwich structures, subjected to a repeated impact of the sandwich panels up to fatigue, and the development of criteria useful for materials selection. These sandwich panels have shown a better performance in terms of impact energy absorbing properties and strength respect to traditional sandwich structures. The predicted fatigue behavior of sandwich panel compared fairly well with results from finite element analysis. Analytical predictions of these were also found to be in good agreement with experimental data. Specimen deformation behavior and fracture features are correlated to deformation curves obtained during the testing. Extensive experiments are carried out to characterize different oriented

sandwich panels for the mechanical behavior as well.

## INTRODUCTION

### 1.1 Introduction to Composite Materials

Increasing performance demands for modern technology applications make it necessary to look for new materials. It is difficult to achieve high and strict performance standards using any one material, hence new materials are fabricated by combining two or more conventional materials. These materials named as composite materials give unique combination of properties, which cannot be obtained from any single conventional material. A formal definition of composite materials give by ASM Handbook [4] is macroscopic combination of two or more distinct materials, having a recognizable interface between them.. Composites are normally made by incorporating some reinforcement such as fibres in a bulk material known as matrix. Some of the main advantages of composite materials are high strength, modulus, bending stiffness and chemical resistance. Properties of composites can also be tailored according to specific design requirements, directional and spatial properties. Defining a composite material needs information on three aspects

- Matrix material: e.g. metal, polymer or ceramic
- Reinforcements: e.g. continuous or discontinuous fibres or particles
- Structure: e.g. laminated or sandwich

The matrix holds the reinforcements in an orderly pattern. Because the reinforcements are usually discontinuous, the matrix also helps to transfer load among the reinforcements. Matrix

materials are usually some type of plastic, and these composites are often called reinforced plastics. There are other types of matrices, such as metal or ceramic, but plastics are by far the most common. There are also many types of plastics, but a discussion of them is beyond the scope of this week's column. Suffice it to say for now that the two most common plastic matrices are epoxy resins and polyester resins.

Metal Matrix Composites (MMCs) - mixtures of ceramics and metals, such as cemented carbides and other cermets

Polymer Matrix Composites (PMCs) -

Thermosetting resins are widely used in PMCs

Examples: epoxy and polyester with fibre reinforcement, and phenolic with powders

Ceramic Matrix Composites (CMCs) -  $Al_2O_3$  and SiC imbedded with fibres to improve properties, especially in high temperature applications

## 1.2 Functions of the Matrix Material

- Provides the bulk form of the part or product made of the composite material
- Holds the imbedded phase in place, usually enclosing and often concealing it
- When a load is applied, the matrix shares the load with the secondary phase, in some cases deforming so that the stress is essentially born by the reinforcing agent.

## 1.3 Reinforcements- Fibres

Reinforcements basically come in three forms: particulate, discontinuous fibre, and continuous fibre. A particle has roughly equal dimensions in all directions, though it doesn't have to be spherical. Gravel, microballoons, and resin powder are examples of particulate reinforcements. Reinforcements become fibres when one dimension becomes long compared to others. Discontinuous reinforcements (chopped fibres, milled fibres, or whiskers) vary in length from a few millimeters to a few centimeters. Most fibres are only a few microns in diameter, so it doesn't take much length to make the transition from particle to fibre.

Function is to reinforce the matrix phase  
Imbedded phase is most commonly one of the following shapes:

- Fibres
- Particles
- Flakes



Fig 1.1 Possible physical shapes of imbedded phases in composite materials: (a) fibre, (b) particle, and (c) flake

### 1.3.1 CONTINUOUS VS. DISCONTINUOUS FIBRES

With either particles or short fibres, the matrix must transfer the load at very short intervals. Thus, the composite properties cannot come close to the reinforcement properties. With continuous fibres, however, there are few if any breaks in the reinforcements. Composite properties are much higher, and continuous fibres are therefore used in most high performance components, be they aerospace structures or sporting goods.

Continuous Fibres - very long; in theory, they offer a continuous path by which a load can be carried by the composite part

Discontinuous fibres (chopped sections of continuous fibres) -

Short lengths ( $L/D =$  roughly 100)

Important type of discontinuous fibre are whiskers - hair-like single crystals with diameters down to about 0.001 mm (0.00004 in.) with very high strength

### 1.3.2 Fibre Orientation – Three Cases

- One-dimensional reinforcement, in which maximum strength and stiffness are obtained in the direction of the fibre
- Planar reinforcement, in some cases in the form of a two-dimensional woven fabric
- Random or three-dimensional in which the composite material tends to possess isotropic properties

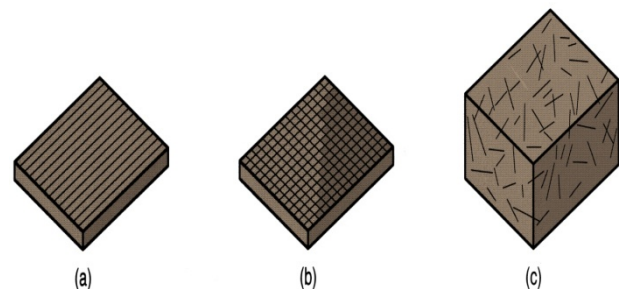


Figure 1.2 - Fibre orientation in composite materials:

(a) One-dimensional, continuous fibres; (b) planar, continuous fibres in the form of a

woven fabric; and (c) random, discontinuous fibres

### 1.3.3 Materials for Fibres

Fibre materials in fibre reinforced composites:

- Glass – most widely used filament
- Carbon – high elastic modulus
- Boron – very high elastic modulus
- Polymers - Kevlar
- Ceramics – SiC and Al<sub>2</sub>O<sub>3</sub>
- Metals - steel

The most important commercial use of fibres is in polymer composites. Mainly, the following different types of fibres namely, glass fibres, silicon carbide fibres, high silica and quartz fibres, aluminum fibres, metal fibres and wires, graphite fibres, boron fibres, aramid fibres and multiphase fibres are used. Among the glass fibres, it is again classified into E-glass, A-glass, R-glass etc. There is a greater market and higher degree of commercial movement of organic fibres. The potential of fibres of graphite, silica carbide and boron are also exercising the scientific mind due to their applications in advanced composites. Over 95% of the fibres used in reinforced plastics are glass fibres, as they are inexpensive, easy to manufacture and possess high strength and stiffness with respect to the plastics with which they are reinforced. Their low density, resistance to chemicals, insulation capacity are other bonus characteristics, although the one major disadvantage in glass is that it is prone to break when subjected to high tensile stress for a long time. However, it remains break-resistant at higher stress-levels in shorter time frames.

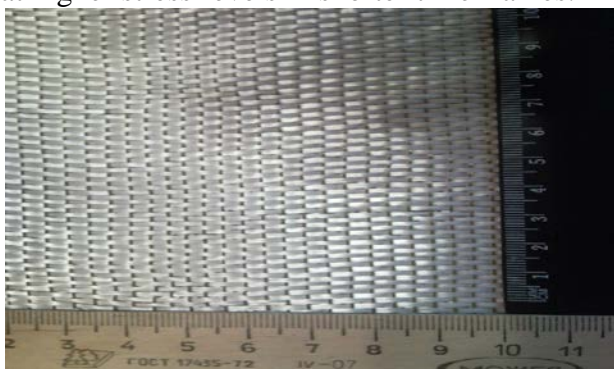


Figure a UD glass fibres

Figure b woven roving



As reinforcement, metal fibers have many advantages. They are easily produced using several fabrication processes and are more ductile, apart from being not too sensitive to surface damage and possess high strengths and temperature resistance. However, their weight and the tendency to react each other through alloying mechanisms are major disadvantages.

Ceramic fibers improve vastly in performance when a fine metal outline is incorporated with refractory ceramics by improving their thermal shock and impact resistance properties. Metal wires, of the continuous version, also reinforce plastics like polyethylene and epoxy. Such combinations ensure high strength, light weight and good fatigue resistance. Besides, continuous metal fibers are easily handled, unlike glass fibers. Better flexural properties are observed in some metal fibers reinforced plastic composites which also offer improved strength and weight, than glass fibers. However, their poor tolerance of high temperature and the resultant steep variations of thermal expansion coefficient with the resins are a discouragement that limits their application.

Alumina aluminum oxide fibers, basically developed for use in metal matrices are considered a potential resin-matrix composite reinforcement. It offers good compressive strength rather than tensile strength.

#### ARAMID FIBRES

Aramid Fibers Aramid fibers are made aromatic polyamides which are long polymeric chains and aromatic rings. They are structures in which six carbon atoms are bonded to each other and to combinations of hydrogen atoms. In aramid fibers, these rings occur and reoccur to form the fibers. They were initially used to reinforce automobile tires. Since then, they have also found other uses like bullet proof vests. As high strength applications, their use in power boats is not uncommon. Aramids have high tensile strength, high modulus and low weight. Impact-resistant structures can be produced from aramids. The density of aramid fibers is less than that of glass and graphite fibers. They are fire resistant apart from being high-temperature resistant and unaffected by organic solvents

fuels. But their resistance in acid and alkaline media is poor. They are supple and allow themselves to be woven into matrices by simple processes. Aramid fibers have a negative coefficient of thermal expansion in the fiber direction and failure of aramid fibers is unique. When they fail, the fibers break into small fibers, which are like fibers within the fibers. This unique failure mechanism is responsible for high strength.

#### **QUARTZ AND SILICA FIBRE**

Quartz and Silica Fibers typically contain about 50 to 70% silica. Silica glass is a purer glass fiber that can be made by treating fiberglass in an acid bath, which removes all impurities without affecting the silica. The final product contains 93 to 99% silica. Quartz is even more pure, and quartz fibers are made from natural quartz crystals that contain 99.9% silica, possessing nearly all the properties of pure solid quartz. Ordinary fiberglass, high silica and quartz fibers share several characteristics and can be produced in a range of fiber diameter. Roving or yarns and other forms of fibers can be made from high silica as well as quartz too. They differ from glass in many factors, however, especially in heat-related properties. Although quartz crystals are commonly available, pure crystals are hard to come by. On the other hand, high silica comes from the same material as glass fibers and is easily accessible. However, quartz makes up for its rarity with its capacity to withstand high temperatures, which silica is incapable of. Barring this difference, silica and quartz are similar in other respects. They are highly elastic and can be stretched to 1% of their length before break point. Both silica and quartz are not affected by acid attacks and are resistant to moisture. Owing to their thermal properties, silica and quartz are the natural choice as fibers in several applications. They have good insulating properties and do not melt at temperature up to 1600°C. In addition, they have a low thermal expansion coefficient which makes them withstand high temperatures. While use of the term carbon for graphite is permissible, there is one basic difference between the two. Element analysis of polyacrylo-nitrile (PAN) base carbon fibers show that they consist of 91 to 94% carbon. But graphite fibers are over 99% carbon. The

difference arises from the fact that the fibers are made at different temperatures.

#### **1.3.4 Structure of Composite**

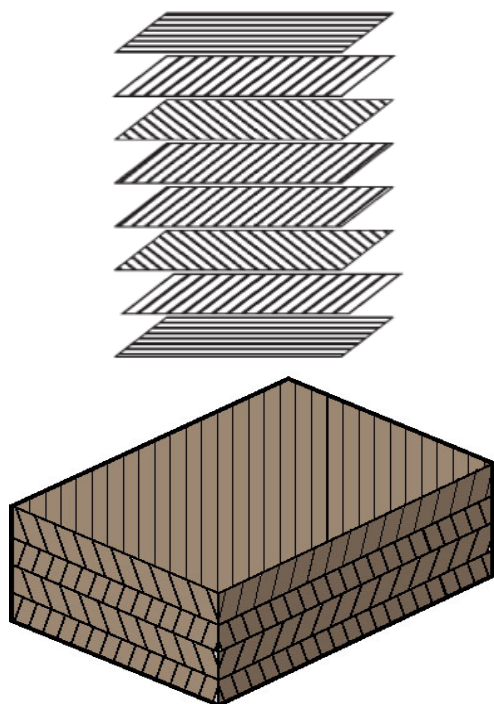
Composite properties are best in the direction of the fibres. Perpendicular, or transverse, to the fibres, the matrix properties dominate because load must be transferred by the matrix every fibre diameter. Because most structures are not loaded in a single direction, even though one direction may dominate, it is necessary to orient fibres in multiple directions. This is accomplished by stacking multiple plies together. Such a stack is called a laminate.

The most efficient composites have most of their fibres oriented in the primary load direction, and just enough fibres oriented in the other directions to carry secondary loads and hold the structure together. Efficiency means both low weight and low cost, because any fibres which don't carry much load could probably be removed.

#### **1.3.5 Laminar Composite Structure**

Composite materials are available as plies or lamina. A single ply consists of fibres oriented in a single direction (unidirectional) or in two directions (bidirectional; for example a woven fabric). There are other forms, but these are the most important for this discussion. Two or more layers bonded together in an integral piece constitutes a lamina

Example: plywood in which layers are the same wood, but grains are oriented differently to increase overall strength of the laminated piece



(a)  
Figure 1.3- laminar composite structures: (a) conventional laminar structure

### 1.3.6 Sandwich Structure

Sandwich composites comprise of two thin but stiff face sheets attached on either side of a lightweight, thick slab known as core. Many variations of this definition are available but the key factor in making this type of materials remains the lightweight core, which reduces the overall density of the material and stiff skins providing strength. The structure of sandwich composites is shown in Figure Integral bonding between skins and core prevents the interfacial failure under the applied load enhancing the flexural properties of sandwich composites. There is no general rule about the relationship between the thickness of skin and core. It depends on the application and required properties. Major advantage of sandwich structured composites is the possibility of tailoring properties by choosing appropriate constituting materials and their volume fractions.

### 1.4 Components in Sandwich Composites

Sandwich composites primarily have two components namely, skin and core as shown in Figure. If an adhesive is used to bind skins with the core, the adhesive layer can also be considered as an additional component in the

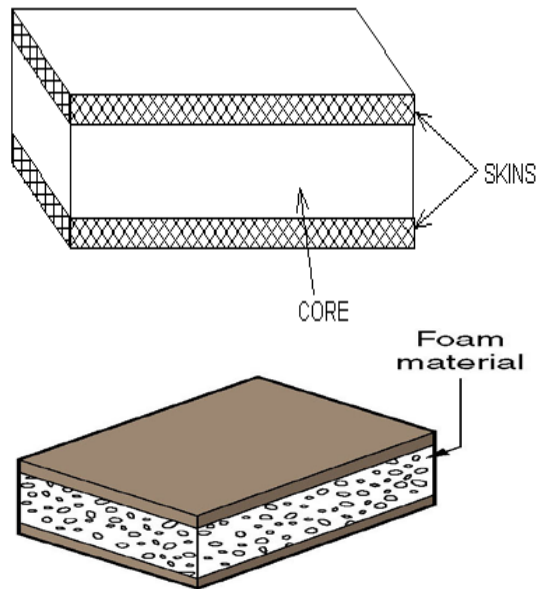
structure. The thickness of the adhesive layer is generally neglected because it is much smaller than the thickness of skins or the core. The properties of sandwich composites depend upon properties of the core and skins, their relative thickness and the bonding characteristics between them.

#### 1.4.1 Core

Based on the performance requirements, large numbers of materials are used as core popular core materials can be divided into three classes as described below.

1. Low density solid materials: open and closed cell structured foams, balsa and other types of wood.
2. Expanded high-density materials in cellular form: honeycomb, web core.
3. Expanded high-density materials in corrugated form: truss, corrugated sheets.

High-density materials used for the purpose of making expanded core include aluminum, titanium and various polymers. The structure of the core material affects the interfacial contact area between skins and the core. Expanded high density materials normally provide much smaller contact area compared to the solid low density materials. The choice of appropriate structure for core provides additional parameter to design a sandwich composite as per given specifications or service conditions. The use of cores like closed cell structured foam gives some distinct advantages over open cell structured foams and cores. The specific compressive strength of close cell structured foams is much higher. They also absorb less moisture than open cell structured foam.



(b)  
Figure 1.4 - laminar composite structures: (b) sandwich structure using foam core

### 1.4.2 Skins

A wide variety of materials are available for use as skins. Sheets of metals like aluminum, titanium and steel and fibre reinforced plastics are some of the common examples of skin materials. In case of fibre reinforced skins, the material properties can be controlled directionally in order to tailor the properties of the sandwich composite. Fibre reinforced Polymers are used widely as skins due to their low density and high specific strength. Another advantage offered by the use of polymer composites in skins is that the same polymer can be used to make the skin and the core. Cross-linking of polymer between core and skin would provide adhesion strength level equal to the strength of the polymer. This provides possibility of making the skin an integral part of the structure eliminating the requirement of the adhesive. When an adhesive is used to bond the skin and the core together, selection of adhesives becomes very important, as they should be compatible with both the skin and the core materials. The adhesion must have desired strength level and should remain unaffected by the working environment. In case of metallic components, welding or brazing is used as a means of binding the core and skins together. Use of adhesives is also possible but is limited to such cases where one or more of the components cannot withstand heat.

Choice of skins is important from the point of view of the work environment as this part of the structure comes in direct contact with the environment. Corrosion, heat transfer characteristics, thermal expansion characteristics, moisture absorption and other properties of the whole sandwich composite can be controlled by proper choice of skin material. In most cases both skins of the sandwich are of the same type, but could be of different type depending upon specific requirements. Difference may be in terms of materials, thickness, fibre orientation, fibre volume fraction or in any other possible form.

## 1.5 Applications of Sandwich Composites

There are several applications that require materials of low density, high strength and high damage tolerance. Due to their lightweight, sandwich composites are widely used in various kinds of vehicles used for air, ground or sea transportation. Some of the main areas of applications of sandwich composites are listed below. There are a lot of Commercial Applications of Composite materials as Composites are the fastest growing "materials" market segment. Sporting goods, Aircraft, automobile, shipbuilding, are just a few examples. Tennis rackets, golf clubs; bumpers, door panels, dashboard, even engine components of modern automobiles; look closely at a Boeing 777.

- Cars and boats

Fibreglass, made of glass fibres held together by resins, was one of the earliest composites of the modern age. It was first widely used commercially in the 1950s as a lightweight alternative to steel and wood. Most cars today have fibreglass bumpers covering a steel frame and are used over wheel wells and other cosmetic parts of a car or truck. Fibreglass has become the standard material in recreational boats, from stern to bow. It has limited but useful applications for military and commercial boat use.

- Insulation

While fibreglass can be molded into car, boat, plane and other hardened materials it can also be used as insulation when strands of fibre are interwoven with glass "wool." Fibreglass wool is a thick, fluffy material used for thermal

insulation and sound absorption. Its versatility allows it to be used for home and building insulation, automobile engine compartments, ship and submarine bulkheads and hulls, acoustical paneling, and furnace and air conditioning units.

- Aerospace – much of the structural weight of today’s airplanes and helicopters consist of advanced FRPs
- Automotive – somebody panels for cars and truck cabs Continued use of low-carbon sheet steel in cars is evidence of its low cost and ease of processing
- Sports and recreation- Fibreglass reinforced plastic has been used for boat hulls since the 1940s Fishing rods, tennis rackets, golf club shafts, helmets, skis, bows and arrows.
- Armor  
Composites have shown remarkable resilience in ballistics protection for lightweight vehicles. Composite armor uses materials of varying hardness and elasticity for heat and shock absorption. Composite materials protect against both kinetic and chemical weapons. While passive armor is designed to absorb impacts and penetration of ammunition, active and reactive materials are designed to deflect or destroy incoming ammunition.
- Packaging materials.
- Thermal and electrical insulation.
- Storage tanks.

## 2. SAMPLE PREPARATION

The preparation of the sandwich panels , and it has been by compression moulding techniques.

Material used in the preparation of composite sandwich laminates

- UD fibres.
- Epoxy resin : lapox.
- Hardener: k6
- 2 jars (500ml and 1 ltr to add lapox and hardener).
- Brushes 1 inch and 2 inch to apply lapox to the fibre sheets.
- Polyurethane and polyphenolic foams
- Roller to evenly distribute the resin to the fibres.
- Mould sized 350 x 350mm

- Moiler film.

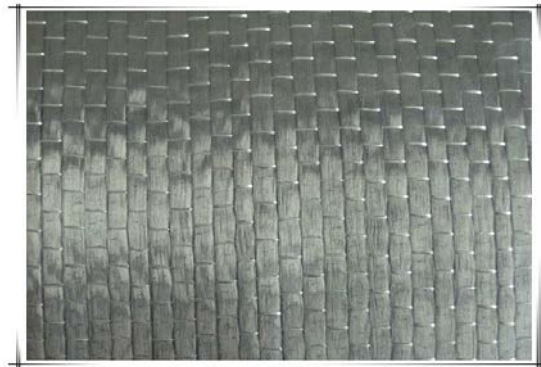


Figure a unidirectional fibre



Figure b Epoxy resin ( LAPOX)



Figure c polyurethane foam



Figure d polyphenolic foam

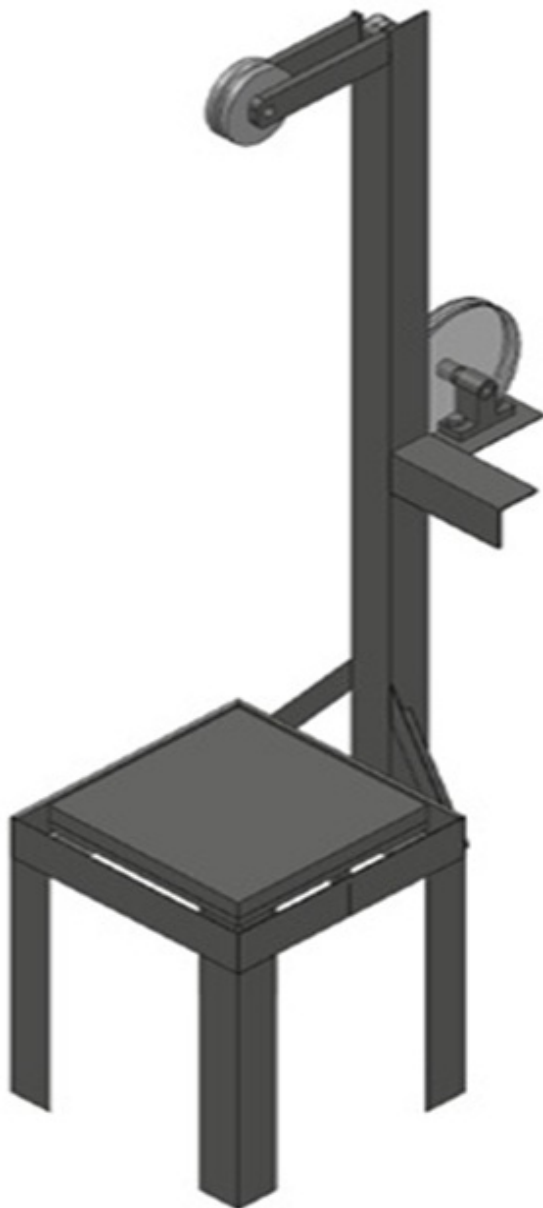
### **2.1 Step By Step Procedure To Prepare The Sandwich Composite Laminates**

Here are some of the steps to prepare the sandwich laminates in a sequential manner

- Firstly raw material was brought.
- The E-GLASS fibres were cut into pieces of size 250x250 8 sheets of the same size of the fibre are cut. A moiler film was also cut into the size of fibre pieces. After the fibres are ready the polyurethane P.U.foam was cut into the same size of the fibres that is 250x250 and the foam thickness was 15mm. only the single sheet of foam was cut which was to be placed in between the fibres.
- Then for the preparation of the laminates the resin used was epoxy resin and the hardener was used to harden the resin.
- Then the surface of the mould was cleaned so that the surface finish of the laminate should be smooth. Then after cleaning the surface the releasing agent was sprayed on the mould so that after the laminate is ready it should not get stick to the surface of the mould.
- And the mould is kept to dry after spraying the releasing agent. it approximately takes half an hour for the mould to get dry.
  - After the mould is dry it is ready to make a laminate in the mould.
  - Two measuring jars were used to measure the resin and a hardener, the jars was 1lts and 500 ml.
  - The resin and hardener was mixed at 1:10 ratio.
- 300 ml of resin was filled in the jar. And 30 ml of hardener was filled in another jar.
- These two were kept ready and when the laminate was getting started these resin and hardener were mixed thoroughly in another jar.
- Then the moiler film was kept in the mould at the bottom. And the first sheet of fibre was placed inside the mould and the resin was applied on the fibre.
- After applying the resin to fibre with the brush, the roller is used to evenly distribute the resin to the surface of the fibre. The roller is rolled thoroughly so that all the edges of the fibre get the resin distributed evenly.
- We should see that the resin should get evenly distributed to all the corners and surface of the fibre.
- Then the second layer of fibre was placed and the resin was applied on the fibre and the resin was evenly distributed on the second fibre sheet with the help of roller.
- Again the third sheet was placed and the resin was applied on the fibre and the resin was evenly distributed on the third fibre sheet with the help of roller.
- While placing the fibre sheets we should see that the orientation of the fibre sheets should be in same direction.
- Then the fourth layer was placed and the same process is being carried out.
- Now the foam was placed after the 4 layers of fibre, and the resin was applied on the surface of the foam.
- Then the fifth layer of the fibre was placed and the resin was applied in the same manner as above.
- And similarly more three layers was placed in the same manner.
- After all the 8 layers are placed on the mould, after the application of resin to the last layer of the fibre, the miler film is placed on the top of the fibres for the smooth surface finish for the laminate.
- A heavy metal sheet of the size of laminate is being kept on the fill them, so that the resin gets distributed to all the layers inside the mould.



- Now the mould is kept untouched so that it should get dry and the mould is left for 24 hours. and the brushes and jars are cleaned with the help of turpentine oil so that the resin does not get stick to it.
- And the next day the laminate is ready in the mould. then the miler film is removed and the laminate is taken out.
- Hence the same procedure is carried out for making the other laminates of different fibres of different orientations.
- **2.3 MODELLING OF TEST RIG**
- **Modelling of the test rig in solid works 2008**



## **2.4 FABRICATION OF FATIGUE**

### **TEST RIG:**

#### **List of materials and its specifications**

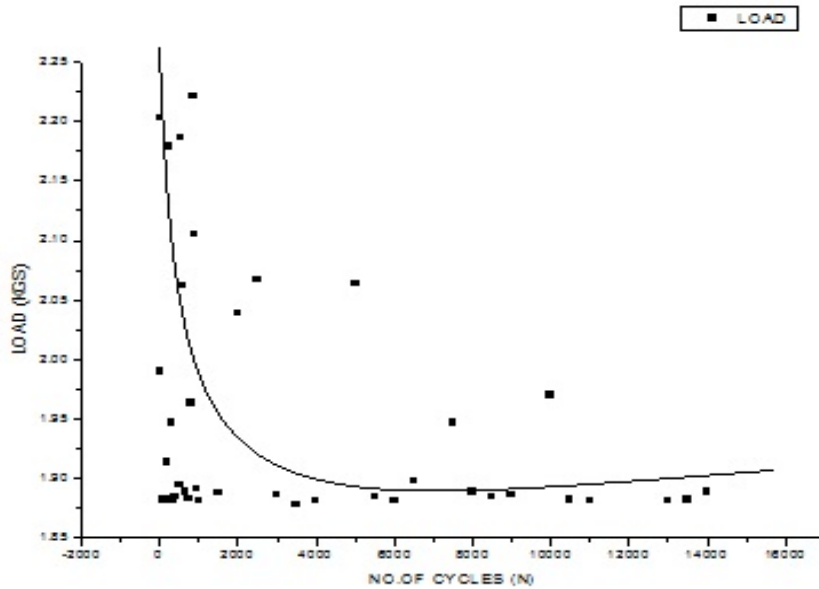
S. No	DESCRIPTION	MATERIAL	DIMENSIONS (INCH)	QUANTITY
1.	L-angle plates	Mild steel	(2.5x2.5) 2.45mts long	1
2.	Pulley	Nylon	Dia 4	1
3.	Pulley	Nylon	Dia 2	1
4.	Pulley	Nylon	Dia 10	1
5.	Circular Bob	Mild steel	Dia 1	1
6.	Bearings	Mild steel	Dia 1	2

## **RESULTS AND DISCUSSION**

**3.1 Laminate orientation( 0-90-90-0/0-90-90-0) polyurethane**

S.NO	Impact load in(kgs)	S.NO	Impact load in(kgs)	S.NO	Impact load in(kgs)
1	2.203	41	2.042	81	1.892
2	1.99	42	2.074	82	2.211
3	1.882	43	2.049	83	2.026
4	1.882	44	1.881	84	1.883
5	1.914	45	1.882	85	1.882
6	2.179	46	1.889	86	1.883
7	1.947	47	2.152	87	1.989
8	1.882	48	2.091	88	2.13
9	1.885	49	1.889	89	1.889
10	1.895	50	1.883	90	1.878
11	2.186	51	1.93	91	1.878
12	2.062	52	2.214	92	2.131
13	1.889	53	1.979	93	1.99
14	1.883	54	1.879	94	1.885
15	1.883	55	1.878	95	1.879
16	1.963	56	1.891	96	1.883
17	2.221	57	2.152	97	2.095
18	2.105	58	2.036	98	2.111
19	1.891	59	1.891	99	1.896
20	1.881	60	1.878	100	1.882
21	1.888	61	1.878	101	1.885
22	2.039	62	2.111	102	1.997
23	2.067	63	2.16	103	2.147
24	1.886	64	1.922	104	1.919
25	1.878	65	1.883	105	1.876
26	1.881	66	1.881	106	1.881
27	2.13	67	1.935	107	2.018
28	2.064	68	2.175	108	2.162
29	1.885	69	1.996	109	1.888
30	1.881	70	1.885	110	1.882
31	1.898	71	1.882	111	1.882
32	2.179	72	1.937	112	2.17
33	1.947	73	2.202	113	1.984
34	1.889	74	1.989	114	1.889
35	1.885	75	1.882	115	1.885
36	1.886	76	1.875	116	1.898
37	2.218	77	1.977	117	2.19
38	1.97	78	2.153	118	1.901
39	1.882	79	1.901	119	1.883
40	1.881	80	1.885	120	1.878

**GRAPHS LOAD VS NO,OF CYCLES**

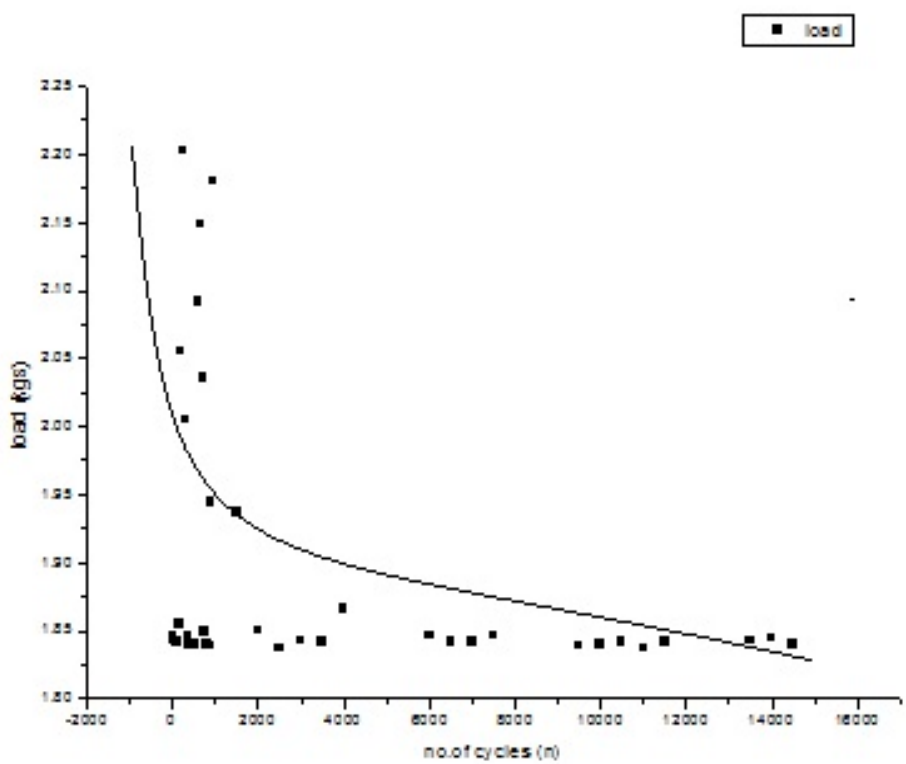


**3.2 Laminate orientation( 0-90-90-0/0-90-90-0) polyphenolic**

S.NO	Impact load in(kgs)	S.NO	Impact load in(kgs)	S.NO	Impact load in(kgs)
1	1.839	41	1.944	81	1.928
2	1.922	42	2.18	82	1.837
3	2.152	43	2.067	83	1.833
4	2.46	44	1.937	84	1.832
5	1.964	45	1.85	85	1.826
6	1.855	46	1.837	86	1.829
7	1.843	47	1.843	87	1.824
8	1.843	48	1.842	88	1.83
9	1.836	49	1.866	89	1.827
10	2.025	50	1.99	90	1.84
11	2.195	51	2.185	91	2.03
12	2.049	52	1.996	92	2.029
13	2.009	53	1.846	93	2.133
14	1.855	54	1.842	94	2.12
15	1.846	55	1.842	95	2.186
16	1.849	56	1.846	96	2.149
17	1.842	57	1.973	97	2.084
18	1.86	58	2.165	98	2.059
19	2.039	59	1.958	99	2.062
20	2.183	60	1.839	100	1.976
21	2.16	61	1.84	101	1.918
22	2.068	62	1.842	102	1.842
23	1.941	63	1.837	103	1.829
24	1.846	64	1.842	104	1.83
25	1.843	65	2.03	105	1.832
26	1.842	66	2.157	106	1.829
27	1.855	67	1.892	107	1.826

28	2.055		68	1.843		108	1.826
29	2.203		69	1.845		109	1.826
30	2.005		70	1.84		110	1.827
31	1.846		71	1.899		111	1.85
32	1.84		72	2.023		112	1.907
33	1.84		73	2.178		113	1.943
34	1.839		74	1.826		114	2.012
35	2.092		75	1.833		115	2.169
36	2.149		76	1.976		116	2.198
37	2.036		77	2.104		117	2204
38	1.849		78	2.221		118	2191
39	1.84		79	2.178		119	2105
40	1.839		80	2.087		120	2206
				1.928			

GRAPHS LOAD VS NO,OF CYCLES

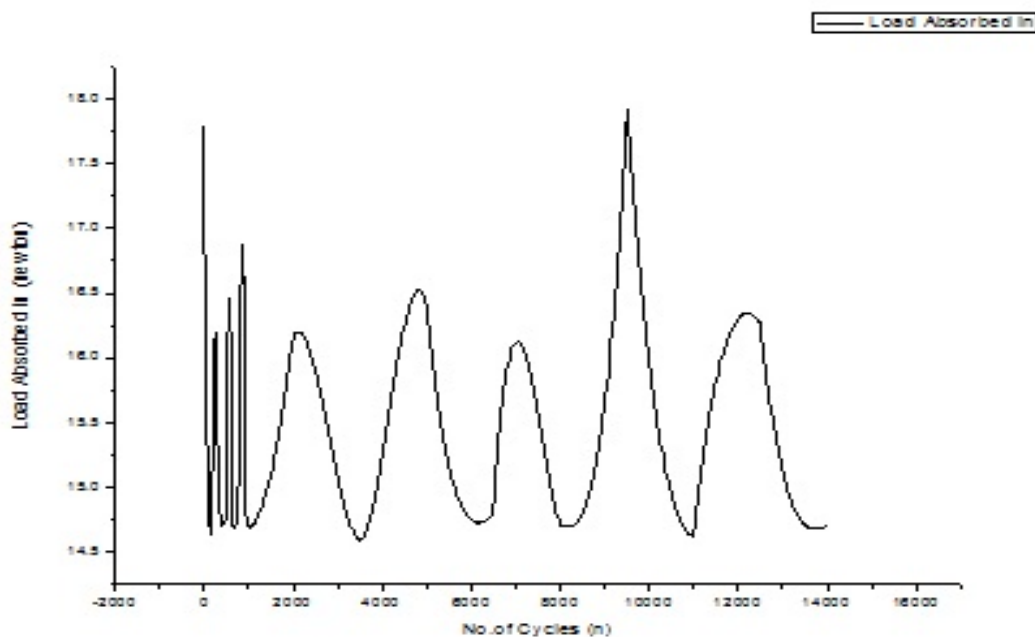


**Laminate 0-90-90-0/0-90-90-0( polypurethene)**

S.NO	Impact load on laminate in(Newton)	Impact load on load cell in (Newton)	Load absorbed by laminate in(Newton)
1	21.604	3.825	17.779
2	19.515	3.825	15.690
3	18.456	3.825	14.631
4	18.456	3.825	14.631
5	18.770	3.825	14.942
6	21.369	3.825	17.544
7	19.094	3.825	15.269

8	18.456	3.825	14.631
9	18.486	3.825	14.661
10	18.584	3.825	14.759
11	21.437	3.825	17.612
12	20.221	3.825	16.396
13	18.525	3.825	14.700
14	18.466	3.825	14.641
15	18.466	3.825	14.641
16	19.251	3.825	15.426
17	21.781	3.825	17.956
18	20.643	3.825	16.818
19	18.544	3.825	14.719
20	18.446	3.825	14.621
21	18.515	3.825	14.690
22	19.996	3.825	16.171
23	20.270	3.825	16.445
24	18.495	3.825	14.670
25	18.417	3.825	14.592
26	18.446	3.825	14.621
27	20.888	3.825	17.063
28	20.241	3.825	16.416
29	18.486	3.825	14.661
30	18.446	3.825	14.621
31	18.613	3.825	14.788
32	21.369	3.825	17.544
33	19.094	3.825	15.269
34	18.525	3.825	14.700
35	18.486	3.825	14.661
36	18.495	3.825	14.670
37	21.751	3.825	17.926
38	19.320	3.825	15.494
39	18.456	3.825	14.631
40	18.446	3.825	14.621
41	20.025	3.825	16.200
42	20.340	3.825	16.514
43	20.094	3.825	16.269
44	18.446	3.825	14.621
45	18.456	3.825	14.631
46	18.525	3.825	14.700
47	18.927	3.825	15.102
48	20.506	3.825	16.681

**Graph load absorbed vs no.of cycles**

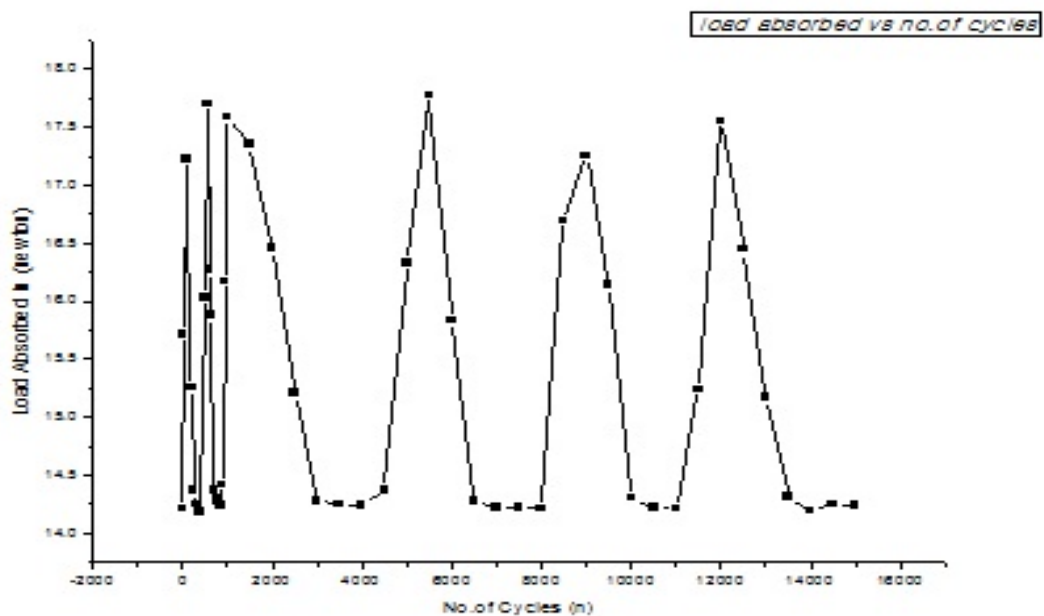


**Laminate 0-90-90-0/0-90-90-0( polyphenolic)**

S.NO	Impact load on laminate in(Newton)	Impact load on load cell in (Newton)	Load absorbed by laminate in(Newton)
1	18.034	3.825	14.209
2	19.534	3.825	15.709
3	21.103	3.825	17.22
4	21.045	3.825	15.258
5	19.083	3.825	15.258
6	18.191	3.825	14.366
7	18.074	3.825	14.249
8	18.074	3.825	14.249
9	18.005	3.825	14.18
10	19.859	3.825	16.034
11	21.526	3.825	17.701
12	20.094	3.825	16.269
13	19.702	3.825	15.877
14	18.191	3.825	14.366
15	18.103	3.825	14.278
16	18.133	3.825	14.308
17	18.064	3.825	14.239
18	18.24	3.825	14.415
19	19.996	3.825	16.171
20	21.408	3.825	17.583
21	21.182	3.825	17.357
22	20.28	3.825	16.455
23	19.035	3.825	15.21
24	18.103	3.825	14.278
25	18.074	3.825	14.249

26	18.064	3.825	14.239
27	18.191	3.825	14.366
28	20.153	3.825	16.328
29	21.604	3.825	17.779
30	19.662	3.825	15.837
31	18.103	3.825	14.278
32	18.044	3.825	14.219
33	18.044	3.825	14.219
34	18.034	3.825	14.209
35	20.516	3.825	16.691
36	21.075	3.825	17.25
37	19.966	3.825	16.141
38	18.133	3.825	14.308
39	18.044	3.825	14.219
40	18.034	3.825	14.209
41	19.064	3.825	15.239
42	21.379	3.825	17.554
43	20.27	3.825	16.445
44	18.996	3.825	15.171
45	18.142	3.825	14.317
46	18.015	3.825	14.19
47	18.074	3.825	14.249
48	18.064	3.825	14.239

**Graph load absorbed vs no.of cycles**



## **CONCLUSIONS**

- The present work is to evaluate the fatigue strength and behavior of the laminates at different orientations
- The most valuable outcomes achieved in this work were to withstand the material behavior on cyclic loading conditions
- The experimental results for(90-0-90-0-90/90-0-0-90) polyphenolic orientation of

the fiber is the best observed results herein.

- All the experimental investigation of fatigue tests was conducted under the same conditions using same machine.
- Apart from that the relative S-N diagram also concludes to the better load bearing capacity in the fibre of (90-0-90-0-90/90-0-0-90) polyurethane
- The alternating stress vs. mean is better observed in the (0-90-90-0/90-0-0-90) type of laminate.
- The aim of the present work is to improve the knowledge and understanding the behavior of the sandwich composite laminates by different fatigue test results

### **REFERENCES**

- Broutman, L. J. and Sahu, S. "Progressive Damage of a Glass Reinforced Plastics During Fatigue", Proceedings of the Reinforced Plastics and Composites Institute Annual Conference, vol. 11, section 11-D, New York, pp. 1-12, 1969.
- Rotem, A. "Fatigue and Residual Strength of Composite Laminates", Engineering Fracture Mechanics, vol. 25 nos 5/6, pp. 819-827, 1986.
- Stinchcomb, W. W. and Bakis, C. E. "Fatigue Behavior of Composite Laminates" in Fatigue of Composite Materials, Reifsnider, K. L. ed., Elsevier Science Publishers, New York, pp. 107-108, 1990.
- Mandell, J. F. et al, "Tensile Fatigue Performance of Glass Fiber Dominated Composites", Composites Technology Review, vol. 3, no. 3, pp. 96-102, Fall 1981.
- Mandell, J. F. "Fatigue Behavior of Fiber-Resin Developments in Reinforced Plastics-2, Properties of Laminates, Pritchard, G. ed., Applied Science Publishers, London, pp. 67-107, 1982.
- Shih, G. C. and Ebert, L. J. "The Effect of the Fiber/Matrix Interface on the Flexural Fatigue Performance of Unidirectional Fiberglass Composites", Composites Science and Technology, vol. 28, pp. 137-161, 1987.
- Kensche, C. W., and Kalkuhl, T. "Fatigue Testing of GL-EP in Wind Turbine Rotor Blades", European Community Wind Energy Conference Proceedings, 1990.
- Kensche, C. W. "High Cycle Fatigue of Glass Fibre Reinforced Epoxy Materials for Wind Turbines", DLR-Forschungsbericht 92-17, 1992.
- Kensche, C. W., and Seifert, H. "Wind Turbine Rotor Blades Under Fatigue Loads", German Aerospace Research Establishment, Stuttgart, 1990.
- Mandell, J. F., et al, "Fatigue Performance of Wind Turbine Blade Composite Materials", SED-vol. 14 ASM Wind Energy Conference, 1993.