PREDICTION OF MATERIAL STRENGTH AND INTERFACIAL PROPERTIES OF CARBON FIBER REINFORCED POLYMER (CFRP) COMPOSITE MATERIALS

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Abstract - Recent trend in engineering and technology, composite material play a vital role in various application like automobile sector, aerospace application etc.,Due to light weight with the equivalent strength to weight ratio, carbon fiber powdered reinforced polymer composites play a vital role., since the particular material is selected and try to map for the application. (i.e.) for pump impeller. The present studiers revels that there is a formation of corrosion and cavitations in the pump impeller, whereas carbon fiber is good in corrosive resistance and it is one of prompt material for selected application. The die had been designed according to prepare the composite plate with the required dimensions, the proper weight ratio calculation had been analyzed with the particular die and composite plate is prepare the specimen is cut as per the ASTM standard for the tensile test, flexural test and the impact test to predict the strength. And based on the strength, specimen is selected, to map with the application by using the liquid penetrate non-destructive testing the crack formation had been predicted such as shrinkages, pin holes, blow holes etc and also by using the ultrasonic non-destructive testing the thickness variation is predicted in the particular composite plate. Finally the results revels that the strength of the composite material is better than the metals, castiron, structural steel. This is to implement in the pump impeller.

***Keywords**: Non-Destructive Testing, Weight RatioCcalculation, Tensile strength, Flexural strength andImpact strength*

1. INTRODUCTION

A materials system composed of suitably arranged mixture or combination of two or more micro or macro constituents with an interface separating them that differ in form and chemical composition, were the carbon fibre which is composed of carbon atoms bonded together to form a long chain. This is the super strong material that's also extremely lightweight. Five times stronger than steel, two times stiffer, and about two third times less in weight.

The present study with which many metallic materials had been evaluated with their properties like metal alloys, cast iron, aluminium alloy and structural steel are compared with the carbon fibre reinforced polymer composite, whereas the cast iron possess high strength, vibration damping, low thermal expansion, lubrication retention and wear resistance. and few properties like light weight, less brittle, large co-efficient of expansion, easy machining, good formability and zero toxic are the few properties which exhibits in aluminium alloy. And some of the properties of structural steel are high toughness, ductility, weld ability and durability, and it is compared with the properties of carbon fibre reinforced polymer composites such as High Strength to weight ratio, Rigidity, Corrosion resistance, Electrical Conductivity, Fatigue Resistance, Good tensile strength but Brittle, whereas the carbon fibre is light weight than any of the metal and also fatigue failure is less since there is less possibilities of occurring failure during the performance.

The matrix gives the configurations and safeguard from the external environment to the fibre. The chemical, thermal and mechanical properties and their performance are maintained by the resin. It manages the position of fibers under loading. The matrix resin deforms and distributes the stress to the higher modulus fiber constituents. It should not shrink too much during curing to avoid the internal strain on the reinforcing fibers. There are various testing methods somehow to destruct the test specimens and evaluate their strength. Such as tensile testing, flexural testing, hardness testing, etc. In certain applications the evaluation of engineering materials or structures without impairing their properties is very important, (i.e.) quality control of the products, failure analysis or prevention of the engineered systems in service. In this research area ultrasonic thickness measurement is used to detect the thickness and also liquid penetrant testing is adopted for checking the surface defects.

2 MATERIALS AND METHODOIGY

The Polymer matrix composites (PMCs) which comprise of short or continuous fibres bound together by organic polymer matrix. The reinforcement in a PMC provides high strength and stiffness. The Polymer matrix composite material is designed so that the mechanical loads to which the structure is subjected in service are supported by the reinforcement. The function of the matrix is to bond the fibres together which it transfer loads between them.

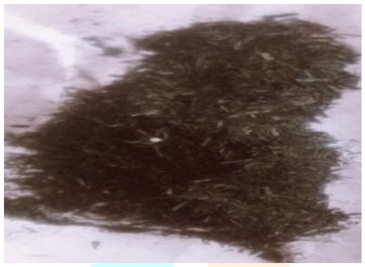
The Thermosetting resins which consists of polyesters, vinyl esters, epoxies and polyamides. Thermosetting polyesters are commonly used in fibre-reinforcement. However the viscosity of these resins is low certain chemical reactions that crosslink the polymer chains which connect the entire matrix together in a three-dimensional network is known curing. Here the general purpose resins like polyester resin is used for the reinforcement for this project work. And the general properties of the polyester resin are Easy handling, Low cost, Dimensional stability, Good mechanical and thermal resistance, Good electrical properties. While carrying out the process Hardener is a curing agent which is used for polyester resins.The polyester resin requires initiating curing process; it is also called as catalyst. The general properties are good mechanical strength, good resistance to atmospheric and chemical degradation and excellent electrical property.and also the polyester resin is then said to be cured, it is a chemically consistent hard solid. The cross linking polymer or curing process is called polymerization. The side by side nature of this cross-linking of molecular chains tends to means that laminate suffer from brittleness.

Great care is needed in the preparation of the resin prior to moulding. The resin and any additives must be carefully stirred to disperse all the components evenly before the catalyst is added. The string must be thorough and careful as any air introduced into the resin mix affects the quality of the final moulding. This is especially, when laminating with layers of reinforcing materialas air bubbles can be formed in the resultant laminate. This will weaken the structure. It is also important in adding the accelerator and catalyst in carefully measured amount to control the polymerization.

2.1 METHODOLOGY

The basic common methodology is used for step by step procedure are discussed below to prepare the composite structure for this project are

Initially matrix material such as resin and hardener are selected, following that carbon fibre is selected for reinforcement. Generally the carbon fibre is quiet expensive which is not easily available material. However it is long lasting and needs only less maintenance. At last the composite material is prepared by using the Hand lay-up method is one of the simplest method of composite processing. The infrastructural requirement for this method is also minimal. The processing steps are quite simple. First of all, a mould release silicone spray had been sprayed on the surface to avoid sticking of the polymer to the surface. Along with wax is also applied on the both lower and upper die. The carbon fibre is also taken according to the weight percentage of die. Then the thermosetting polymer in liquid form is mixed thoroughly in the suitable proportions with the prescribed hardener (curing agent), with the addition of carbon fibre to the resin and poured into the mould to get a desired shape and structure.



The above figure which shows the carbon fibre powder used as the material to prepare the composite material.

The above contents describes about proper methodology from material selection to final stage of composite plate preparation, the material is selected based on light weight and corrosive resistance. And the resin used in this project is general purpose polyester resin, hardener HY951 is used as a catalyst along with the resin during the process of reinforcement. The composite plate should be prepared with the correct proportion as per the weight ratio of the die which is made to prepare the particular composite material.

3. WEIGHT RATIO CALCULATION

The total weight of the plate =70 grams

(i.e.) By taking the 70 grams as 100 Percentage the further calculation is done.

Sample No-1

The first sample of composite plate is prepared by using the 3 grams of fibre and the 67 grams of resin.

Taking 70 grams as 100 percentage,

For fibre, = 3 / (67+3) = 4.28 %

For Resin

= 67 / (67+3) = 95.71%

Therefore, the above weight ratio calculation is done for the first sample of composite material. As per the requirement of die which is made for composite plate preparation, the total capacity of the die is 70 grams; thereby the calculation is done for the three grams fibrecomposition.The first sample of composite material is prepared as per the above calculation additionally to create the proper bonding the hardener is used.

Sample No-2

The total weight of the plate =70 grams

(i.e.) By taking the 70 grams as 100 Percentage the further calculation is done.

The second sample of composite plate is prepared by using the 6 grams of fibre and the 67 grams of resin.

Taking 70 grams as 100 percentage,

For fibre, = 6 / (64+6) = 8.51 %

For Resin = 64 / (64+6) = 91.428%

Therefore, the above weight ratio calculation is done for the second sample of composite material. As per the requirement of die which is made for composite plate preparation, the total capacity of the die is 70 grams; thereby the calculation is done for the six grams of fibrecomposition.The second sample of composite material is prepared as per the above calculation additionally to create the proper bonding the hardener is used.

Sample No-3

The total weight of the plate =70 grams

(i.e.) By taking the 70 grams as 100 Percentage the further calculation is done.

The third sample of composite plate is prepared by using the 9 grams of fibre and the 61 grams of resin.

Taking 70 grams as 100 percentage,

For fibre, = 9 / (61+9) = 12.8571 %

For Resin

= 61 / (61+9) = 87.1438%

Therefore, the above weight ratio calculation is done for the third sample of composite material. As per the requirement of die which is made for composite plate preparation, the total capacity of the die is 70 grams; thereby the calculation is done for the nine grams fibrecomposition.The third sample of composite material is prepared as per the above calculation additionally to create the proper bonding the hardener is used.

Here this chapter describes about the design and modelling of the die which is made to fabricate the composite material. The model is created in solidworks software; Main aim is to fabricate the die in light weight since mild steel will be the suitable material to make the particular die, however finally the die had been fabricated as 15 kg. Based on the die the weight ratio calculation had been made, the material is mixed with the proper proposition to obtain the composite material.

4.EXPERIEMENTAL PROCEDURE OF PREPARING COMPOSITE MATERIAL

The composite material had been prepared with the three varying proposition of carbon fiber to the resin. Which is described in detail at below paragraphs.

4.1 COMPOSITE SAMPLE-1

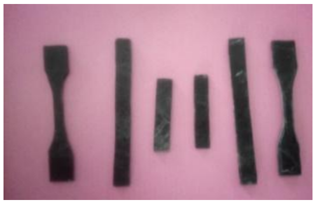
The particular sample is taken from the mould with the first ratio of 4.28% fibre and the 65.72% resin, this sample is also prepared by the hand layup technique. The fibre and polyester resin would get completely mixed with the hardener to avoid air bubbles formation and it should be mixed in the constant speed. The resins with the fibre are cured around 24 hours with the room temperature. The amount of load is applied depends upon the material.Since the material will get completely compressed and would get the required thickness.


The above figure determines the composite plate samples which is prepared in the die, and later on it is cut as per the ASTM standards.

The particular material had been cut as per the ASTM standard for the tensile test specimen D638 Type IV,ASTM standard for the tensile test, flexural strength and impact strength.The above figure 5.1 indicates the composite material is prepared with the 3 grams of fibre. And cut as per the ASTM standard, the tensile test specimen will be in the dimensions of (115*19.5*3mm), the flexural test specimen will be in the dimensions of (127*12.70*3mm), the impact test specimen will be in the dimensions of (64*13*3mm).

3.3 COMPOSITE PLATE SAMPLE 2

The particular sample is taken from the mould with the first ratio of 8.51% fibre and the 61.47% resin, this sample is also prepared by the hand layup technique. The fibre and polyester resin would get completely mixed with the hardener to avoid air bubbles formation it should be mixed in the constant speed and the resins with the fibre are cured around 24 hours with the room temperature. The amount of load is applied depends upon the material, since the material will get completely compressed and would get the required thickness.

The above figure determines the composite plate samples which is prepared in the die, and later on it is cut as per the ASTM standardards.

The particular material had been cut as per the ASTM standard for the tensile test specimen D638 Type IV, ASTM standard for thetensile test, flexural strength and impact strength. The below figure 5.2 indicates the composite material is prepared with the 6 grams of fibre.And cut as per the ASTM standard, The tensile test specimen will be in the dimensions of (115*19.5*3mm), The flexural test specimen will be in the dimensions of (127*12.70*3mm), The impact test specimen will be in the dimensions of (64*13*3mm).

4.2 COMPOSITE PLATE SAMPLE 3

The particular sample is taken from the mould with the first ratio of 12.85% fibre and the 57.45% resin, this sample is also prepared by the hand layup technique. The fibre and polyester resin would get completely mixed with the hardener to avoid air bubbles formation it should be mixed in the constant speed and the resins with the fibre are cured around 24 hours with the room temperature. The amount of load is applied depends upon the material, since the material will get completely compressed and would get the required thickness.

The particular material had been cut as per the ASTM standard for the tensile test specimen D638 Type IV, ASTM standard for thetensile test, flexural strength and impact strength. The below figure 5.3 indicates the composite material is prepared with the 9 grams of fibre.And cut as per the ASTM standard, The tensile test specimen will be in the dimensions of (115*19.5*3mm), The flexural test specimen will be in the dimensions of (127*12.70*3mm), The impact test specimen will be in the dimensions of (64*13*3mm.

The above figure determines the composite plate samples which is prepared in the die, and later on it is cut as per the ASTM standards.

This chapter describes, about the methodology in preparation of the composite material,with the three propositions like three grams, six grams and Nine grams of fibre in the total composition, which is reinforced with the resin for preparation of the composite material. The material which is required are taken in the correct proportion and carefully stirred in constant speed, which will prevent in formation of air bubbles and poured into the mould by hand-lay-up method. And the moulding will be in the loading condition for 24 hours at the room temperature. Then the plate is removed from the mould and cut as per the ASTM standard for tensile test, flexural test and the impact strength with based on D638 series.

5. NON DESTRUCTIVE TESTING IN COMPOSITE MATERIAL

The non-destructive testing is one of the testing methods to predict the crack formation like shrinkages, blow holes and pin holes etc., in this project few non-destructive testing methods are adopted to find out the defects and the thickness variation in composite material. The techniques are described below.

5.1 LIQUID PENETRANT TESTING

Liquid penetrate inspection (LPI) is one of the most widely used non-destructive evaluation (NDE) methods. Its popularity can be attributed to two main factors, which are its relative ease of use and its flexibility. The technique is based on the ability of a liquid to be drawn into a "clean" surface breaking flaw by capillary action. . This method is an inexpensive and convenient technique for surface defect inspection. The limitations of the liquid penetrant technique include the inability to inspect subsurface flaws and a loss of resolution on porous materials. Liquid penetrant testing is largely used on nonmagnetic materials for which magnetic particle inspection is not possible. Materials that are commonly inspected using LPI include the following; metals (aluminium, copper, steel, titanium, etc.), glass, many ceramic materials, rubber, plastics. Liquid penetrant inspection is used to inspect of flaws that break the surface of the sample. Some of these flaws are listed below; fatigue cracks, quench cracks grinding cracks, overload and impact fractures, porosity, laps seams, pin holes in welds, lack of fusion or braising along the edge of the bond line.

This process which involve six stages are surface cleaning, Application of penetrant, Removal of excess penetrant, Application of developer, Inspection of test surfaceand Post-inspection cleaning.

The above figure which indicates the initial process in the liquid penetrant testing (i.e.) pre cleaning process to remove the dirt from the surfaces and then followed by application of penetrant will indulge into the material for the further inspection.

The above figure which indicates, the developer which is applied after the penetrate is applied ,the main function of the developer is to enlarge the defects which is present up on the surface, then after few minutes the plate which the developer is applied indicates the defects like pinholes,blowholes,shrinkage defects etc. Then the surface which tends to post cleaning process is nothing but after inspection process by using a thinner the surface had been cleaned properly.

5.2 ULTRASONIC THICKNESS MEASUREMENT

In the field of industrial ultrasonic testing, ultrasonic thickness measurement is a method of performing non-destructive measurement of a local thickness of a solid element, based on the time taken by the ultrasound wave to return to the surface. This type of measurement is called ultrasonic thickness measurement.

The wave is usually emitted by a piezoelectric cell that is built into the measurement sensor and the same sensor is used to record the reflected wave.

Here we evaluated the surface cracks like pinholes, surface cracks and blow holes etc. Were by using the liquid penetrant non-destructive testing for the indication of the surface crack formation in the composite plate. This test is more preferable because of quicker and cost efficient process and the major disadvantage in this testing which we cannot predict the sub surface discontinuities. Theultrasonic non-destructive testing is employed to check the thickness variation in the particular composite plate; the thickness varies among around with 0.1 mm allowance completely along the whole surface.

6. RESULTS AND DISCUSSION

The specimen which is cut as per the ASTM standards are evaluated their mechanical strength like tensile test, flexural strength and impact strength are discussed in detail.

6.1 TENSILE TESTING

The tensile test are carried out in the each sample of composite material with the dimensions according to ASTM standards of 115 * 19.5 * 3mm thickness, their individual strength are included in the below table 7.1

Specimen	Tensile strength (N)
1	896.6842041
2	817.3568726
3	1380.548963

Table 7.1 Tensile Strength of Each Specimen

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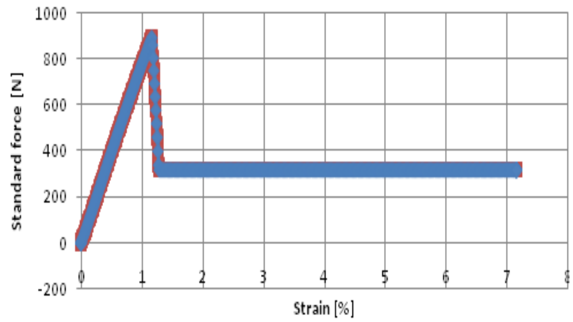
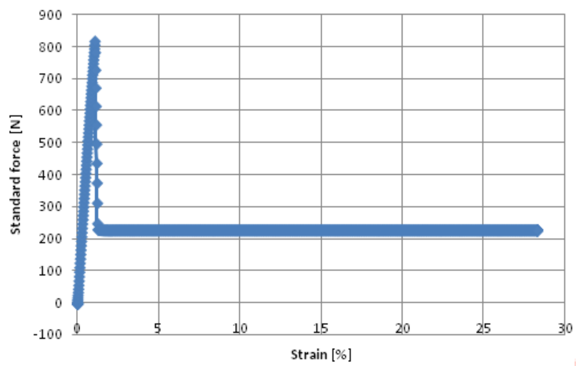
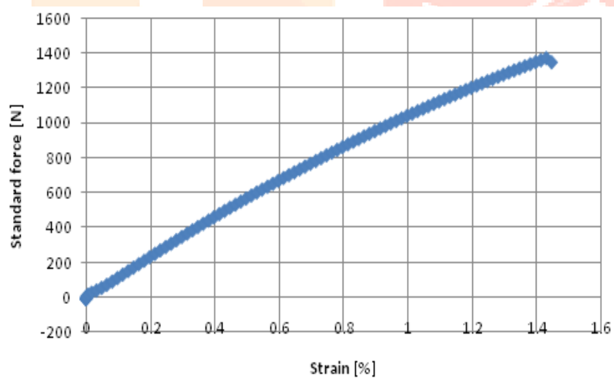
The specimen were cut with the three proportions like 3 grams of fiber, 6 grams of fiber and 9 grams of fiber among those proposition specimen with the nine grams proposition posses greater tensile strength. The following below graphs indicates the ultimate tensile load of the composite material.







The above graphs represent the flexural strength of the each specimen.

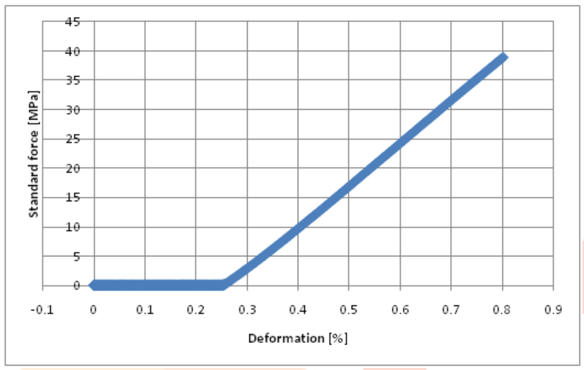
6.2 FLEXURAL STRENGTH TESTING

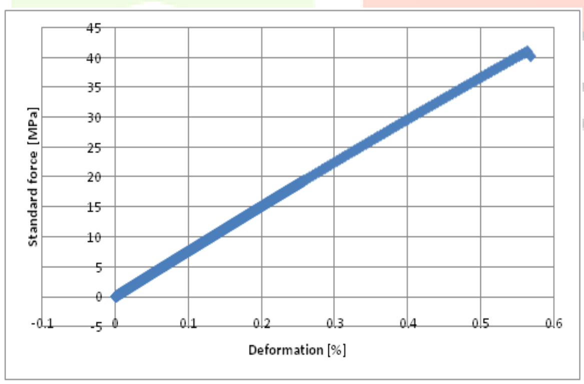
The flexural test are carried out in the each sample of composite material with the dimensions according to ASTM standards of 127 * 12.70 * 3mm thickness, their individual strength are included in the below table 7.2.

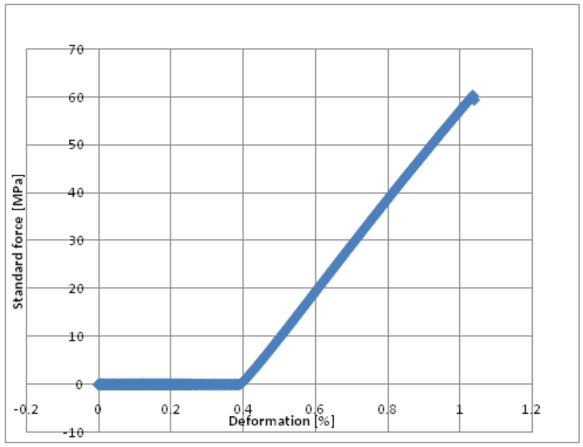
Table 7.2 Flexural Strength of Each Specimen

Specimen	Flexural strength (MPa)
1	38.84118625
2	41.0115133
3	60.3838471

The specimen were cut with the three proportions like 3 grams of fiber, 6 grams of fiber and 9 grams of fiber among those proposition specimen with the nine grams proposition and the six grams of fiber also slightly posses greater flexural strength.







The above graphs represents the flexural strength of the each specimen.

6.3 IMPACT STRENTH TEST

The impact test are carried out in the each sample of composite material with the dimensions according to ASTM standards of 64 * 13 * 3mm thickness, their individual strength are included in the below table 7.3.

Table 7.3 Impact Strength of Each Specimen

Specimen	Tensile strength (Joules)
1	7.8
2	9.12
3	12.4

The specimen were cut with the three proportions like 3 grams of fiber, 6 grams of fiber and 9 grams of fiber among those proposition specimen with the nine grams of fiber posses greater flexural strength.

The results revels that the composite material with the nine grams of proposition posses the greater tensile, flexural and impact strength from the result clearly states that nearly 12.8% fiber in that particular composition posses the expected strength thereby increasing the fiber proposition still it is possible to achieve the greater strength.

7. CONCLUSION

The present work was carried out with an aim of preparing the composite material which is light weight in application and greater strength, following that the composite material is prepared by using carbon fiber powder. Composite samples are prepared by using carbon fiber powder and general polyester resin is used for reinforcement. Mechanical properties of the developed samples were tested according to ASTM standards and one sample which posses the greater strength will be taken into the account for the future application.

From the above results, the composite materials are prepared by the three compositions like 3 grams, 6 grams and 9 grams with the thickness of 3mm. Among those compositions the 9 gram composite material posses the greater strength. And also finally achieved the equivalent strength of that material, here we conclude that by varying the thickness and the proposition of the fiber used still we can achieve the high strength (i.e.) more than that of steel or cast iron with equivalent light weight material. The future scope can be applied in the pump impeller because it posses the greater strength and corrosive resistance.

REFERENCE

1. Beard M.D, " Non-destructive testing in glass fiber reinforced polymer composites" journal of polymer testing, ELSEVIER, Poland 2003
2. C.Boller, " Enhanced assessment of ageing phenomenon in steel structure based on material data and non-destructive testing" Research article volume 4710, Germany 2016
3. Chang hang Xu, Jing Xie, "Improving defect visibility in square plate thermography of metallic components" Journal of mechanical system, ELSEVIER, volume 0432, 2015
4. KaiyiZheng, " Improved non-destructive testing of carbon fibre reinforced polymer composites" Journal of polymer testing, ELSEVIER, volume 0416, china, 2016.
5. Liang cheng, GuiyunTian. "Comparison of non-destructive testing methods on detection of delamination in composites" Research article, Journal of sensors, Hindawi publications, volume 2012, Article ID 408437, Newcastle University,uk.
6. Mathias Kersemans, Ives, DeBaere, "Non-destructive damage assessment in fibre reinforced composites with pulsed ultrasonic polar scan" journal of Polymer Testing, ELSEVIER Volume 2014, 9052, Belgium. 2014 edition.
7. Nongi.S. Na, "Distinguishing crack damage from de-bonding damage of glass fibre reinforced polymer plate using Piezoelectric transducers based Non-destructive testing" Journal of Composite structure ELSEVIER, volume 0263-8223, Korea institute of civil engineering & building technology, Republic of Korea, 2017.
8. PawalKoproswski, " AA6013 Aluminium alloy deformed by forward and backward rotating of die(KoBo) Microstucture and mechanical properties control by changing die frequency" journal of material processing technology ELSEVIER, volume 4328-2006, Poland, 2016.
9. Peng chi peng, " A study on behaviour of steel structure subjected to fire using non-destructive testing" Research article, volume 47-10, Germany, 2016.
10. RavibabuMulaveesala, Juned .A.Siddiqui , "Non-destructive testing and evaluation of composite by IR imaging techniques" Research article, Proceeding of SPIE volume, 8705, Graduate school of science university, china, 2015.
11. RuizenYeng, "Progress and trends in non-destructive testing and evaluation of wind turbine blade" Journal of Renewable and sustainable energy , ELSEVIER, volume 4316-2345, 2016.
12. Rasmika.H, " carbonfibre reinforced polymer composite", Research article, Journal of science and technology, Gujarat, India, 1992.

13. S.Eckel, E.Meraghmi, “Investigation of Damage in composites using Non-destructive nonlinear Acoustic spectroscopy” Research Article, Society for experimental mechanics, volume 217, Karlsurhe Germany, 2016.
14. ZhiyaanShen, “Direct wire piezoelectric ultrasonic transducers for non-destructive testing of metal plates, IEEE journal of sensors, volume 11, June 2017.