TESTING AND ESTIMATION OF MECHANICAL PROPERTIES OF E GLASS (V-9) COMPOSITE MATERIAL

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Abstract

Heat resistant composites are widely used for high temperature thermal protection systems and as flame deflectors for aerospace applications. Advanced composites made of fiber reinforced polymer matrix composites because of their strength, stiffness, low weight and their excellent thermal properties made them to replace metallic components. In this project work E-glass (v-9) phenolic and Rayon phenolic laminates were made by wet hand lay-up auto clave vacuum bagging process and their properties were evaluated by destructive and non-destructive testing methods. Laminate with known defect was examined by Ultrasonic method. Effect of modification of matrix system was studied on laminate properties. Composite made with modified phenolic resin was compared with conventional phenolic composite. Defect in the composite was analysed by Ultrasonic Test and Radiography methods. Oxy-acetylene erosion tests were carried out on laminate specimens and data was generated for ablative materials characterization.

1. Introduction:

Today's Heat resistant composites are essential for the successful launch and operation of all space vehicles. The selection of a composite material depends upon the mission of the space craft. While often the temperature capability is a major concern, the goal remains to protect the internal components at a minimal weight. This means extra insulation if the exterior material has a high heat capacity. In order to meet the mission objectives and the criteria the heat resistant material essential properties are it should have high heat of ablation, specific heat and low thermal conductivity, expansion coefficient, erosion rate.

Fiber reinforced polymer matrix composite materials has constituted a major breakthrough in the construction of lightweight structures. In particular significant benefits have been realized in the aerospace sector to meet the severe performance requirements with stringent demands of reliability. Almost all aerospace structural components – airframes of fighter aircraft, helicopters, control surface and fins of civil aircraft, various planes in satellites, antennas, rocket motor casings and some complete airframes of small aircraft are witnessing an increasing use of the advanced composites. An important technological development that has contributed significantly to this growth of composites is the development of strong and stiff fibers such as Glass, Carbon and Aramid along with concurrent developments in the

polymer chemistry resulting in a various polymeric materials to serve as matrix materials. In particular the versatility of the technology of the carbon fibers having various properties has played a key role in this growth. With complimentary developments in computer hardware and software technology, and in computational methods of analysis rendering help to the analyze and understand the material behavior and to provide predictive as well as design tools, the complexity of the polymer – matrix composites has been overcome to facilitate the extensive applications. Composites have the applications in many fields some of them are given in the following, since we are interested in aerospace applications it illustrated briefly. The creation of reliable heat resistant laminate composites for space applications requires precision design and proper tests. Because composite materials are necessary to meet heat resistant requirements for the aerospace applications such as nose cones, flame deflectors, airframes etc., some of aerospace applications where different types of materials are being used.

2. Experimental procedure

2.1 Work piece material

In this project the matrix is conventional phenolic resin and it is modified with Di-amine and ether. By this modification it is observed that when phenolic resin is modified with Di- amine the gel time is increased. And point of trouble is decreased considerably. Similar changes are observed in the properties of the resin by modifying with ether.

a) E-Glass (V-9)/Phenolic composite
b) E-Glass (V-9)/Di-amine modified phenolic composite
c) E-Glass (V-9)/ether modified phenolic composite
d) Rayon carbon/ether modified Phenolic composite
e) Rayon carbon/Di-amine modified Phenolic composite

2.2 Preparation of Laminate by Hand Lay-Up Process:

Even though the method has been replaced with automated techniques, the lay-up of pre impregnated material by hand is the oldest and most common fabrication method for advanced composite structures. Furthermore, the basic features of the method remain unchanged.

Autoclave Curing: Autoclaves have been used extensively for processing high-performance composite materials in the civilian and military aerospace industries. An autoclave consists of a large cylindrical metal pressure vessel with end enclosures that is thermally insulated and heated. Most autoclaves have a forced-hot-gas circulation system as well. An autoclave is pressurized using air or an inert gas such as nitrogen

Laminate Machining & Cutting:

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laminates made by fiber reinforcement's polymer matrixes normal cutter will not be useful. Hence it should be cut by the machine, since it is having the diamond edge to cut so that it can appear like smooth surface since it is having the diamond edge

2.3 Testing of composite material

2.3.1 Non Destructive Tests

NDT is used to detect defects and as a check either in new items or in items already in service, as maintenance checks. In both cases the items is not damaged in any way by the test procedure. The main aim is to detect poor compaction leading to resin-rich areas or low fibre loading, bad surface appearance or internal defect such as:

Lack of reinforcement, Porosity, Poor fibre- matrix bonding (delamination), Cracks of all sizes, Failure of the adhesive bond between components, Inclusions

2.3.2Destructive Tests

The destructive tests are to determine the physical properties of the material. For the laminates that we made with fibre reinforcement's and matrix the destructive tests are done according to the ASTM standards. The test procedures are as follows.

(a) Density Test (ASTM-D-792):

(Density of object/density of fluid)= (weight/weight-apparent immersed weight).

(b) *Resin Content Test:*

This test is done by burn off method because the fabric in laminate is E-Glass V-9. For Rayon fibre we use nitric acid digestion method

©Nitric Acid Digestion Method (ASTM D-3171):

This test is done using nitric acid.Measure the temperature of the Rayon carbon using pykinometer. Keep the rayon carbon in the nitric acid until they are digested. Then separate the acid and fibre. Now the fibre is free of resin, hence measure the weight of that fibre. Calculate the difference between the total test specimen and the fibre is resin content value.

Table:1 Density & Resin content test results

Density & Resin content test					
S.NO.	Material	Density (gm/cc)	Resin (% of wt)	Fiber (% of wt)	Vf (% of Vol.)
1	E-GlassV-9/Ph(DA)	1.92	19.16	80.84	61.1
2	E-GlassV-9/Ph(E)	1.767	19.1	80.9	56.27
3	Rayon/Ph(DA)	1.3	28.49	71.51	53.12
4	Rayon/Ph(E)	1.29	29.13	70.87	52.24

(d) Ilss (ASTM D 2344):

Keep the specimen in the UTM with the span length of four times of the thickness of specimen. Now gradually apply the load on mid span of the specimen. Note down at which load the shear is occurred. Using that load calculate the ILSS of the specimen. Repeat this for ten specimens and consider the average value of which.

(e) Flexural Strength (ASTM D-790):

The FLEXURAL STRENGTH (FS) is done using a 3-point test of flexure The specimen is as per the standard dimensions. The material direction under investigation must be oriented along the length of the specimen.

3. Results and discussion

The following are the test results of composite laminates made for this project work. These test results are obtained by destructive testing process, the test results are given in below tables for comparison. Flexural load and inter laminar shear strength graphs are given in below figures.

Table 2 Test results comparison

S.NO.	Material	Density (gm/cc)	Resin content (% of wt)	Fiber content (% of wt)	Vf (% of Vol.)
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2	E-GlassV-9/Ph(E)	1.767	19.1	80.9	56.27
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Table 3 Test results comparison

S.NO.	Material	ILSS (Mpa)	F.S (Mpa)	Young's Modulus E (Gpa)	Impact Energy I (KJ/sq.m)	Erosion rate (m/s)
1	E-GlassV-	29.53	462.78	44.[illegible]	265.35	0.000374

	9/Ph(DA)					
2	E-GlassV-9/Ph(E)	14.45	220.92	26.74	121.83	0.000436
3	Rayon/Ph(DA)	16.32	205.69	23.43	48.74	0.000126
4	Rayon/Ph(E)	13.13	106.64	19.9	61.54	0.000133
5	E-GlassV-9/Ph	32.79	365.72	30.54	223.51	0.000294

Discussion

It is observed from the tested data E-glass V-9/phenolic conventional composite compared with modified phenolic E-glass V-9 composite, the Flexural strength and Impact strength of the Di-amine modified phenolic composite gave higher values. Whereas ether modified phenolic composite with E-glass V-9 gave poor values indicates the compatibility problem of the matrix to reinforcements. Where ever Impact application is more one can go for Di-amine modified phenolic composite. The density variation in the composite is because of the compatibility of the matrix to reinforcements. Consolidation of composite during fabrication plays a major role on properties of the material. It is obvious from the test data better compaction has high density and will have low porosity. Composite density is calculated theoretically may not always be same with the experimentally determined value. This is due to poor compaction and voids present in the composite. A good composite for better properties should have higher density. Composite with modified Di-amine is having is having good compatibility so is its density. Even though E-glass V-9 is having high density its composites are used as insulating applications particularly where large amounts of heat to be absorbed or deflected.

Rayon carbon/phenolic composite erosion rate is low due to amorphous nature of the material. Aerospace applications such as heat shields, nose cones and nozzles where ablative property is important these rayon/phenolic are used because they absorb large quantity of heat with the sacrificial loss of minimum material. A Known defect which was identified with NDT tests such as Ultrasonic test and Radiography test. Ultra sonic through transmission loss observed at particular zone gave the resemblance of introduced defect. This is studied by Radiography which shown the defect by the difference of the material densities. Both these NDT tests are complimentary to each other. Defect in the composite leads to bad performance so composite products for aerospace applications should meet all quality control checks before being inducted into the machine.

4. Conclusions

The Applications of fibre reinforced polymer matrix composites for aerospace structures have been studied. Different fibre reinforced polymer matrix composite laminates were fabricated by Autoclave vacuum bagging process. Specimens were cut by diamond edge cutter as per ASTM standards and their physical, mechanical and thermal properties were evaluated by destructive and non-destructive techniques. Conventional phenolic resin and modified phenolic resin were studied with E-glass V-9 and Rayon carbon fabrics. Phenolic resin is used as a matrix material because of its excellent thermal properties. Phenolic resin modified by Di-amine exhibited high

flexural and impact strength. Composites made of E-glass V-9 and Rayon carbon replaced many metallic components because of their low density and high heat capacity. For high temperature applications in aerospace carbon phenolic are used as ablative materials because of their low erosion. E-glass composites because of their insulating character utilized for heat resistant composite. Quality control checks play crucial role in the fabrication of aerospace components. Defect free components ensure better performance of the mission.

In this project work we dealt with fabrication and testing of aerospace composite materials. Composite laminate properties were evaluated both by destructive and non-destructive techniques. Fibre volume fraction, density, non-destructive evaluations are essential for the acceptance of any composite product for its intended end use.

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