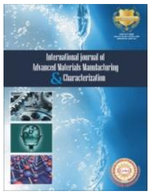

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Heat Resistant Composite Materials for Aerospace Applications

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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 study bi-directional E-glass/ phenolic and Rayon/ phenolic laminates were made by auto clave vacuum bagging process and their properties were evaluated by destructive and nondestructive 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 analyzed by UT and Radiography methods. Oxy-acetylene erosion tests were carried out on laminate specimens and data was generated for ablative materials characterization.

Introduction

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

Selection of Materials:

Since E-Glass V-9 is a conventional fibre for structural applications at high temperatures, it is also the insulating and since it is cheap in cost and easily available which is being used for many aerospace applications, hence it is selected.Though the

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rayon carbon is very expensive, it is amorphous material for ablative purpose and is having vast applications in aerospace industry, hence it is selected. Phenolic resin is the conventional matrix material which is used for aerospace applications to with stand high temperatures.

Experimental work

In this study the matrix is conventional phenolic resin 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.For this study four types of laminates were considered, they are, i).E-Glass (V-9)/Di-amine modified phenolic composite,ii).E-Glass (V-9)/ether modified phenolic composite,iii).Rayon carbon/ether modified Phenolic composite, iv).Rayon carbon/Di-amine modified Phenolic composite.

The following steps are involved in the experimental work.

1.Preparation of laminate

2.Sample preparation

3.Destructive tests

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. Various steps are involved in the hand lay-up of a flat composite laminate. Each step must follow in successive fashion in order to obtain a high-quality composite laminate after final processing. some steps in the hand lay-up of a flat composite laminate is shown in Figures3.1-3.7. A description of these steps is as follows.

Step 1.The surface of the tool is cleaned and a release agent is applied.

Step 2.An optional sacrificial layer is laid up on the tool surface.

Step 3.A peel ply is placed on top of the sacrificial layer.

Step 4.The pre impregnated plies are cut according to size.

Step 5.The prepreg ply is oriented and placed upon the tool or mold.

Step 6. A flexible resin dam is anchored to the sacrificial layer.

Step 7.Another peel ply is placed on top of the laminate to protect the laminate surface.

Step 8.A sheet of porous release film is laid over the dam and the laminate.

Step 9.Next, bleeder plies are laid up over the release film.

Step 10.The vacuum bag is made ,the mould is kept inside the bag and sealed,and kept inside the autoclave.

Sample Preparation

The samples are to be prepared for testing as per ASTM standards. And to cut the laminates made by fiber reinforcement's polymer matrixes normal cutter will not be useful. Hence it should be cut by the machine shown in the figure 3.2.1 since it is having the diamond edge to cut so that it can appear like smooth surface after cutting by which. A laminate which is cut by the diamond edge cutter is as shown in the figure 3.2.2.

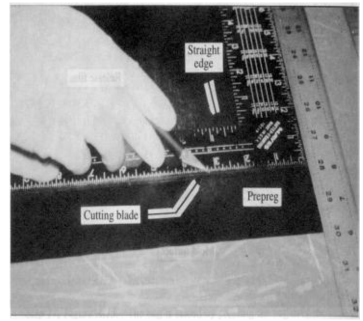

Fig 3.1 The mold is covered with a release film

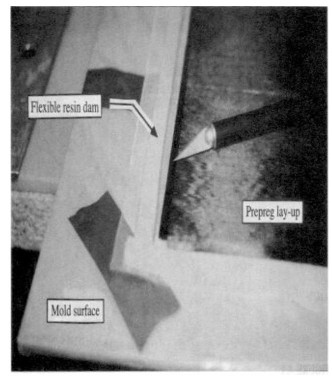

Fig 3.3 Pre preg lay up

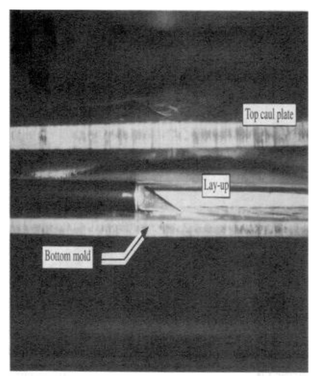

Fig 3.4 Top plate is placed over the mould

Fig3.6.Mould inside the vacuum bag

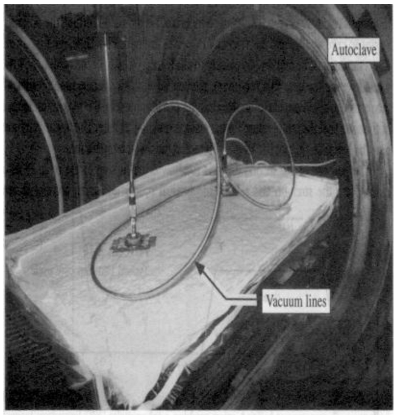

Fig 3.7.The mould inside auto clave

Destructive 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.

1.Testing of physical properties
2.Testing of mechanical properties
3.Oxyacetylene erosion test

Testing of physical properties

Physical properties like density, resin content, fiber content and fiber volume fractions are measured as per ASTM Standards. The test samples are prepared accordingly. The results of physical properties of samples are tabulated in table.3.3.1.Density test(ASTM-D-792),Density of composite is determined by Archimedes principle according to it, any object, completely or partially immersed in a fluid, is buoyed by a force equal to the weight of the fluid displaced by the object. Resin content test(ASTM D-2584), is done by burn off method.

Table 3.3.1 Density & Resin content test results

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-9/Ph(DA)	29.53	462.78	44.01	265.35	0.000374
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

Testing of mechanical properties

To study the mechanical properties of the samples, the following tests were carried out, ILSS (ASTM D 2344), Flexural strength (ASTM D-790), Impact strength (ASTM D 5941).The test results were tabulated and is given in table.3.3.2

Table 3.3.2 Mechanical properties Test results

S.NO.	Material	Thickness(mm)	Burn through time (sec)	Erosion rate (m/S)
1	E-GlassV-9/Ph(DA)	4.01	10.72	0.000374067
2	E-GlassV-9/Ph(E)	4.9	11.22	0.00043672
3	Rayon/Ph(DA)	4.32	34.4	0.000125581
4	Rayon/Ph(E)	5	37.71	0.000132591

Oxyacetylene erosion test

This test method is intended to screen the most obvious poor materials from further consideration. Since the most combustion gases more closely resemble the environment generated in rocket motors, this test method is more applicable to screening materials for nozzles and motor liners than for aerodynamic heating. In this test we could not calculate the heat flux and could not measure the velocity the flame though it is a neutral flame. Hence it can give information about the comparison of erosion rates of the different materials. The test results were tabulated and is given in table.3.3.3.

Table 3.3.3 Test results comparison

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

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/phenolics 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.

Fig 3.2.1 Cutting of Laminate

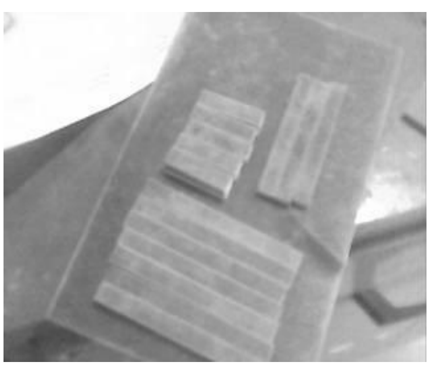
Fig 3.2.2 Specimens cut from laminate

Conclusions

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. Modified phenolic resin with E-glass V-9 and Rayon carbon fabrics were studied. 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 phenolics 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 study we dealt with fabrication and testing of aerospace composite materials. Composite laminate properties were evaluated both by destructive and non destructive techniques. Fiber volume fraction, density, non destructive evaluations are essential for the acceptance of any composite product for its intended end use.

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