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Reinforcement of Carbon Fibre in Aerospace Industries

R. Bhuvaneshwaran[1], T. Chella Kumaran[2], P. Hema Chandran[3]
[1,2,3]*Student, Department of Mechanical Engineering, Sri Rama Krishna Engineering College, Coimbatore, India*

***Abstract*: In aircraft structural integrity analysis, the damage tolerance and fatigue life is investigated against a cyclic loading spectrum. The particular spectrum includes the stress/loading levels counted during a flight of certain duration. The occurrences of load factors may include higher gravitational acceleration 'g' levels. While maintaining a certain g level occurrence at higher angle of attack, wing structure vibrates with the amplitudes of its natural frequencies. The cyclic stress amplitudes of vibration depend upon the natural frequencies of vibrating structure, i.e. lower frequency gives higher amplitudes and vice versa. To improve the dynamic stability, modal parameters of simple carbon fiber sandwich panels have been adjusted by tailoring the fiber orientation angles and stacking sequence. In this way, the effect of change in structural dynamic characteristics on fatigue life of this simplified structure has been demonstrated. The research methodology followed in this work consists of two phases. In the first phase, aero-elastically tailored design was finalized using FEM based modal analysis and unsteady aerodynamic analysis simulations followed by experimental modal analysis. In the second phase, fatigue and damage tolerance behavior of material was investigated using different fracture mechanics based techniques.**

***Keywords*: Dynamic, fiber and laminar tensil**

1. Introduction

The strength of composite materials along planes parallel to the principal fiber orientation could significantly exceed the tensile strength. The low inter-laminar strength leads to such type of failure as de-lamination in transverse direction. This may cause a loss of the load-carrying capacity of aerospace structures normal to laminate loaded planes. Consequently, there is a need to investigate possible ways to improve the inter-laminar tensile strength of layered composite materials. Nowadays an active study of such a reinforcing techniques, as an additional reinforcement of composite material are carried out. Stitching, tufting, previous work with needling, fiber-flocking, needling refer to this method. The objective of this paper is to consider two ways of three-dimensional reinforcement, namely needling and short-fiber reinforcement.

A. Needling

Needling is the procedure of connecting several layers by means of continuous filaments. This method improves strengthening a fracture toughness and prevents the spread of delamination couples with the action of percussive loads. In this case, the needling technology can be used to reinforce unit areas or regions of detail connection. At the same time, the method has a negative impact. Needling material violates the integrity of the structure of the fibers in the needling area, which significantly affects the strength properties of the final product. Another approach is the introduction of special reinforcing particles into the inter-laminar voids. This article discusses the reinforcement of composite material by thin, short (less than 2 mm) carbon fibers. These particles were obtained by cutting the individual fibers of a thin layer of polymerized unidirectional composite. Short fibers exhibit high stiffness which allow them to penetrate into the woven structure of laminate during its stacking. An important feature of this method is that the application of special reinforcing particles on each layer preserves the integrity of the filament structure for the fabric itself. In addition, it prevents loss of strength in-plane of stacking composite material.

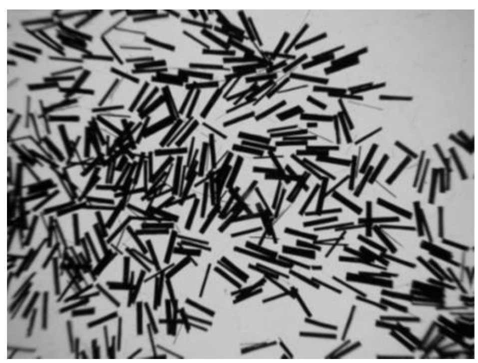

Fig.1. Reinforcing particles

Each of these methods has its advantages and disadvantages. The purpose of this paper is to investigate the efficiency of needling and fiber-reinforcement for enhancing interlaminate tensile strength.

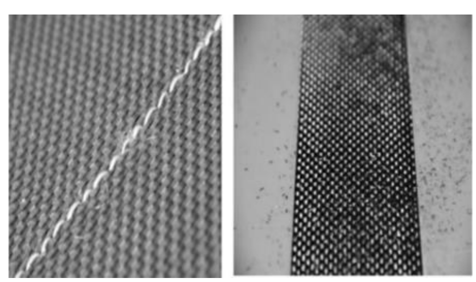

Fig.2. Needling vs. Reinforcement

B. Needling vs. reinforcement

The efficiency of two approaches, needling and fiber-reinforcement, to enhance the load-carrying capacity was studied in the next stage. The needling of carbon preform was carried out with a single-row seam at the point of maximum curve. Aramid yarn was used as the punching material. Hand-machined stitches which do not disband during the yarn breakage, were used with a pitch of 2 mm between the ties. This is necessary in order to ensure seam operation after cutting of the blank samples. The reinforcement by particles was performed by the special application short carbon fibers to each layer of the preform. This technique was used only for radial transition area because delamination occurs there. The particles were applied using a grid with a mesh size of 5 mm to ensure a uniform distribution of fibers over the surface of each layer. In this case, the density of spreading between a pair of layers is 0, 00694 g/cm2.

C. Advantages of carbon reinforcement

Due to the high demand for lightweight structures, materials like carbon fiber reinforced polymers (CFRP) have increasing shares in the overall material compositions of aerospace products. CFRP now accounts for 50% of the structural mass of the modern wide-body aircraft Airbus A350 XWB [1]. Material properties, such as the low thermal expansion and high strength to weight ratio combined with the possibility to achieve high bending stiffness by using sandwich structures have also created a high demand within the production of space systems. Currently, Thermoset materials are predominantly used as polymer resin in CFRP manufacturing .On the one hand, these materials offer significant cost advantages and heat-resistance. On the other hand, their properties inhibit melting or deforming after curing and lead to challenges when it comes to joining different parts.

2. Preparation of carbon fiber

Carbon fibers reinforced ultra-high temperature ceramic (UHTC) composites, consisting of carbon fibers embedded in a UHTC-matrix or a C–SiC–UHTC–matrix, are deemed as the most viable class of materials that can overcome the poor fracture toughness and thermal shock resistance of monolithic UHTC materials, and also improve the oxidation resistance and ablation resistance of C/C and C/SiC composites at ultra-high temperatures. Hence carbon fibers are used in aerospace application.

A. Chemical vapor infiltration

CVI is a ceramic engineering process whereby matrix material is infiltrated into carbon fibrous preforms by use of reactive gases at elevated temperatures (900–1200 °C) to form fiber-reinforced composites. Well-processed CVI-derived composites with a high-purity and well-controlled composition and microstructure matrix generally possess excellent mechanical and anti-ablation properties as a consequence of the slow, steady build-up of matrix material around the fiber network.CVI has been widely employed for preparation of C and SiC matrix and is also viable for fabricating UHTC composites. For example, HfC and ZrB2 can be prepared according to the following equations, respectively. The major drawbacks of CVI are the very slow rate of deposition, leading to a large material energy input and a high final cost, as well as the very limited infiltration depth, especially for the big Hf, Zr or Ta-containing radicals. So the CVI is mainly used to prepare the UHTC coating, such as TaC, HfC/TaC and HfC/ZrC coating; and only a few references about preparation of the bulk composites are reported. Sayir used this method to fabricate C/HfC, C/TaC and C/HfC/TaC composites with a pyrolytic graphite interface by using TaCl5–CH4–H2–Ar,Hf Cl4–TaCl5–CH4–H2–Ar, and HfCl4–TaCl4–CH4–H2–Ar systems as gas sources.

B. SOL-GEL

Sol-gel has been widely used in the fine synthesis of ceramics, to gain oxides or other compounds by a process of hydrolysis, condensation gelation gradually and post-processing using organic and/or inorganic compounds as raw materials. Matrix composites. Recently, researchers have used this method to introduce UHTC matrix during fabrication of UHTC matrix composites. With H3BO3 and polyvinyl alcohol (PVA) as raw materials for gel precursor, Chen et al.[80] introduced a porous C–B4C matrix into a 3D carbon fiber preform by impregnation of gel precursor, followed by a heat-treatment process for pyrolysis and carbon thermal reaction. Then the C–B4C matrix reacted with the molten ZrSi2 to finally form the ZrB2–ZrC–SiC matrix. The combined processes are sometimes used to optimize the densification of fiber preforms or/and the microstructure and property of the composites based on the processes discussed previously displaying advantages and drawbacks.

3. Experimentation

A. Curved-beam structural elements

Determination of the material's ultimate stress in transverse direction is an important challenge from the viewpoint of structural design. For this purpose, the experimental and analytical analyses of radial stresses and destructive forces was carried out in the area of a bending curved-beam element. The curved-beam element is a sample consisting of two straight legs connected by a 900 bend with a 10 mm inner radius. The samples were made on the basis of a composition including 16 layers of carbon fabric CC201 and epoxy system SR8100/SD8824 using the vacuum infusion method.

The blank was cut on samples using abrasive cutting after the resin polymerization. Each batch includes 8 specimens with the following parameters: thickness t = 3, 2 mm and width w = 25 mm. The study of the inter-laminar tensile strength of the curved-beam element was carried out in several stages. The values of destructive forces were determined experimentally for the samples without reinforcement on the first stage. Tests were carried out in a specially designed and manufactured tool using a universal servo-hydraulic machine with the maximum closeness to the requirements of ASTM D6415 standard.

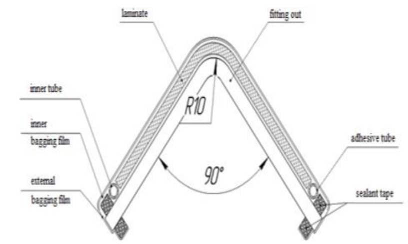

Fig. 3. Vacuum system for curved-beam element

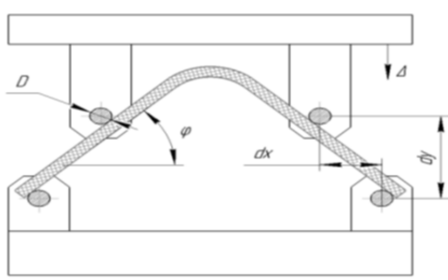

Fig. 4. Testing scheme for curved-beam element

The samples were loaded with the bending moment at a speed of 3 mm per minute. Simultaneous recording of the hydraulic rod movements and emerging efforts was carried out automatically. The destruction usually occurs at the point of maximum inflection due to delamination. The experimental results allow the values of the destroying efforts which began with the failure of samples to be obtained.

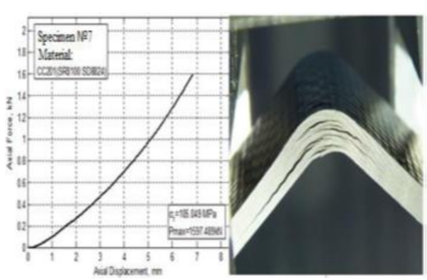

Fig. 6. Loading and destruction

4. Experimental results

The following features of specimen destruction have been identified for different reinforcing techniques during the tests. The de-lamination occurred in the non-stitched area in the samples needled with aramid filament. Filament break occurs after its tension reaches the limit state which led to the final destruction. Such fracture behavior can be explained by the fact that the yarn tension during the needling procedure of the preform was chosen in such a manner that prevents folding of the upper and the lower layers. In turn, this has led to the fact that fabric layers were compressed and filament tension was loosened during the laminate filling using vacuum infusion. In the case of samples reinforced with the short fibers, the delamination is similar to the case of samples without reinforcement in transverse direction.

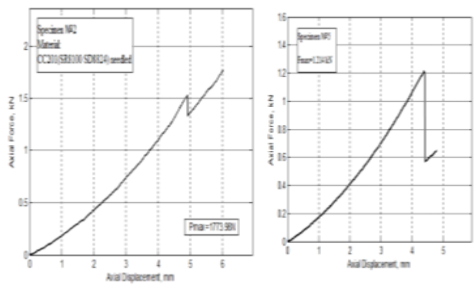

Fig. 5. Comparison of destructive forces in needling and reinforcing.

5. Conclusion

Based on the test results, the destructive forces of samples without reinforcement and specimens with spatial reinforcement were compared. Analyzing the results, it can be concluded that needling with aramid filament in a single-row improves inter laminar characteristics by the order of 13%. Reinforcement with short fibers did not give the expected enhancement of inter laminar strength. It is planned to carry out a number of experiments related to the variation of needling parameters and studying of combined reinforcing techniques in the near future. Based on the assessment it is found that the reinforcement of carbon fiber parts helps in improving the strength and fatigue resistance of the aircraft parts.

References

[1] M. Wiedemann, M. Sinapius, Adaptive, Tolerant and Efficient Composite Struc-tures, Springer Science & Business Media, 2012.
[2] R.Witik, F.Gaille, R.Teuscher, H.Ringwald, V.Michaud, J.-AMånson, Assessing the economic and environmental potential of out of autoclave processing, in: 18th ICCM, 2011.
[3] D.P.Raymer, Aircraft Design: A Conceptual Approach and Rds-Student, Software for Aircraft Design, Sizing, and Performance Set, AIAA Education, AIAA, 2006.
[4] W.J. Marx, D.N. Mavris, D.P. Schrage, A hierarchical aircraft life cycle cost analy-sis model, in: Aircraft Engineering, Technology, and Operations Congress, 1995.
[5] O.Jolliet, M.Margni, R.Charles, S.Humbert, J.Payet, G.Rebitzer, R.Rosenbaum, IMPACT 2002+: a new life cycle impact assessment methodology, Life Cycle Assess. 8(6) (2003) 324.
[6] O.Dababneha, T.Kipouros, A review of aircraft wing mass estimation methods, Aerosp. Sci. Technol. (2017).
[7] A.J.Timmis, A.Hodzic, L.Koh, M.Bonner, C.Soutis, A.W.Schäfer, L.Dray, Environmental impact assessment of aviation emission reduction through the implementation of composite materials, J.Life Cycle Assess. 20(2) (2015) 233–243.
[8] R.Dhingra, J.G.Overly, G.A.Davis, et al., Life-Cycle Environmental Evaluation of Aluminum and Composite Intensive Vehicles, CCP, 1999.
[9] J.Kasai, Life cycle assessment, evaluation method for sustainable development, JSAE Rev. 20(3) (1999) 387–394.
[10] S.Das, The Cost of Automotive Polymer Composites: A Review and Assessment of DOE's Lightweight Materials Composites Research, National Laboratory Oak Ridge, Tennessee, USA, 2001.
[11] E.Shehab, W.Ma, A.Wasim, Manufacturing cost modelling for aerospace composite applications, in: Concurrent Engineering Approaches for Sustainable Product Development in a Multi-Disciplinary Environment, 2013, pp.425–433.