AIJREAS VOLUME 9, ISSUE 5 (2024, MAY) (ISSN-2455-6300)ONLINE
Anveshana's International Journal of Research in Engineering and Applied Sciences

OPTIMIZATION AND SIMULATION OF COMPOSITE FIBER CONFIGURATIONS FOR AEROSPACE APPLICATIONS

Kanchamu Manjula
Research Scholar
Shri JJT University
Rajasthan.

Dr. Gangadhar Reward
Professor
Shri JJT University
Rajasthan.

Dr. Sudhir Baijnath Ojha
Associate Professor
SSGB College of Engineering
Bhusawal.

ABSTRACT

This study investigates the composite materials used in Aircraft structure and also reviews the advanced composites as structural materials. At present composites material are becoming important in Aerospace engineering due to its increased strength at lower weight, stiffness and corrosion resistance. For the Aerospace Engineering there are huge progress of material science and engineering with the technological challenges in terms of the development of sophisticated and specialized materials e.g composite materials. Composites materials are intended to be used more extensively as an alternative of aluminum structure in aircraft and aerospace applications. This is due to their attractive properties as high strength-to-weight ratio and stiffness-to-weight ratio. Besides that it clarifies the growing interest for composites materials due to advantages of lightweight, high strength, high stiffness, superior fatigue life, tremendous corrosion resistance and low cost manufacturing. In this study, a finite element analysis (FEA) of fiberglass unidirectional Etype was analyzed in the framework of ABAQUS finite element commercial software. The analysis was done to quantify the mechanical properties and response of unidirectional E-glass in term of tensile, compression and thermal responses.

Keywords: *Aircraft structure, composites as structural materials, aerospace, stiffness-to-weight ratio, high stiffness, E-glass.*

INTRODUCTION

Composite materials have been widely adopted by engineers in the design of structures that traditionally have employed metals for a range of applications. The mechanical properties of composites such as high stiffness and strength per unit weight make them an attractive material choice for the designer. The dynamic response of these materials is also important when the structure of interest is subjected to crash or impact loads which are experienced in many transportation-related applications. Impact analyses of composite structural systems have been carried out for a variety of architectures and applications. They include components and systems for the defense industry, marine structures and those dealing with generic modeling and application. The motivation to use composite structures for aerospace vehicles is exceptionally strong as weight savings are of premium interest. Simulation tools are a powerful resource in the development, design, and certification of aerospace systems. Aerospace engineers are looking at graphene and other advanced materials as key enabling technologies for the next generation of aircraft and space vehicles. The ability to produce structures and devices that are lighter, stronger, more resilient, use less energy and that have new capabilities can only happen if we have a new class of materials with which to build these next generation objects. In addition, the trend in aerospace engineering is to increase the functionality of parts so that they solve several problems at the same time. Engineers have achieved this progress, for example, by either modifying the polymer matrix or adding a multifunctional coating that incorporates graphene. A review of the modeling schemes can be found in open literature. Current research has shown that the combined roles of laboratory testing to characterize material behavior and generate validation data, and of numerical modeling across various length scales is necessary to generate an efficient and accurate framework to design the next generation aerospace vehicles. This necessitates rigorous model development and checking to make certain that the model is constructed and applied correctly, generating accurate results for the application of interest.

LITERATURE REVIEW

Stylianos Markolefas (2023) An important step towards improving performance while reducing weight and maintenance needs is the integration of composite materials into mechanical and aerospace engineering. This subject explores the many aspects of composite application, from basic material characterization to state-of-the-art advances in manufacturing and design processes. The major goal is to present the most recent developments in composite science and technology while highlighting their critical significance in the industrial sector—most notably in the wind energy, automotive, aerospace, and marine domains. The study in this collection discusses the difficulties of gaining an in-depth understanding of composites, which is necessary to maximize their overall performance and design. The collection of study within this topic addresses the challenges of achieving a profound understanding of composites, which is essential for optimizing design and overall functionality.

Sarfaraz Kamangar (2022) Recent advances in aircraft materials and their manufacturing technologies have enabled progressive growth in innovative materials such as composites. Al-based, Mg-based, Ti-based alloys, ceramic-based, and polymer-based composites have been developed for the aerospace industry with outstanding properties. However, these materials still have some limitations such as insufficient mechanical properties, stress corrosion cracking, fretting wear, and corrosion. Subsequently, extensive studies have been conducted to develop aerospace materials that possess superior mechanical performance and are corrosion-resistant. Such materials can improve the performance as well as the life cycle cost. Then it focuses on the studies conducted on composite materials developed for aircraft structures, followed by various fabrication techniques and then their applications in the aircraft industry.

Mohammed Al Awadh (2022) The use of carbon fiber reinforced plastic (CFRP) is increasing in engineering applications such as aerospace, automobiles, defense, and construction. Excellent strength-to-weight ratio, high impact toughness, and corrosion resistance make CFRP highly suitable for aerospace applications. Curing temperature, curing time, and autoclave pressure are among the most important curing parameters affecting the properties of CFRP. Tensile strength, impact toughness, and hardness of CFRP were selected as desirable properties for optimization. The cured samples were subjected to tensile strength, impact toughness, and hardness tests at room temperature as per relevant ASTM standards. Analysis of variance (ANOVA) was used, and it was found that tensile strength, impact toughness, and hardness were influenced most significantly by temperature and time.

R.S. Rajeev (2021) FRCs are used as primary structures for aerospace vehicles, launch vehicles/space craft for space exploration and in the field of spots and games. As long as weight reduction and cost reduction with improved efficiency remain important design consideration, FRCs remain to stay in aerospace and sports industries. Only FRCs can achieve the desired strength-to-weight ratio without compromising on any of the specification requirements. For military aircrafts and also for spacecrafts, increase in the payload capacity, which is the most important parameter for future missions, can be achieved only through FRCs due to the design flexibility and choices. Discovery of new fibers and matrices, development of novel process techniques and novel testing methods will accelerate the use of FRCs for aerospace applications. Fiber reinforced composites (FRCs) now became inevitable and markedly persuaded in the area of sports and games due to its classical properties such as lightweight, super strength, high intensity, good toughness, superior shock absorption and user easiness.

Mongkol Thianwiboon (2019) The main objective of this research is to find the optimized lay up for the after body of the amphibious plane which can carried load according to ASTM F2245 (Standard Specification for Design and Performance of a Light Sport Airplane). The finite element analyses of hybrid carbon/glass composites are carried out using ANSYS ACP under assumption that the hybrid carbon/glass fiber composites could combine the strong sides of carbon and glass fiber reinforced polymer to balance between strength, weight and cost to achieve the requirement for each design of the aircraft. While the stress of the carbon and glass fiber in the structure are within the safety limit, the results show that the weight is minimum when the laminate ply pattern consists of 3.18mm foam core (D) sandwiched by 3 layers of carbon woven fabrics on both side.

Particulate composites

CFRP and GFRP are fibrous composite materials; another category of composite materials is particulate composites. Metal matrix composites (MMC) that are currently being developed for the aviation and aerospace industry are examples of particulate composites and consist, usually, of non-metallic particles in a metallic matrix; for instance silicon carbide particles combined with aluminium alloy.

Differences between fibrous and particulate composites

Probably the single most important difference between fibrous and particulate composites, and indeed between fibrous composites and conventional metallic materials, relates to directionality of properties. Particulate composites and conventional metallic materials are isotropic, i.e. their properties (strength, stiffness, etc.) are the same in all directions; fibrous composites are anisotropic, i.e. their properties vary depending on the direction of the load with respect to the orientation of the fibres. Imagine a small sheet of balsa wood: it is much easier to bend (and break) it along a line parallel to the fibres than perpendicular to the fibres. This anisotropy is overcome by stacking layers, each often only fractions of a millimeter thick, on top of one another with the fibres oriented at different angles to form a laminate. Except in very special cases, the laminate will still be anisotropic, but the variation in properties with respect to direction will be less extreme.

Composite advantages

In addition to the main benefit of reduced weight and formability, composite materials offer better resistance to some forms of corrosion than metal alloys and good resistance to fatigue ' a crack in the brittle fibre is halted, temporarily at least, when it meets the tougher resin matrix.

Disadvantages

The few disadvantages of composite materials are the raw materials expenses compared to most metal alloys, the higher cost of fabricating composite components in many cases and their susceptibility to moisture ingress in some cases.

Use of composites in aircraft design

Among the first uses of modern composite materials was about 30 years ago when boron-reinforced epoxy composite was used for the skins of the empennages of the U.S. F14 and F15 fighters. Initially, composite materials were used only in secondary structures, but as knowledge and development of the materials has improved, their use in primary structures such as wings and fuselages has increased. The sidebar on page 15 lists some aircraft in which significant amounts of composite materials are used in the airframe.

RESEARCH METHODOLOGY

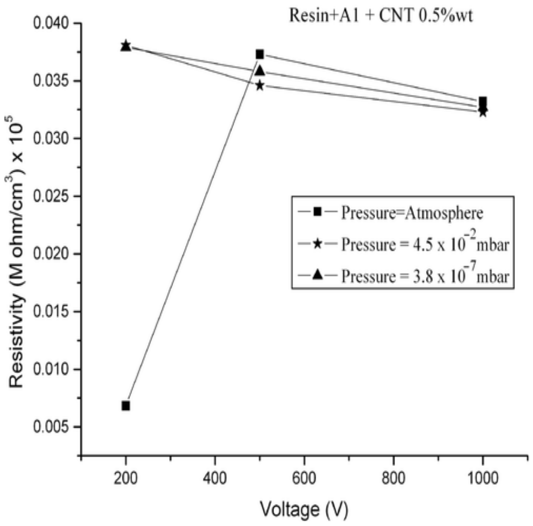
Few researchers paid attention on RSM to optimize the responses without constraints. Therefore, the investigators must continue implementing a multi-objective optimization method for optimizing responses of composites allowing the constraints. The materials and experimentation were discussed. The methodology of optimizing process parameters was divided into four phases. TLBO is such a technique employed here to optimize the process parameters and maximize the mechanical properties of GFRP composite allowing the constraints. The injection pressure and number of layers were considered as input parameters. The constraints are Reynolds number and void content. In view of these input parameters and constraints, fifteen experiments were established on a multi-level full factor basis. The designs of experiments (DOE) are detailed. In addition, ANN was introduced to predict the responses to the given input variables. RSM has been used to know the interaction effect of the number of layers and injection pressure on responses (mechanical properties). The optimal input parameters for mechanical properties using TLBO algorithm were determined. The initial populations consisting of inputs and out puts are initiated. The knowledge transfer then takes place between the teacher and the learners. And also interaction takes place among the learners. The difference in mean values was determined with the help of mean values. The new values were obtained and combined with the initial population.

RESULTS AND DISCUSSION

Analyzing the data it is observed that the resistivity of samples with the curing agent A1 is found to be a few times lower than the samples with curing agent PAP8. It is important to note that the absolute change in resistivity is less over a wide voltage range of 200 volts to 1000 volts for the sample with A1 curing agent whereas for the sample with PAP8 curing agent the resistivity changes marginally more with increasing voltage. Note that the resistivity data were collected with the same samples at two different times of the year in order to have a rough estimate of the influence of climatic and environmental conditions on the performance.

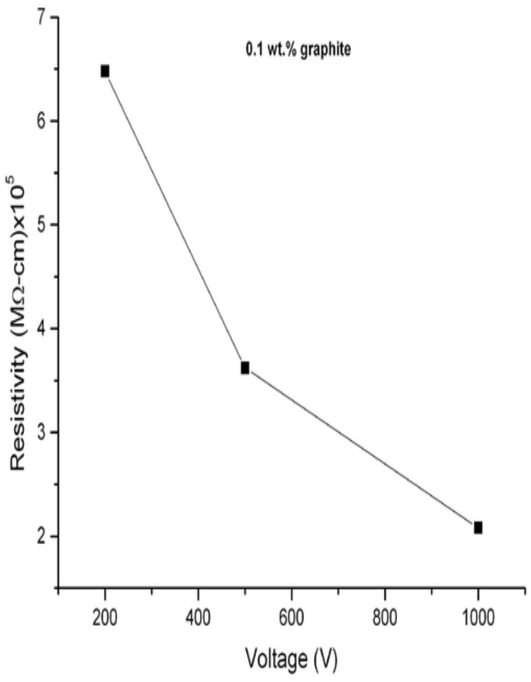
Studies of resin with CNTs

Resistivity measurements were performed for composites with A1 resin in combination with carbon nano-tubes. Composites were made replacing graphite with CNTs. The quantity of CNTs added was 0.5 wt% of the resin mixture the plot of resistivity vs. voltage for this sample. As can be observed the resistivity value changes drastically with the addition of a small quantity of CNTs. The Resin A1 with no graphite or CNT has a resistivity in the range of few tens of M ohms (×105)/cm^3 whereas when 0.5 wt% of CNT is added the resistivity reduces by a factor of 103 to values ranging from 0.01 to 0.04 MΩ (×105)/cm^3.



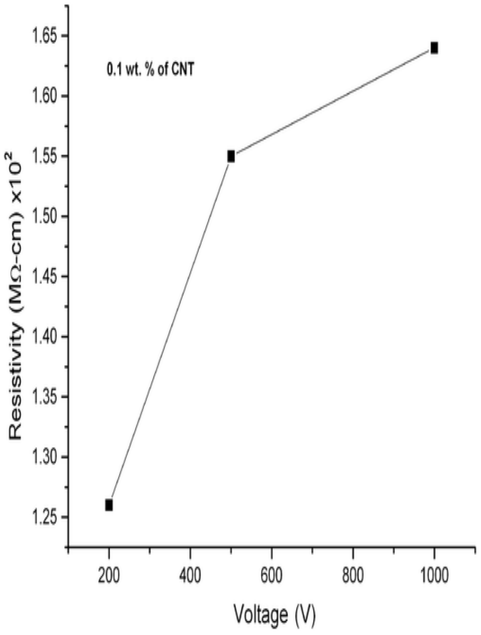
Graph 1: Plot of resistivity vs. voltage for composites of Resin A1 with CNT's.

Composites of resin A1 mixed with both graphite as well as CNTs were studied separately with two compositions of 0.1 and 0.5 weight%. Graph 1 show the plot of these studies done under atmospheric conditions.



Graph 2: Plot of resistivity vs. voltage for 0.1 wt% of graphite.

Resistivity measurements were performed for composites with A1 resin in combination with graphite and carbon nanotubes. Comparing graph 1 and 2 it can be seen that the resistivity decreases for the CNT composite (a few hundred mega ohm centimeters) by three orders of magnitude as compared to graphite composite (few hundred thousand mega ohm centimeters).



Graph 3: Plot of resistivity vs. voltage for 0.1 wt% of CNT's.

Comparing graph 2 and 3, which show plots for 0.5 wt%, it can be seen that the difference in the resistivity between the addition of CNTs and graphite amounts to six orders of magnitude (CNT − a few × 105 and graphite − a few × 1011). As it can be seen, an increase of wt% from 0.1 to 0.5 of graphite only decreases the resistivity by a few times, whereas, in the case of CNTs, an increase of 0.1 to 0.5 wt% decreases the resistivity by three orders of magnitude. The resistivity value changes drastically with the addition of a small quantity of CNTs.

CONCLUSION

This study has thoroughly reviewed the contemporary progress in the field of carbonaceous fillers reinforced polymer matrix composites' mechanical properties, their structural applications and critically analyzed some widely used manufacturing methods. The appropriateness of FEA simulation has been considered in dimensioning E-glass structures. The results obtain from ABAQUS have been compared with experimental result for unidirectional E-glass which can be treated as transverse isotropic. At first, the mechanical performance of carbon fiber-reinforced polymer composites was analyzed compared with the high-performance glass and aramid fiber-based composites and the summary was recorded. Research is also ongoing to improve repair techniques. Moreover, standards are being set-up for the testing and computerization of mechanical and corrosion property. Since the development of new fire retarding elements, the availability of polymers with higher temperature ratings, the relative ease of fabrication, and fair cost. So it is important to realize that the use of composites requires an integrated approach between user and designer/manufacturer to ensure functionality. However, it can be undoubtedly said that GO and functionalized GO provide better reinforcing efficacy than graphene itself. Dispersion homogeneity is deemed to be the most vital issue for these nano-fillers. Furthermore, 3D printing was dictated as an avant-garde technology to manufacture carbon fiber-based polymeric composites regardless of their strength and energy issues.

REFERENCE

1. *Loukham Shyamsunder (2022), "Impact simulation of composite panels for aerospace applications",Composites Part B: Engineering,ISSNno:1359-8368, Vol.247,https://doi.org/10.1016/j.compositesb.2022.110320*
2. *Mohammed Al Awadh (2022), "Optimization of Carbon Fiber Reinforced Plastic Curing Parameters for Aerospace Application",Appl. Sci.,ISSNno :2076-3417,Vol.12(9),Pages.4307.https://doi.org/10.3390/app12094307*
3. *Sarfaraz Kamangar (2022), "Scientific Advancements in Composite Materials for Aircraft Applications: A Review",Polymers,ISSNno:2073-4360,Vol.14 (22),Pages.5007.https://doi.org/10.3390/polym14225007*
4. *R.S. Rajeev (2021), "25 - Fiber reinforced composites for aerospace and sports applications",Fiber Reinforced Composites,ISSNno:1530-7964,Pages.821-859.https://doi.org/10.1016/B978-0-12-821090-1.00023-5*
5. *Stylianos Markolefas (2023), "Composites in Aerospace and Mechanical Engineering",Materials (Basel),ISSNno:1996-1944,Vol.16(22),Pages.7230.doi :10.3390/ma16227230*
6. *V.P.Khambalkar (2016),"Feasibility Testing of Aeroblast Sprayer",Asian*

Resonance, ISSNno:2349-9443,Vol.V,No:I,

7. *R. D. Brazee (2007),"A History Of Air-Blast Sprayer Development And Future Prospects",American Society of Agricultural and Biological Engineers, ISSNno:0001-2351,Vol.51(2),Pages.405-410.*
8. *Christian E. Willert (2021),"Three-dimensional imaging of swirled spray injection in a generic aero engine burner under realistic operating conditions", Experiments in Fluids,ISSNno:1432-1114,Vol.63,No.1,https://doi.org/10.1007/s00348-021-03343-z*
9. *Juntao Chang (2022),"Recent research progress on airbreathing aero-engine control algorithm",Propulsion and Power Research,ISSNno:2212-540X,Vol. 11,Issue.1, Pages.1-57.https://doi.org/10.1016/j.jppr.2022.02.003*
10. *Mongkol Thianwiboon (2019), "Optimization of a Hybrid Carbon/Glass Composites Afterbody of the Amphibious Plane with Finite Element Analysis",Engineering Journal,ISSNno:0125-8281,Vol.23,Issue.5,DOI:10.4186/ej.2019.23.5.125*