A SCHEMATIC STUDY AND APPORACH ON AIRFOIL STRUCTURE USING FEM

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Abstract:
An airfoil or aerofoil is the cross-sectional shape of a wing or blade of a turbine, rotor or propeller. An aerodynamic force is produced when an airfoil moves through a fluid. These forces are the very reason of lift produced in an aircraft or to produce a downward force on an automobile to improve traction. The efficiency of an airfoil is characterized mainly on its profile section and its aerodynamic design. In the present study a NACA 2412 AIRFOIL model is selected and analyzed. The material used for the analysis of airfoil is polymer composite, because of its unique and better mechanical properties than the conventional materials. Polymer composites are the materials which consist of two or more constituents combined at a polymer scale regime in such a manner that it gives improved properties (such as elastic, damping, wear and corrosion resistant etc.) as compared to other conventional materials. In the present study, free vibration and static structural analyses are cared out in order to investigate the effect of carbon polymer tube content on the static and dynamic responses of NACA 2412 aero foils. To find the lift and drag forces that the airfoil generates are found from computational fluid dynamics module available in LS DYNA. Finally the calculated lift and drag forces are utilized to perform static structural analysis. Several parameters such as total deformation, equivalent stresses and shear stresses are measured for different polymer tube content, airflow rate, and orientation of the airfoil.

Key words: *LS DYNA, Airfoil, Polymer Composites*

1.0 INTRODUCTION

In the earliest days, the only means of locomotion was by walk when man was in the early stages of development of his livelihood. Since then, man has achieved faster and more comfortable ways of travelling such as bikes, cars, trains and specially airplanes. From the day of its invention airplanes have been gone through many stages of advancement and today it is considered as one of the fastest option of transportation available. In World War II it had got the popularity as a modern war machine and had played an important role in the war. Popularity of airplanes in today's era has led to many innovative research and inventions to manufacture faster and more cost effective planes. The present study is all about to determine how to attain maximum performance from an airfoil section made up of polymer composite structure.

An airplane's airfoil is a cross-section of the wing which is somewhat similar to the cross section of wings of a bird. The main objective airfoil is to provide vertical lift to an aircraft during the take-off and when it is in flight. The airfoil structure also has a negative effect called Drag, which opposite to the forward motion of the airplane. The magnitude of lift required by a plane is decided according to the purpose for which it is to be used. The planes which are heavy and which are used to transfer heavier loads require more lift while plane used for lighter loads need less lift. Thus, airfoil section is designed depending on its weight and upon the use of airplane. Lift force thus produced acknowledges the vertical motion of the plane, which depends on the horizontal velocity of the aircraft. So, by calculating the coefficient of lift, the lift force can be determined. Once lift force and vertical acceleration is calculated the next step is to determine the horizontal velocity produced.

Aerodynamics is a field of science which focuses mainly on concentrating on the behavior of air movement, when associated with a solid model, such as turbine blade, propeller, airfoil etc. An aerodynamic energy is handled by the model based on airfoil when it travels through a fluid environment.

Composites

Composite materials has been used in a wide range of applications in various engineering fields such as ships, submarines, aerospace structures, civil engineering structures, machine components, chemical industrial applications, etc. In the recent years the importance of composite materials has been recognized by many researchers and commercial organizations. These organizations have put a lot of effort in developing innovative and better techniques to improve the properties of composite as per human needs.

Motivation of the Present Work

Composites made up of carbon polymer tubes play a very important role in engineering field because of its unique physical, mechanical and thermal properties. Some of its useful properties are superior length-to-diameter ratio, has diameter of 3 to 9 nm, length is in millimeter range, they are efficient electrical conductors; these can act both as thermal conductors and thermal insulators, better wear and corrosion resistance, also good fatigue resistant and has good elevated temperature properties. It is possible to construct the directional effective properties of POLYMER based composites thereby providing the ability to control wear, corrosion, deformation and dynamic response of the system. Composites are two or more phase composites in which constituents are mixed up to form hybrid in a hierarchical manner. Carbon fibers are distributed uniformly in the nano composite matrix to form the hybrid composite which is required for analysis

Scope of the Present Thesis

The aim of the present work is to develop an airfoil model for uniformly distributed single walled carbon polymer tubes based nano composite using LS DYNA program and evaluate its effective properties by applying various boundary conditions. A finite element model is proposed for the analysis and subjected to discretization. As discussed earlier in recent years laminated composite shell panels are being widely used in various engineering fields where they are subjected to large amplitude vibrations. Hence the airfoil model which is to be analyzed in this study is made up of nano composite structure. The application of nano composites is either weight critical such as in aerospace or performance critical as in non-corrosive and non-magnetic nano composites in naval industries. Though the scope of nano composites in the field of aviation is abundant, the scarcity of ample knowledge of researchers around the world until now has been very much restrictive. Hence a lot of effort has been put forward and dedicated to develop newer and innovative approaches to impart knowledge on nano composites materials, structural analysis and structural mechanics. The present study is an attempt to present unified and assimilated approach to nano composite materials and its application in aviation field.

2.0 LITERATURE REVIEW

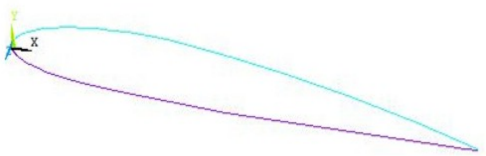
Lu [1] investigated using an empirical force constant model the elastic properties of carbon polymertubes and nanoropes. It was found that the elastic moduli of single and multiwall polymertubes are insensitive to structural variables such as helicity, radius and the number of walls**.** Gultop [2] determined the impact perspective degree on Airfoil performance. The main reason for this study was to find out the conditions where the ripple conditions can be avoided throughout wind tunnel tests. This resulted increase in the aeroelastic insecurities at Mach number 0.55, which came out to be higher than the wind tunnel Mach number of velocity of 0.3. Goel [3] used Quansi – 3D analysis codes to devise a method of optimization of Turbine Airfoil. In his paper the complexity of 3D modeling is solved by modeling it in multiple 2D airfoil sections and then joining them in radial direction using first and second order polynomials which leads to no roughness in the radial direction.

Prabhakar [4] analyzed the NACA 4412 airfoil profile and studied its profile for consideration of an airplane wing .The NACA 4412 airfoil was created using CATIA V5 and analysis was carried out in ANSYS 13.0 FLUENT software at an inlet speed of 340.29 m/sec for different angles of attack of 0˚, 6, 12 and 16˚. Standard k-ε turbulence model was assumed for Airflow. Fluctuations of dynamic pressure and static pressure are presented graphically in form of filled contour. Habali and saleh [5] discussed a selection procedure for airfoil section and aerodynamic design of a rotor blade. They used Glass Fiber Reinforced Plastic for designing the rotor blade and conducted a static proof load test to determine the load carrying capacity. Feistauer et al [6] presented a brief study on numerical simulation of interaction of two dimensional incompressible viscous fluids and vibration analysis of airfoil with large amplitude. Gharali and Johnson [7] used ANSYS Fluent 12.1 to stimulate numerically flow of an oscillating freestream over a stationary S809 airfoil. A comparison study is performed in this study to choose the model. Several simulations were conducted based on different Reynolds numbers from 0.026 to 18. Qu et al [8] carried out a numerical simulation on the landing process of a NACA 4412 airfoil considering the influence of dynamic ground effect (DGE). Murugan et al [9] studied variable camber morphing airfoil incorporating compliant ribs and flexible composite skins. A hierarchical modeling framework is utilized in this study to decouple the compliant ribs and airfoil skin. Koziel and Leifsson [10] presented an automated low-fidelity model selection procedure is presented. A comparison study is carried out in this paper to compare the standard and proposed approach within the scope of aerodynamic design of transonic airfoil. Huang et al [11] conducted a research on plunging motion, varying pitching, and varying incoming flow for NACA 0012 airfoil section. This study mainly concentrates on observing the real characteristics and response of airfoil of rotor blades in unsteady flow field. Li et al [12] successfully fabricated the inter laminar reinforced and toughened CFRP composites in which MWNTs-EP/PSF (polysulfone) hybrid nono fibers with preferred orientation were directly electro spun onto the carbon fiber/prepegs. The facture toughness was attained a maximum at 10 wt% MWNTs-EP loading and then decreases. With increased MWNTs-EP loading the flexural properties and inter laminar shear strength of composite are improved. Shokrieh and Rafiee [13] developed a stochastic multi-scale modeling technique to estimate the mechanical effective properties of carbon polymer tube rein forced polymers. A full range multi scale technique is implemented to consider parameters of nano, micro, meso and macro-scales and developed full stochastic integrated modeling procedure. It has been proved that mean values can be replaced with that of random distribution of carbon polymer tube length and volume fractions. Rafiee et al [14] studied the nonlinear free vibration of carbon polymer tubes/fiber/polymer composite multi scale plates with surface-bonded piezoelectric actuators. First order shear deformation theory (FSDT) and von karman geometrical nonlinearity are used as the governing equations for the piezoelectric polymer tubes/polymer/fiber multi scale laminated composite plates. Modeling is accomplished using the Halpin-Tsai equations and fiber micromechanics in hierarchy to predict the effective properties of the hybrid composite.

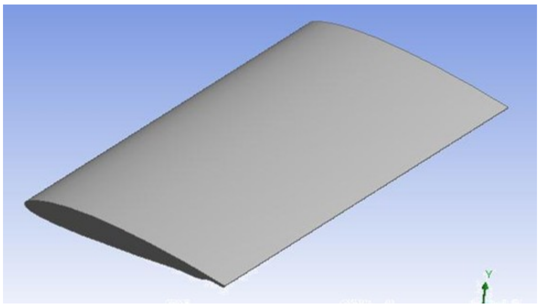
3.0 METHODOLOGY

Material Modeling

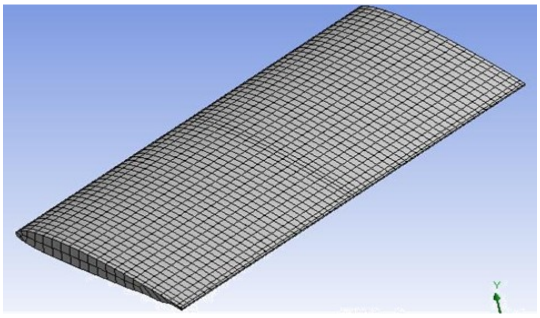
Nano composite model of uniform thickness is proposed. The mixture used consists of isotropic matrix which is basically the epoxy resin and POLYMER. For the polymer matrix through the thickness the Polymer are aligned uniformly. The POLYMER which is used in the modeling are assumed to be isotropic. That is they are assumed to have similar properties along all the direction of orientation. The dispersion of POLYMER in the matrix is assumed to be uniform and perfect. As the dispersion is also considered as isotropic so each POLYMER has same mechanical properties and aspect ratio. Due to simplicity of the experiment all Polymer are taken as straight POLYMER and it is assumed that there is no void present in the matrix. In the hybrid analysis the fiber-matrix bonding is also considered as perfect. All the constituent materials are considered to be linearly elastic throughout the deformation.



Profile of NACA 2412 airfoil model



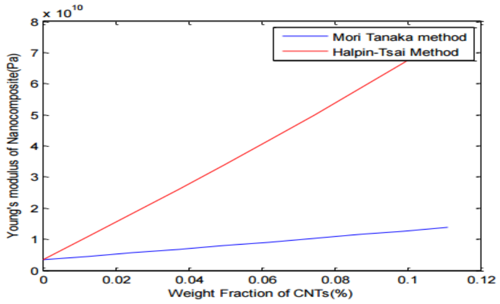
Solid LS DYNA model of airfoil



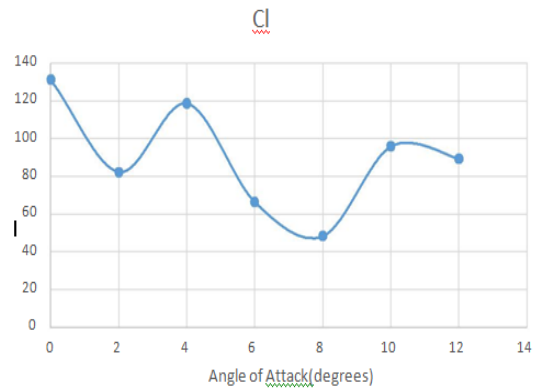
Meshed model of airfoil

4.0 RESULTS AND DISCUSSION:

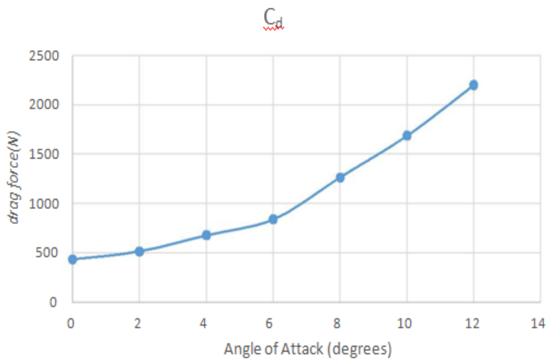
The result obtained is in good agreement with the paper used as reference for this study. The elastic properties obtained from Halpin-Tsai method are found to be higher than that of elastic properties obtained from Mori Tanaka method which is obvious as referred to some published literature. A plot has been presented below showing variation of Young's modulus obtained from both Halpin-Tsai and Mori Tanaka method with different percentage of volume fraction of Polymer.



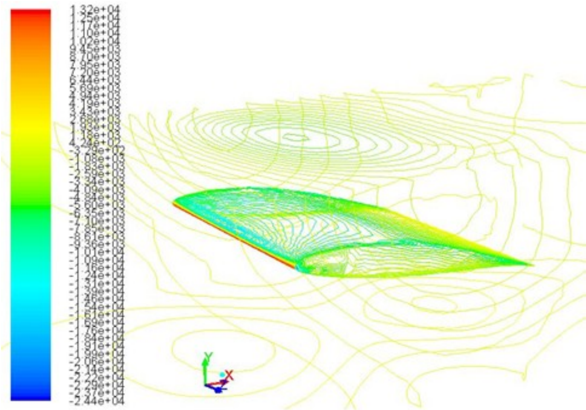
Variation of Young's modulus with different percentage of polymertube



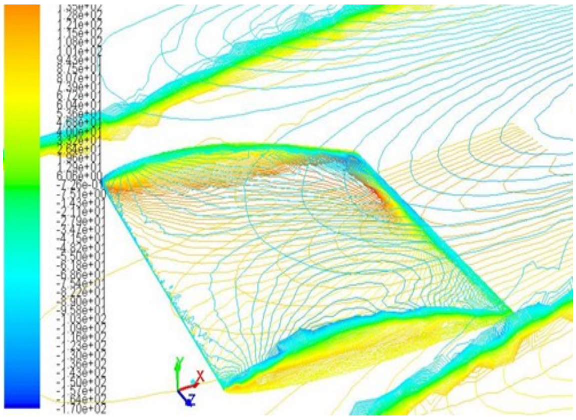
Variation of lift coefficient with angle of attack



Variation of drag coefficient with angle of attack



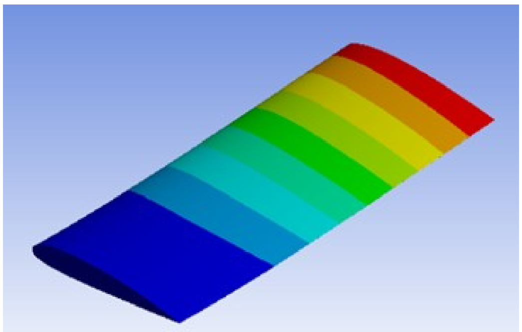
Pressure contours on the airfoil model



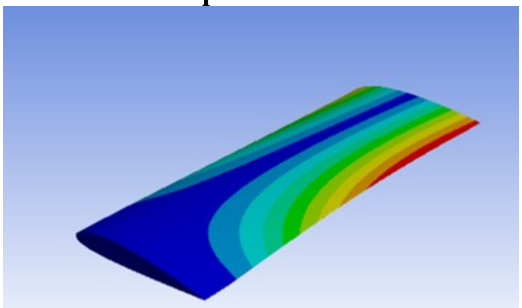
Velocity contours on the airfoil model

Table shows Variation of natural frequency with different polymer tube percentage

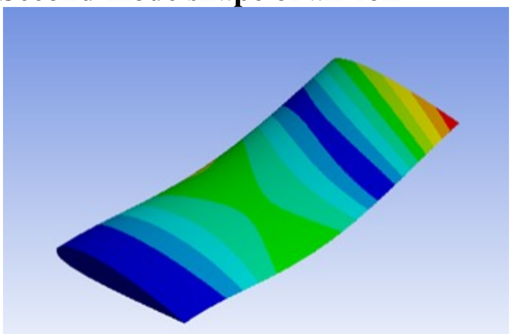
Percentage of carbon polymertube (%)	Density(kg/m^3)	First Natural Frequency(Hz)	Second Natural Frequency(Hz)	Third Natural Frequency(Hz)
0	1200	2.4231	8.6659	15.404
0.0111	1201.7	2.808	10.043	17.851
0.0222	1203.3	3.1465	11.253	20.003
0.0333	1205	3.4527	12.348	21.949
0.0444	1206.7	3.7344	13.356	23.740
0.0556	1208.3	3.9967	14.294	25.407
0.0667	1210	4.2426	15.173	26.970
0.0778	1211.7	4.4758	16.007	28.453
0.0889	1213.3	4.6987	16.804	29.870
0.1	1215	4.7730	17.056	31.127



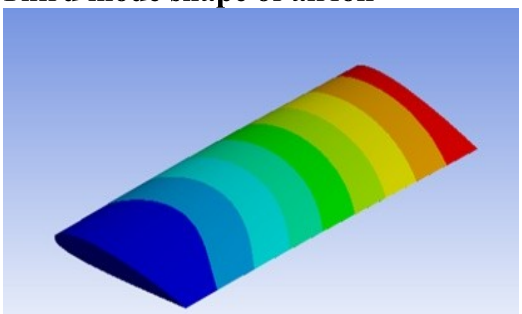
First mode shape of air foil



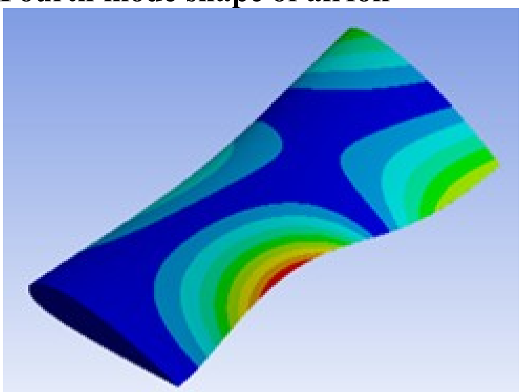
Second mode shape of air foil



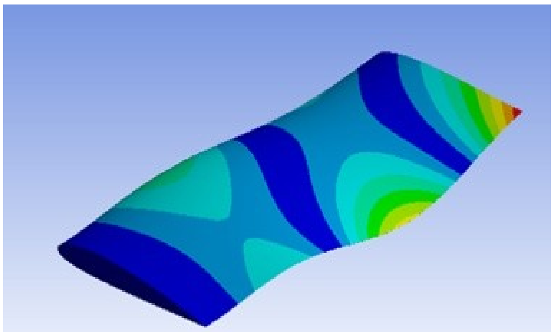
Third mode shape of airfoil



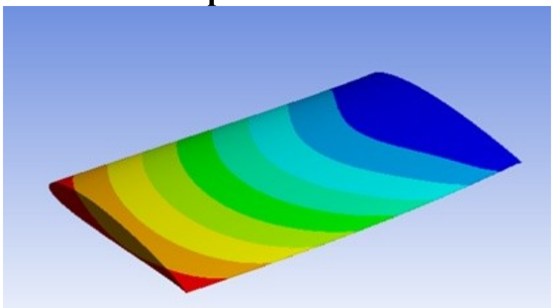
Fourth mode shape of airfoil



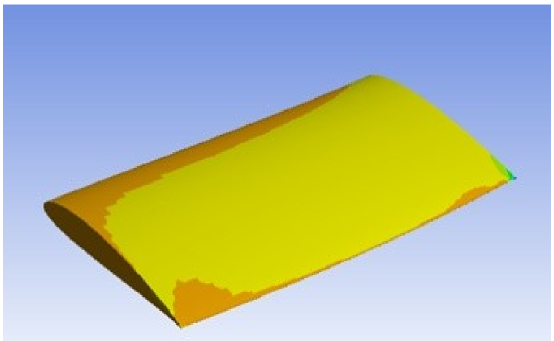
Fifth mode shape of airfoil



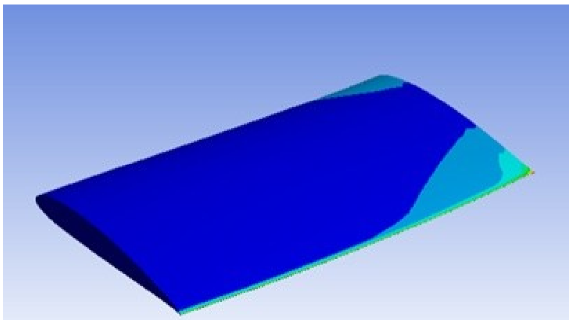
Sixth mode shape of airfoil



Total deformation of the airfoil



Shear stresses of the airfoil



Stress intensity distribution of airfoil

5.0 CONCLUSION

An investigation of the NACA 2412 airfoil model made up of polymer composite material is performed and analysed. The airfoil model is then subjected to CFD analysis where the aim is to determine the different forces acting on an airfoil model when it is operational in its working environment. Lift and drag are the two forces acting on the airfoil model and due to these forces an airplane gets its required lift. These forces are computed with the help of modeling software Ansys-Fluent. Lift and drag for various angle of attack is computed and plotted which shows an increase in lift and drag forces as the angle of attack increases. Free vibration analysis of the selected airfoil model is performed by developing a model using Ansys (APDL) workspace. Different mode shapes are obtained in this analysis with different frequency. At last using the lift and drag forces obtained from the CFD analysis static structural analysis is performed to determine total deformation, shear stress, equivalent stress and stress intensity. Here in this study it is shown that the proposed method successfully simulates the flow around a conventional wing. The method employed here is under the same conditions as those used by various authors and the comparison results are found to be satisfactory.

The main conclusions that can be drawn are:

1. With increase of percentage of volume fraction of Polymer the elastic properties of polymer nanocomposite increases.
2. Natural frequency of polymer nanocomposite increases with increase in percentage of volume fraction of Polymer.
3. Total deflection of the model decreases with increase of percentage of volume fraction of Polymer.
4. Lift and drag forces of the airfoil section increases with increase in angle of attack.
5. Static structural analysis is carried out with satisfactory results.

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