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FLEXURAL ANALYSISON LAMINATED SANDWICH PLATES WITH REINFORCED CARBON NANOTUBE

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Abstract:

This paper deals with the improvement of Poisson's ratio and flexural strength in sandwich plate by adding carbon nanotubes. The sandwich plates were analyzed by using Nastran /Patransoftwares.The comparisons of sandwich plate with and without addition of carbon nanotubes were analyzed. It further concentrates on the reduction of displacement in x, y and z directions in a sandwich plate with an applied tensilestress and compressive stress. As a result of nanotube reinforcement over a sandwich panel we observed thatdue to increased face sheet Poisson's ratiothere was a reduction in compressive stress, tensile stress and displacement in all directions. The sandwich plate with nanotube reinforcement has enhanced mechanical properties compared to a sandwich plate without addition of carbon nanotubes. The sandwich plates enhanced with carbon nanotubes, especially with a higher face-sheet Poisson's ratio, is found to be feasible for aerospace application.

Key words: Poisson’s ratio, sandwich plate, carbon nanotube and mechanical properties

I. Introduction

In order to meet the increasing demand for high strength, lightweight aerospace and fatigue-resistantaerospace structures, those are able to withstand the rigors of air and space flight while still maximizing the thrust-to-weight ratio of the resulting vehicles. Sandwich construction results in excellent thermal insulation, acoustic damping, fireretardation, ease of machining, ease of forming, high specific strength, stiffness, good fatigue performanceand corrosive resistance. The theoretical sandwich panel consists of twofacesheetand a core. The facesheetis madefrom woven silicon carbide fiber and the core is fromPVC foam and multi-wall carbon nanotubes (MWCNT) that were grown directly on the fibers, aligned normal to the fiber direction.

The analysis of sandwichplates with laminated compositefacesheets were developed using higher order finite element model. In this model, classical plate theory has been used on thefacesheets in which transverse and normal stress can be determined. Three dimensional continuums were considered as core in which shear stress can be determined. The through-thickness representation of the displacement field used from mixed form and the displacements werecalculated [1].The reduction of bending strength of foam-cored sandwich specimens were caused by the stiffness degradation of foam due to the aging of polyurethane foam during fatigue cycles. However, the bending strength of the stitched specimen has improved by 50 % compared with the non-stitched specimen, and the stiffened specimen is over 10 times stronger than the non-stitched. Bending strength is also improved by increasing the stitch thread diameter and decreasing the stitching thread distance [2]. The initiation of the various failure modes in composite sandwich beams depends on the material properties of the constituents (facings, adhesive, and core), geometric dimensions and a type of loading. The appropriate failure criteria should account for the complete state of stress at a point, including two- and three- dimensional effects [3].Their researchwas performed on analytical evaluation of FRP corrugated sheet. They fabricated and tested fiber-reinforced corrugated sheet employing 4-point bend loading in ANSYS. ANSYS was used to perform theoretical analysis and the comparison between theoretical and experimental values showed that both the values are same. This research basically provides the idea about the ANSYS software and it also provides the necessary steps for theoretical analysis [4]. In this study, the effect of various sewing threads, stitch row orientations and spacing were evaluated. The obtained data indicates that the stitching in through the thickness direction considerably increases the impact damage tolerance especially at low temperature. The stitching with suitable sewing thread cab reduces the sensitivity of ductile behavior of composite to the variation of temperature.Thesandwich panel reinforced with MWCNT has higher face sheet Poisson's ratio due to its reduced displacement in all direction under the applied load.This reinforced sandwich panel was then compared to the same without MWCNT. Finally, the effect of increased facesheet Poisson's ratio of the panel reinforced with MWCNT,is analyzed for both displacement and stress and it was shown that there is a significant reduction in the displacements in all directions and compressive and tensile stresses in the panel. Sandwich plate is fabricated using facesheets of a silicon carbide microfiber composite reinforced with carbon nanotubes.Carbon nanotubes are commonly used in aircraft industry because of several advantages. One of the common uses is - additive to epoxy matrix whichincreases the elastic modulus of composites [5], [6]. If the nanotubes are not aligned correctly in composites, the elastic properties of the latter will not reach the full potential. Also, when there are variations in dispersion of composites due to use of nanotubes, with respect to applied load, stiffness of the composite will not reach the full potential [7]. In this analysis it is concluded that the carbon nanotubes reinforced sandwich panel when compared to a similar sandwich panel containing the same woven composite, but without the addition of carbon nanotubes shows a reduction in the maximum displacement under the same load. Finally, the deflection of the sandwich panel is sensitive to small changes in the facesheets' overall Poisson's ratio. There is a small increase in thePoisson's ratio of epoxy facesheets in the sandwich panel. But the displacement and stress decrease under the same load. The light weight of the nanotubes, which are used in the sandwich structure, produced a large gain in the strength to weight ratio. This would be used in aerospace structures without affecting the other engine requirements. It may also be used as manufacturing technology for advances in nanotubes, uses in Commercial applications.

II. Method of analysis

The analysis is carried out with Nastran/patranmodified for sandwich panels and the analysis consists of computing the deflections and stresses in sandwich panel under uniform or concentrated loads. This sandwich model was used in the current analysis, because of its ability to produce the stresses in all nodes of sandwich plates. Also, it is very effective to use foam core in sandwich plate. The reasonsfor the selection of foam core are that they are significantly lighter, cheaper, and more easily molded than metal honeycomb and foam core adds on further resistance to carrying loads between the facesheets and the core. The proposed model of sandwich plate dimensions and properties were detailed in Jessica.d.albernaz [6].
It is used to analyze the displacements and stresses in sandwich panel. For comparative purposes, two sandwich panels were analyzed. In the first one,facesheetsare made of the woven composite enhanced with carbon nanotubes.The second is a sandwich panel containing the same composite without carbon nanotubes.

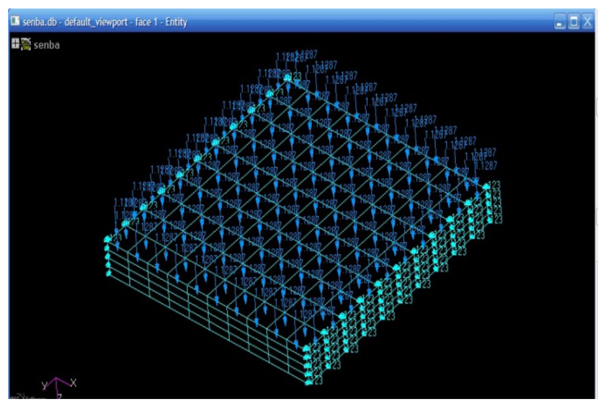

Fig 1 Loads and Boundary conditions of Sandwich Panel

The sandwich plate is analyzed as a simply supported beam with three point bending under the loading by using Nastran/Patran. Each sandwich panel is exposed to four different uniformly distributed loads: 500, 1000, 1500, and 2000N applied to eachpanel over the top facesheet. The sandwich panel is synthesized with dimensions of 40mm by 40mm by using weight optimization in which the thickness of the core is different for the two types of sandwich panels analyzed. But, the thickness of the facesheet is same for both sandwich panels by Jessica.d.albernaz [6].

III. The proposed sandwich panel properties

Various mechanical properties of the facesheets and the core are required for the analysis and these inputs are shown in Table [1]. The facesheet may be considered as two dimensional orthotropic material and core as 3d orthotropic material. But, PVC foam core can be taken as isotropic which is based on the calculation of Young's modulus, Poisson's ratio if the secondary and tertiary values are equal. After the completion of weightoptimization, both sandwich panel facesheetthickness is observed to be 0.53mm. The sandwich panel enhanced with nanotubes has a core thickness of 4.3mm, and the panel without enhanced nanotubes has core thickness of1.8mm [6].

Table 1 Sandwich panel properties for analysis

Property	**Value(nanotube enhanced panel)**	**Value(nanotube non-enhanced panel)**
Facesheet		
E_{11} & E_{22}	24.30 Gpa	23.10 Gpa
G_{12}	2.05 Gpa	2 Gpa
G_{23}& G_{31}	1.13 Gpa	1.13 Gpa
V_{12}	0.31	0.31
Thickness	0.53 mm	0.53 mm
density	1800 kg/m^3	1800 kg/m^3
Core		
E_{11},E_{22}& E_{33}	0.1 Gpa	0.1 Gpa
G_{12},G_{23}&G_{31}	0.037 Gpa	0.037 Gpa
V_{12},V_{13}&V_{21}	0.35	0.35
V_{23},,V_{31}&V_{32}	0.35	0.35
Thickness	1.8 mm	1.8 mm
density	100 kg/m^3	100 kg/m^3

IV. Results

Both the sandwich panels were analyzed, after the complete sets of properties were fed to the program as input. The output produces x, y, and z direction-deflections, tensile stresses and compressive stresses in sandwich panel under the uniformly applied load. The analysis is used to determine the face-sheet Poisson's ratio on sandwich panel through using a different epoxy in the face-sheets. The analysis of sandwich panel with enhanced nanotubes was underthe load of 2000 N while varying the Poisson's ratio from 0.31 to 0.35.The results were compared with the maximum z-direction displacement and tensile stress in the non-reinforced sandwich panel.

The maximum deflection of the two sandwich plates in x and y directionsis shown in figures [2] and [3], the curves are both linear. The nanotube enhanced panel has reduced deflection in all directions when compared to non- enhanced panel, these two directions gives the greatest benefit from the addition of carbon nanotubes. The deflection of the sandwich panel as in all directions is directly proportional to the applied uniform load in z direction. The enhanced panel shows increased young's modulus due to high young's modulus of the added nanotubes.When the applied is loadincreaseddifference in displacements in bothpanels will alsoincrease. The result shows that, nano- tube enhanced sandwich panel has a comparatively reduced deflection in all direction under same applied load.

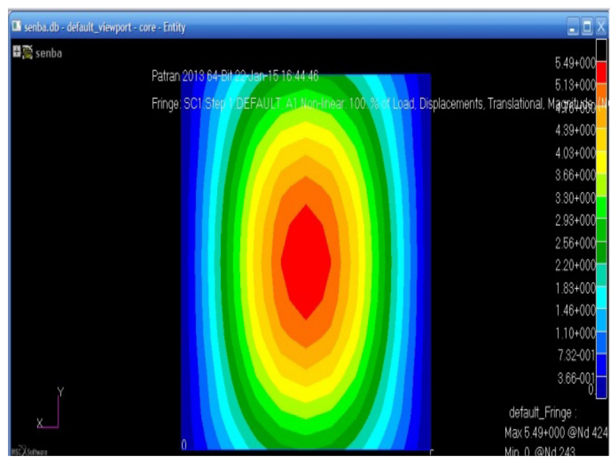

Fig 2 Sandwich panel with uniformly distributed load

Table 2 Sandwich plate with uniformly distributed load

Load (N)	**Deflection(nanotube-enhanced panel)**		**Deflection(nanotube-non enhanced panel)**	
	x-direction (mm)	**y-direction (mm)**	**x-direction(mm)**	**y-direction (mm)**
500	0.30	0.17	0.47	0.35
1000	0.53	0.39	0.68	0.59
1500	0.71	0.59	0.84	0.83
2000	0.85	0.72	0.97	1.04

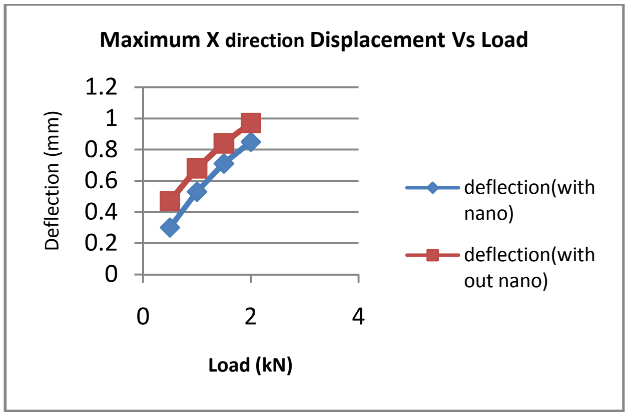

Fig 3 Maximum X-displacement Vs Load

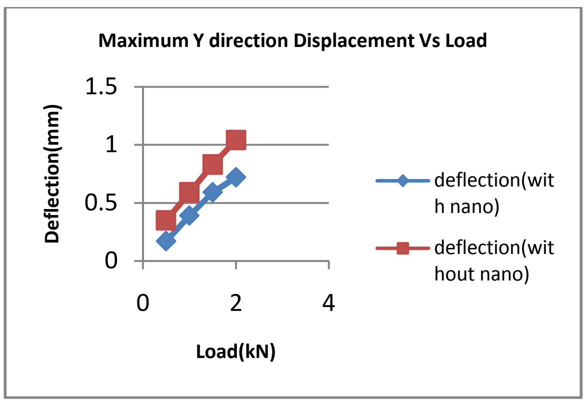

Fig 4 Maximum Y-displacement Vs Load

Similarly, the sandwich panel enhanced with CNT has less deflection in tensile and compressive stresses when compared to the one with no enhancements, both in facesheets as well as the core. Table [2] shows that the maximum tensile stress to meet at the maximum load for sandwich panel enhanced with nano is 8.66mm andnon-enhanced with nano panel reaches at 12.1mm.

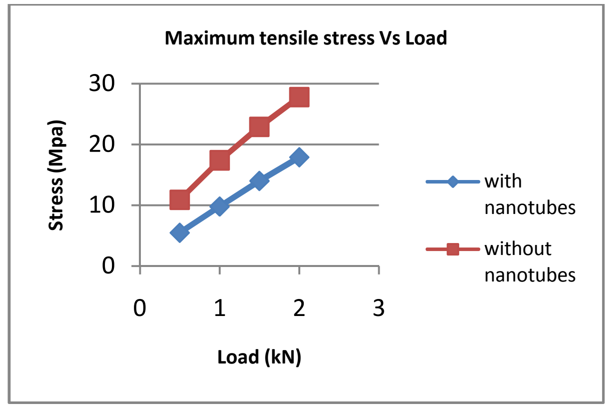

Fig 5 Maximum Tensile Stress Vs Load

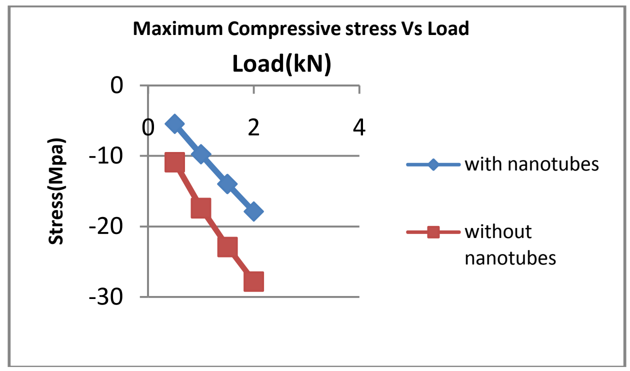

Fig 6 Maximum Compressive Stress Vs Load

Finally, the facesheet's increased Poisson's ratio may be accomplished by using different epoxy to create the composite facesheets. Bisphenol-A epoxy is used in the current analysis. Bisphenol-F is another epoxy, which has the Poisson's ratio of 0.42 when added resulting in afacesheetPoisson's ratio value of 0.35 for sandwich panel enhanced with carbon nanotubes. Moreover, this new value 0.35is larger than the current value 0.31 with a difference of 0.05. The analysis of the sandwich panel-nanotube enhanced was repeated with a facesheet Poisson's ratio value ranging from 0.31 to 0.35 as shown in figure [7]. The maximum z-direction displacement, tensile stress, and Compressive stress were analyzed at 2000 N and 5000 N uniform loading. The effect of increased Poisson's ratio value was chosen at (5000 N) higher loads. Facesheet with higher Poisson's ratio would yield greater benefit in terms of decreased tensile stress and displacement, provided the panel can withstand additional tension.

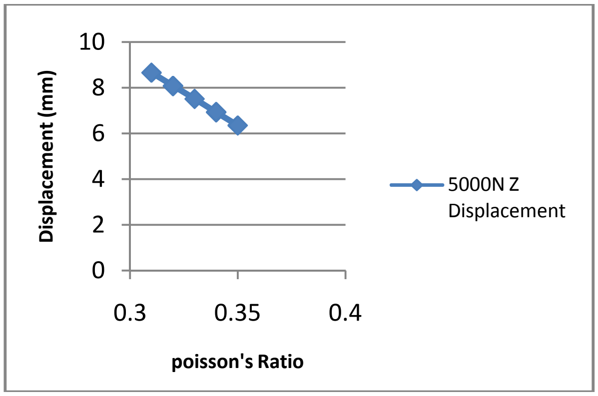

Fig 7 Maximum Z- displacement v_s. Poisson's Ratio

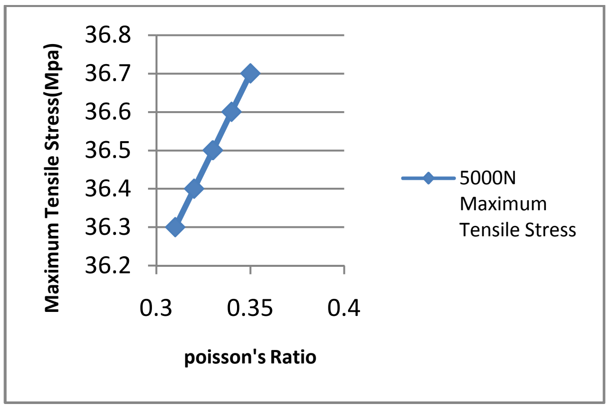

Fig 8 Maximum Tensile Stress Vs Poisson's Ratio

V. Conclusions

The analyzed results show that theoretically, sandwich panel enhanced with nanotubes clearly has the upper hand due to increase in properties than sandwich panel without enhancement of nanotubes under the same applied uniform load. The tensile and compressive stress is reduced in all directions within the sandwich panel when the nanotube is incorporated. The displacement in x and y directions by the addition of nanotube is 1.14 times reduced than non-enhanced panel at the maximum load, which is shown in table [2]. The tensile and compressive stresses are also increased when compared between enhanced panel and non-enhanced panel under the same amount of applied load.

The face-sheet Poisson's ratio is higher and even reduced the displacement and stress in nanotube-enhanced panel. The reduction in displacement and stress is not only the current study, as the sandwich panel does not experience failure at the maximum load of 2000 N. In all cases, the displacement analysis demonstrates that nanotube-enhanced panel is stiffer, undergoing lesser stress under the same load. The sandwich plate enhanced with carbon nanotubes, especially with a higher face-sheet Poisson's ratio, was found to be a feasible for applications related to aerospace structure. The analysis and results for use of sandwich panels enhanced with nanotube forests with stronger, lightweight, and stress-resistant aerospace material, can be made possible using nanotechnology.

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