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Stress Analysis of BWB Composite Bulkhead Beam using Ansys.

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ABSTRACT
The concept of Blended wing body (BWB) in modern aviation is a potential breakthrough. Hybrid wing body is a fixed- wing aircraft having no clear dividing line between the wings and the main body of the aircraft. In order to obtain a more efficient structure to withstand more stress, one must increase the bending stiffness using deep sandwich shell with light weight & high strength composite skin with composite deep stiffener. The bulkhead member is one that which undergoes more loads. In this Project we use the combined advantage of using a symmetrical section & the Coupling Load to determine the stress property for a curvilinear bulkhead structural member. This project focuses on the composite member analysis using Carbon Nano Tube (CNT) as a core material instead of the normal steel metal material. The strength parameter is evaluated using Ansys simulation tool. This paper is a part 1 of the experimental work.

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I. INTRODUCTION

Bulkhead is a frame like structure. In Semi-Monocoque structure, series of frames in the shape of fuselage cross section are held in position on a rigid fixture and these frames are joined with light weight longitudinal elements called stringers. Passenger aircraft fuselage is not only under the manuverable loading, it undergoes high internal pressure loading at high altitudes. So there is a need to give much priority to the BWB bulkhead.

Fig :1Boeing X-48B Blended Wing Body

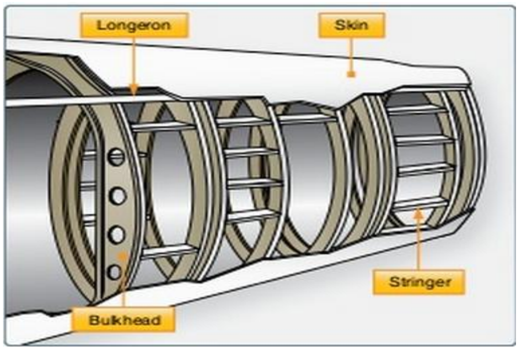

Fig: 2 Interior of Fuselage bulkheads

By using composite materials we can obtain more efficient structure. A Composite is a combination of two or more materials joined permanently together so that the strength of the combined materials is greater than any of the component materials [4]. Composite is a homogeneous material by synthetic assembly of two or more materials to obtain the specific properties.

Example: Wright Flyer 1, 1903

The aircraft was constructed of wood with cotton
Fabric glued to the frame [4].

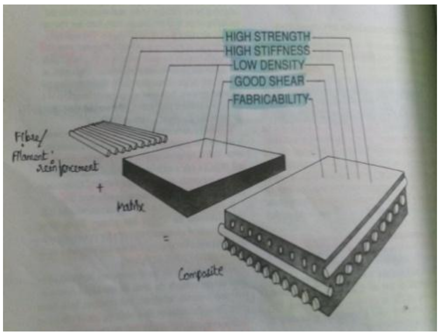

Fig:3 Composite structure

GENERAL CHARACTERISTICS OF COMPOSITES:

I. Composites =Fibre/Filament reinforcement + Matrix
II. Transverse property [**4**] is an ability of matrix to transfer loads from one fibre to another. Greater the ratio of reinforcement fibres to matrix, greater the strength of composite.
III. High material strength to weight ratio, coupled with corrosion and fatigue resistance.
IV. It reducing aerodynamic and parasite drag.
V. Composite materials used in aircrafts parts [**4**] like landing gear, doors, flaps, vertical stabilizer, horizontal tail structures, propellers, internal turbine engine parts, helicopter rotor blades and flight control surfaces.
VI. Advanced composite materials [**4**] like Kevlar/Carbon fibre/Graphite, Quartz, Boron, Tungsten, Silicon Carbide, Ceramics, Spectra, etc.,

CARBON NANO TUBES:

Carbon Nano Tube is a tubular form of carbon with **1-3 mm** diameter and a length of few nm to microns. Generally carbon in the solid phase exists in different allotropic forms like graphite, diamond, fullerence and Nano tubes [5]. Carbon Nano Tubes (**CNT's**) can be single walled and multi walled, but those having the lowest diameter and the most defect less structure. Hence, the outstanding mechanical properties of Nano tubes, especially the single walled ones. But the single walled Nano tubes are expensive. CNT's are very strong, withstand extreme strain in tension and possess elastic flexibility [**5**]. Mechanical properties of CNT's in radial (**transverse**) direction is found to be young's modulus in the order of **270** to **950 GPa** and the tensile strength in order of **11** to **63 GPa[6].**

Although, graphene sheets have **2D** symmetry, carbon Nano tubes by geometry have different properties in axial radial directions. It has been shown that CNT's are very strong in axial direction. Radial direction elasticity of CNT's is important especially for Carbon Nano tube composites where embedded tubes are subjected to large deformation in the transverse direction under the applied load.

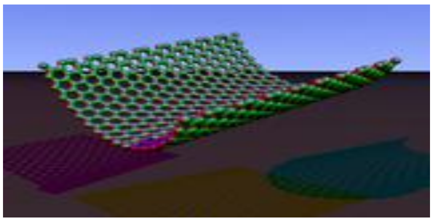

Fig: 4 Carbon Nano tube

Temperature stability [**7**] of CNT's estimated up to 2000℃in vacuum and about 750℃ in air. Hardness of Nanomaterials [**5**] is **5** times more than the bulk materials. Strength of Nano materials [**5**] is **3** to **10** times higher than the bulk materials. Behaviour of bulk materials [**5**] can be changed, but cannot enter inside the Nano particles. Electrical properties, resistivity of Nano particles [**5**] are increased by **3** times. The wear resistance of Nano particles [**5**] is **170** times higher than the bulk materials.

FABRICATION OF CARBON NANOTUBE:

CNT'S can be synthesized [**5**] by any one of the following methods.

A. PYROLYSIS OF HYDROCARBONS:

CNT's are synthesized by the pyrolysis of hydrocarbons such as acetylene at about 700℃ in the presence of Fe-silica or Fe-graphite catalyst under inert conditions.

B. LASER EVAPOURATION:

It involves vaporization of graphite target, containing small amount of Cobalt and Nickel, by exposing it to an intense pulsed laser beam at higher temperature (1200℃) in a quartz tube reactor. An inert gas such as argon or helium is simultaneously allowed to pass into the reactor to sweep the evaporated carbon atoms from the furnace to the colder copper collector, on which they condense as CNT.

C. CARBON ARC METHOD:

It is carried out by applying direct current (**60-100A** and **20-25V**) arc between graphite electrodes of **10-20**micrometre diameter.

D. CHEMICAL VAPOUR DEPOSITION (CVD):

It involves decomposition of vapour of hydrocarbons such as methane, acetylene, ethylene, etc., at high temperatures (1100℃) in presence of metal Nano particle catalysts like nickel, cobalt, iron supported on **MgO** or $\mathbf{Al_2O_3}$. Carbon atoms produced by the decomposition condense on a cooler surface of the catalyst.

PROPERTIES OF CNT [**10**]:

TENSILE STRENGTH	**= 3.8 GPA.**
YOUNG'S MODULUS	**= 293 GPA**
ELECTRICAL CONDUCTIVITY	**= 1200 S/CM**
THERMAL CONDUCTIVITY	**= 40 W/M K**

Combination of high strength and thermal conductivity is applicable for aerospace technologies and innovations [**10**]. It can withstand under bending and maintain electrical conductivity after being bend for **1000** cycles [**10**].

AEROSPACE APPLICATIONS OF CNT:

CNT has a great scope in Aerospace application based on its properties and its modern fabrication techniques. Currently there are many researches are under Carbon Nano Fibres.

STRUCTURAL STRESS ANALYSIS:

Stress analysis is an Engineering discipline covering methods to determine the stresses and strains in materials when structures are subjected to forces or loads. It is also used in maintenance of such structures, and to investigate the causes of explain structural failures. It may be performed through classical mathematical techniques, analytic mathematical modelling or computational simulation, through experimental testing techniques, or a combination of methods.

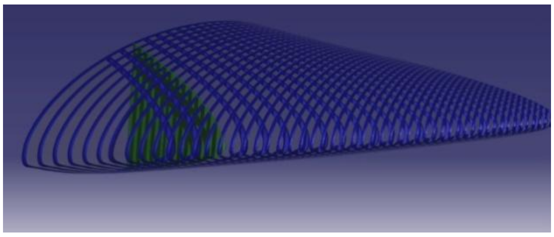

Fig: 5 Stress Analysis of BWB

ASSUMPTIONS:

Before numerical simulations [**8**] the following assumptions have been made:

i. The only one external loading comes from internal cabin pressure and is equal to 0.1234 MPa.
ii. Distance between successive frames (bulkhead) is constant and equal to 2m.
iii. Vertical pillars are placed in the plane of airplane symmetry and on the walls of passenger compartments.
Iv The Alignment of composite is assumed to be unidirectional.

Table: Estimated elastic constants of fiber in Carbon Epoxy Carbon Nano Tube.Composite

S.No	Elastic Constant	V_f @0.70
1	E1(GPa)	85.14
2	E2(GPa)	85.144
3	E3(GPa)	16.06
4	ɤ12	0.04
5	ɤ23	0.78
6	ɤ13	0.78
7	G12(GPa)	4.36
8	G23(GPa)	4.8
9	G13(GPa)	4.8

SECTION MODULUS:

Section Modulus [9] is a geometric property for a given cross section used in the design of beams or flexural members. Other geometric properties used in design include area for tension and shear, radius of compression and moment of inertia and polar moment of inertia for stiffness.

Section Modulus, S = (I / y)

Where,

I =moment of inertia, in mm^4.

y =distance from neutral axis to outer surface, in mm.

Types of Section Modulus:

1. Elastic Section Modulus (**S**)
2. Plastic Section Modulus (**Z**)

SECTION MODULUS FOR I SECTION BEAM:

When the Neutral Axis N-A passes through the centre and x axis of the beam, then **Section modulus,**

$$S = \frac{BH^2}{6} - \frac{bh^3}{6H}$$

When the Neutral Axis N-A passes through the centre and y axis of the Beam, then

S.No	Area m^2	X mm	Y mm	X_i mm	Y_i mm	$A(X-X_i)^2$ mm^4	$A(Y-Y_i)^2$ mm^4
1.	14000	140	2 5	140	305	0	109.76E7
2.	2040	140	305	140	305	0	0
3.	14000	140	585	140	305	0	202.16E7
					□	**0**	**311.92E7**

Note:

Keep units consistent for the input design variables in inches or mm. S**ection Modulus,**

$$S = \frac{B^2(H-h)}{6} - \frac{h(B-b)^3}{6B}$$

THEORETICAL CALCULATION FOR I SECTION:

The given I section is symmetry about both x axis and y axis. If two or more axes of symmetry, then centroid will coincide with the intersection of these two axis.

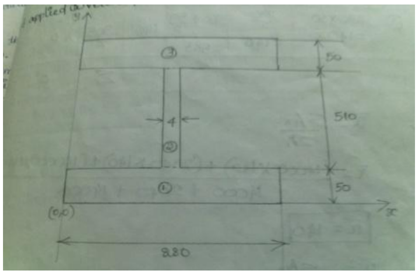

Fig: 7 I section of the BWB bulkhead

Here Ixy = 0, due to double axis symmetry section.

$X_i= \sum A_x/\sum A$

$X_i= [(14000*140) + (2040*140) + (14000*140)]/ [14000+2040+14000]$

$X_i=140$ mm

$Y_i=\sum A_y/\sum A$

$Y_i= [(14000*25) + (2040*305) + (14000*585)]/ [14000+2040+140000]$

$Y_i=305$ mm

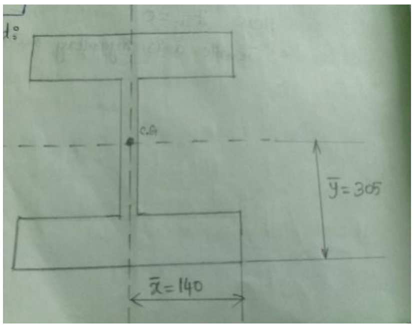

Fig: 8 Location of centroid of I section

MOMENT OF INERTIA:

$I_{xx}= [bd^3/12] +A(y-y_i)^2$

$I_{xx}=I_{xx1}+I_{xx2}+I_{xx3}$

$I_{xx}= [(280*50^3)/12] + [(4*510^3)/12] + [(280*50^3)/12] +3119200000$

$I_{xx}=3169250333\ mm^4$

$I_{yy}= [db^3/12] +A(x-x_i)^2$

$I_{yy}=I_{yy1}+I_{yy2}+I_{yy3}$

$I_{yy}= [(50*280^3)/12] + [(510*4^3)/12] + [(50*280^3)/12] +0$

$I_{yy}=182936053.3\ mm^4$

TO FIND BENDING STRESS:

Let us assume, apply bending moment in vertical plane be M_x and Apply bending moment in horizontal plane be M_y.

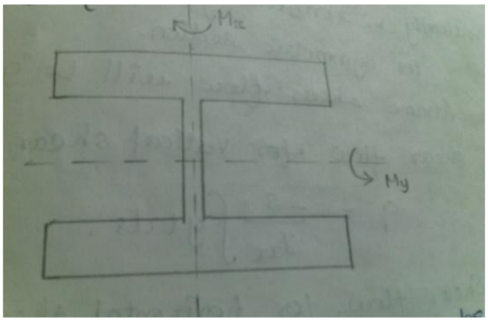

Fig: 9 I section under Bending

Bending equation is given by,

Bending Stress,

$$\sigma= [M*y]/I$$

Bending Moment in vertical plane:

Bending stress, $\sigma = [M_x*y]/I_{xx}$

$\sigma = [M_x*y]/3169250333$

$\sigma = [3.16*10^{-10}]*M_x*y$ N/mm^2

Bending Moment in horizontal plane:
Bending stress, $\sigma = [M_y*y]/I_{yy}$
$\sigma = [M_y*y]/182936053.3$
$\sigma = [5.47*10^{-9}]*M_y*y$ N/mm^2

TO FIND SHEAR FLOW:

Now, let us apply the shear load on vertically and horizontally and shear flow will be "**q**"

For symmetric section,

Shear flow for vertical shear load,

$$\mathbf{q}= \frac{-s}{Ixx} \int ytds$$

Shear flow for horizontal shear load,

$$\mathbf{q}= \frac{-s}{Iyy} \int xtds$$

ANALYSIS RESULTS:
The simulation of BWB composite bulkhead beam was analysed using ANSYS tool and compared with the theoretical values.

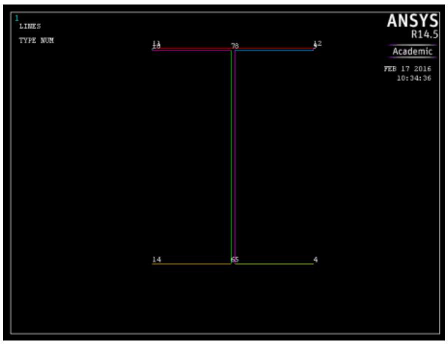

Fig: 10 2D -I section

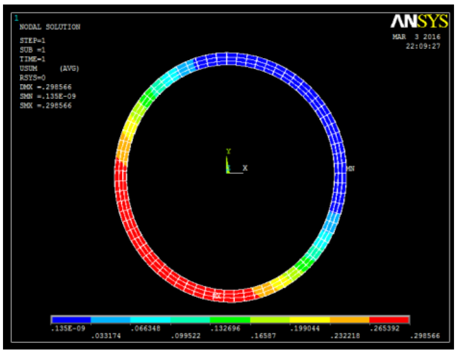

Fig: 11 Structural Analysis of Bulkhead beam- Displacement

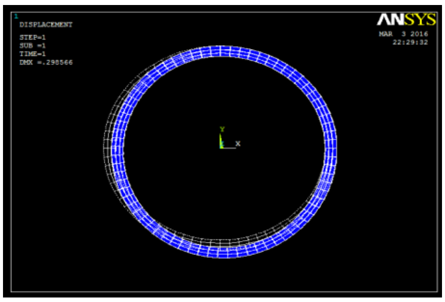

Fig: 12 Structural Analysis of Bulkhead beam.

Fig: 13 Analysis of Bulkhead beam – Failure Criteria

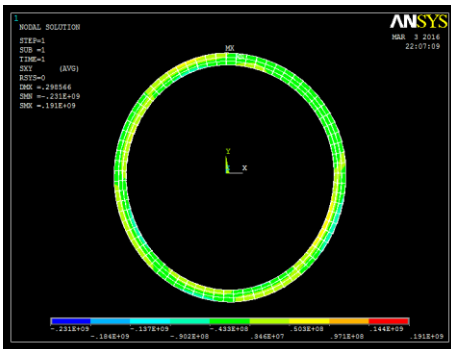

Fig: 14 Analysis of Bulkhead beam- Total Mechanical & Thermal Strain.

II. CONCLUSION:

The simulation of BWB composite bulkhead beam is done by using ANSYS and the results are compared with the theoretical values. As of now, we have concluded that by using the Carbon Nano Tube composites in BWB bulkhead, we can obtain the combined advantage of both efficient fuselage structure and can perform new adventures using modern aerospace technologies.

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