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Engineering

ANALYSIS OF FUSELAGE SIDE PANEL WITH STIFFENERS

E S Elumalai	Assistant Professor, School of Aeronautical Science. Hindustan Institute of Technology and Science, Chennai.
G Kavitha	Hindustan Institute of Technology and Science, Chennai.
G Krishnaveni	Hindustan Institute of Technology and Science, Chennai.

ABSTRACT The results from an experimental and analytical study of a composite sandwich fuselage side panel for a transport aircraft are presented. The panel has two window cutouts and three frames, and has been evaluated with internal pressure loads that generate biaxial tension loading conditions.

Design limit load and design ultimate load tests have been performed on the composite panel (graphite-epoxy sandwich panel) with the middle frame removed to demonstrate the suitability of this two-frame design for supporting the prescribed biaxial loading conditions with twice the initial frame spacing of X inches (20 inches). The two-frame panel was damaged by cutting a notch that originates at the edge of a cutout and extends in the panel hoop direction through the window-belt area. This panel with a notch was tested in a combined-load condition to demonstrate the structural damage tolerance at the design limit load condition.

The two panel configurations successfully satisfied all desired load requirements in the experimental part of the study, and the three-frame and two-frame panel responses are fully explained by the analysis results. The results of this study suggest that there is potential for using sandwich structural concepts with greater than the usual X (20)-in.-wide frame spacing to further reduce aircraft fuselage structural weight.

KEYWORDS :

INTRODUCTION

Having composite structures with vast application the aircraft industry due its unique properties compared to many metals. It has the advantages of high strength to weight ratio and high stiffness to weight ratio. This property of high stiffness to weight ratio can be used as advantage to fuselage sidepanels for transport aircraft. This paper composes the experimental and analytical study of a composite sandwich fuselage side panel for a transport aircraft. The panel has two window cutouts and three frames, and has been evaluated with internal pressure loads that generate biaxial tension loading conditions.

Design limit load and design ultimate load tests will be performed on the composite panel (graphite-epoxy sandwich panel) with the middle frame removed to demonstrate the suitability of this two-frame design for supporting the prescribed biaxial loading conditions with twice the initial frame spacing of X inches (20 inches). The two-frame panel was damaged by cutting a notch that originates at the edge of a cutout and extends in the panel hoop direction through the window-belt area. This panel with a notch was tested in a combined-load condition to demonstrate the structural damage tolerance at the design limit load condition.

The two panel configurations has to successfully satisfy all desired load requirements in the experimental part of the study, and the three-frame and two-frame panel responses can be fully explained by the analysis results. The results of this study suggest that there is potential for using sandwich structural concepts with greater than the usual X (20)-in.-wide frame spacing to further reduce aircraft fuselage structural weight.

SOFTWARE USED

Here we had used the MSC Nastran & Patran software for the analysis purpose.

GENERAL DESCRIPTION:

MSC Nastran offers a complete set of linear static and dynamic analysis capabilities along with unparalleled support for super elements enabling users to solve large, complex assemblies more efficiently. MSC Nastran also offers a complete set of implicit and explicit nonlinear analysis capabilities, thermal and interior/exterior acoustics, and coupling between various disciplines such as thermal, structural, and fluid interaction. New modular packaging that enables you to get only what you need makes it more affordable to own MSC Nastran than ever before.

MSC Patran is the widely used pre/post-processing software for Finite Element Analysis (FEA), providing solid modeling, meshing, analysis setup and post-processing for multiple solvers including MSC Nastran, Marc, Abacus, LS-DYNA, ANSYS, and Pam-Crash. Patran provides a rich set of tools that streamline the creation of analysis ready models for linear, nonlinear, explicit dynamics, thermal, and other finite element solutions. From geometry cleanup tools that make it easy for engineers to deal with gaps and slivers in CAD, to solid modeling tools that enable creation of models from scratch, Patran makes it easy for anyone to create FE models. Meshes are easily created on surfaces and solids alike using fully automated meshing routines, manual methods that provide more control, or combinations of both. Finally, loads, boundary conditions, and analysis setup for most popular FE solvers is built in, minimizing the need to edit input decks. Patran's comprehensive and industry tested capabilities ensure that your virtual prototyping efforts provide results fast so that you can evaluate product performance against requirements and optimize your designs.

WHY DO WE PREFER CARBON FIBER?

Carbon fiber is a material consisting of fibers about 5–10 μm in diameter and composed mostly of carbon atoms. The carbon atoms are bonded together in crystals that are aligned parallel to the long axis of the fiber. The crystal alignment gives the fiber high strength-to-volume ratio (makes it strong for its size). Several thousand carbon fibers are bundled together which can then be woven into a fabric. First of all carbon fibers are very light fibers resulting in lightweight structures. The exceptional impact properties make carbon fiber advantageous in various industry segments. During an impact carbon fibers disintegrates (metal instead would simply deform) which can make it is a very efficient energy dissipation mechanism. Although carbon fiber is fairly expensive compared to other more common fibers like fiberglass, the price is steadily decreasing due to the progress of production technology. Another major advantage is its thermal expansion is basically zero – this means that a metal for instance is expanding when heated, carbon fiber remains in its basic form. For specific projects where thermal stability is required carbon fiber can be a tremendous benefit. Moreover, the material can resist very high temperatures (1000 Celsius). Carbon fiber composite structures do not suffer any fatigue issues if designed and dimensioned properly. Finally, carbon fiber is permeable to X-ray and does not corrode, which is a huge issue with metals. The material is much strong as other materials or as stiff as many other materials such as glass fiber. Also the carbon fiber has higher density than glass fiber.

GEOMETRY

Considering a sixteen layer carbon fiber reinforced polymeric composite materials with symmetric ply orientation. Each layer of the composite material is of 0.125mm thick, therefore the total thickness of the composite material considered is 2mm thick. A typical carbon reinforced polymer composite material at fuselage side panel and also with J-section near window cutouts with quad type meshing is shown below:

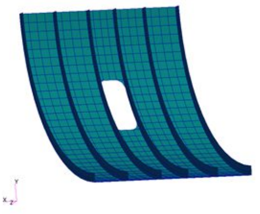


Fig 1 Normal stiffener

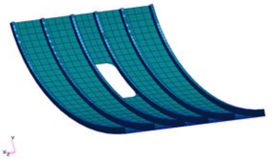


Fig 2 J-section stiffener

TABULATIONS AND ANALYSIS:

Table 1 MATERIAL PROPERTIES FOR THE STIFFENED SIDE PANEL

Material properties		Value
Longitudinal Young's Modulus	E_{11}	131GPa
Transverse Young's Modulus	E_{22}	13 GPa
Poisson's Ratio	v_{12}	0.38
In-plane Shear Modulus	G_{12}	6.41 GPa
Longitudinal Tensile Ultimate Strain	X	0.0110
Longitudinal Compression Ultimate Strain	X_c	0.0086
Transverse Tensile Ultimate Strain	Y	0.0036
Transverse Compression Ultimate Strain	Y_c	0.0100
In-plane Shear Ultimate Strain	T	0.0150

Table 2 Data assigned for the proposed side panel for both normal and J-section stiffeners

S.NO	PROPERTY NAME	VALUE ASSIGNED
1.	Elastic Modulus min	1.3E+011
2.	Elastic Modulus max	1.2999999E+010
3.	Poisson's Ratio	0.38
4.	Shear Modulus	6.4E+009
5.	Tension Strain Limit min	0.011
6.	Tension Strain Limit max	0.0035999999
7.	Compression Strain Limit min	0.008600003
8.	Compression Strain Limit max	0.0099999998
9.	Shear Strain Limit	0.015
10.	Bonding Shear Stress Limit	5000

Since the ply orientation for the matrix material is of symmetrical orientation. The orientation angles for the sixteen layer carbon fiber reinforced polymer are shown below table:

Table 3 PLY Orientation Angle

LAYER	THICKNESS	PLY ORIENTATION ANGLE
1	1.250000E-1	0°
2	1.250000E-1	45°
3	1.250000E-1	-45°
4	1.250000E-1	90°
5	1.250000E-1	90°
6	1.250000E-1	-45°
7	1.250000E-1	45°
8	1.250000E-1	0°
9	1.250000E-1	0°
10	1.250000E-1	45°
11	1.250000E-1	-45°
12	1.250000E-1	90°
13	1.250000E-1	90°
14	1.250000E-1	-45°
15	1.250000E-1	45°
16	1.250000E-1	0°

COMPOSITE MATERIAL PROPERTIES

The below table shows the values of the membrane, the bending and the coupling matrices i.e. The values of the A, B&D matrices.

Where,
A-MEMBRANE or EXTENSIONAL MATRIX
B-BENDING MATRIX
D-COUPLING MATRIX

Table 4 MEMBRANE OR EXTENSIONAL MATRIX

1.18E+011	3.74E+010	0.00E+000
3.74E+010	1.18E+011	-2.5E+003
0.00E+000	-2.5E+003	4.02E+010

Table 5 BENDING MATRIX

0.00E+000	-5.7E+002	0.00E+000
-5.7E+002	5.12E+002	0.00E+000
0.00E+000	0.00E+000	1.28E+002

Table 6 COUPLING MATRIX

4.52E+010	1.20E+010	9.27E+008
1.20E+010	3.41E+010	9.27E+008
9.27E+008	9.27E+008	1.30E+010

FAILURE INDICES

The failure indices makes the meshing of the fuselage side panel near window cutouts in quad type meshing and gives the analysis report by the NASTRAN which explains the failure of the material at various elements and nodes of the mesh.

Table 7 Quad Verification Summary at Various Cases

Test	Total Failed	Worst Case	At Element
Aspect	0	Max=2.8940377	20932
Warp	0	Max=0.00010410908	21406
Skew	0	Min=86.497704	21305
Taper	0	Max=0.020562777	21516
Normal Offset	0	Max=0	0

We are going to compare the stress and strain loads in both normal stiffener and the J-section stiffener. Both the stiffener is going to be analyzed at various loading conditions. The loads that are commonly subjected to the stiffeners are as follows:

Uniaxial cutouts
Bi-axial cutouts
Shear cutouts

UNIAXIAL LOAD

Uniaxial load means the load that is subjected to the material in only one directions i.e., along x-axis only. The deformation pattern of the normal stiffener and the J-section stiffener near the window cutouts of the sixteen layer polymeric composite material is shown below and their corresponding maximum and minimum values are tabulated.

UNIAXIAL LOAD APPLIED TO THE STIFFENER

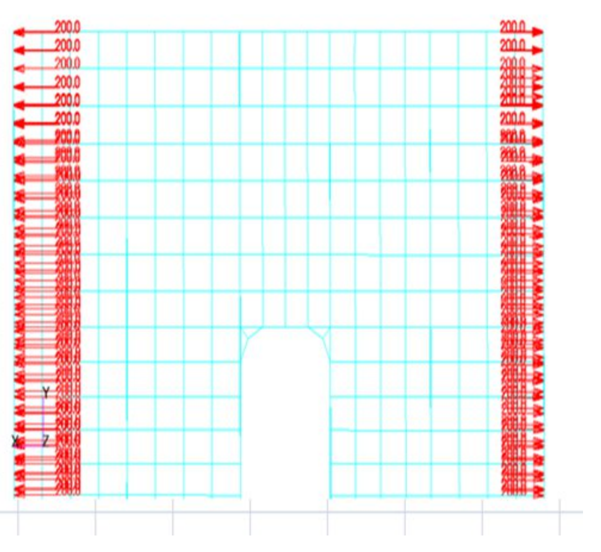


Fig 3 Uniaxial Load to the Stiffener

DEFORMATION PATTERN FOR THE NORMAL STIFFNER

WHEN THE LOAD IS APPLIED:

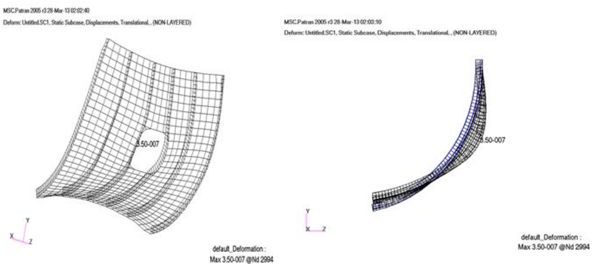


Fig 3.1 Deformation Pattern of the Normal Stiffener

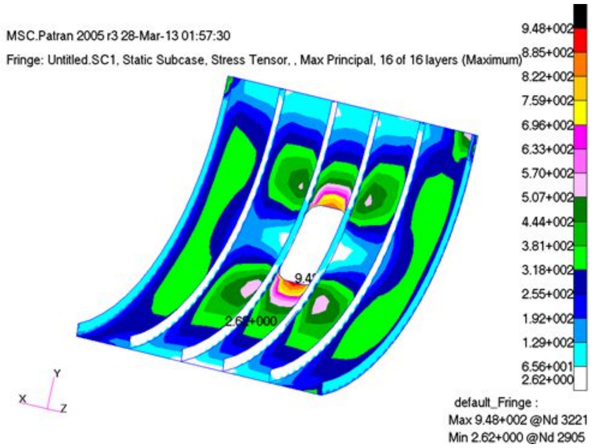


Fig 3.2 Analysis Report For Sixteen Layer Normal Stiffener

DEFORMATION PATTERN FOR THE J-SECTION STIFFNER WHEN THE LOAD IS APPLIED

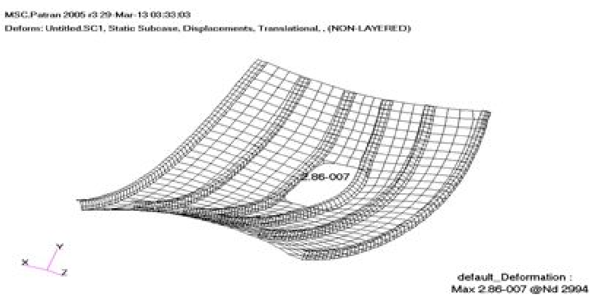


Fig 3.3 Deformation Pattern for the J-Section Stiffener

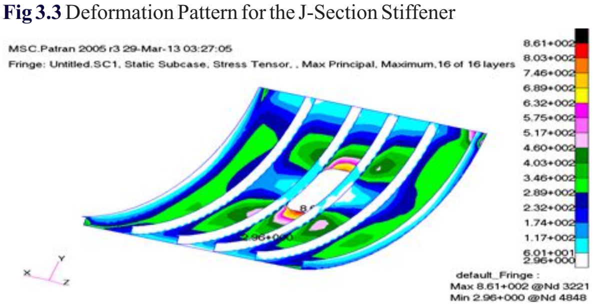


Fig 3.4 Analysis Report For Sixteen Layer J-Section Stiffener

UNIAXIAL LOAD	MAXIMUM VALUE	MINIMUM VALUE
NORMAL STIFFENER	9.48E+002	2.62E+000
J-SECTION STIFFENER	8.61E+002	2.96E+000

The above analysis shows the deformation result for all the sixteen layers. Let us now see the strain analysis for each layer of the composite material. The below table explains the maximum and minimum strain values for both normal and J-section stiffener in all the sixteen layers when the uniaxial load is applied

Table 8 UNIAXIAL LOAD FOR NORMAL STIFFENER

UNIAXIAL LOAD LAYER	MAXIMUM VALUE	MINIMUM VALUE
1	9.48E+002	1.52E-004
2	6.71E+002	4.34E-005
3	6.68E+002	6.42E-005
4	3.19E+002	2.74E-004
5	4.29E+002	5.43E-004
6	7.14E+002	3.47E-004
7	7.52E+002	4.03E-004
8	9.46E+002	2.05E-002
9	9.46E+002	1.38E-001
10	8.01E+002	4.16E-004
11	8.03E+002	2.87E-004
12	4.18E+002	3.82E-004
13	4.69E+002	1.16E-004
14	8.56E+002	2.77E-005
15	8.82E+002	2.82E-006
16	9.44E+002	0

Some of the analysis reports for the normal stiffeners which are subjected to uniaxial load are shown below:

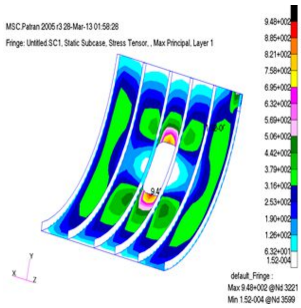


Fig 3.5 Analysis Reports for the Normal Stiffeners of Layer 1

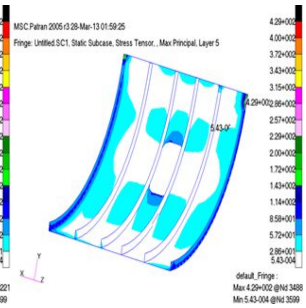


Fig 3.6 Analysis Reports for the Normal Stiffeners of Layer 5

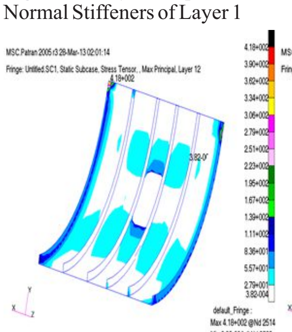


Fig 3.7 Analysis Reports for the Normal Stiffeners of Layer 12

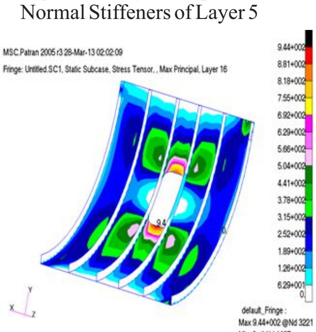


Fig 3.8 Analysis Reports for the Normal Stiffeners of Layer 16

Table 9 UNIAXIAL LOAD FOR J-SECTION STIFFENER

UNIAXIAL LOAD LAYER	MAXIMUM VALUE	MINIMUM VALUE
1	8.55E+002	1.93E-004
2	6.32E+002	6.74E-004
3	6.21E+002	1.47E-003
4	3.74E+002	2.07E-003
5	5.06E+002	3.42E-003
6	6.68E+002	5.95E-003
7	6.95E+002	8.87E-003
8	8.58E+002	1.17E-001
9	8.58E+002	1.09E-001
10	7.33E+002	8.60E-003
11	7.47E+002	5.39E-003
12	3.98E+002	4.33E-003
13	3.57E+002	1.35E-003
14	7.95E+002	5.19E-004
15	7.96E+002	6.72E-005
16	8.61E+002	0

Some of the analysis reports for the J-section stiffeners which are subjected to uniaxial load are shown below:

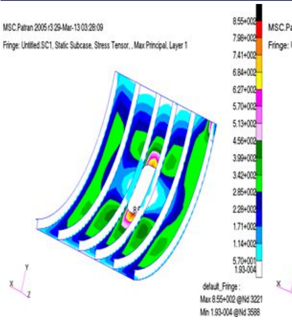


Fig 3.9 Analysis Reports for the J-Section Stiffeners of Layer 1

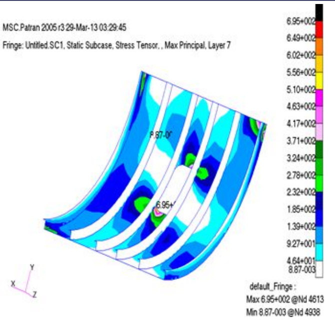


Fig 3.10 Analysis Reports for the J-Section Stiffeners of Layer 7

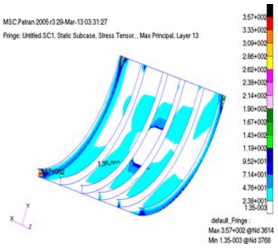


Fig 3.11 Analysis Reports for the J-Section Stiffeners of Layer 13

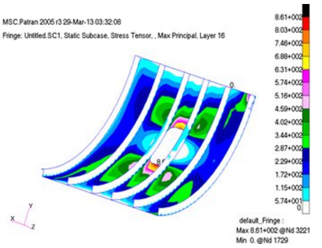


Fig 15 Analysis Reports for the J-Section Stiffeners of Layer 16

BI-AXIAL CUTOUTS

Biaxial load means the load that is subjected to the material into directions i.e, along x-axis and y-axis. The deformation pattern of the normal stiffener and the J-section stiffener near the window cutouts of the sixteen layer polymeric composite material is shown below and their corresponding maximum and minimum values are tabulated.

BIAXIAL LOAD APPLIED TO THE NORMAL STIFFENER:

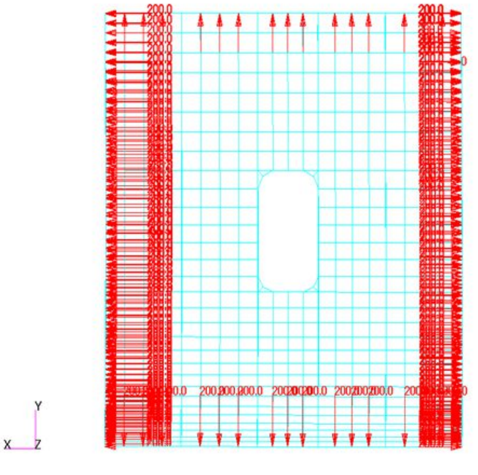


Fig 4 Biaxial Load Applied to the Stiffener

DEFORMATION PATTERN FOR THE NORMAL STIFFNER WHEN THE LOAD IS APPLIED:

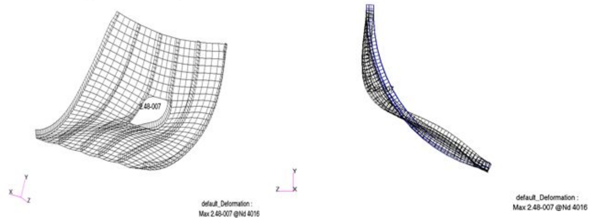


Fig 4.1 Deformation Pattern for the Normal Stiffener

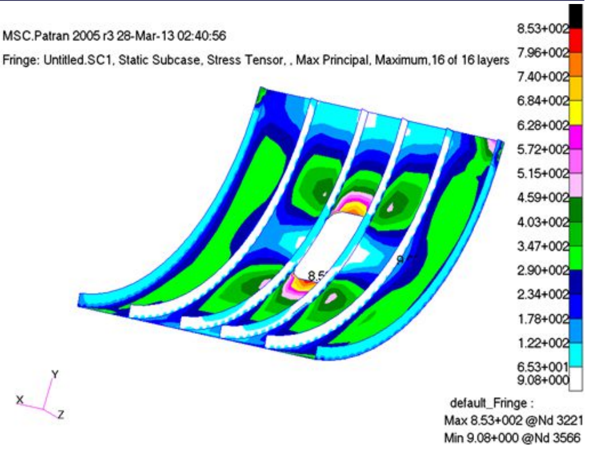


Fig 4.2 Analysis Report for Sixteen Layer Normal Stiffener

DEFORMATION PATTERN FOR THE J-SECTION STIFFNER WHEN THE LOAD IS APPLIED:

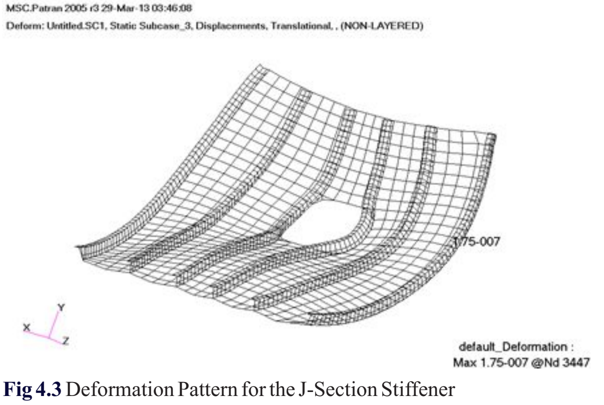


Fig 4.3 Deformation Pattern for the J-Section Stiffener

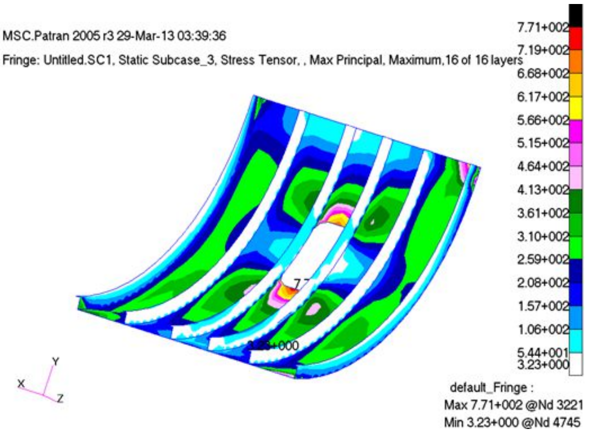


Fig 4.4 Analysis Report For Sixteen Layer J-Section Stiffener

BIAXIAL LOAD	MAXIMUM VALUE	MINIMUM VALUE
NORMAL STIFFENER	8.53E+002	9.08E+000
J-SECTION STIFFENER	7.71E+002	3.23E+000

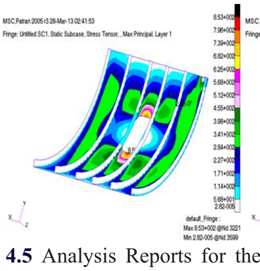
The above analysis shows the deformation result for all the sixteen layers. Let us now see the strain analysis for each layer of the composite material. The below table explains the maximum and minimum strain values for both normal and J-section stiffener in all the sixteen layers when the biaxial load is applied:

Table 10 BIAXIAL LOAD FOR NORMAL STIFFENER

BIAXIAL LOAD LAYER	MAXIMUM VALUE	MINIMUM VALUE
1	8.53E+002	2.82E-005
2	5.75E+002	7.75E-005

3	5.98E+002	9.73E-005
4	3.04E+002	2.89E-004
5	4.11E+002	4.47E-004
6	6.33E+002	6.94E-004
7	6.37E+002	5.32E-004
8	8.31E+002	1.36E-001
9	8.28E+002	2.96E-001
10	6.74E+002	4.81E-004
11	6.92E+002	6.16E-004
12	3.89E+002	2.80E-004
13	4.37E+002	1.50E-004
14	7.26E+002	3.30E-004
15	7.35E+002	1.42E-005
16	8.06E+002	0

Some of the analysis reports for the normal stiffeners which are subjected to biaxial load are shown below:



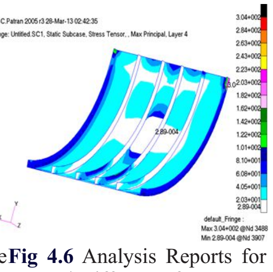
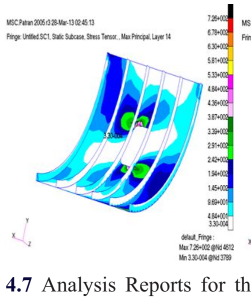


Fig 4.5 Analysis Reports for the Normal Stiffeners of Layer 1

Fig 4.6 Analysis Reports for the Normal Stiffeners of Layer 4



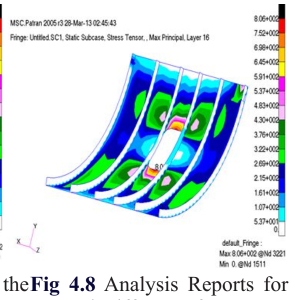


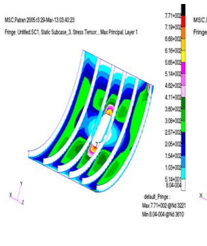
Fig 4.7 Analysis Reports for the Normal Stiffeners of Layer 14

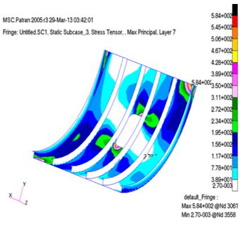
Fig 4.8 Analysis Reports for the Normal Stiffeners of Layer 16

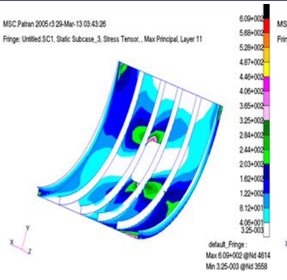
Table 11 BIAXIAL LOAD FOR J-SECTION STIFFENER

BIAXIAL LOAD LAYER	MAXIMUM VALUE	MINIMUM VALUE
1	7.71E+002	8.04E-004
2	5.94E+002	9.36E-005
3	5.51E+002	5.01E-004
4	3.53E+002	4.44E-003
5	4.79E+002	8.46E-003
6	5.72E+002	2.98E-003
7	5.84E+002	2.70E-003
8	7.50E+002	1.31E-001
9	7.47E+002	1.29E-001
10	6.00E+002	2.90E-003
11	6.09E+002	3.25E-003
12	3.71E+002	5.45E-003
13	3.62E+002	1.60E-003
14	6.41E+002	8.95E-004
15	6.41E+002	1.65E-005
16	7.27E+002	0

Some of the analysis reports for the J-section stiffeners which are subjected to biaxial load are shown below:







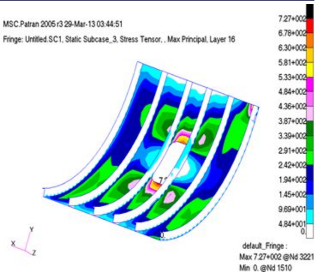


Fig 4.11 Analysis Reports for the J-Section Stiffeners of Layer 11

Fig 4.12 Analysis Reports for the J-Section Stiffeners of Layer 16

SHEAR CUTOUTS

Shear load means the load that is subjected to the material along its surfaces. Here the complementary shear load is applied. The deformation pattern of the normal stiffener and the J-section stiffener near the window cutouts of the sixteen layer polymeric composite material is shown below and their corresponding maximum and minimum values are tabulated.

SHEAR LOAD APPLIED TO THE NORMAL STIFFENER:

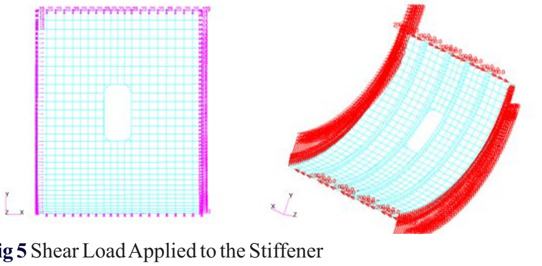


Fig 5 Shear Load Applied to the Stiffener

DEFORMATION PATTERN FOR THE NORMAL STIFFNER WHEN THE LOAD IS APPLIED:

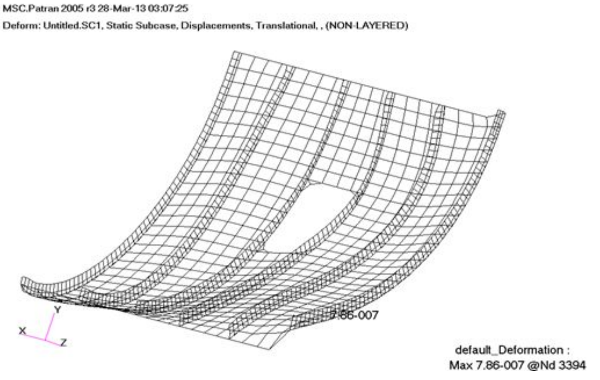


Fig 5.1 Deformation Pattern for the Normal Stiffener

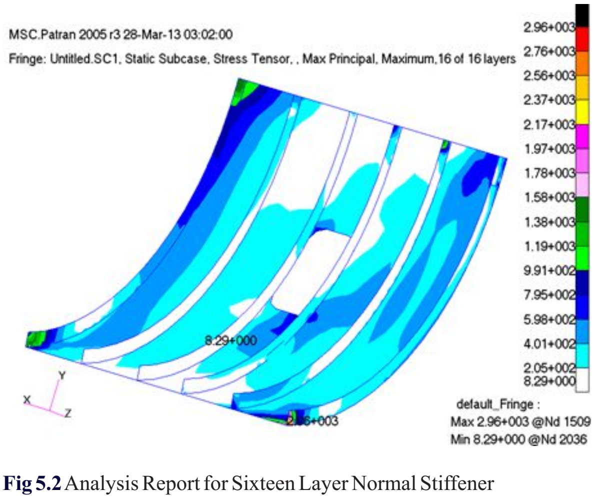


Fig 5.2 Analysis Report for Sixteen Layer Normal Stiffener

DEFORMATION PATTERN FOR THE J-SECTION STIFFNER WHEN THE LOAD IS APPLIED:

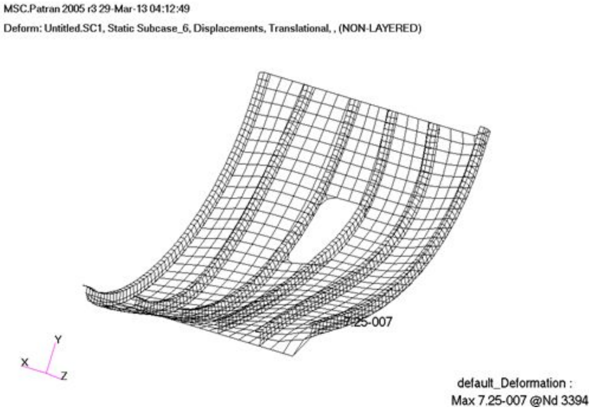


Fig 5.3 Deformation Pattern for the J-Section Stiffener

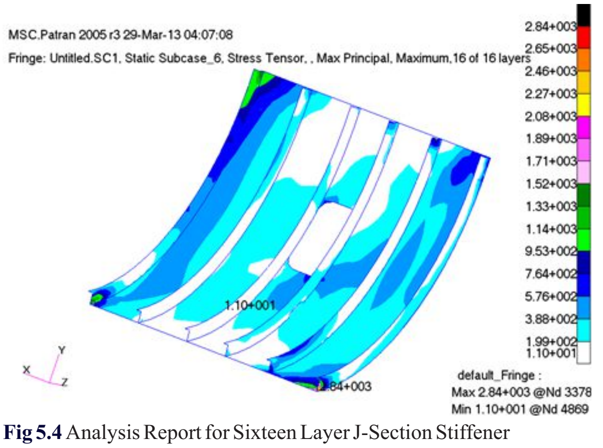


Fig 5.4 Analysis Report for Sixteen Layer J-Section Stiffener

SHEAR LOAD	MAXIMUM VALUE	MINIMUM VALUE
NORMAL STIFFENER	2.96E+003	8.29E+000
J-SECTION STIFFENER	2.28E+003	1.10E+001

The above analysis shows the deformation result for all the sixteen layers. Let us now see the strain analysis for each layer of the composite material. The below table explains the maximum and minimum strain values for both normal and J-section stiffener in all the sixteen layers when the shear load is applied

Table 12 SHEAR LOAD FOR NORMAL STIFFENER

SHEAR LOAD LAYER	MAXIMUM VALUE	MINIMUM VALUE
1	1.44E+003	1.05E-004
2	1.96E+003	3.09E-003
3	1.38E+003	1.51E-003
4	1.76E+003	1.04E-003
5	1.56E+003	1.81E-003
6	1.34E+003	9.92E-003
7	1.37E+003	4.86E-002
8	1.51E+003	1.02E-002
9	1.54E+003	1.03E-002
10	1.83E+003	3.89E-002
11	1.27E+003	1.00E-002
12	1.62E+003	1.20E-003
13	1.65E+003	5.66E-004
14	1.23E+003	9.24E-004
15	2.96E+003	1.16E-004
16	1.72E+003	0

Some of the analysis reports for the normal stiffeners which are subjected to shear load are shown below:

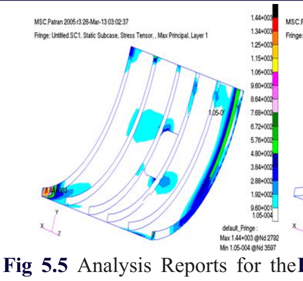


Fig 5.5 Analysis Reports for the Normal Stiffeners of Layer 1

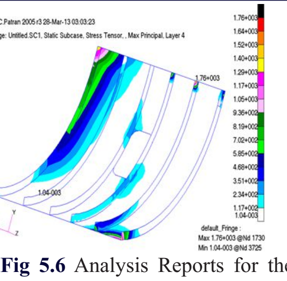


Fig 5.6 Analysis Reports for the Normal Stiffeners of Layer 4

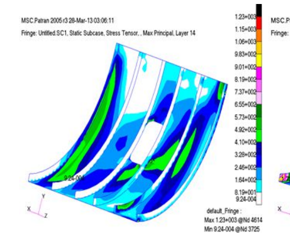


Fig 5.7 Analysis Reports for the Normal Stiffeners of Layer 14

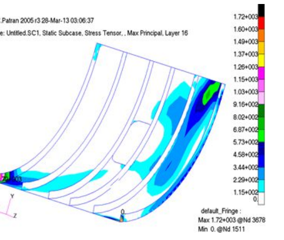


Fig 5.8 Analysis Reports for the Normal Stiffeners of Layer 16

Table 13 SHEAR LOAD FOR J-SECTION STIFFENER

SHEAR LOAD LAYER	MAXIMUM VALUE	MINIMUM VALUE
1	1.32E+003	5.63E-004
2	1.54E+003	7.74E-003
3	1.36E+003	7.57E-003
4	1.45E+003	1.21E-002
5	1.43E+003	2.28E-002
6	1.13E+003	6.79E-002
7	1.42E+003	1.74E-001
8	1.44E+003	3.44E-002
9	1.47E+003	3.14E-002
10	1.81E+003	1.51E-001
11	1.09E+003	1.09E-001
12	1.57E+003	1.30E-002
13	1.60E+003	3.66E-003
14	1.06E+003	9.10E-003
15	2.84E+003	1.02E-003
16	1.68E+003	0

Some of the analysis reports for the J-section stiffeners which are subjected to shear load are shown below:

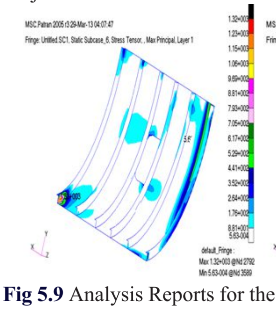


Fig 5.9 Analysis Reports for the J-Section Stiffeners of Layer 1

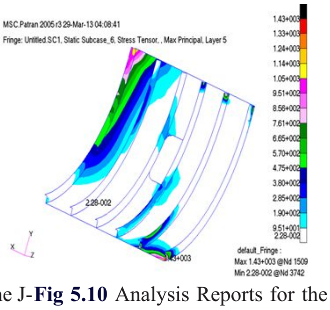


Fig 5.10 Analysis Reports for the J-Section Stiffeners of Layer 5

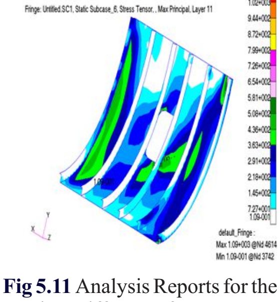


Fig 5.11 Analysis Reports for the J-Section Stiffeners of Layer 11

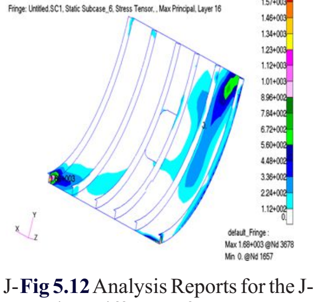


Fig 5.12 Analysis Reports for the J-Section Stiffeners of Layer 16

COMPRESSION LOAD:

The compression load is the compressive force applied to the polymeric material. The window cutouts in fuselage side panel are of subjected to compressive loads to which the material sets to deform. The application of compressive load and its deformation pattern for both normal stiffener and the J-section stiffener are shown below:

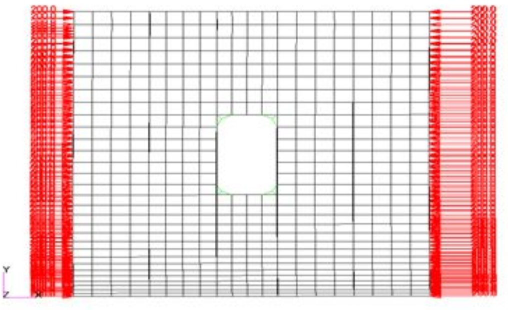


Fig 6 Compression Load Applied to the Stiffener

NORMAL STIFFENER

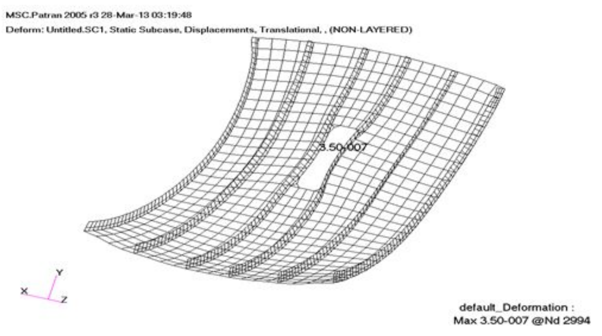


Fig 6.1 Deformation Pattern for the Normal Stiffener

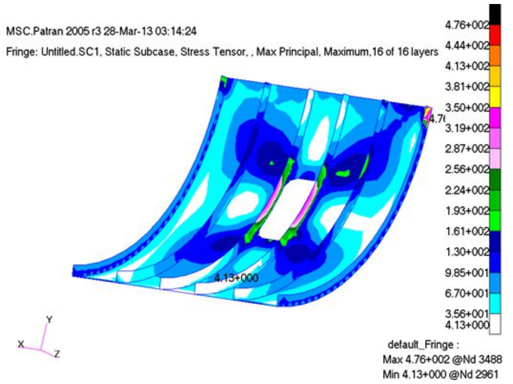


Fig 6.2 Analysis Report for Sixteen Layer Normal Stiffener

J-SECTION STIFFENER:

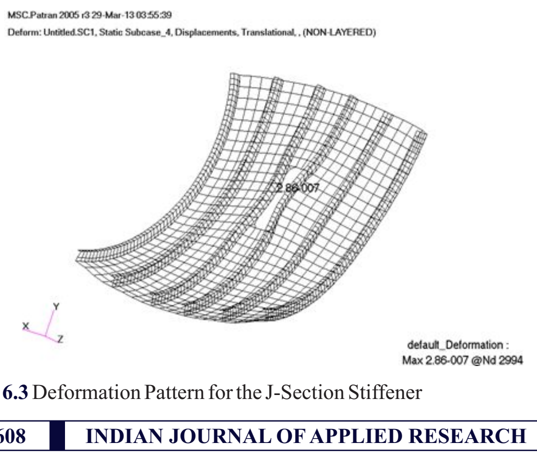


Fig 6.3 Deformation Pattern for the J-Section Stiffener

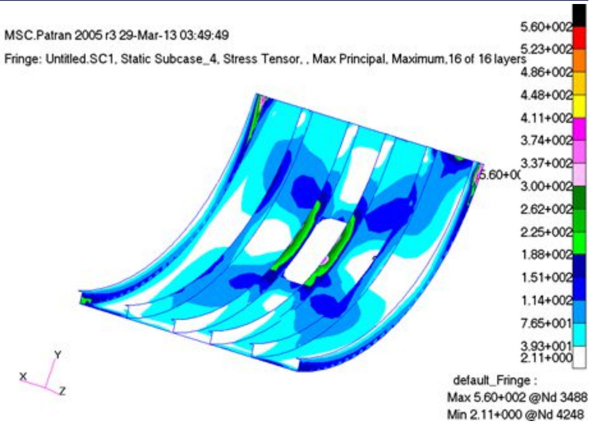


Fig 6.4 Analysis Report For Sixteen Layer J-Section Stiffener

COMPRESSION LOAD	MAXIMUM VALUE	MINIMUM VALUE
NORMAL STIFFENER	4.76E+002	4.13E+000
J-SECTION STIFFENER	5.60E+002	2.11E+000

The above analysis shows the deformation result for all the sixteen layers. Let us now see the strain analysis for each layer of the composite material. The below table explains the maximum and minimum strain values for both normal and J-section stiffener in all the sixteen layers when the compressive load is applied.

Table 14 COMPRESSION LOAD FOR NORMAL STIFFENER

COMPRESSION LOAD LAYER	MAXIMUM VALUE	MINIMUM VALUE
1	1.30E+002	3.07E-005
2	2.23E+002	1.60E-004
3	1.95E+002	2.79E-004
4	3.37E+002	1.28E-001
5	4.29E+002	2.14E-001
6	4.57E+002	9.65E-004
7	4.72E+002	1.05E-003
8	4.76E+002	4.12E-003
9	4.73E+002	4.15E-003
10	4.53E+002	1.12E-003
11	4.29E+002	1.06E-003
12	3.95E+002	1.08E-002
13	4.16E+002	4.14E-003
14	2.79E+002	2.75E-004
15	4.26E+002	4.05E-005
16	3.82E+002	0

Some of the analysis reports for the normal stiffeners which are subjected to compressive load are shown below:

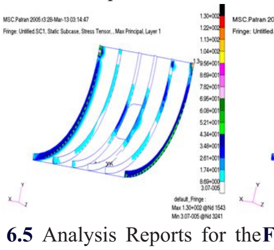


Fig 6.5 Analysis Reports for the Normal Stiffeners of Layer 1

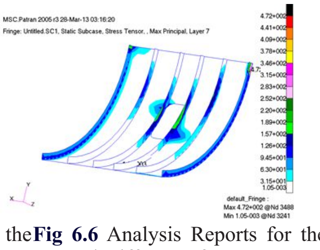


Fig 6.6 Analysis Reports for the Normal Stiffeners of Layer 7

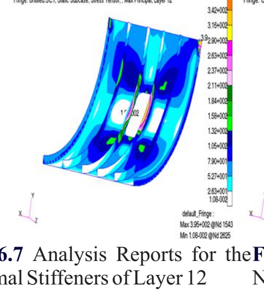


Fig 6.7 Analysis Reports for the Normal Stiffeners of Layer 12

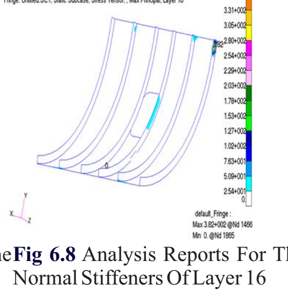


Fig 6.8 Analysis Reports For The Normal Stiffeners Of Layer 16

Table 15 COMPRESSION LOAD FOR J-SECTION STIFFENER

COMPRESSIONLOAD LAYER	MAXIMUM VALUE	MINIMUM VALUE
1	1.65E+002	1.03E-004
2	2.03E+002	4.16E-004
3	2.52E+002	9.08E-004
4	3.88E+002	5.64E-002
5	5.05E+002	1.88E-002
6	5.39E+002	1.91E-003
7	5.58E+002	1.66E-003
8	5.60E+002	1.06E-003
9	5.57E+002	9.99E-004
10	5.36E+002	1.52E-003
11	5.04E+002	1.83E-003
12	3.73E+002	9.55E-003
13	3.53E+002	5.00E-003
14	2.89E+002	4.26E-004
15	2.28E+002	4.80E-005
16	1.27E+002	0

Some of the analysis reports for the J-section stiffeners which are subjected to compressive load are shown below:

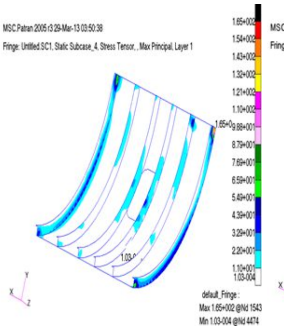


Fig 6.9 Analysis Reports for the J-Section Stiffeners of Layer 1

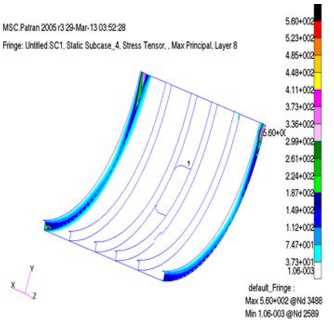


Fig 6.10 Analysis Reports for the J-Section Stiffeners of Layer 8

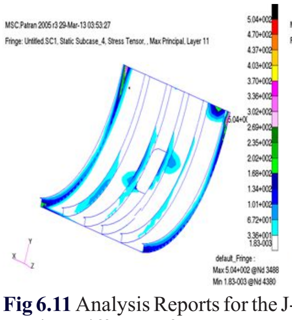


Fig 6.11 Analysis Reports for the J-Section Stiffeners of Layer 11

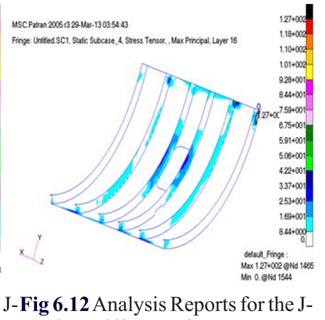


Fig 6.12 Analysis Reports for the J-Section Stiffeners of Layer 16

RESULT

FOR UNIAXIAL LOAD:

UNIAXIAL LOAD	MAXIMUM VALUE	MINIMUM VALUE
NORMAL STIFFENER	9.48E+002	2.62E+000
J-SECTION STIFFENER	8.61E+002	2.96E+000

FOR BIAXIAL LOAD:

BIAXIAL LOAD	MAXIMUM VALUE	MINIMUM VALUE
NORMAL STIFFENER	8.53E+002	9.08E+000
J-SECTION STIFFENER	7.71E+002	3.23E+000

FOR SHEAR LOAD:

SHEAR LOAD	MAXIMUM VALUE	MINIMUM VALUE
NORMAL STIFFENER	2.96E+003	8.29E+000
J-SECTION STIFFENER	2.28E+003	1.10E+001

FOR COMPRESSION LOAD:

COMPRESSION LOAD	MAXIMUM VALUE	MINIMUM VALUE
NORMAL STIFFENER	4.76E+002	4.13E+000
J-SECTION STIFFENER	5.60E+002	2.11E+000

FOR PRESSURE LOAD:

PRESSURE LOAD	MAXIMUM VALUE	MINIMUM VALUE
NORMAL STIFFENER	1.84E+004	1.12E+002
J-SECTION STIFFENER	1.76E+004	7.40E+001

CONCLUSION

The results from an experimental and analytical study of a composite sandwich fuselage side panel for a transport aircraft are presented. The panel has two window cutouts and three frames, and has been evaluated with internal pressure loads that generate biaxial tension loading conditions.

Design limit load and design ultimate load tests have been performed on the composite panel (graphite-epoxy sandwich panel) with the middle frame removed to demonstrate the suitability of this two-frame design for supporting the prescribed biaxial loading conditions with twice the initial frame spacing of X inches (20 inches). The two-frame panel was damaged by cutting a notch that originates at the edge of a cutout and extends in the panel hoop direction through the window-belt area. This panel with a notch was tested in a combined-load condition to demonstrate the structural damage tolerance at the design limit load condition.

The two panel configurations successfully satisfied all desired load requirements in the experimental part of the study, and the three-frame and two-frame panel responses are fully explained by the analysis results. The results of this study suggest that there is potential for using sandwich structural concepts with greater than the usual X (20)-in.-wide frame spacing to further reduce aircraft fuselage structural weight.

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