ISSN (O): 2393-8609

International Journal of Aerospace and Mechanical Engineering

Volume 1 – No.1, September 2014

Stiffened Wing Panel Buckling

Satyam Saini
Department of Aerospace Engineering
University of Petroleum and Energy Studies
satyamsaini15@gmail.com

Garima Choudhary
Department of Aerospace Engineering
University of Petroleum and Energy Studies
garima.ch1999@gmail.com

Sandeep Sharma
Technical Head
Aerosphere
sandeeps.aero@gmail.com

ABSTRACT
One of the main failure modes of an aircraft is buckling. Stringers are often bonded to composite panel skins to help increase the panel's buckling strength; however, if there is a defect in the bond between the stringer and the panel, the structure may be weakened. Developing analysis tools that can accurately simulate the behavior of composite materials is critical to the successful design and use of composite structures. The pre-design of aircraft wing structures relies on finite element models of significantly reduced complexity in which only spar and rib components are explicitly modeled, whereas the wing skin-stringers stiffened panels are implicitly represented by stiffness-equivalent elements. This conventional procedure enables a fast solution technique for large problems.

General Terms
Buckling: It is the failure of a structural member which is under high compressive stress in a direction normal to the direction of compressive load.

Skin Stringer: The stringers and rings or ribs are attached to the skin by means of rivets or spot welds.

Effective width: The part of the skin which carries additional stress along with stringer.

Wing Ribs: To hold the skin- stringer wing surface to contour shape internal structure support units are presented known as wing ribs.

Keywords
Wing Box, Inter-Rivet Buckling, Flexural Instability, Torsional Instability, Skin-Stringer Panels, Ribs and Spars, Maximum Shear Flow

1. INTRODUCTION
Aircrafts are primarily constructed from thin metal skins which are capable of resisting in plane tension and shear loads but buckle under comparatively low value of in-plane compressive loads. That's why the skin is stiffened by longitudinal stringers which can do both resist the in-plane compressive loads as well as resist small distributed loads normal to the plane of the skin.

The information that analysts and designers seek from the simulation of stringer-stiffened panels includes:

- the total load-carrying capability of the panel
- the load at which a crack in the stringer bond line initiates
- The stringer debonding and/or crack growth characteristics.

In this study, the experimental test results and the simulation data are correlated well, indicating that the software was able to predict the behavior of the skin-stringer test panel.
Engineers used a flat composite panel with an unbounded region introduced in a portion of the bond between the skin and a single stiffening stringer.

2. GENERAL CONSTRUCTION OF A WING SKIN STRINGER PANEL
Skin form a major part of an aircraft during its construction, providing as a covering to the structural members and components. In general, the skin is designed to resist in-plane tension and shear load but buckle for a comparatively lower values of in-plane compressive loads. Therefore, there should be a supporting mechanism provided to resist these compressive loads. Longitudinal stringers are used for this purpose. They stiffen the wing to resist the in-plane buckling loads as well as the normal distributed loads over the skin. In order to maintain the chord-wise contour of the wing and provide an aerodynamic shape to the wing, wing ribs are used at various intervals to support the stringer-skin construction.

- Buckling of skin does not mean failure of panel. The panel carries additional load until the stringer fails. The skin which is adjacent to stringer carries additional load due to stringer support.
- In this way the stringer stabilizes the skin against buckling. The part of the skin which carries additional stress along with stringer is known as *effective width.*

2.1 Typical skin- stringer panels
The stringers and rings or ribs are attached to the skin by means of rivets or spot welds.

Some of the popular stringer skin constructions used in modern aircraft industry are:

1. Extruded stringers (I, J, Y, Z and hat).
2. Formed stringers (Z and hat).

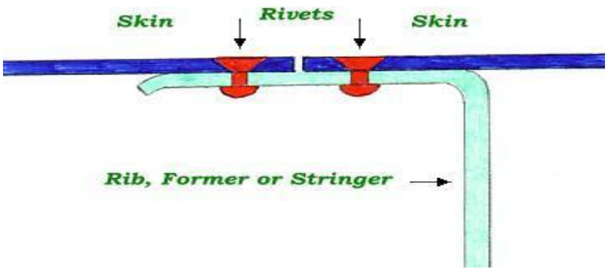


Fig.1: Skin- stringer Panel

There are several types of instabilities that can occur in a stringer panel:

Table 1. Types of Buckling

Type of buckling	Definition
Skin(Initial) Buckling	This generally involves the formation of waves over the skin that is between the stringers with a certain amount of waving in the stringer web and some lateral displacement in the stringer flange
Local Instability	It is a short wavelength buckling that takes place in stringer web and flange which are displaced in a plane normal to their depth
Flexural Instability	It just like a simple strut instability of the skin-stringer construction in a plane normal to the plane of skin accompanied by a certain amount of twisting
Torsional Instability	In this type of instability the skin is rotated about a longitudinal axis just like a solid body. There are also small displacements normal to the plane of skin an distortions in the stringer cross-section.
Inter-Rivet Buckling	It is similar to the buckling of a short strut between the rivets and can be avoided by decreasing the rivet pitch
Wrinkling	In this mode the skin develops short wavelength buckling like an elastic strut and can be avoided by placing closely the line of attachment of stringers web

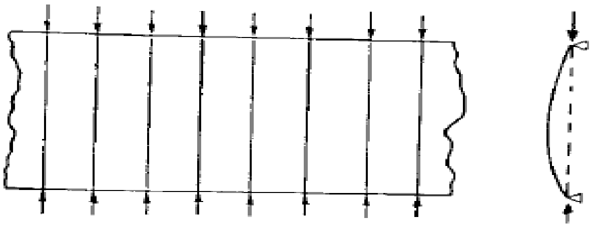


Fig.2: Panel Instability of a skin- stringer panel

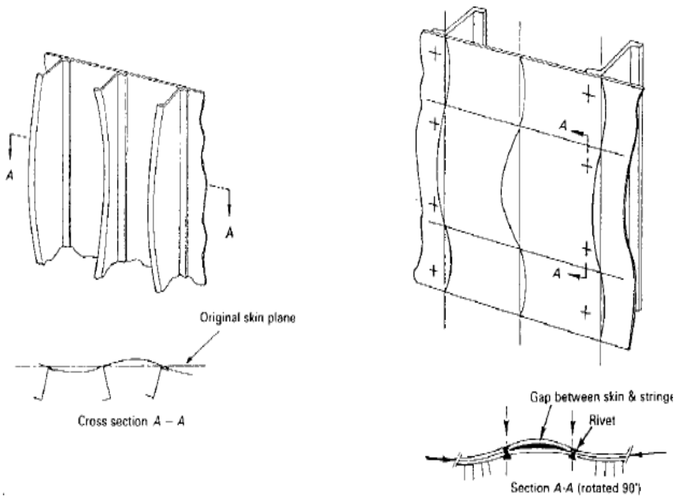


Fig.3: Torsional buckling of a skin-stringer panel (left) and Inter-rivet buckling and wrinkling of a skin- stringer panel (right)

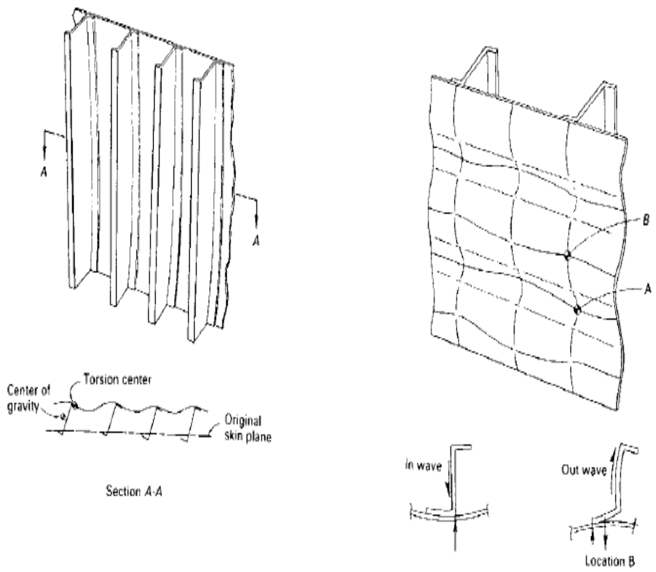


Fig.4: Flexural and torsional buckling of a skin stringer panel (left) and Wrinkling of a skin- stringer panel (right)

ISSN (O): 2393-8609
International Journal of Aerospace and Mechanical Engineering
Volume 1 – No.1, September 2014

3. TYPES OF LOADS ACTING ON WING PANEL

3.1 Aerodynamic loads

The main aerodynamic forces that are acting on a wing panel are lift force, drag force, pitching moment and thrust. Various loads like the stringers axial forces components in the rib plane, concentrated forces transmitted to the ribs due to landing gear, body forces in the form of gravitational forces and inertia forces due to wing structural masses are also acting on the wing.

The resultant lift forces that are acting along a certain cross section of a wing will be considered as the concentrated force acting on quarter chord length. All these aerodynamic loads will be resisted by the internal resistance in the wing structure.

One main assumption that is considered while designing the stiffened panels is that the stringers are considered as a member which are responsible about the bending resistance, while the skin is designed to just carry in plane stresses in the form of in plane shear stresses and tensile stresses, but its resistance to compressive stresses is very limited due to its instability under slightly compressive loads. The variation of the bending stress along the stiffened panels will generate a flexural shear flow in the plane of the airfoil.

3.2 Wing station external loads

Wing station is subjected to three types of loading:

1. **Shear force in the form of**

Vertical Shear Force: It is a total lift summation from wing tip to the wing station and further this is multiplied by the maneuvering condition factor plus factor of safety for load and calculation tolerance.

Horizontal Shear Force: It is the total drag summation from wing tip to wing station further this drag force obtained from wind tunnel calculations must be multiplied by maneuvering condition factor plus safety factor. Inertia forces with the mass of the wing portion must be multiplied by the acceleration of flight in the horizontal direction.

2. **Twisting Moment**

The lift force is always calculated with respect to the aerodynamic centre of the wing cross section which with an acceptable approximation considered as the airfoil quarter chord location. This lift force at the quarter chord has a twisting effect.

3.3 Concentrated loads

Mainly the design of the ribs is basically based on the assumption of the idealized beam, that the stiffeners are responsible about carrying the entire load, while the shear webs are just loaded in pure shear.

Therefore the stiffeners arrangement in web differs accordingly to the location and direction of the concentrated force acting on the rib.

4. ANALYSIS OF STIFFENED SKIN-STRINGER PANEL

The analysis was on an existing MSC Patran database that contains the panel model, boundary conditions, and loading definitions. Finite element model require the same basic grid points, element data, and unique load case.

Following were the main steps followed for the analysis in MSC Patran:

- Stiffened panel is imported with the given conditions.

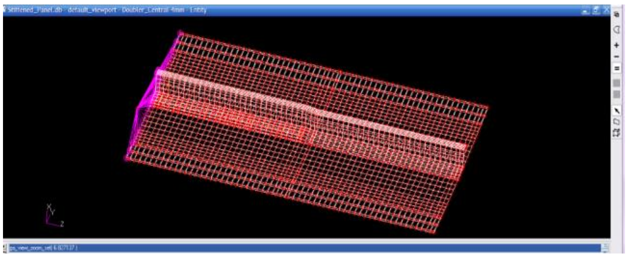


Fig. 5 Meshed Model

- Imported model is reviewed in different views. Shell elements, bar elements, boundary conditions were shown.

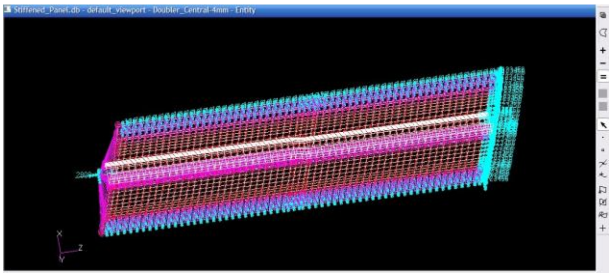


Fig.6 Boundary conditions

- Compressive load is applied as an enforced of .28 inch applied to an RBE2 that spans the free end of the panel.

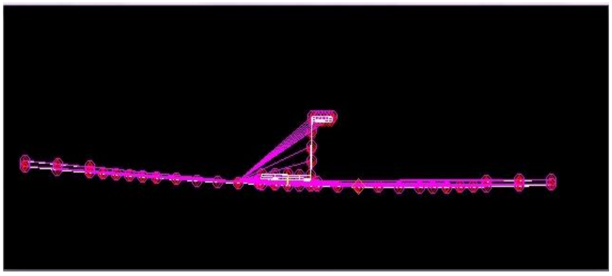


Fig.7 Load Applied

ISSN (O): 2393-8609

International Journal of Aerospace and Mechanical Engineering

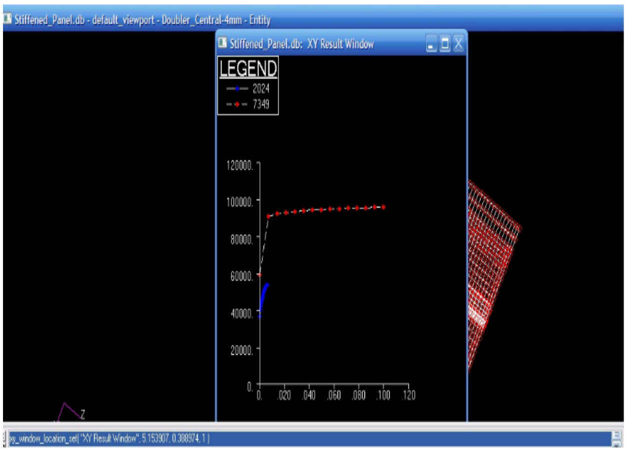
Volume 1 – No.1, September 2014

- Corresponding material and thickness is assigned to individual members of the panel and the assembly of panel is analyzed.

Table 2. Element thickness and material

Element name	thickness	Material name	area
Skin	0.07999in	2024T3	-
Stiffener	0.16in	7349T	-
Stiffener	0.28in	7349T	-
Stiffener ame	0.16in	7349T	-
pbar(fastener)	-	Rivet	0.0277in^2
Prop_db1	0.16	2024T3	
Prop_db2	0.16	2024T3	

- Then stress- strain curve is plotted and contact bodies are examined from Load/BC.
- The load parameters and solution parameters are set for the analysis of the entire model.
- After these steps, an analysis set up is made by using the Analysis button and the solution type is set to implicit Non- linear and stress components will be shown as the result of the analysis.
- For the final result review, the result menu is used animation time. Select displacement type, translation in deformation result menu.



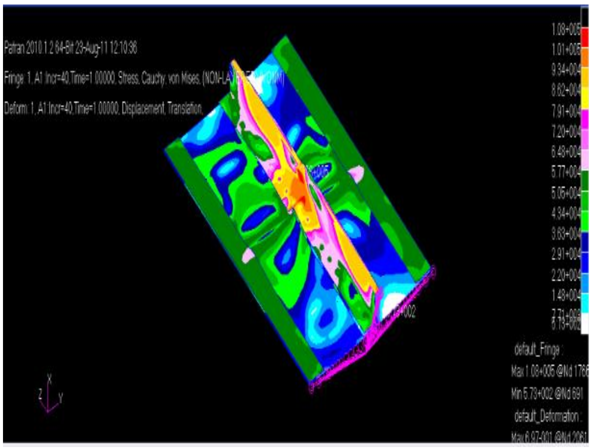


Fig.8: Stress- Strain Curve for the given Stiffened panel after analysis (left) and stress distribution over the stiffened panel (right

5. CONCLUSION

In this project MSC Patran is used to analyze stiffened panel of the wing of an aircraft. Material nonlinearity is considered. The nonlinear buckling result obtained, shows the substantial agreement with the experimental test data of stiffened panel under compression using the material Al 2024- T3.

The close agreement of this analysis and test provides confidence in using the MSC Patran as a reliable way to analyze structure for certification of a large transport aircraft with FAA.

6. REFERENCES

[1] R.J. Stann, Wing Panel Compression Test Model DC-10 Aircraft. Report No.0038, Douglas Aircraft Company, May 1969.

[2] Kuhn P, Stresses in Aircraft and shell structures, McGraw-Hill Book Company, 1956

[3] Airplane stress analysis, NACA report No. 82.

[4] Niu M, Airframe Stress Analysis and Sizing, Conmilit Press Ltd., 1997.

[5] Wagner, H. “Remarks on Airplane Struts and Giders Under Compressive and Bending Stresses”. Index Values. NACA TM 500, 1929.