Structural Analysis of Different Skin Stringer Panels

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Abstract*—This project report presents a comprehensive study on the structural analysis of skin-stringer panel. Stringers are critical longitudinal components that contribute significantly to the strength and rigidity of the aircraft's fuselage by distributing aerodynamic loads and reducing skin buckling. The study explores structural analysis of three various skin-stringer panels-Omega, L-shaped, and Z-shaped stringers that are most often utilized in aerospace applications to provide strength and stiffness to aircraft fuselages. The research aims to assess their performance under compressive and bending loads to identify the most effective design for weight savings and structural integrity. The design process of project was carried out on CATIA V5, with each type of stringer modelled and combined with a skin panel and Z-section frame. Finite Element Analysis (FEA) is done on ANSYS Workbench to simulate the distribution of stresses, deformation, and buckling response under 1000 N/m² applied to skin and 4900 N/m² loads applied to the stringer joints. The material chosen for analysis was 2024-T3 aluminum alloy, commonly used in aerospace due to its high strength-to-weight ratio.

***Keywords*— ANSYS, CATIA, Finite Element Analysis, Skin – Stringer Pannels**

I. INTRODUCTION

Stringers in an aircraft are long slender structural elements that run along the length of the fuselage providing crucial support to the skin and help maintain the fuselage shape. They are part of a semi monocoque commonly used in aircraft, where the load is distributed between the skin and the internal components like frames and stringers. By reinforcing the fuselage stringers, the aircraft withstand aerodynamic forces pressurization cycles and structural loads during takeoff and landing. They also help in balancing weight and strength. Their durability structural support and load distribution makes it an important and indispensable component in modern aircraft.

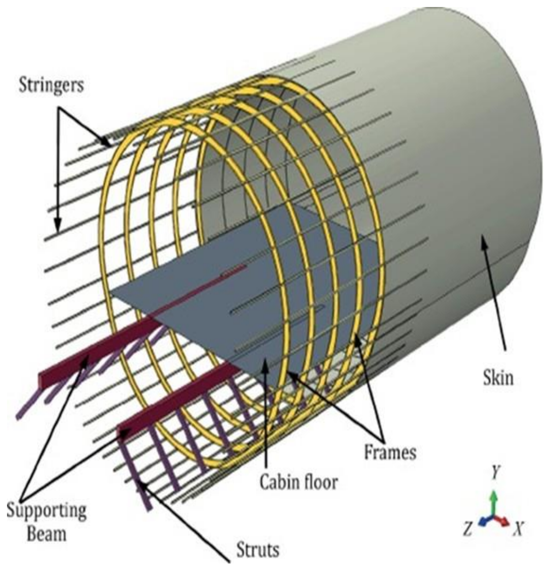

Fig. 1 Skin – Stringer panel

II. OBJECTIVE

To conduct FEM analysis on stringers with different cross-sections and in a stringer-frame-skin assembly. The analysis will be done on L-stringer, Z-stringer and omega stringer. Compare the mechanical performance of all three and identify the best design for strength.

III. LITERATURE REVIEW

If you are using Word. The development of aircraft structures has witnessed a progression from fabric and wooden structures to composite structures. Stringers have been a key component in providing stability for the aircraft. Originally aircraft did not have any internal stringers, only external bracing. With the advent of the semi-monocoque structures in 1930s the stringers started to appear in conjunction with the skin to reduce the buckling resistance. During World War two aluminum stringers were widely seen and the jet age bought increased loads and pressurization to the aircraft structures. Prompting the use of composite structures along with advanced manufacturing process.

Analytical methods like Euler buckling and plate theory offer quick and effective early-stage prediction of structural behavior while element methods give complex analysis of complex modelling and failure analysis and optimizing opportunities. It allows the designers to simulate buckling, damaging and load sharing in skin stringer panel using appropriate materials and geometries. It also supports nonlinear buckling analysis to get the optimum results to develop safe efficient and light structures.

IV. METHODOLOGY

Use either SI (MKS) or CGS as primary units. The Skin stringer panels were designed in CATIA V5. Then exported into ANSYS Workbench for analysis compressive loads were applied on the Stringers as well as the skin. The material selected was 2024 T3 aluminum.

V. DESIGNING

The flat panel specimen was designed with the following features. The dimensions used are $1x1m^2$. Two omega shaped stringers one jogged and one straight and a z- shaped frame. CATIA V5 was used for 3D modelling.

Considering the stringers, an omega section, L section, and Z section was selected as it provides high inertia and torsional stiffness, which is beneficial for highly pressurized panels such as fuselage panels. Frames are highly loaded elements that experience bending loads caused by the non-circular section of the fuselage. The frame web cannot withstand these loads, and an inner chord is necessary to provide stability and stiffness under compression loads thus a ‘Z’ section is used.

The dimensions of the frame section, with a length of 1000 mm, the minimum frame bending radius was set to 3.5 mm. The minimum frame bending radius was set to 3.5 mm.

To eliminate the possibility of debonding at the frame skin joint near the mouse hole area stringer fitting was used to overcome the debonding problem.

A large panel of 1 sq m is used for designing specimen.

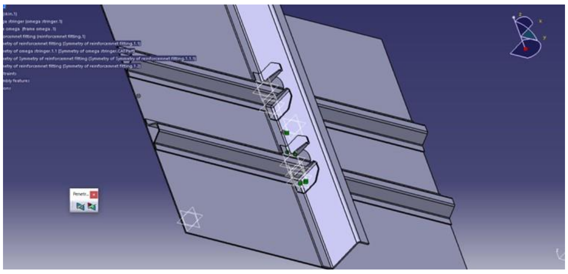

Fig. 2 Omega Stringer Panel

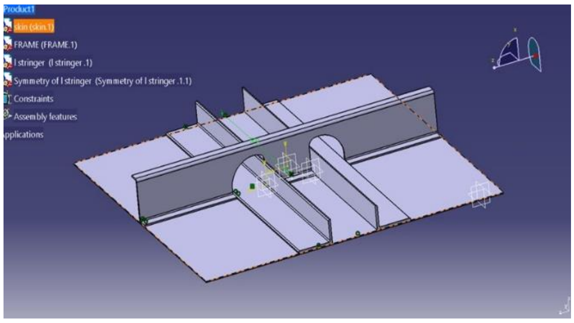

Fig. 3 L Stringer Panel

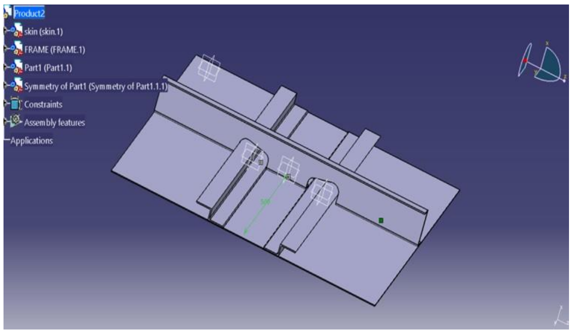

Fig. 4 Z Stringer Panel

VI. ANALYSIS AND RESULTS

The software used was ANSYS 2025 workbench and the file was imported from CATIA V5 in IGES format. The material used was 2024 T3 Aluminum with Young’s Modulus = 73 GPa, Poisson Ratio = 0.33 and Density = 2780 Kg/m^3. The loads applied were 4900 N/m^2 compressive stress at stringer joints: 1000 N/m^2 pressure on skin panel. The fixed supports were added at the frame – stringer joints.

The Total deflection of Omega Stringer is uniform compared to other types of stringers and it has a smooth distribution of stress throughout. This happens because a reinforcement panel is added which helps in stress distribution throughout the panel hence it is the best design.

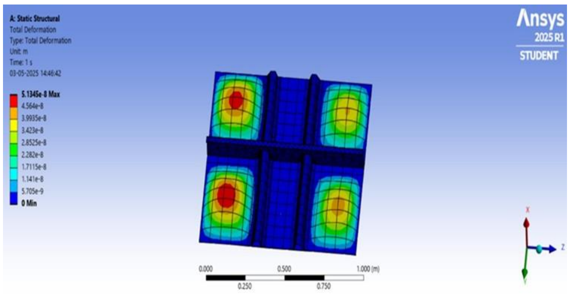

Fig. 5 Total Deformation on Omega Panel

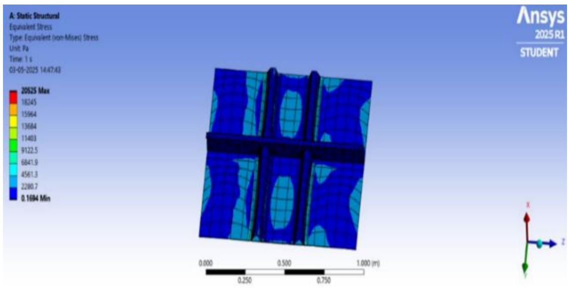

Fig. 6 Equivalent Stress on omega Panel

The analysis of L stringers shows that it has the most amount of deformation and the equivalent stress is not uniformly distributed. This happens as there is no external structures to support the skin stringer panel.

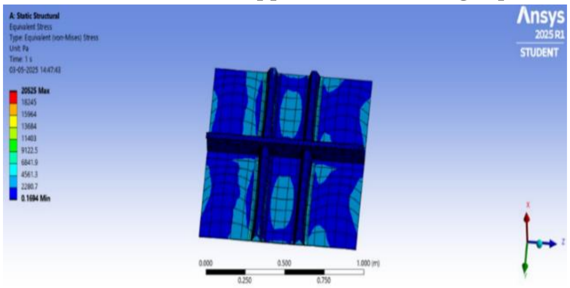

Fig. 7 Total Deformation in L Panel

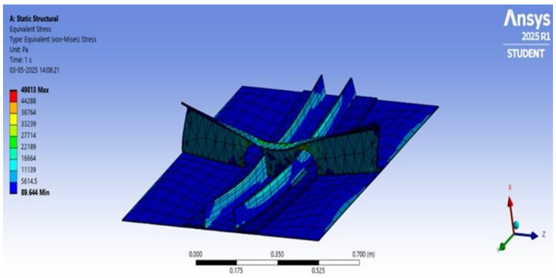

Fig. 8 Equivalent Stress on L panel

On Z stringer the maximum deformation occurs at the middle of the skin where there is no stringer panel to support the skin and when the deformation is less on the stringer as it is supposed to withstand the stress which is derived from flight loads.

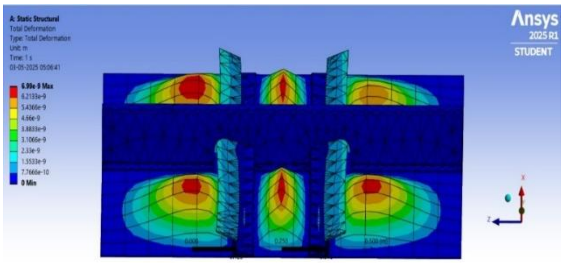

Fig. 9 Total Deformation on Z panel

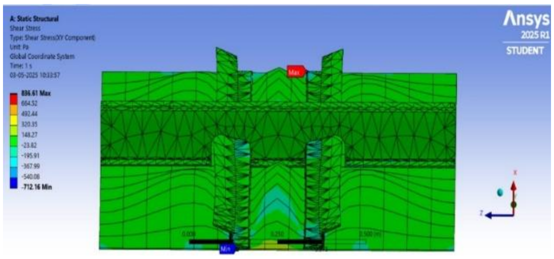

Fig. 10 Equivalent Stress on Z panel

VII. CONCLUSION

This research performed a comprehensive structural analysis of three stringer panel configurations Omega shaped L – Shaped and Z – Shaped stringers to assess their performance under simulated aerospace loading conditions to identify the most efficient design. load distribution, and weight optimization in aircraft fuselage structures.

Omega Stringers showed better performance, with uniform stress distribution and low deformation because of their closed-section shape and built-in reinforcement. Their design prevents localized buckling and increases structural toughness, making them suitable for high-load applications.

Z-Stringers exhibited moderate performance with stress concentrations at the joints but substantial stiffening advantage to the skin panel. Their offset flanges also offered torsional resistance, although inferior to Omega stringers in total deformation control.

L-Stringers, though cheap and straightforward, had the greatest deformation and non-uniform patterns of stress, reflecting shortcomings in dealing with compressive and bending loads relative to more complex profiles.

This research makes an addition to aerospace structural optimization, offering empirical evidence to aid in the choice and design the stringer panels for safer, lighter and more efficient aircraft.

VIII. FUTURE WORK

The future work might investigate the composite material stringers CRFP, hybrid laminate to provide increased strength to weight ratio. Dynamic and fatigue analysis under cyclic loading conditions to determine long term durability.

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