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Linear Static Structural Analysis of Omega Stringer and Splice Joints in Aircraft Fuselage

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ABSTRACT

The splice joints play a fundamental role in providing structural integrity in framed structure. Design of splice joint to acquire circumferential hoop loads and axial loads is a challenge. The circular frames provide circumferential stiffness to the structure without allowing the structure to buckle. Design and simulation of these circular frames is very challenging. The stringers are linear structure which provides axial stiffness to fuselage. Splice joints are used for the fuselage structure. Force due to Cabin pressurization can be considered as one of the critical load cases for the fuselage structure. The splice joint is one of the critical locations for fatigue crack to initiate. So in order to avoid failure of these splices a robust design has to be made which bears the capabilities of overcoming such issues.

Keywords: Aircraft, Fuselage, Stringers, Frame, Splice Joints.

1. INTRODUCTION

Stringer is somewhat thin partition of material which is joined to the skin of the carrier. In the fuselage, stringers are associated with edges which are in the longitudinal heading of the flying machine. The greatest single thing of the fuselage structure is the skin and its stringer. It is furthermore the most segregating structure since it passes on most of the fundamental burdens as a result of fuselage curving, shear, torsion and inside pressure. End to end of stringers is associated by splice joint.

The investigations are carried out on splice joints for skin of a stringer in aircraft to access stress concentration, Linear static analysis for various load conditions, Joint sensitive analysis for composite joints and also for metallic joints, to bring in the behavioural difference in the structure for similar joint with two combinations.

2. METHODOLOGY

The methodology adopted for carrying out linear stress analysis on omega stringer involves;

1. Modelling is carried out using UG software and the meshing is done using the ANSYS Workbench
2. The meshed file is then exported to the ANSYS Workbench for further analysis.
3. The Boundary conditions are applied for the meshed model for evaluation of results.
4. The stress and Deformation results are evaluated for the Metallic and composite stringer.

3. GEOMETRIC MODELLING

3.1 Geometry of Stringer:

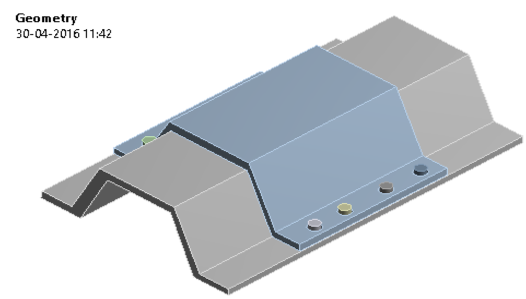

Figure 1: 2D Model of Omega Stringer and Splice Joint

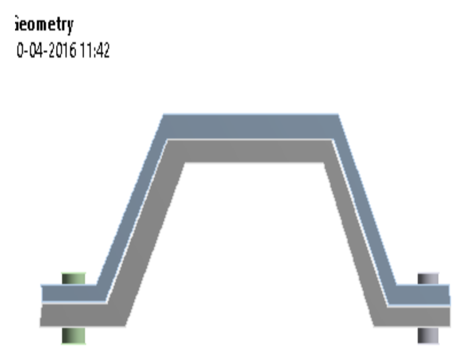

Figure 2: Front View of Splice Joint

The Figure.1and Figure.2 shows the isometric view and front view of the omega stringer and splice joint.

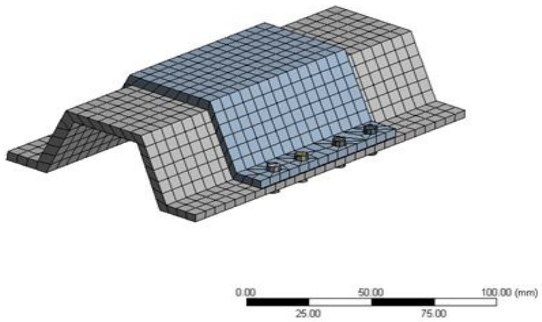

Figure 3: Meshing of Omega Stringer and Splice Joint

Table – 1: Dimensions of the Stringer

Sl. No.	Name	Dimension
1	Stringer height (h_{str})	35mm
2	Stringer width (d_{str})	20mm
3	Stringer length	80mm each

The Splice joint is 30mm wide and 60mm long, Bolt diameter 4mm.

3.2 Finite Element model and Loads on Aluminium Alloy Omega Stringer

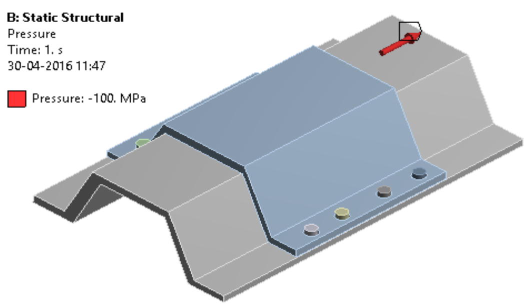

Figure 4: Application of Load on Omega Stringer

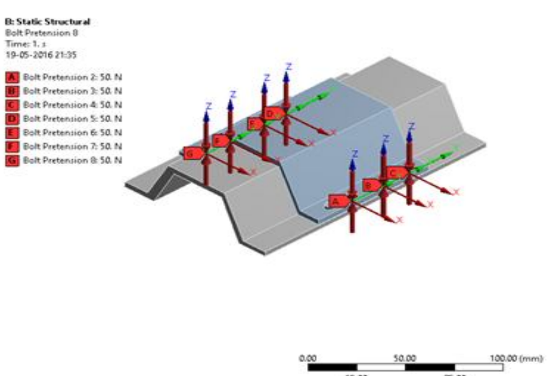

Figure 5: Application of Bolt Pretension

The Figure 4 and Figure 5 shows the loading condition of stringer, one end is fixed and other end is applied with the tensile load of 100 MPa & bolt pre-tension of 50N is applied for the bolts.

3.3 Finite Element model and Loads on Carbon Fiber Reinforced Polymer (CFRP) Composite Omega Stringer

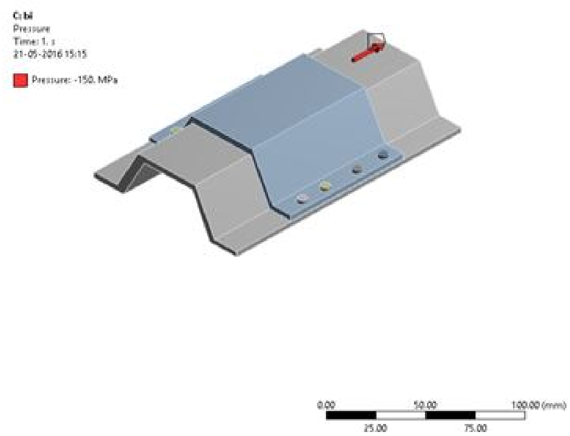

Figure 6: Application of Load on Omega Stringer

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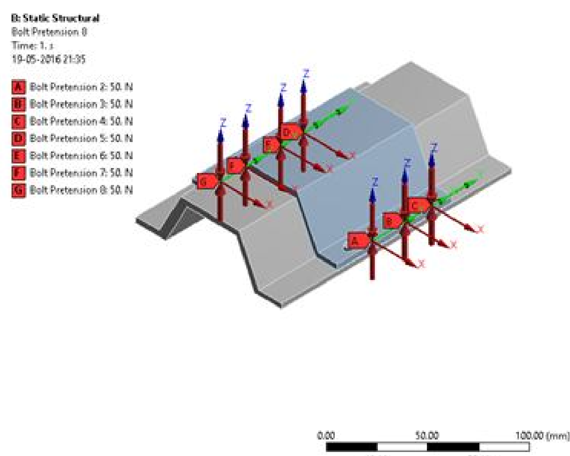

Figure 7: Application of Bolt Pretension

The Figure 6 and Figure 7 shows the loading condition of stringer, one end is fixed and other end is applied with the tensile load of 150 MPa & bolt pre-tension of 50N is applied for the bolts

3.4 Material Properties:

1. **For Aluminum Alloy**

Table – 2: Properties of Aluminum Alloy

Description	Omega-Stringer	Omega-Splice Joint	Bolt
Material Name	Aluminium Alloy 2024 T-351	Aluminium Alloy 2024 T-351	Aluminium
Density (g/cm3)	2.78	2.78	2.78
Young's modulus	73.1 GPa	73.1 GPa	73.1 GPa
Poisson's ratio	0.3	0.3	0.3

The material used here in the Omega stringer and splice joint analysis is Aluminium Alloy 2024 T-351. This alloy material is generally used in the production of aircraft structures. The table above gives the material properties of the material used in the analysis.

2. **For CFRP Composite Material:**

Table – 3: Properties of CFRP Composite Material

Description	Omega-Stringer	Omega-Splice Joint	Bolt
Material Name	Carbon Fiber Reinforced Polymer (CFRP)	Carbon Fiber Reinforced Polymer (CFRP)	Carbon Fiber Reinforced Polymer (CFRP)
Density (kg/m3)	1500	1500	1500
Young's modulus	150 GPa	150 GPa	150 GPa
Poisson's ratio	0.27	0.27	0.27

The material used in the model is a composite material called Carbon Fibre Reinforced Polymer. It is also called as CFRP Composite material and is used in the manufacture of aircraft parts such as fuselage, wings etc. The table above gives the material properties of the CFRP composite material.

4. RESULTS & DISCUSSION

This section presents the results obtained with respect to linear static analysis of stress on omega stringer for both Aluminium alloy and CFRP composite materials

4.1 Linear Static Analysis

4.1.1 Aluminium Alloy Omega Stringer:

Stress on stringer

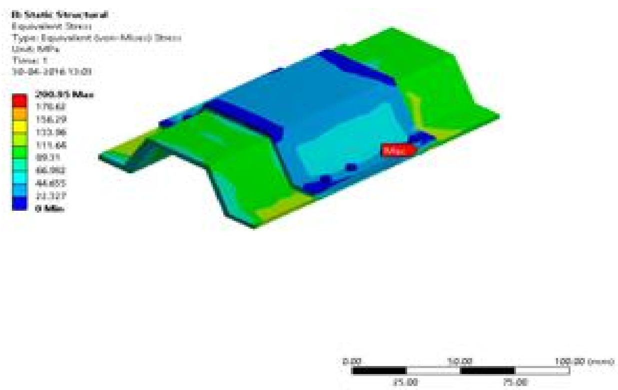

Figure 8: Equivalent Stress

From the Figure 8, it is clear that the equivalent stress acting on the stringer is 200.95 MPa.

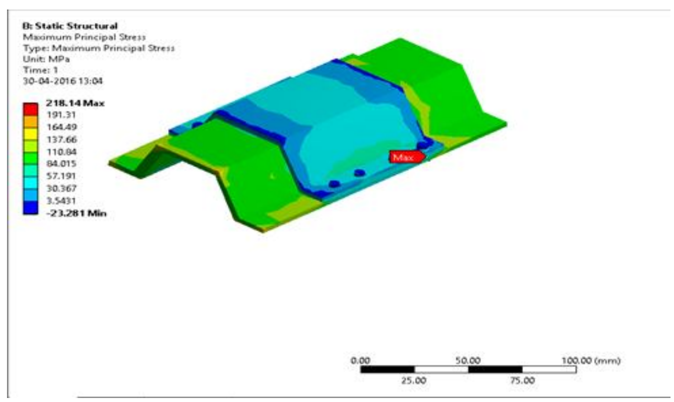

Figure 9: Maximum Principal Stress

From the Figure 9, it is clear that the maximum principal stress acting on the stringer is 218.14 MPa.

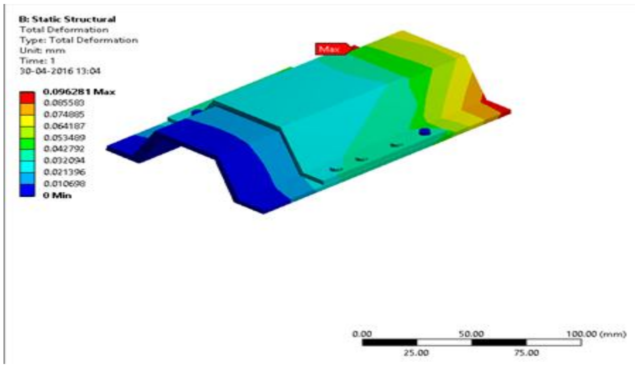

Figure 10: Total Deformation

From Figure.10 it is clear that the total deformation on the stringer is 0.096281mm.

4.1.2 CFRP Composite Omega Stringer

Stresses on Stringer

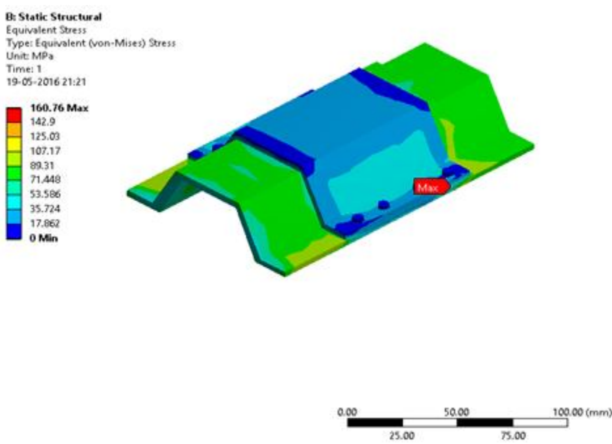

Figure 11: Equivalent Stress

From the Figure 11 it is clear that the equivalent stress acting on the stringer is 160.76 MPa.

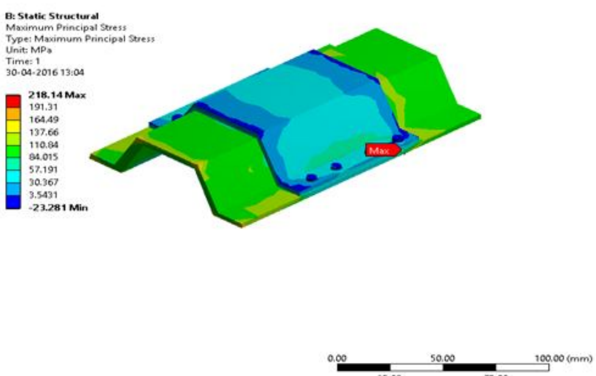

Figure 12: Maximum Principal Stress

From the

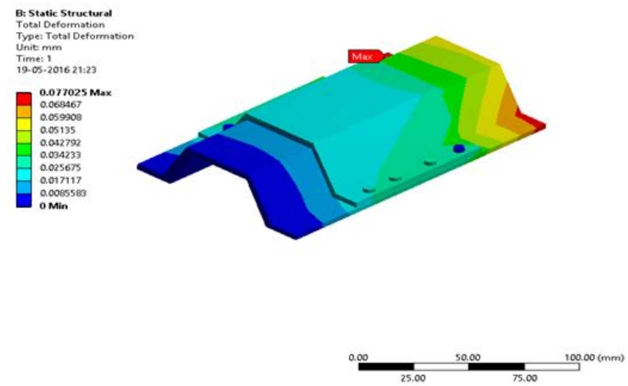

Figure 13: Total Deformation

From the Figure 13, it is clear that the total deformation on the stringer is 0.077025 mm.

5. COMPARATIVE ANALYSIS

Comparison of Omega Stringer for Aluminum Alloy and CFRP Composite Material

Table – 4: Comparison of Omega Stringer for Aluminum Alloy and CFRP Composite Material

Sl. No.	Results	Omega Stringer Aluminium Alloy 2024 T-351	Omega Stringer CFRP composite
1.	Equivalent Stress (MPa)	200.95	160.76
2.	Maximum Principal Stress (MPa)	218.14	200.28
3.	Minimum Principal Stress (MPa)	57.988	46.391
4.	Total Deformation (mm)	0.096281	0.077025

The Table 4 shows the comparative analysis between Omega Stringer for Aluminium Alloy and Omega Stringer for CFRP Composite Material. From the table it is evident that equivalent stress of Omega Stringer for CFRP Composite Material is less than Omega Stringer for Aluminium Alloy. The maximum principal stress of Omega Stringer for CFRP Composite Material is less than Omega Stringer for Aluminium Alloy. The minimum principal stress of Omega Stringer for CFRP Composite Material is less than Omega Stringer for Aluminium Alloy. The total deformation of Omega Stringer for CFRP Composite Material is less than Omega Stringer for Aluminium Alloy. Hence it can be concluded from the above comparison that Omega Stringer for CFRP Composite Material is better than Omega Stringer for Aluminium Alloy.

6. CONCLUSIONS

The development of stress in two combinations of omega stringer and splice joint is discussed. The static analysis is made to evaluate the stress and deformation of metallic and composite stringers and splice joint. The metallic stringer shows a stress of 200.95Mpa and deformation of 0.096281mm and composite stringer show a stress of 160.76Mpa and deformation of 0. 0.077025mm.

Finally it can be concluded that the behavior of omega stringer and splice joint in an aircraft fuselage structure that composite stringer is more efficient and preferable compared to Aluminum Alloy stringer and splice joint.

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