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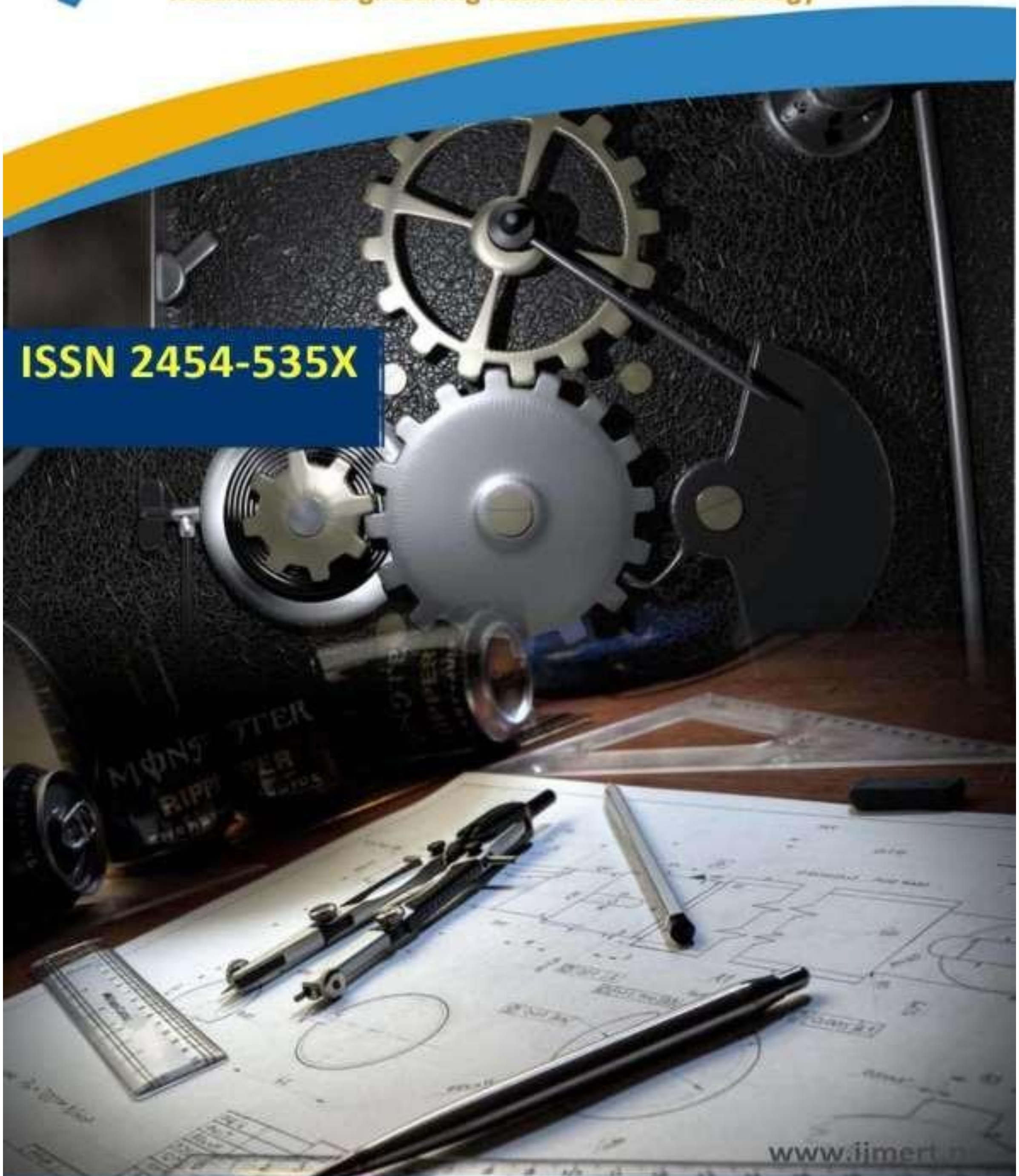

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STRUCTURAL ANALYSIS OF BONDED AND HYBRID JOINTS IN AIRCRAFT FUSELAGE CONNECTIONS

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ABSTRACT

Composite materials are increasingly used in modern aircraft structures due to their high strength-to-weight ratio, corrosion resistance, and design flexibility. Aircraft fuselage structures rely heavily on efficient joining methods for stringer-skin connections and splice joints. Traditional riveted joints, bonded joints, and hybrid joints (bonded + riveted) are commonly used in aerospace applications.

This study presents a comparative structural analysis of bonded, riveted, and hybrid joints used in aircraft fuselage splice connections. A Z-stringer model was developed using ANSYS SpaceClaim and analyzed using ANSYS Workbench. Static structural simulations were performed to evaluate total deformation and equivalent (von Mises) stress distribution.

Keywords: Hybrid joint, Bonded joint, Riveted joint, Aircraft fuselage, Finite element analysis, ANSYS

2. INTRODUCTION

Aircraft fuselage structures are subjected to complex loading conditions including internal pressurization, aerodynamic forces, bending, shear, and fatigue loads. The fuselage skin is reinforced by longitudinal stiffeners known as stringers to prevent buckling and enhance load-carrying capacity.

Splice joints are required to connect fuselage skin panels and stringers. The performance of

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Vol. 18 Issue. 2, April 2026

these joints directly affects aircraft safety and structural efficiency.

Traditionally, riveted joints were the primary joining method. However, advancements in adhesive bonding and hybrid joining technologies have introduced improved alternatives.

This study evaluates:

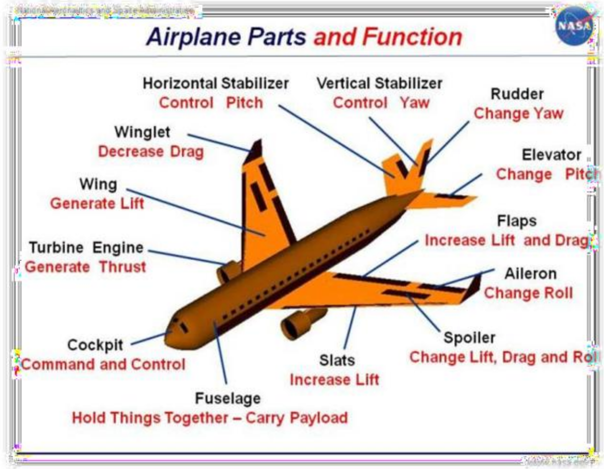
- Bonded joint performance
- Riveted joint performance
- Hybrid joint performance
- Stress and deformation comparison using FEA

AEROPLANE

Airplane, also called aeroplane or plane, any of a class of fixed-wing aircraft that is heavier than air, propelled by a screw propeller or a high-velocity jet, and supported by the dynamic reaction of the air against its wings.

PARTS OF AEROPLANE

- cockpit
- Fuselage
- Empennage
- wings



3.AIRCRAFT FUSELAGE STRUCTURE

Modern aircraft fuselages are primarily constructed using **semi-monocoque structures**. In this design:

- Skin carries tensile and compressive loads
- Frames provide shape and resist circumferential loads
- Stringers prevent buckling and carry longitudinal stresses

3.1 Semi-Monocoque Construction

Semi-monocoque structures combine skin and internal stiffeners to resist applied loads efficiently. This configuration provides:

- High strength-to-weight ratio
- Damage tolerance
- Fatigue resistance

The Z-stringer considered in this study is a common fuselage stiffening component.

a complete fixture for alignment.

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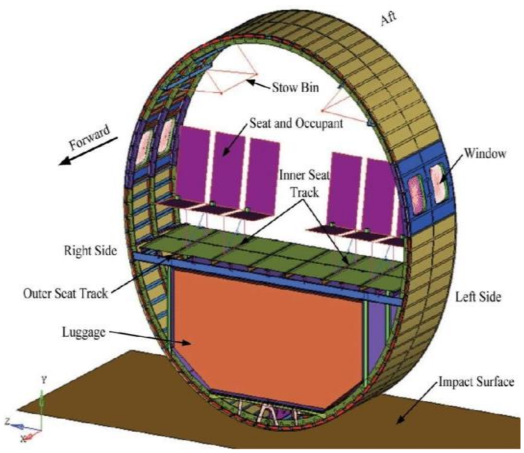
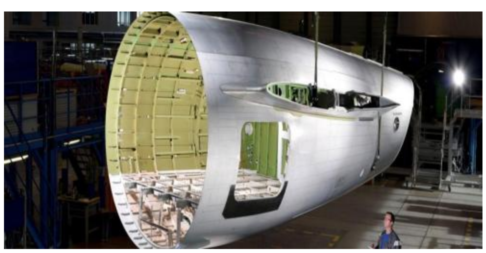
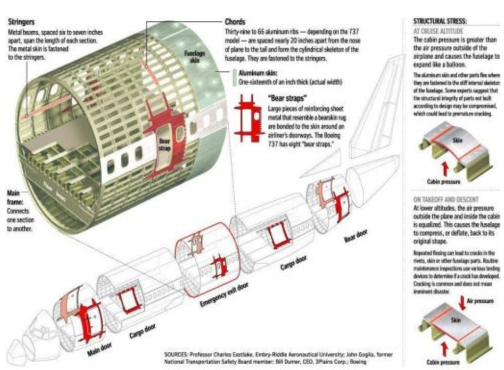
Vol. 18 Issue. 2, April 2026







4. MATERIALS USED IN FUSELAGE STRUCTURES

The skin of an aircraft is the outer surface which covers much of its wingsand fuselage. The most commonly used materials are aluminum and aluminium alloys with other metals, including zinc, magnesium and copper.

TYPES OF MATEARIALS

1. Aluminium
2. Carbon fiber

4.1 Aluminium Alloys

Aluminium alloys are widely used in aircraft fuselages due to:

- Low density
- High specific strength
- Good fatigue resistance
- Corrosion resistance

However, aluminium loses strength at elevated temperatures and is susceptible to fatigue cracking under cyclic loading.

4.2 Carbon Fiber Reinforced Polymer (CFRP)

CFRP offers:

- High stiffness
- Excellent strength-to-weight ratio
- Superior fatigue resistance

International Journal of Mechanical Engineering Research and Technology
ISSN 2454 – 535X www.ijmert.com
Vol. 18 Issue. 2, April 2026

- Corrosion resistance

CFRP is increasingly used in modern aircraft fuselage sections.

1. **TYPES OF JOINTS**

INTRODUCTION

A mechanical joint is a section of a machine which is used to connect one or more mechanical part to another. Mechanical joints may be temporary or permanent, most types are designed to be disassembled. Most mechanical joints are designed to allow relative movement of these mechanical parts of the machine in one degree of freedom, and restrict movement in one or more others. Mechanical joints are much cheaper and are usually bought ready assembled.

Knuckle joint

Turnbuckle

Pin joint

Cotter joint

Bolted joint

Screw joint

Universal

jointBall joint

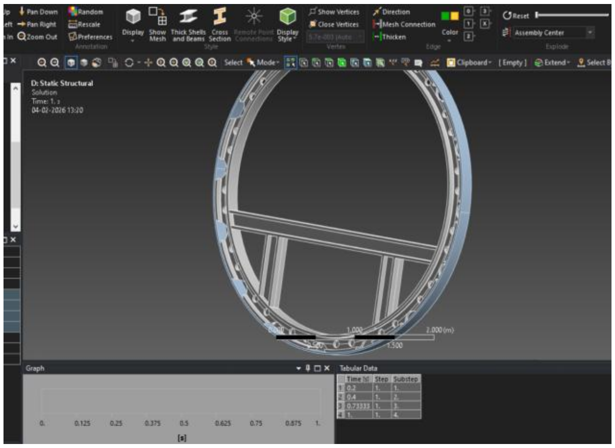
Prismatic

joint

5. TYPES OF JOINTS USED IN AIRCRAFT STRUCTURES

International Journal of Mechanical Engineering Research and Technology
ISSN 2454 – 535X www.ijmert.com
Vol. 18 Issue. 2, April 2026

5.1 Bonded Joint



A permanent joint between parts of machines, building structures, furniture, and prod ucts of light industry; formed by an adhesive. It can hold together various materials, including materials of different types, by providing uniform distribution of stresses.

A bonded joint uses structural adhesive to join components.

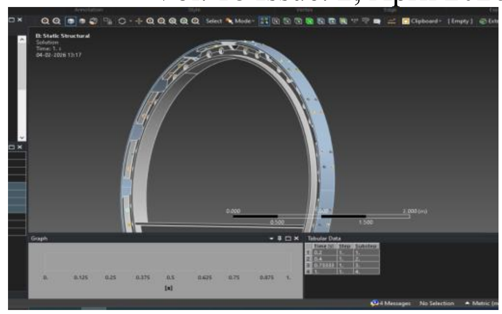
Advantages:

- Uniform stress distribution
- No stress concentration from holes
- Lightweight

Limitations:

- Sensitive to temperature changes
- Poor peel resistance
- Inspection difficulty

5.2 Riveted Joint



The permanent joining of parts by means of rivets; used mainly for fastening sheet and shaped rolled metal. Riveting may be used in lap, abutment, and double-coverplate joints.

Riveted joints are permanent mechanical fasteners widely used in fuselage structures.

Advantages:

- Reliable
- Easy inspection
- Good fatigue performance

Limitations:

- Stress concentration around holes
- Added weight
- Potential crack initiation

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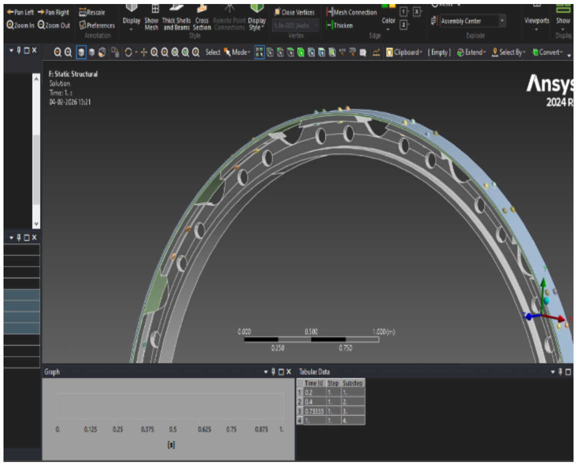
Vol. 18 Issue. 2, April 2026

5.3 Hybrid Joint



Hybrid joints combine adhesive bonding with mechanical fastening.

Benefits:

- Load sharing between adhesive and rivet
- Improved fatigue resistance
- Higher damage tolerance
- Redundant load path

Hybrid joints are increasingly used in aerospace and automotive industries.

6. FINITE ELEMENT METHOD (FEM)

The Finite Element Method (FEM) is a numerical approach used to solve structural engineering problems.

FEM Procedure:

1. Geometry modeling
2. Meshing
3. Material assignment
4. Boundary condition application
5. Load application
6. Solution
7. Post-processing

The Z-stringer splice joint was discretized into finite elements and analyzed using ANSYS.

7. ANSYS MODELLING

The geometry was created using **ANSYS SpaceClaim**, and analysis was conducted in ANSYS Workbench.

7.1 Model Description

- Z-stringer fuselage splice
- Three configurations:
  - Bonded joint
  - Riveted joint
  - Hybrid joint

7.2 Analysis Type

- Static structural analysis
- Outputs evaluated:
  - Total deformation
  - Equivalent (von Mises) stress

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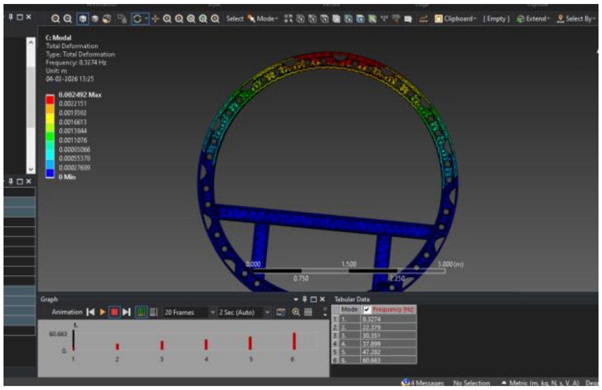
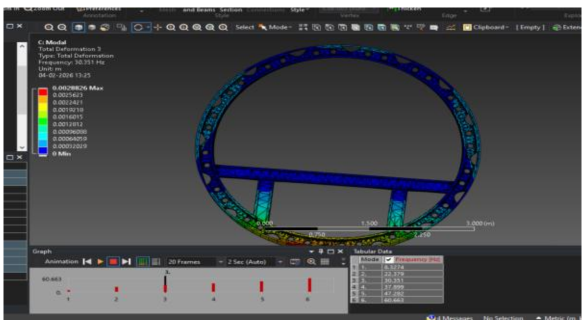
Vol. 18 Issue. 2, April 2026

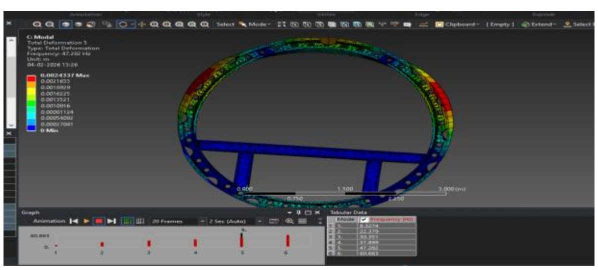
BONDED JOINTS



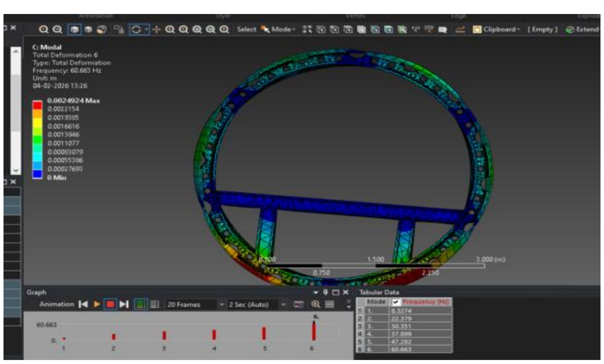
Deformation 1



Deformation 2

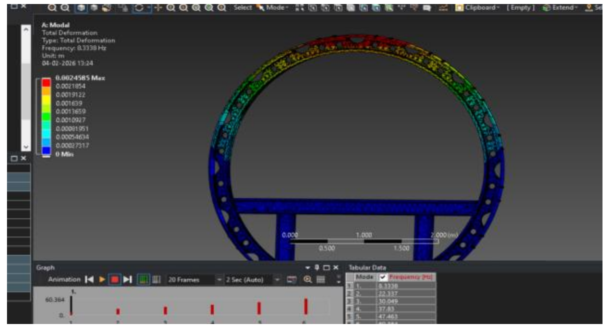


Deformation 3

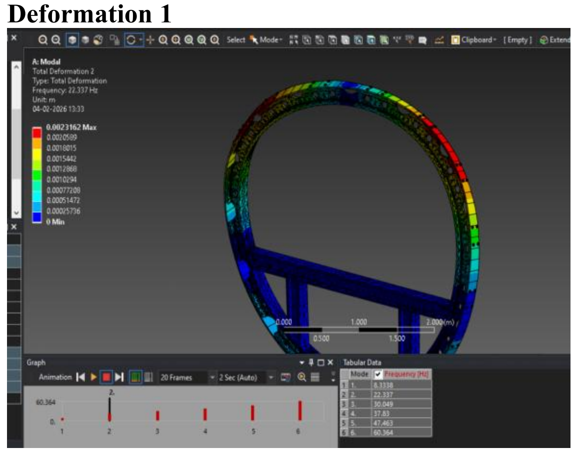


Deformation 4

RIVETED JOINTS



Deformation 1



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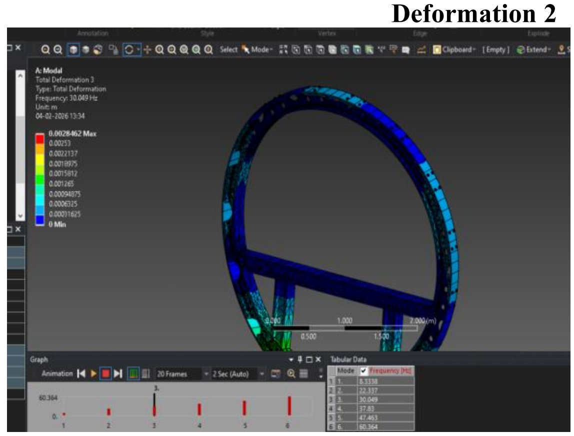
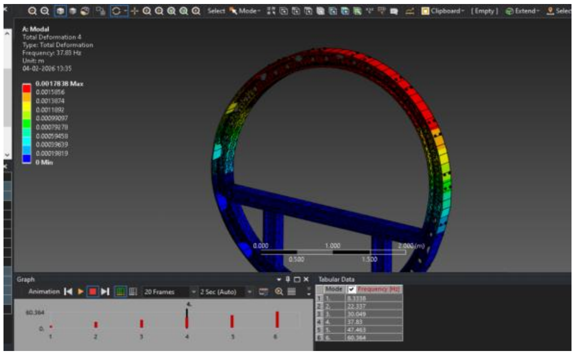


Deformation 3

International Journal of Mechanical Engineering Research and Technology
ISSN 2454 – 535X www.ijmert.com
Vol. 18 Issue. 2, April 2026



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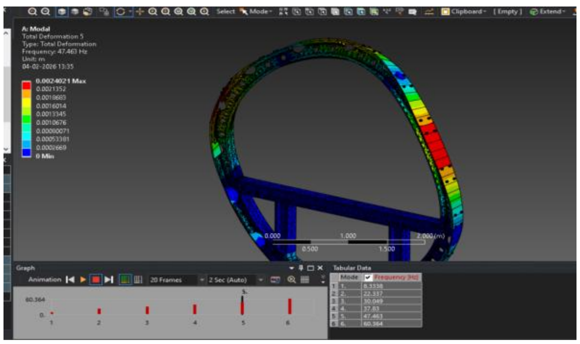

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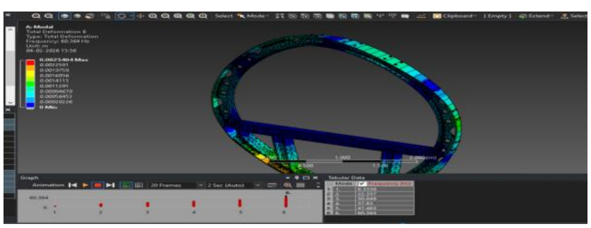
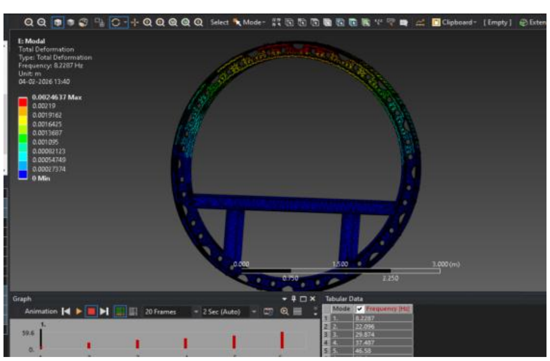
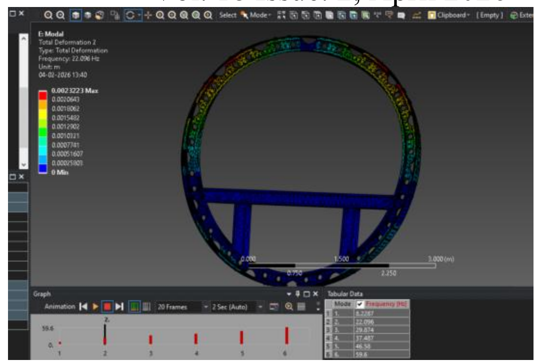


Deformation 6

HYBRID JOINTS



Deformation 1



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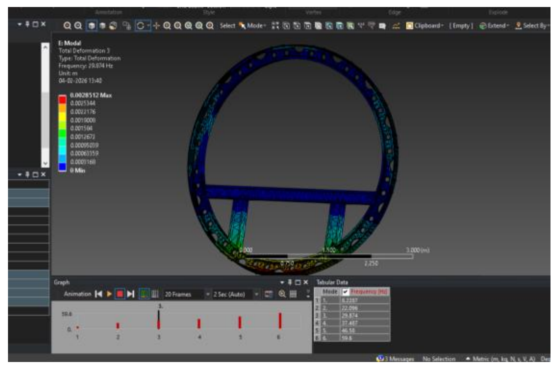

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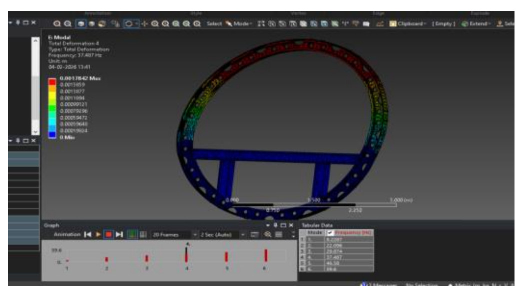

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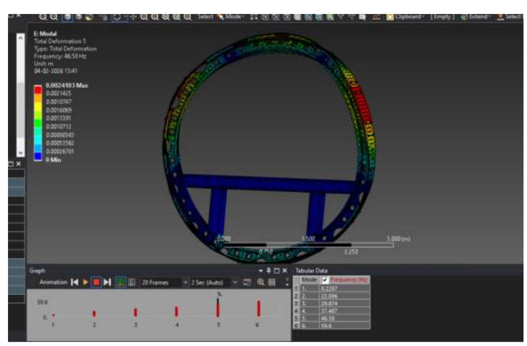

Deformation 5

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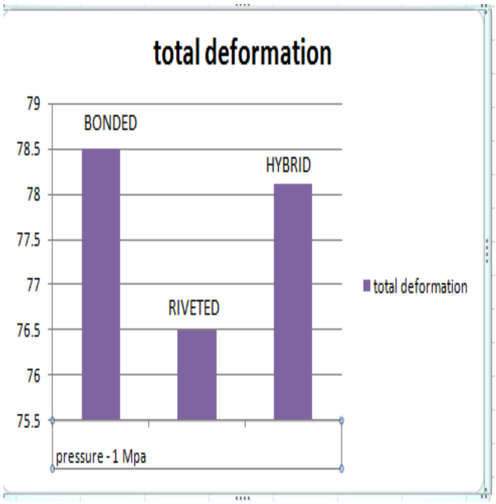
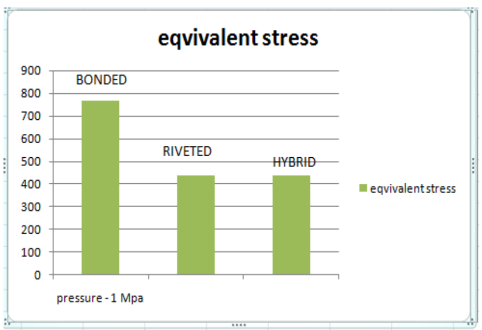
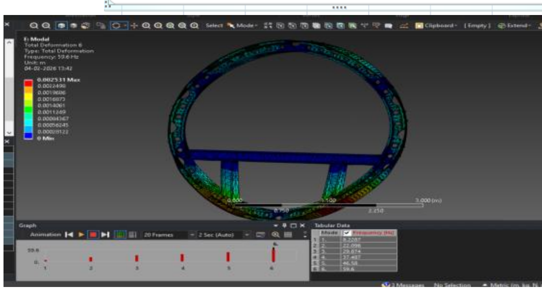
ISSN 2454 – 535X www.ijmert.com
Vol. 18 Issue. 2, April 2026







Deformation 6

8. RESULTS

8.1 Total Deformation

	Total Deformation (mm)	Equivalent Stress (N/m m^2)
Bonded Joint	**78.5**	**767.91**
Riveted Joint	**76.5**	**438.16**
Hybrid Joint	**78.11**	**437.41**

9. DISCUSSION

- Bonded joint shows highest equivalent stress.
- Riveted joint reduces stress but introduces stress concentration.
- Hybrid joint provides:
  - Lower equivalent stress
  - Improved stress distribution
  - Redundant load path

Although deformation differences are small, hybrid joints provide better structural reliability and durability.

10. CONCLUSION

The comparative structural analysis of bonded, riveted, and hybrid joints for aircraft fuselage splice connections has been successfully carried out.

Key findings:

- Hybrid joints demonstrate lower equivalent stress compared to bonded joints.
- Riveted joints perform better than bonded joints in stress reduction.

International Journal of Mechanical Engineering Research and Technology
ISSN 2454 – 535X www.ijmert.com
Vol. 18 Issue. 2, April 2026

- Hybrid joints offer improved fatigue resistance and load-sharing capability.
- Well-designed hybrid joints are preferable for aircraft fuselage applications.

Therefore, hybrid joints are recommended for aerospace structural applications where safety, durability, and load efficiency are critical.

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International Journal of Mechanical Engineering Research and Technology
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Vol. 18 Issue. 2, April 2026

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