**Introduction**

Most of aircraft structures are obtained by assembling small parts, which ultimately form major airframe assemblies like the wings, tail, and fuselage. Thus, joining of components plays a major role in the airframe overall strength, fatigue resistance, and damage tolerance. While the static strength of structures can be determined in pretty straightforward ways, and certainly all structures operate well below these limit loads in service life, the most significant phenomenon under which most structures fail is fatigue, even at loads around 30-40% of the static strength. Thus, it is important to study fatigue failure of engineering structures since it is responsible for many catastrophic accidents.

**Mechanical fasteners** such as rivets, pins, screws, and bolts

- **Advantages:** easy to assemble and less time consuming process
- **Disadvantages:** high stress concentrations around fastener holes, secondary bending predominant

**Adhesive bonding**

- **Advantages:** lower stress concentrations due to distributed load across adhesive layer
- **Disadvantages:** time consuming manufacturing + curing, ability to detect small defects in bondline

**Hybrid joining**

- **Advantages:** mechanical fasteners + adhesive bonding
- **Disadvantages:** higher stiffness of joint, mechanical fasteners provide extra level of protection if adhesive fails

**Joining Techniques**

- **Advantages:** mechanical fasteners + adhesive bonding
- **Disadvantages:** higher stiffness of joint, mechanical fasteners provide extra level of protection if adhesive fails

**Materials and Methodology**

- **Metal** – AA 2024-T3
  - **Composite** – Carbon Fibre Reinforced Epoxy (CFRE), Glass Fibre Reinforced Epoxy (GFRE)
  - **Rivets** – Al blind rivets
  - **Adhesive** – Aralite 2031

| Substrate | Step 1: Static strength (kN) of studied joints | Step 2: Static strength (kN) of studied joints | Step 3: 
<table>
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<tbody>
<tr>
<td>Metal</td>
<td>$F_{riveted} = 4410$ N</td>
<td>$F_{riveted} = 5733$ N</td>
<td>$F_{riveted} = 7483$ N</td>
</tr>
<tr>
<td>Composite</td>
<td>$F_{adhesive} = 4482$ N</td>
<td>$F_{adhesive} = 5827$ N</td>
<td>$F_{adhesive} = 7575$ N</td>
</tr>
</tbody>
</table>

**Dimensions of joint with metal substrate**

**Dimensions of joint with composite substrate**

**Results and Discussion**

- **Static strength:**
  - Metal-metal: $F_{(hybrid)} > F_{(adhesive)} > 3 \cdot F_{(riveted)}$
  - Composite-composite & metal-composite: $F_{(adhesive)} > F_{(hybrid)} > 3 \cdot F_{(riveted)}$
  - Fatigue life:
    - Metal-metal: $N_f(hybrid) > N_f(adhesive) > N_f(riveted)$
    - Composite-metal: $N_f(hybrid) > N_f(riveted) > N_f(adhesive)$
    - Metal-composite: $N_f(hybrid) \geq 8 \cdot N_f(adhesive) > N_f(riveted)$
    - Composite-composite: $N_f(hybrid) > N_f(adhesive) \geq 5 \cdot N_f(riveted)$

**Conclusions**

- **Fatigue life:**
  - Rivet shear failure
  - Adhesive failure
  - Cohesive failure
  - Net-section failure
  - Adhesive + rivet shear failure

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