

# Static strength and fatigue life analysis of aircraft structural repairs

<sup>1</sup> Dept. of Physics - Division of Aerospace Engineering, c/ Esteve Terradas 5, 08860, Castelldefels, Spain

<sup>2</sup> Dept. of Physics & Barcelona Research Centre in Multiscale Science and Technology, av. Eduard Maristany 16, 08019, Barcelona, Spain

## 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 straight forward 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.

## Joining Techniques

**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**

- epoxy, hardeners, and glues

**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**

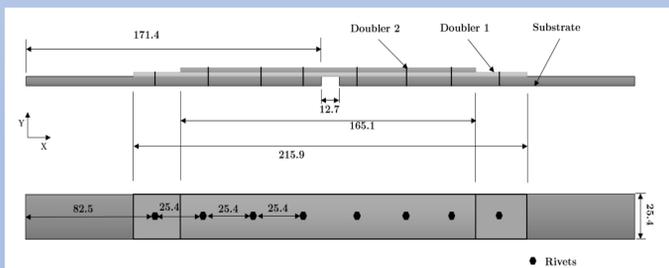
- mechanical fasteners + adhesive bonding

**Advantages:**

- higher stiffness of joint
- mechanical fasteners provide extra level of protection if adhesive fails

**Disadvantages:**

- joining is time consuming process



Dimensions of joint with metal substrate

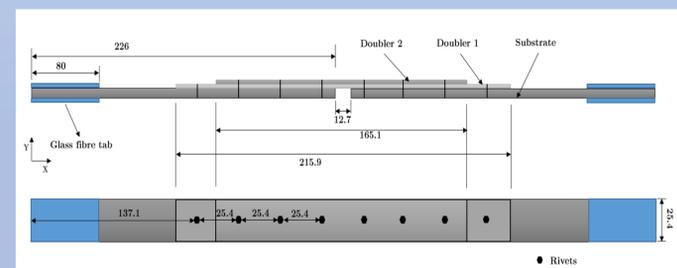
## Materials and Methodology

**Metal** – AA 2024-T3

**Composite** – Carbon Fibre Reinforced Epoxy (CFRE), Glass Fibre Reinforced Epoxy (GFRE)

**Rivets** – Al blind rivets

**Adhesive** – Araldite 2031



Dimensions of joint with composite substrate

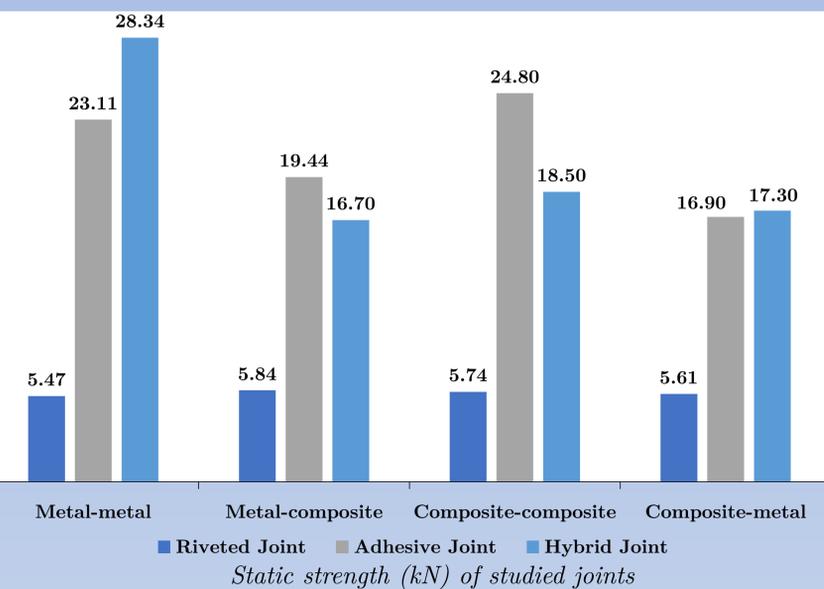
Static tests with Metrotest 810 UTM at displacement of 6 mm/min

Fatigue tests in tension-tension load control with stress ratio of 0.1

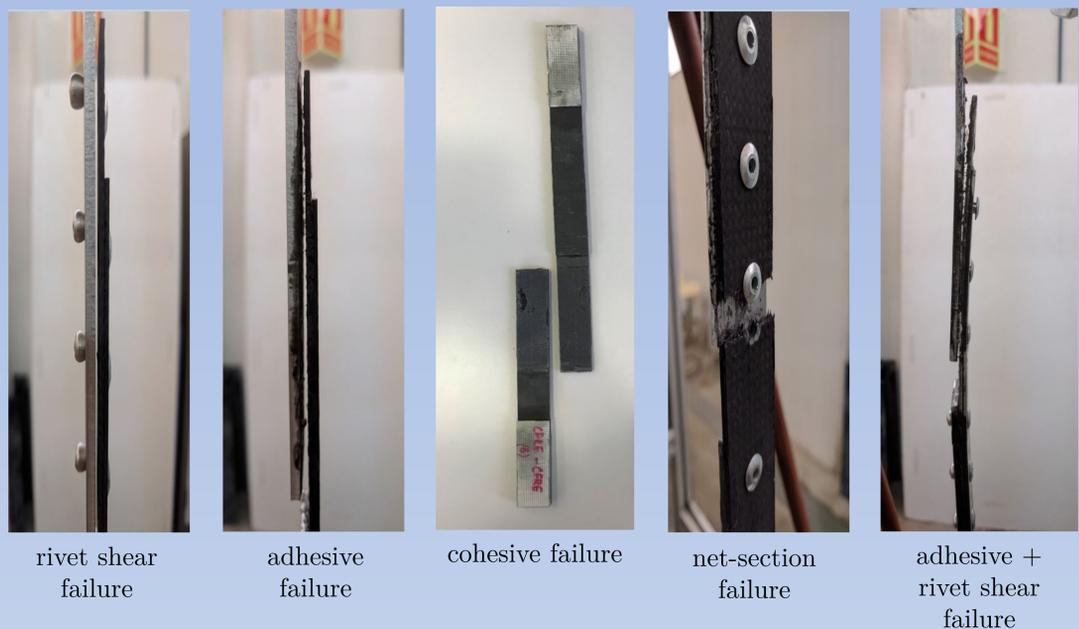
Substrate	Step 1: up to 200,000 cycles	Step 2: up to 400,000 cycles	Step 3: up to failure
Metal	$F_{amplitude} = 4410 \text{ N}$	$F_{amplitude} = 5733 \text{ N}$	$F_{amplitude} = 7453 \text{ N}$
Composite	$F_{amplitude} = 4482 \text{ N}$	$F_{amplitude} = 5827 \text{ N}$	$F_{amplitude} = 7575 \text{ N}$

Loading conditions in fatigue tests

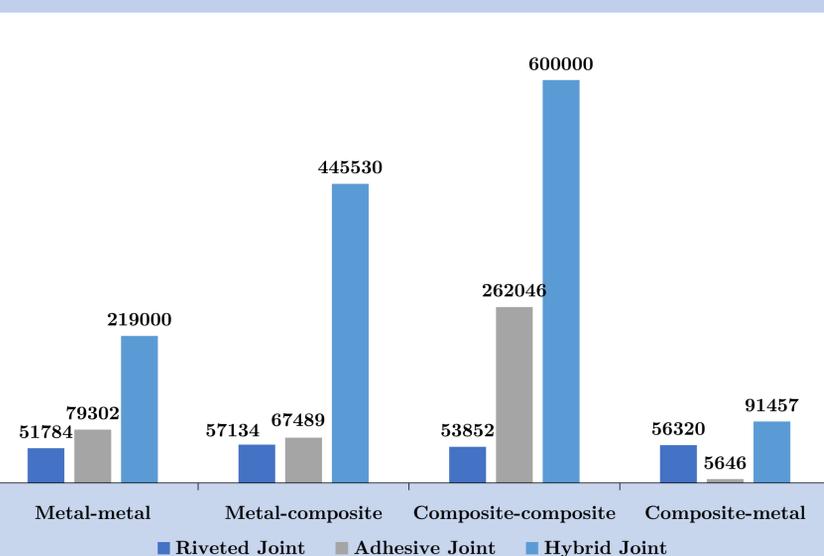
## Results and Discussion



Static strength (kN) of studied joints



Failure modes: rivet shear failure, adhesive failure, cohesive failure, net-section failure, adhesive + rivet shear failure



Fatigue life (number of loading cycles) of studied joints

## Conclusions

➤ **Static strength:**

➤ **Metal-metal:**

$$F(\text{hybrid}) > F(\text{adhesive}) \geq 3 \cdot F(\text{riveted})$$

➤ **Composite-composite & metal-composite:**

$$F(\text{adhesive}) > F(\text{hybrid}) \geq 3 \cdot F(\text{riveted})$$

➤ **Composite-metal:**

$$F(\text{hybrid}) \sim F(\text{adhesive}) \geq 3 \cdot F(\text{riveted})$$

➤ **Fatigue life:**

➤ **Metal-metal:**

$$N_F(\text{hybrid}) > N_F(\text{adhesive}) > N_F(\text{riveted})$$

➤ **Composite-metal:**

$$N_F(\text{hybrid}) > N_F(\text{riveted}) > N_F(\text{adhesive})$$

➤ **Metal-composite:**

$$N_F(\text{hybrid}) \geq 8 \cdot N_F(\text{adhesive}) > N_F(\text{riveted})$$

➤ **Composite-composite:**

$$N_F(\text{hybrid}) > N_F(\text{adhesive}) \geq 5 \cdot N_F(\text{riveted})$$