# Hole to Hole assembly on aeronautical structures

AIRBUS

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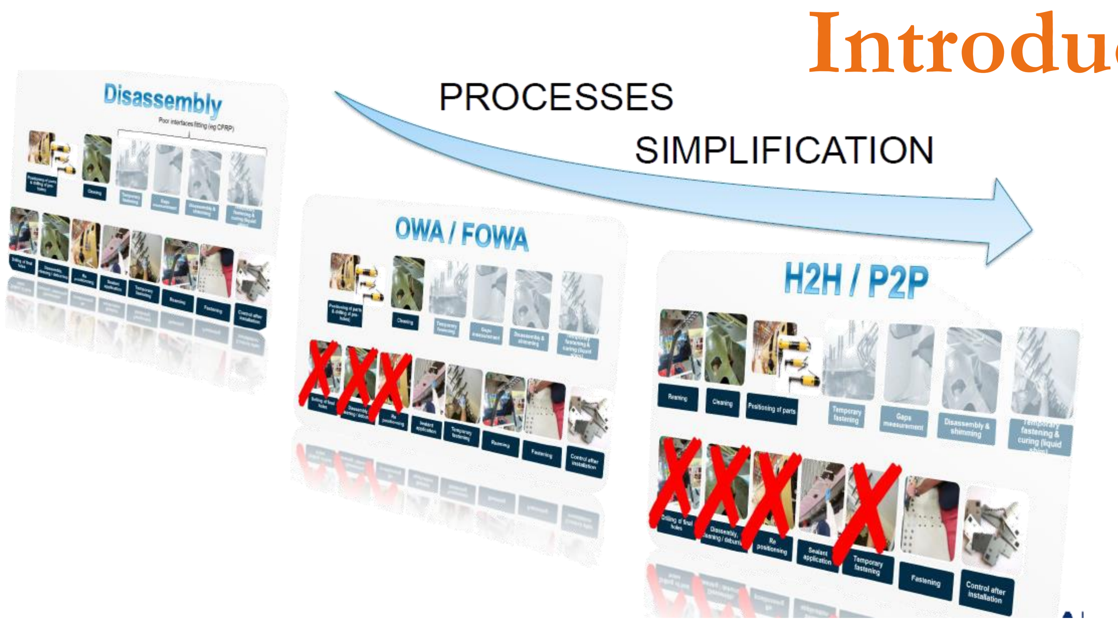
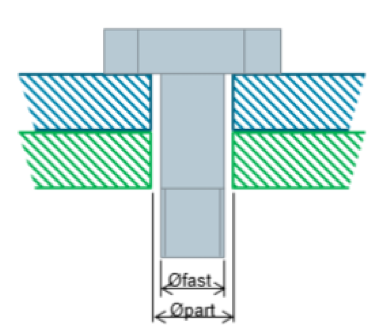
## Introduction & Context

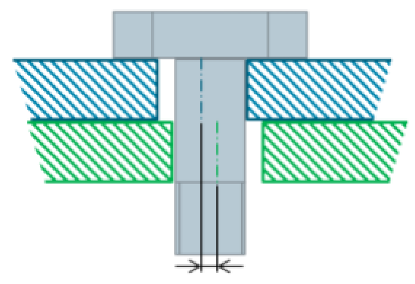



Clearance



*Hole to Hole*

Misalignment



At the dawn of **Industry 4.0**, AIRBUS must rethink and renew its processes and way of working to achieve a durable transition. Even something as basic as structural assembly can be upgraded for better agility and manufacturing efficiency. The **"Hole to Hole"** bolting assembly process introduced by **BLOEM [1]** is potentially a great opportunity to revolutionize assembly lines. However, it represents a leap for mechanical fastening technology. The aim of the study presented is to evaluate the feasibility and the effect of "Hole to Hole" on the mechanical behaviour and strength of bolted joints under static and fatigue loading.

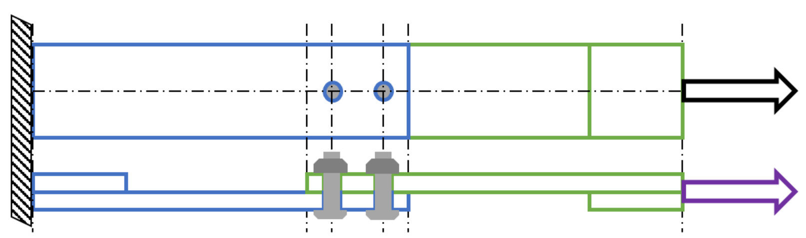
## Specimens & test procedures:

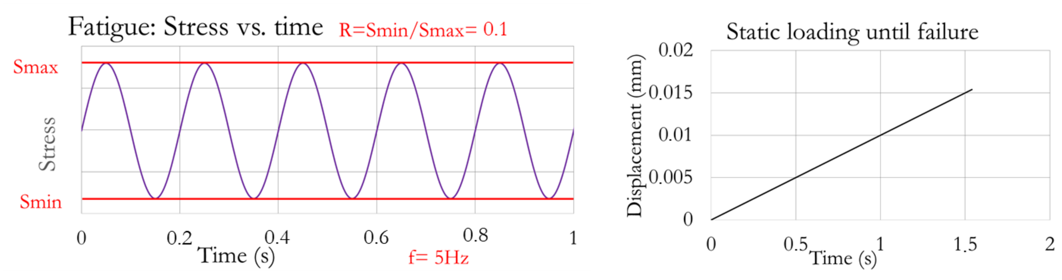
**Test definition:**
- Single lap shear
- Two titanium bolts
- Ti6Al4v specimen material

**Test method:**
- Static: Axial loading until failure, imposed displacement
- Fatigue: Loading Ratio R=0.1, Test frequency: 5Hz

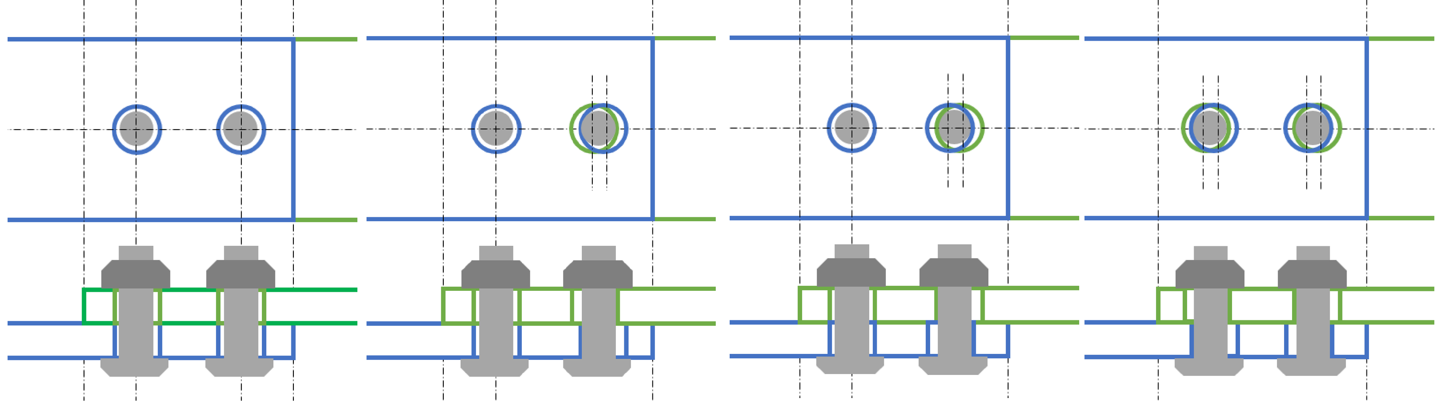
**Test parameters:**
- 5 clearance & misalignments configurations, the misalignment value m is positive for early contact and negative for late contact
- Fastener diameter Ø: [6.35; 12.7] mm
- Thickness ratio t/Ø: [0.25; 0.5; 1]
- Preload level: [35; 50; 65]% of fastener Ultimate Tensile Strength

$OS_{A0}$=0mm
$m_{A0}$=(0;0)mm

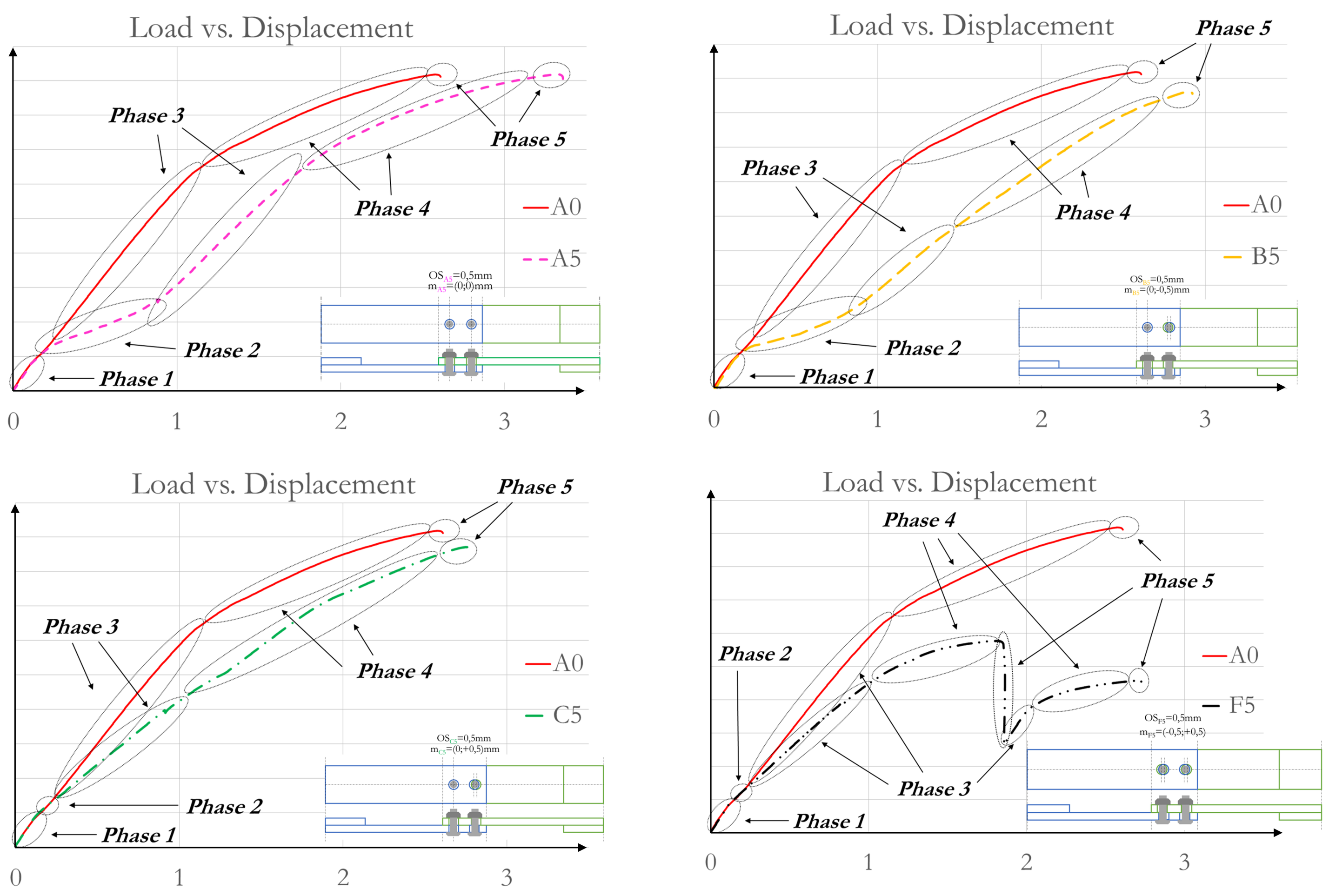





$OS_{A5}$=0.5mm $m_{A5}$=(0;0)mm
$OS_{B5}$=0.5mm $m_{B5}$=(0;-0.5)mm
$OS_{C5}$=0.5mm $m_{C5}$=(0;+0.5)mm
$OS_{F5}$=0.5mm $m_{F5}$=(-0.5;+0.5)



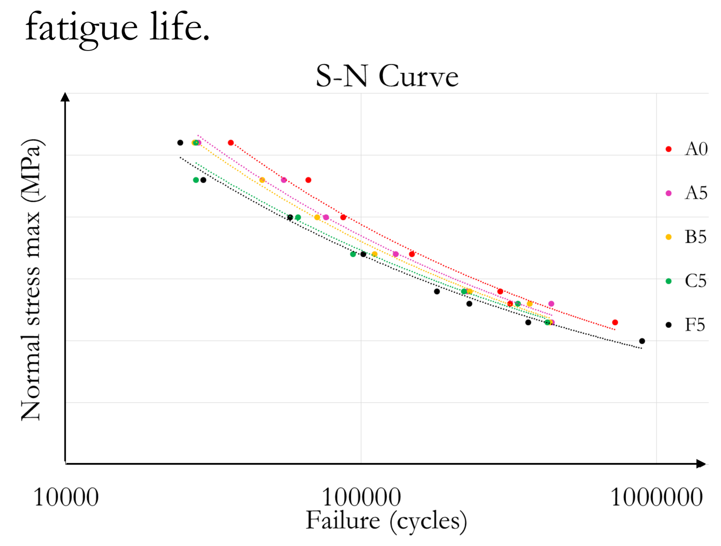
## Clearance & Misalignments Results:




**Global static behavior:**
- ***Phase 1:*** Linear **friction** transfer;
- ***Phase 2:*** **Slipping** phase;
- ***Phase 3:*** **Linear bearing** transfer;
- ***Phase 4:*** **Non-linear bearing** transfer;
- ***Phase 5:*** **Failure**.

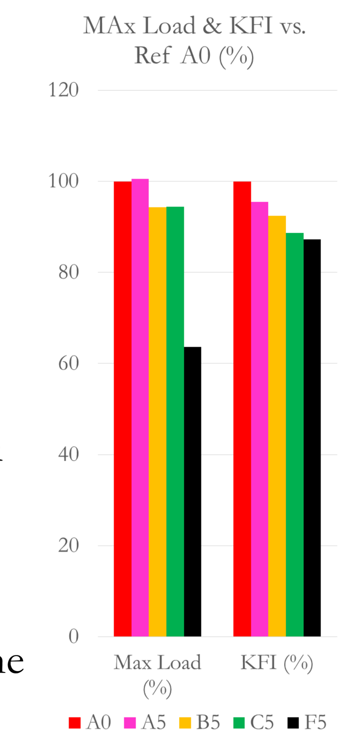
**Static Failure Mode:**
- t/Ø≥0.5: simultaneous **bolt shearing**;
- F5: Not simultaneous as mentioned by **[2] unbuttoning**.

**Fatigue results analysis S-N curves:**
- Performance (KFI): Smax for $10^5$ cycles;
- Clearance induces 5% decrease of fatigue life;
- Misalignments induces 7 to 11% decrease of fatigue life.





**Fatigue Failure Mode:**
- Initiation location depends on bolt technology, preload & misalignment configuration;
- For high & medium preload initiation location is outside the hole.

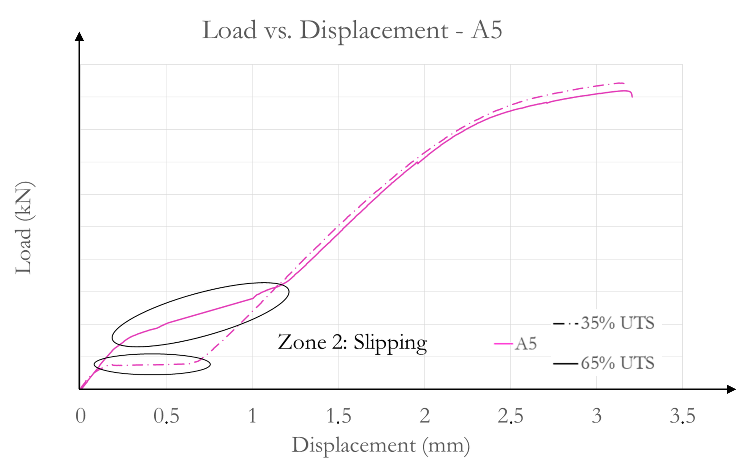



**Conclusion:**
- **Fatigue:** Effect of both clearance and misalignment;
- **Static:** no impact of clearance, strong impact of misalignment.

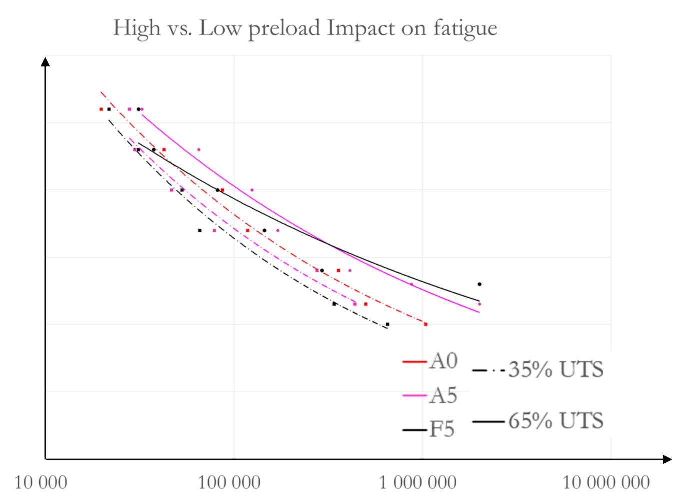
## Assembly Parameter Results: Comparative analysis

**Effect of preload on behavior, strength and fatigue: Low (35%UTS) vs. High (65%UTS)**

**Static:**
- Effect of preload on **slipping phase**;
- However, **no impact on static strength**.



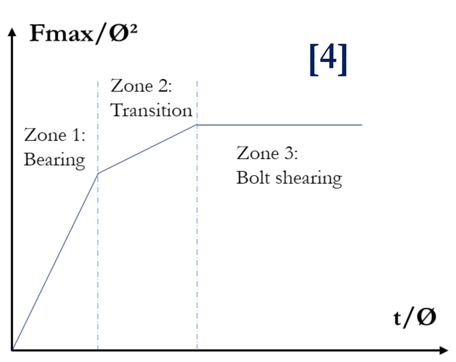

**Fatigue:**
- 65% UTS tightening **significantly improves fatigue life** even for worst case F5;
- Results coherent with **[3]**, fatigue life is improved by higher preload.

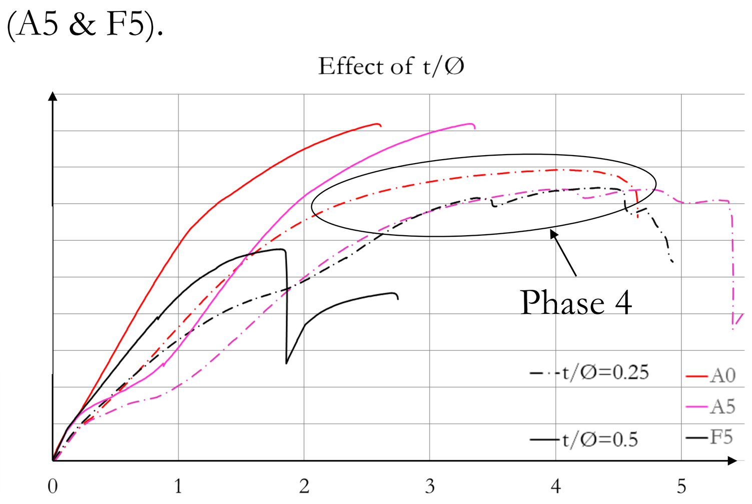


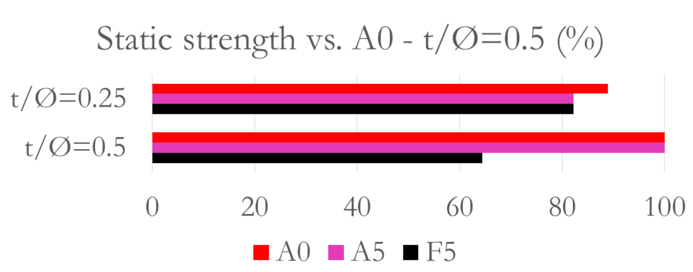

**Effect of thickness ratio t/Ø on static strength: 0.25 vs. 0.5**

- For t/Ø=0.25: **strong plate deformations** during **phase 4** induce large displacement;
- **Failure mode** impacted by thickness ratio t/Ø **[4]**;
- For t/Ø=0.25: Only **5% decrease of performance** in case of clearance & misalignment (A5 & F5).

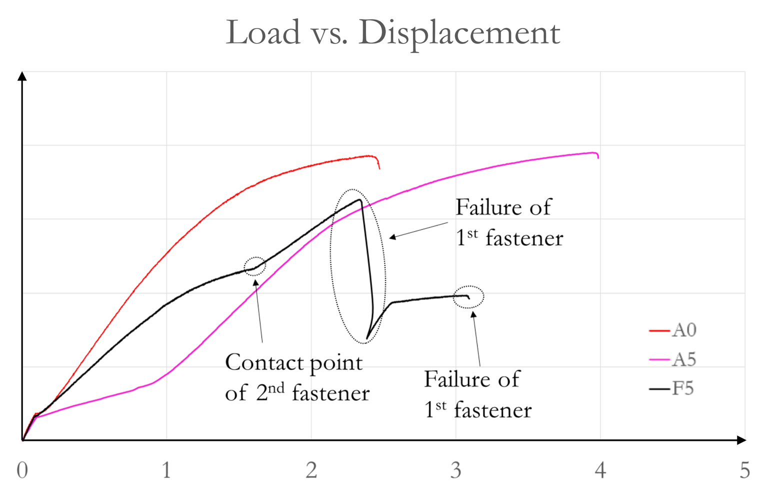
***Static Failure Mode: Adherent shear out***

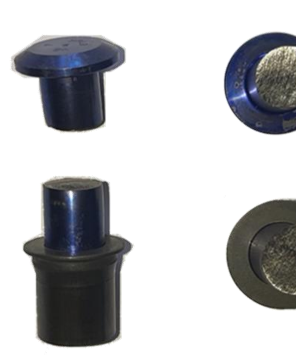



**Effect of fastener diameter Ø on behavior & static strength: Ø =12.7mm**



- **No impact** of bolt diameter on behavior of configurations **A0 & A5** under loading;
- For F5 configuration: **failure of 1st bolt occurs after contact of 2nd bolt**;
- However, the failure mode remains non-simultaneous bolt shearing;
- The static strength decrease between F5 & A0 is about 18% so much lower than the 36% decrease for a diameter of 6.35mm.

## Conclusions & Perspectives:

This study has confirmed that "Hole to Hole" assembly leads to lower static and fatigue performances. However, this impact may be controlled by a wise choice of assembly parameters, such as bolt diameter and bolt preload. This experimental campaign has enabled the construction of a large data base. In the framework of industry 4.0, this data base provides a great opportunity to develop a numerical model for the simulation of different assembly designs. To go further, this numerical design tool based on data computing with a probabilistic approach could even take all the manufacturing process events into account from material elaboration to fastener tightening.

Big Data

Simulation

## Bibliography:

[1] J. BLOEM, "Developments in Hole-to-Hole Assembly", SAE Transactions, Vol. 116, Section 1: Journal of Aerospace (2007), pp. 1087-1097.
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[4] R. CHIERAGATTI, "Faisabilité d'assemblages mixtes boulonnés-collés en aéronautique", Journées Techniques CETIM (2004), Saint-Etienne, France, pp. 1-11, ffhal-01892383.

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