2nd International Conference on Composites Testing and Model Identification

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Effect of Local Constraint on Measured Bearing Stress in Carbon/Epoxy Laminate

Background

- Bearing strength has a strong influence on composite component designs for Airbus aircraft.
- Existing literature has demonstrated a clear link between bearing strength and fastener torque at installation.
- Internal research at Airbus has suggested that for composite materials, the clamping force exerted by a fastener can reduce over the lifecycle of an aircraft due to local relaxation of the material.
- Available data on the effect of clamping force on bearing strength is not detailed enough for use in analysis.

The objectives of this test programme were to provide a robust dataset for the influence of fastener torque on measured bearing strength.

Material & Coupons

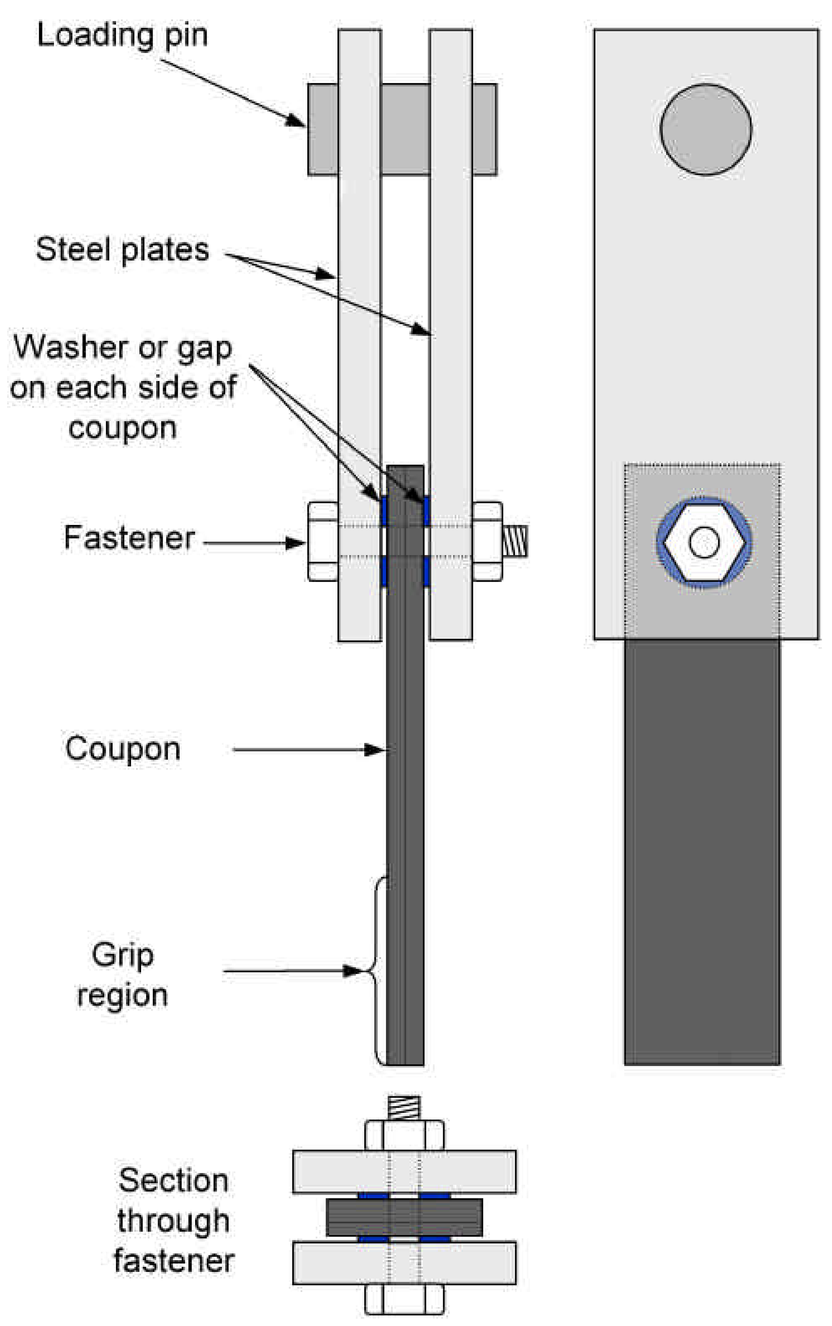
The material used was an aerospace grade unidirectional carbon fibre prepreg tape:

- Standard modulus carbon fibres; 180°C cure modified toughened epoxy resin.
- Quasi-isotropic layup $(45/0/135/90)_{2S}$ (nominal laminate thickness 4.0mm)

The fasteners used were 6.35mm diameter steel hex head bolts with free-running nuts and 12.7mm diameter plain steel washers.

The test matrix consisted of six coupons at each of the following local constraint conditions:

- 0.5mm gap or 0.1mm gap each side of the composite coupon.
- 0.6Nm, 1.3Nm, 2.4Nm, 3.5Nm or 7.0Nm torque applied to the fastener.



Definitions

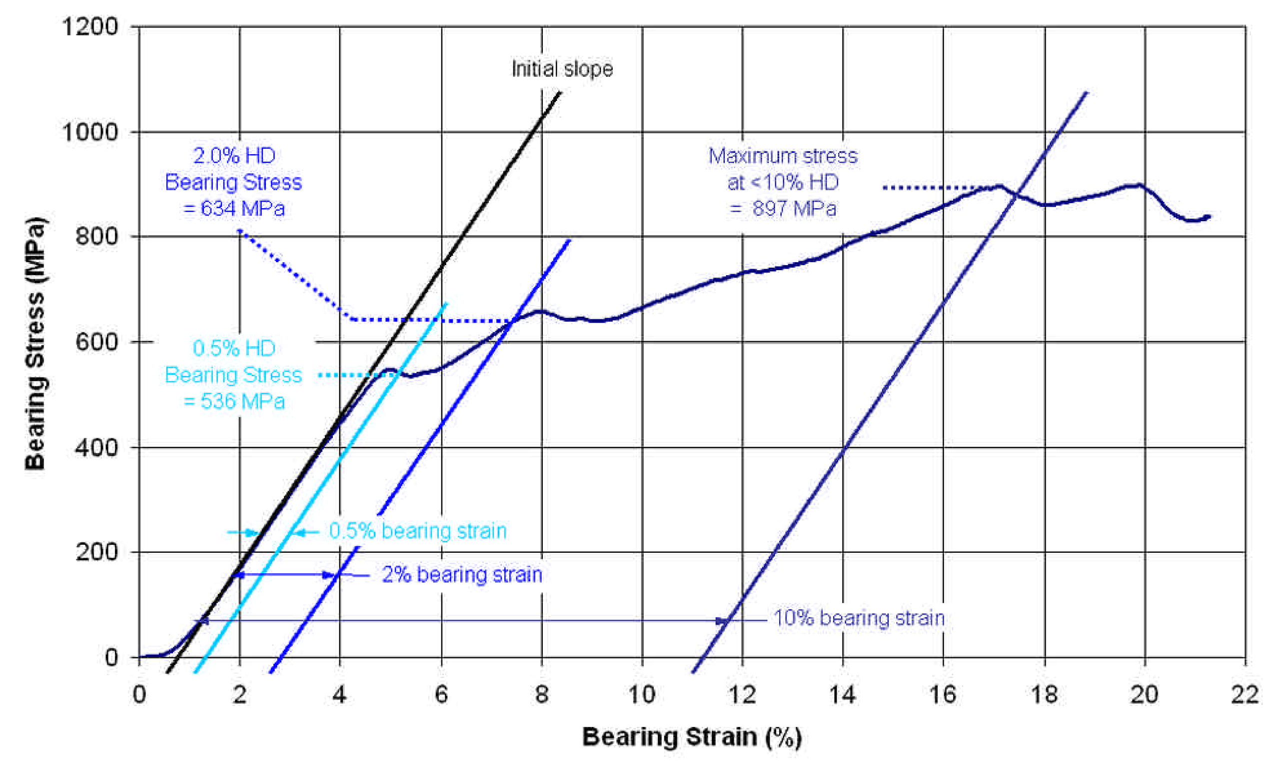
The load and displacement data was converted to normalised Bearing Stress and Bearing Strain using the following formulae:

Bearing Stress (MPa) = Applied load / (fastener diameter • specimen thickness)
Bearing Strain (%) = (Hole elongation / nominal fastener diameter) • 100

The following data were were derived:

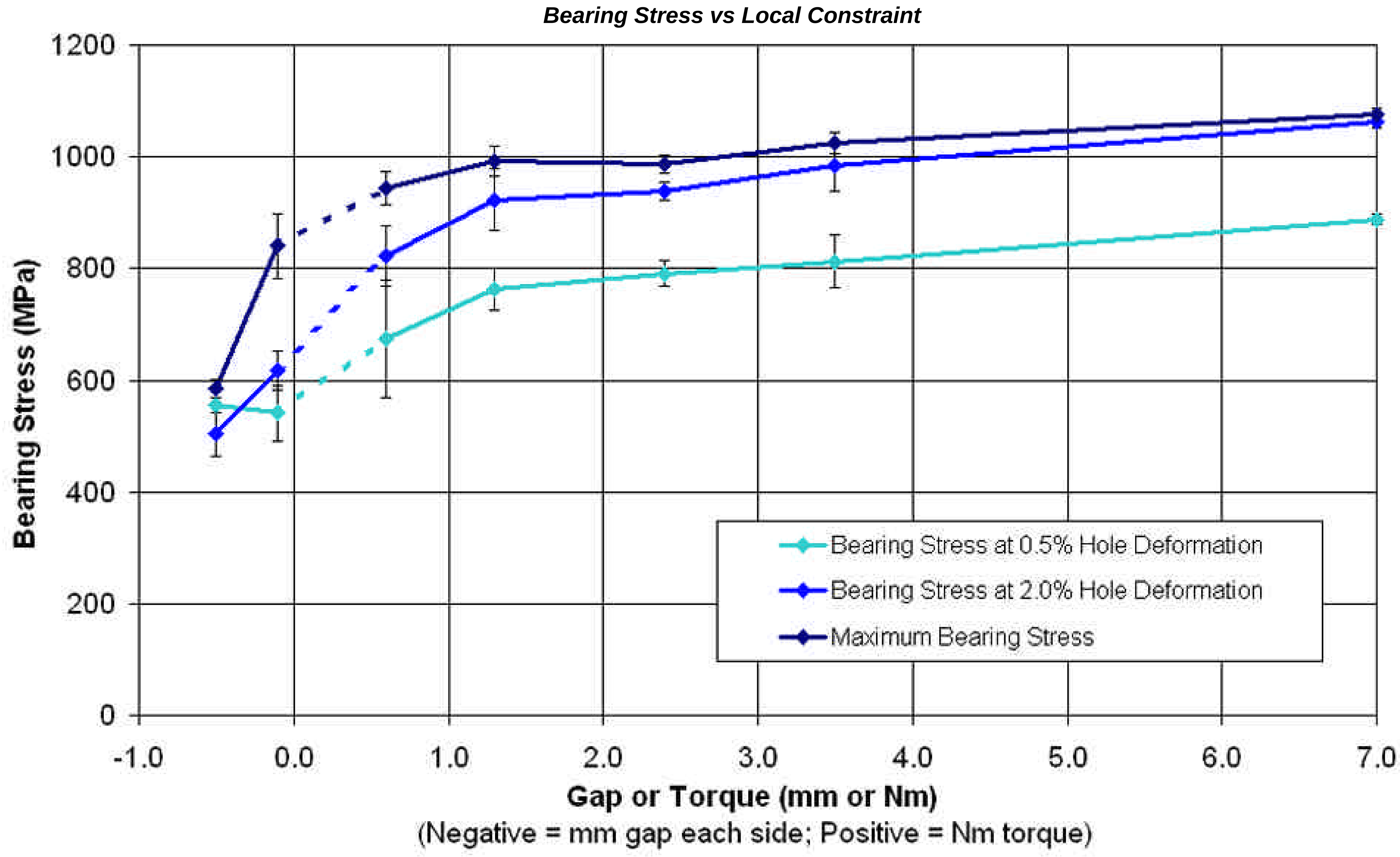
- Bearing Stress at 0.5% Hole Deformation (0.5% HD)
- Bearing Stress at 2.0% Hole Deformation (2.0% HD)
- Maximum Bearing Stress sustained by the coupon before 10% Hole Deformation is reached (<10% HD)

Typical Plot Showing Derivation of Bearing Stress at Various Hole Deformation Values



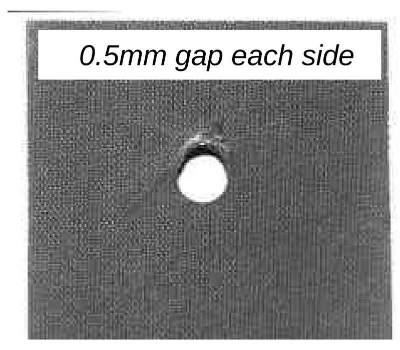
Results

Bearing Stress vs Local Constraint

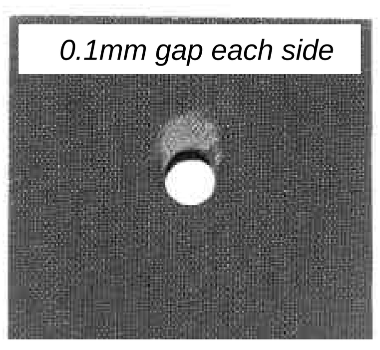


Failure Modes

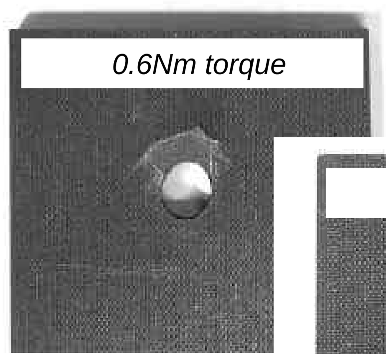
Three failure modes were observed:

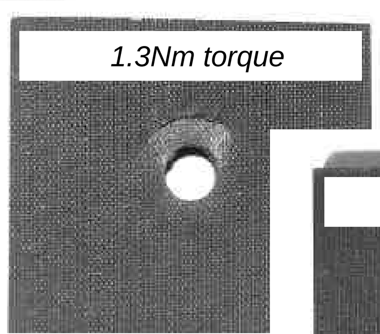


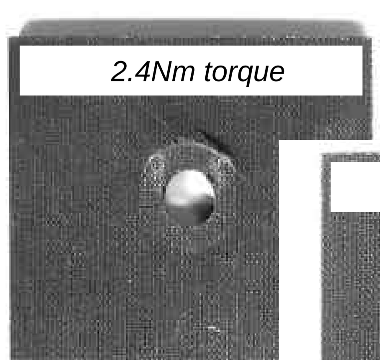
1. Unconstrained local out-of-plane crushing at the loaded surface

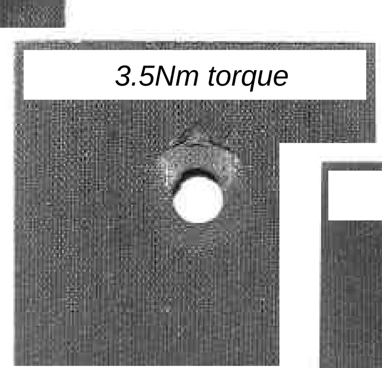


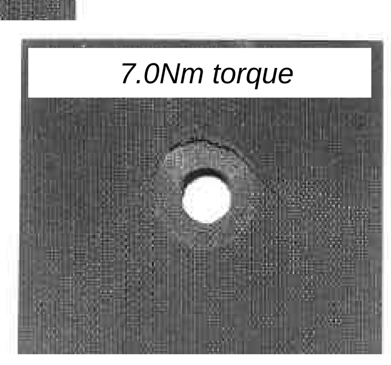
2. Local out-of-plane crushing at the loaded surface, constrained by the loading plates after initial failure





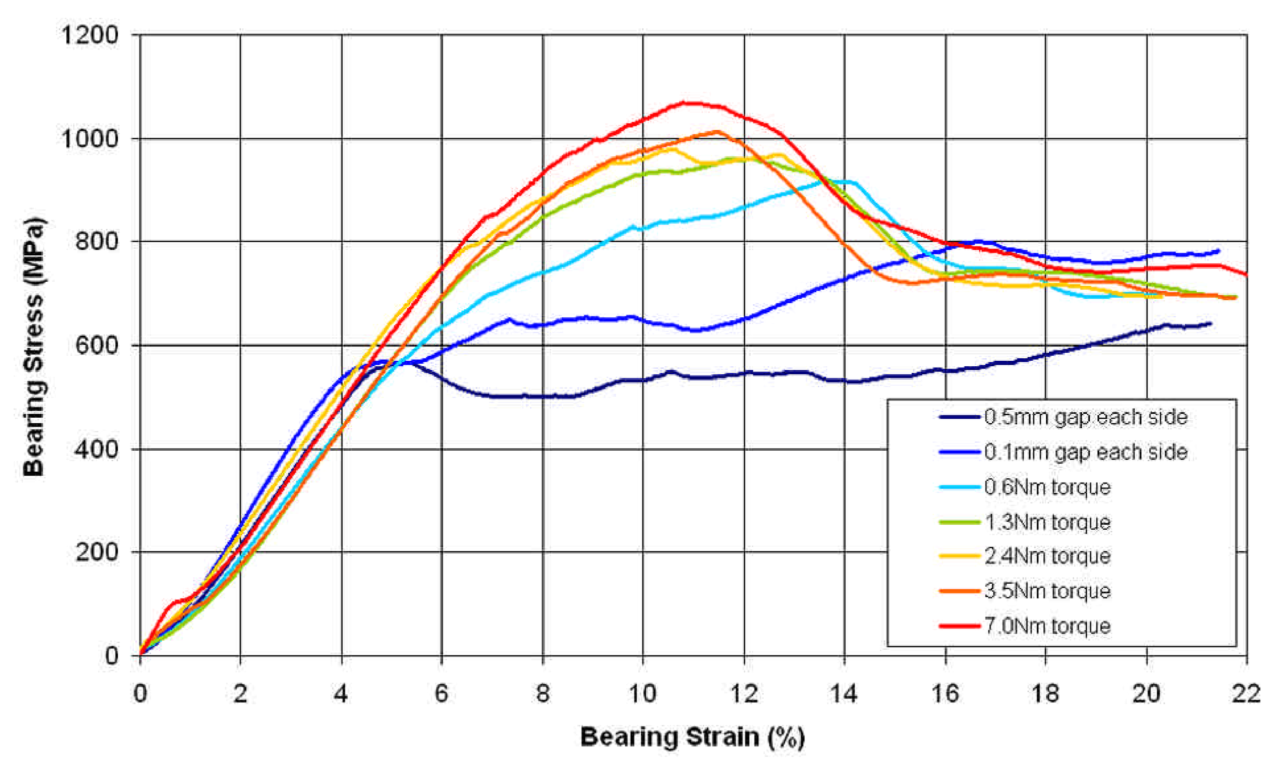






3. Offset compression failure at the washer edge.

Bearing Stress vs Bearing Strain: Typical Curve for Each Constraint Condition



Conclusions

The type and level of local constraint (gap size or applied torque) has a significant influence on the measured Bearing Strength and observed failure mode.

- For gaps between 0.5mm and 1.0mm, the gap size does not influence initial failure loads. However, once failure has initiated, debris filling the gap will increase the measured bearing strength leading to values that do not accurately reflect pin bearing behaviour.
- For torque values above 1.3Nm, there is a slight but steady increase in bearing strength with increasing torque.
- For torque values between 0Nm and 1.3Nm, bearing strength increases rapidly with increasing torque.

Sufficient data has now been generated to support analysis of the effect of end-of-life torque on bearing strength in composite aircraft structures.

23 September 2004

AIRBUS