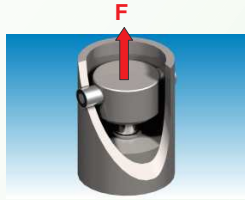


FATIGUE DAMAGE ANALYSIS OF A STEEL – COMPOSITE HYBRID PIN

Andrea Avanzini, Giorgio Donzella, Angelo Mazzù – Dipartimento di Ingegneria Meccanica, Università degli Studi di Brescia, Italy

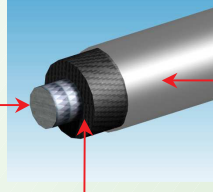
Vanni Zacchè, SIG-Simonazzi, Parma, Italy

Case of study: a reaction pin in a pressurisation device for food industry



Target life: 3×10^6 cycles
with $F_{max} = 100$ kN

29 NCDV 13
steel core



CFRP multilayer composite

NC 35 M1 W
steel bush

- Two CFRP-bush coupling solutions:
1. press – fitted bush
 2. epoxy – based adhesive bush bonding

Fatigue tests

Test parameters

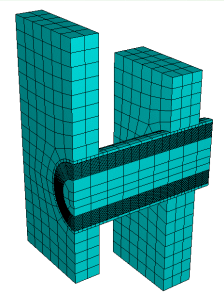
- Sinusoidal loading
- Loading factor $R=0.1$
- Frequency: 5 Hz
- Load levels:
100, 120, 135, 150 kN

Measured parameters:

- Load F by load cell;
- Maximum axial strain by strain gauges;
- Maximum displacement by LVDT



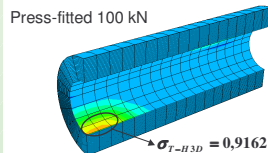
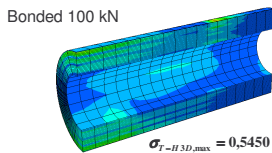
Numerical model



A FEM model was introduced
for evaluating:

1. the composite stiffness
from the total experimental
stiffness;
2. maximum strain and Tsai-
Hill stress in the composite
as a function of the
composite stiffness;
3. bush stresses as a function
of the composite stiffness

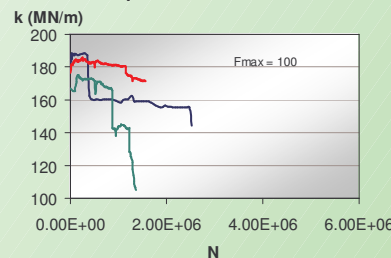
Tsai-Hill stress: the press – fitted specimens were more stressed
since the early cycles



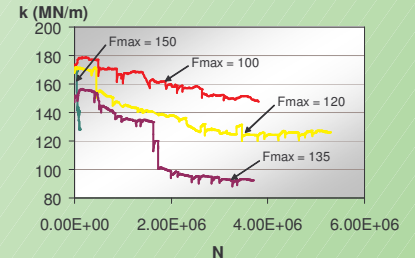
$$\sigma_{T-H3D}^2 = \left(\frac{\sigma_1}{F_1} \right)^2 - \left(\frac{\sigma_1 \sigma_2}{F_1^2} \right) + \left(\frac{\sigma_2}{F_2} \right)^2 + \left(\frac{\sigma_4}{F_4} \right)^2 + \left(\frac{\sigma_5}{F_5} \right)^2 + \left(\frac{\sigma_6}{F_6} \right)^2$$

Fatigue tests results

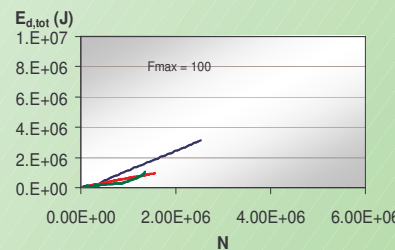
Press-fitted specimens: stiffness loss



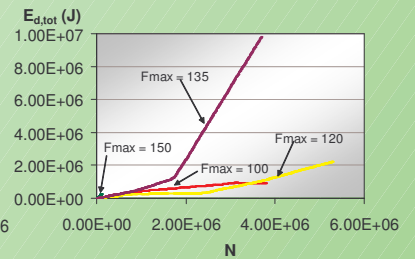
Bonded specimens: stiffness loss



Press-fitted specimens: dissipated energy

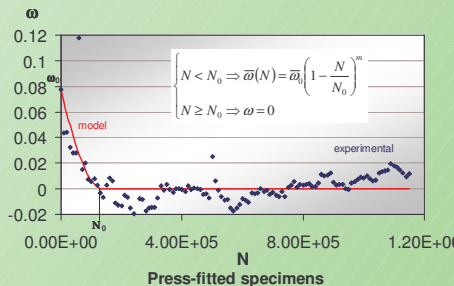


Bonded specimens: dissipated energy

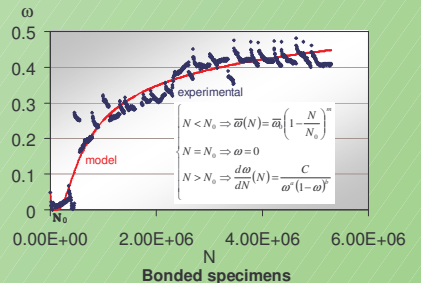


Damage models for CFRP (100 kN)

Press-fitted specimens

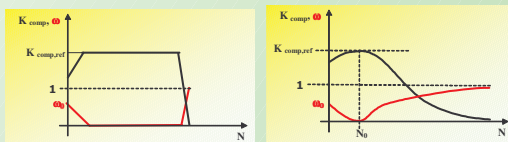


Bonded specimens



$$k_{comp}(N) = \text{composite stiffness after } N \text{ cycles}$$

$$\omega(N) = 1 - \frac{k_{comp}(N)}{k_{comp,ref}} = \text{composite stiffness loss parameter}$$



“Sudden death” model

“Wear out” model

$$\text{Composite strain failure index: } r = \frac{\varepsilon_{comp,max}(N)}{\varepsilon_{comp,lim}}$$

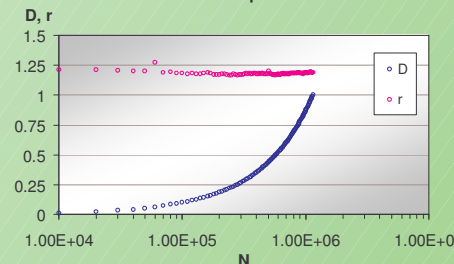
Sines parameter for the bush:

$$\delta_{Sines}(N) = \frac{0,45 \cdot \sigma_{Mixes}(N) - 0,7071 \cdot \sigma_p(N)}{\sigma_{FA}}$$

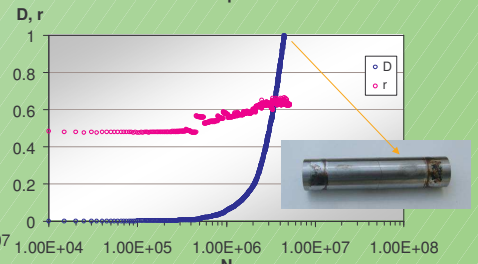
Cumulative damage for the bush:

$$D_{tot}(N) = \frac{1}{N_{FA}} \int_{N_R}^N (\delta_{Sines})^{-1/m} dn$$

Press-fitted specimens



Bonded specimens



Critical conditions for the CFRP since
the early cycles ($r > 1$);

CFRP far from failure condition: the bush
fails first;

Agreement between the models and experimental results