# BURST PRESSURE (HOOP TENSILE STRENGTH) OF COMPOSITE CYLINDERS USING ELASTOMERIC INSERTS

ICCM 23
INTERNATIONAL CONFERENCE ON COMPOSITE MATERIALS
BELFAST 2023
30 JULY – 4 AUGUST

M. Madrid[1,*], J. H. S. Almeida Jr.[2], T. V. Lisbôa[3], C. B. Azevedo[1], R. Marczak[1], and S. C. Amico[1]

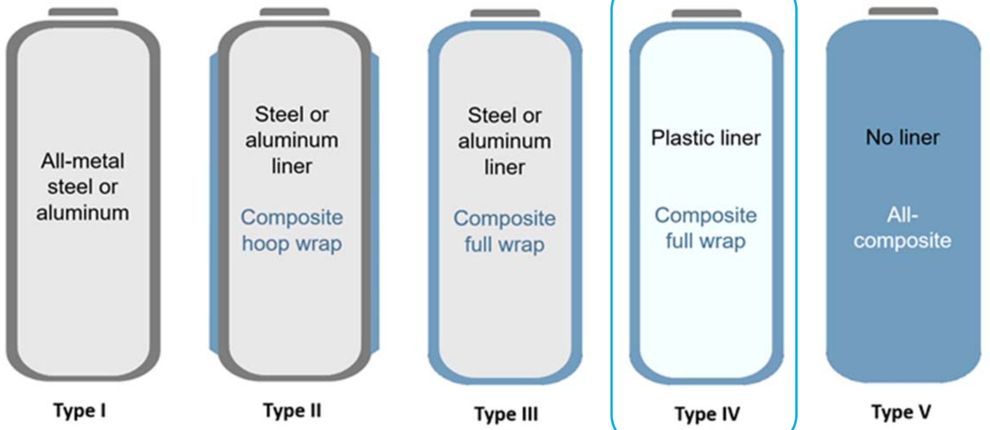
[1] PROMEC, Federal University of Rio Grande do Sul, Porto Alegre, Brazil

[2] School of Mechanical and Aerospace Engineering, Queen's University Belfast, Belfast, UK

[3] Leibniz Institute of Polymer Research, Dresden, Germany

*matheusmadrid@gmail.com

- Pressure vessels:

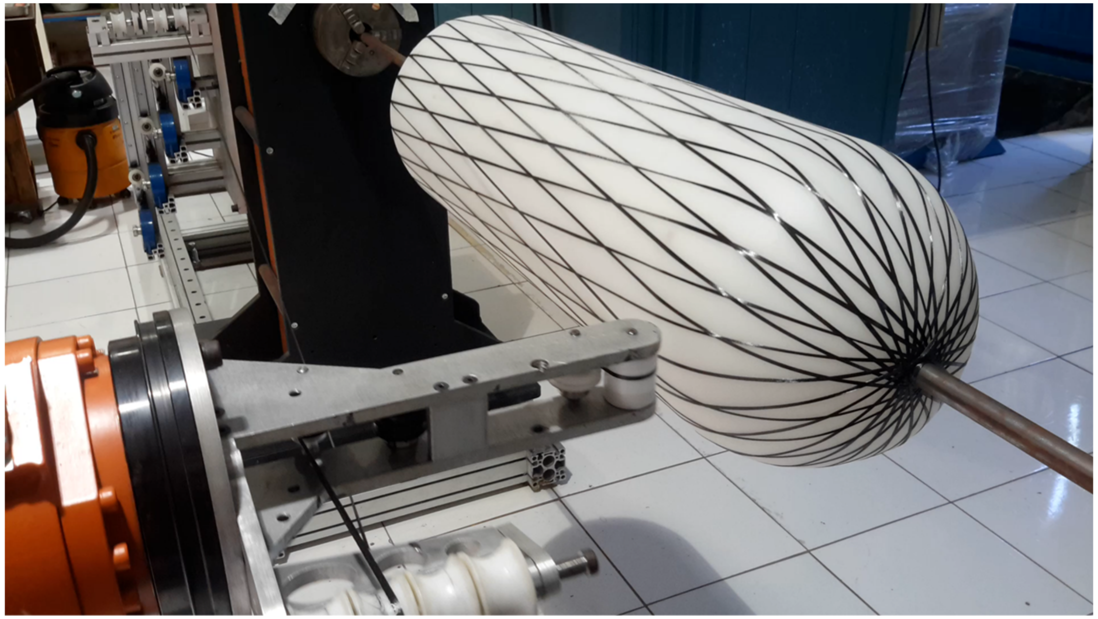



- Applications:




- **Filament winding:**

Tailored strength and stiffness by adjusting the winding angle/pattern/ number of layers.

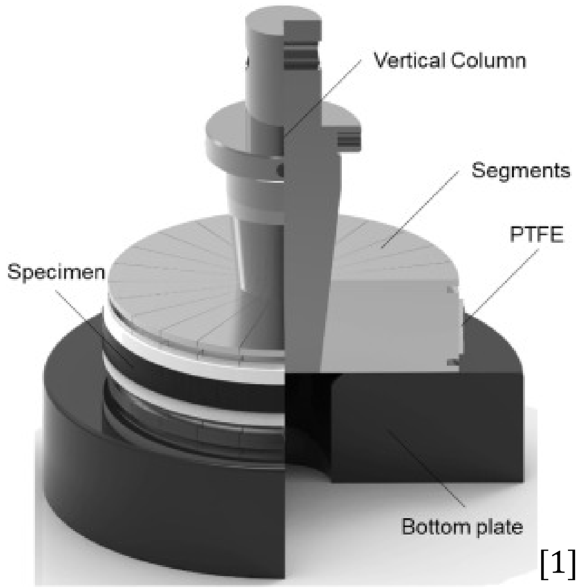


- ⬆ Automation
- ⬆ Fiber positioning accuracy
- ⬆ Fiber volume fraction
- ⬇ Void content

• **Testing:**

Fluid-based pressurization


Stretching of a ring specimen




[1]


[2]


[1] Kim, W. T., & Kim, S. S. (2020). Design of a segment-type ring burst test device to evaluate the pressure resistance performance of composite pressure vessels. *Composite Structures*, 242.
[2] Zhao, Y., *et al.* (2021). Split-disk test with 3D Digital Image Correlation strain measurement for filament wound composites. *Composite Structures,* 263.

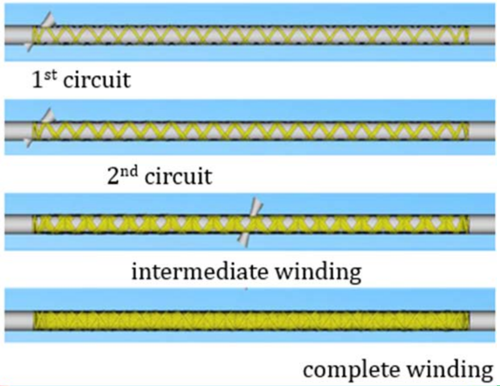
## OBJECTIVE

**To assess the use of the compressed elastomer method for testing internal pressure of filament-wound cylinders/tubes**

- **Specific objectives:**
  - ✓ To assess the mechanical response of cylinders for different winding angles, including the hoop tensile strength (*burst pressure*) and modulus;
  - ✓ To identify advantages and limitations of the method for testing FW cylinders and to provide recommendations for the testing of similar structures.

- Cylinder manufacturing

Carbon-epoxy towpregs




Kuka robot with MFTech system. Stainless-steel mandrel Ø 50.8 mm,

Oven with air circulation for 45 min @140 °C

Length: 110 mm
5 specimens each for: ±35°, ± 45°, ± 55°, ± 75°, ± 90°

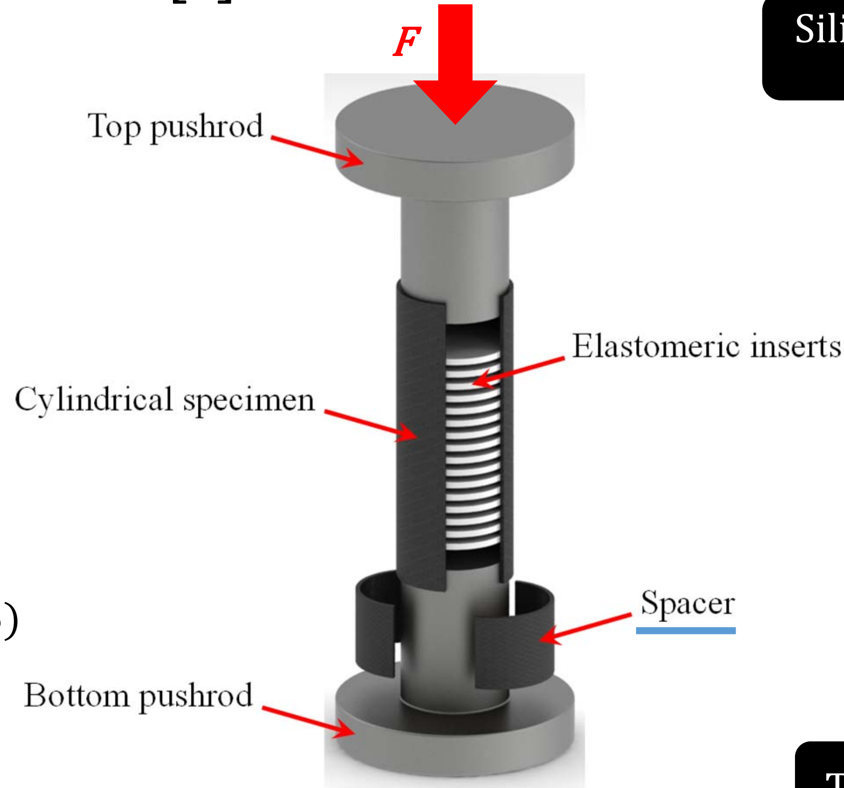
Material → Design → Winding → Curing → Sampling


CadWind® software

Testing

- **Compressed elastomer test method [3]**

Pushrods


Silicone discs
(many)

50 Shore A
3 mm thick

Talcum powder

- **Dimensioning [4]**

$$\beta = \sqrt[4]{\frac{3(1-\nu^2)}{r_i^2\, t^2}}$$

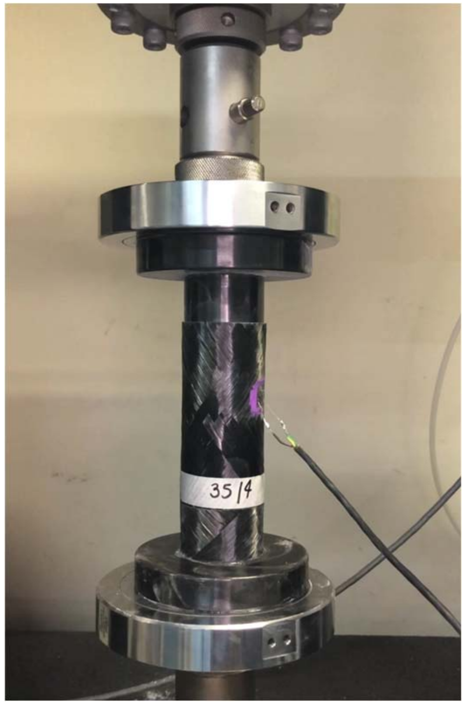
$\nu$: Poisson's ratio (0.5)
$r_i$: inner radius
$t$: wall thickness

Pressurized length $\geq 9/\beta$
Unpressurized ends $\geq 3{,}5/\beta$

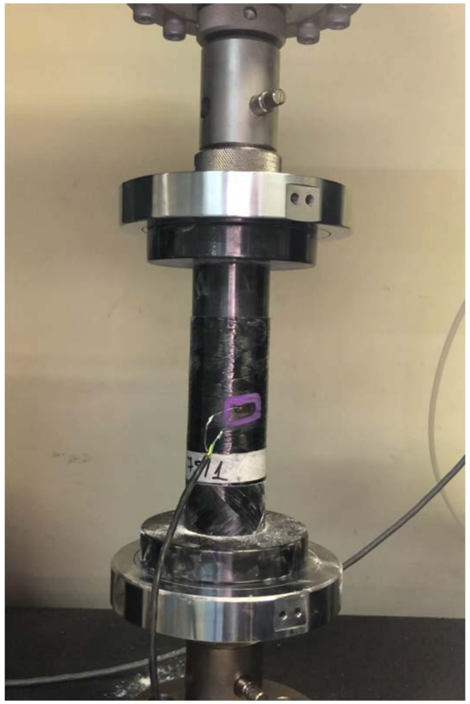
[3] ASTM C1819-21 - Hoop Tensile Strength of Continuous Fiber-Reinforced Advanced Ceramic Composite Tubular Test Specimens at Ambient Temperature Using Elastomeric Inserts
[4] Mosley, K. (1982). The stressing for test purposes of materials in tubular form using elastomeric inserts — experimental and theoretical development. *Proc. of Inst. of Mechanical Engineers*, 196.

- Instron universal testing machine – 100 kN load cell.
- Displacement rate: 10 mm/min.

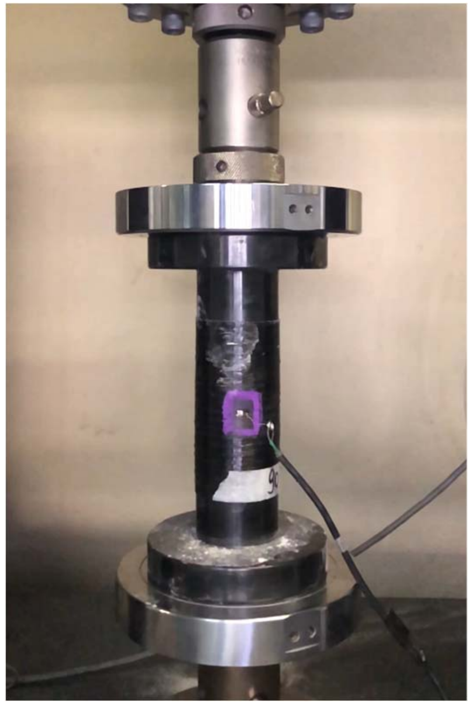
±35°




±75°

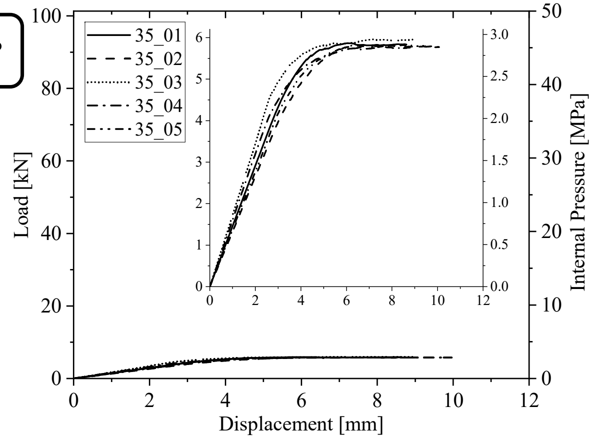


±90°

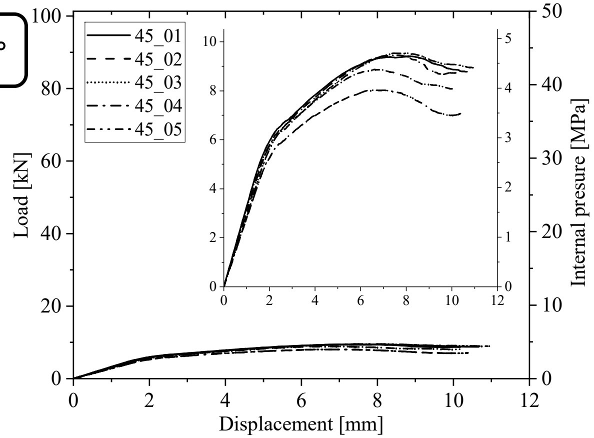


- Load × displacement

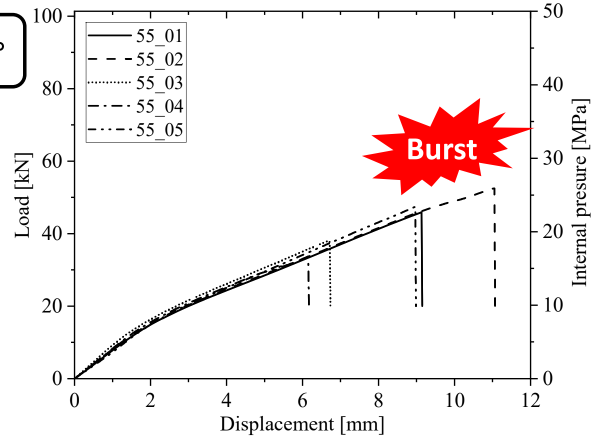
±35°



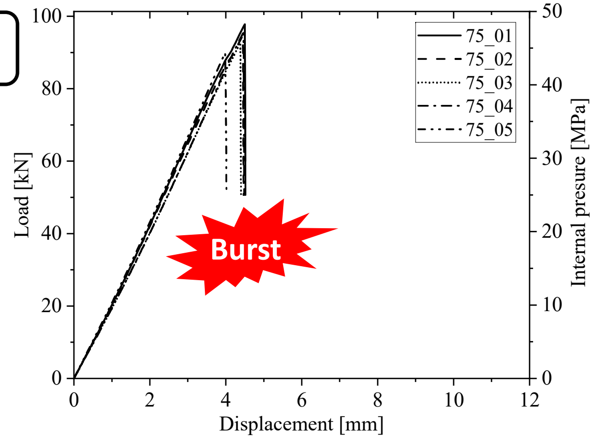

±45°



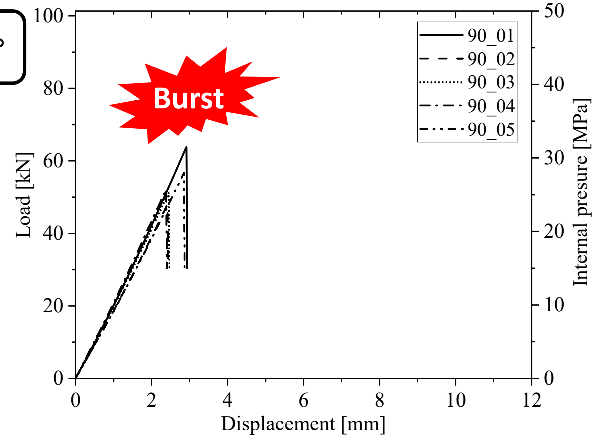

±55°




±75°




±90°




*Equivalent internal pressure:*

$$p = \frac{F}{\pi r_i^2}$$

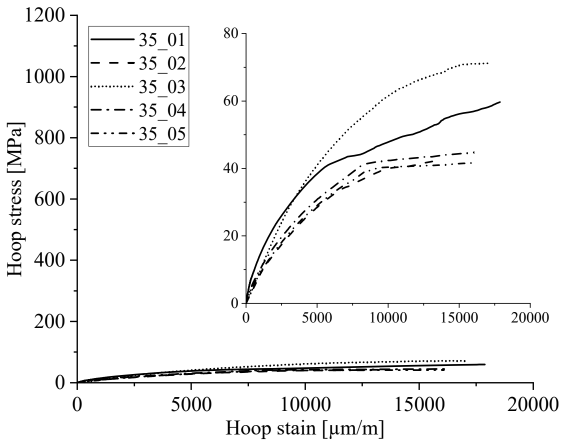
*where: $F$ is the axial load, $r_i$ the inner radius of the cylinder.*

- Typical fracture morphologies

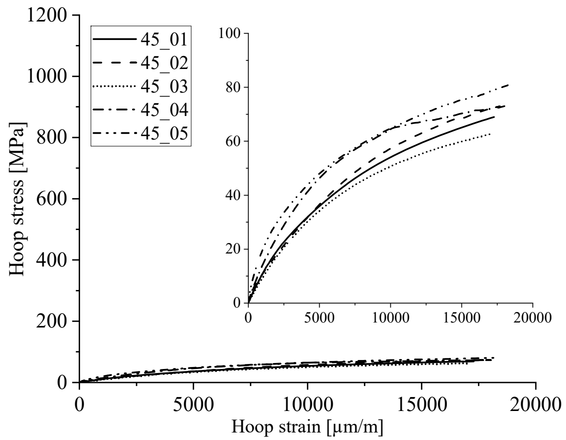
±35° ±45° ±55° ±75° ±90°

- **Hoop stress × hoop strain**

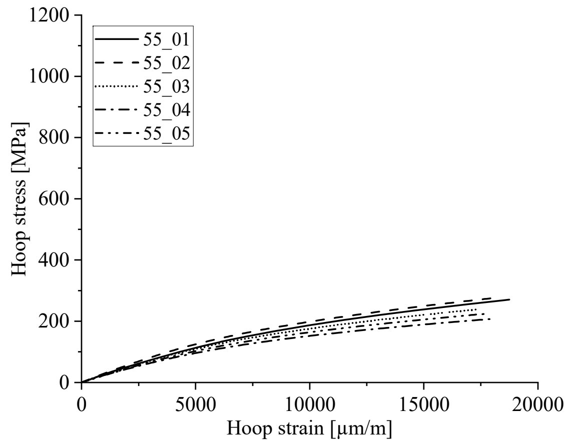
±35°



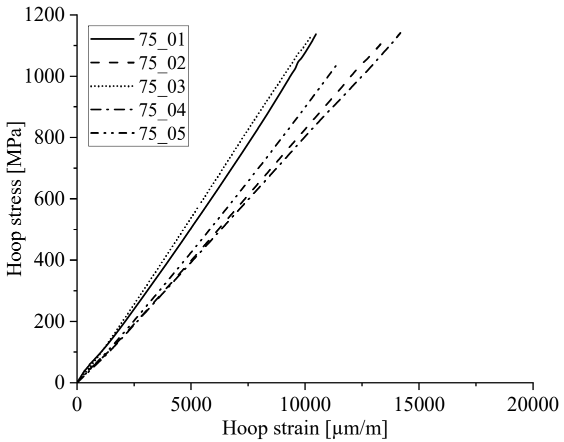

±45°



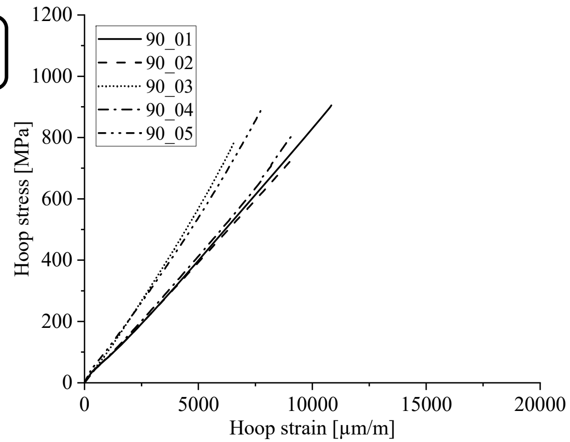

±55°




±75°




±90°




*Hoop tensile stress:*

$$\sigma_h = \eta_m \, p \frac{2\, r_i^2}{\left(r_o^2 - r_i^2\right)}$$

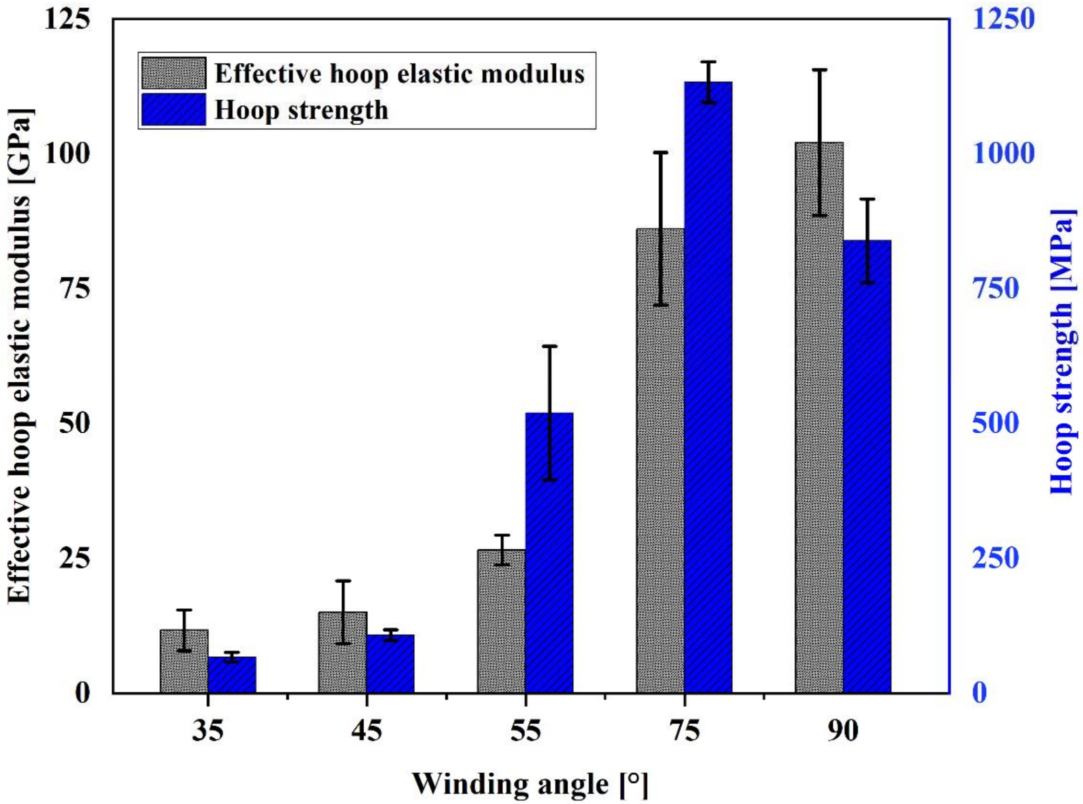
*where: $\eta_m$ is the maximum stress factor [4], $r_o$ the outer radius of the cylinder.*

- Effective mechanical properties in the hoop direction

*Effective modulus of elasticity (hoop direction):*

$$E = \frac{\Delta\sigma_h}{\Delta\epsilon_h}$$

*slope of the stress × strain curve in the linear region (1000-2000 μm/m or 500-1000 μm/m)*



- **The compressed elastomer method enabled:**
  - Good load control.
  - Easy assembly/disassembly.
  - Reduced time and cost requirements.
  - Less critical problems in comparison to fluid pressurization testing (safety and seals).
  - Evaluation of tubes, as opposed to ring specimens.

- **Regarding the mechanical behavior of the FW cylinders:**
  - Greater load capacities for higher WA (up to 75° in relation to the cylinder axis).
  - 35° and 45° failed progressively, primarily by interlaminar mechanisms.
  - 55° failed by wall fracture in the pressurized region and 75° failed explosively.
  - ≈90° failed parallel to the fiber orientation due to axial bending loads at the non-pressurized ends.

# Acknowledgements

UFRGS
FAPERGS
CAPES
CNPq

# Thank you!

Q A

amico@ufrgs.br

ICCM 23
INTERNATIONAL CONFERENCE ON
COMPOSITE MATERIALS
BELFAST 2023
30 JULY – 4 AUGUST