Structural integrity under extreme loads

Topic: Advanced Modelling of Composite Structures

TITLE: COPV Stress Analysis: A Progressive Approach

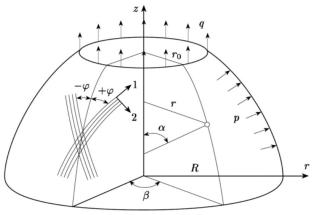

Figure 4.1 A Shell of Revolution

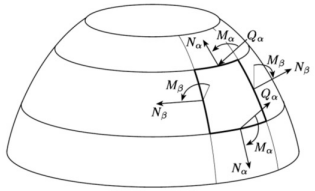

Figure 4.5 Stress Resultants and Couples Acting on the Shell Element

RESEARCH BACKGROUND:

H2 is becoming increasingly appealing as an energy carrier for heavy-weight fuel-cell electric vehicles (FCEV). Due to the low volumetric energy density of H2, its use in FCEVs is possible only when stored at extremely high pressures (350 bar and 700 bar). Composite pressure vessels are the natural choice for a light-weight, high strength design.

Aim of this thesis is the literature analysis of the methods currently available for COPV stress analysis, their classification, reproduction, and critical comparison.

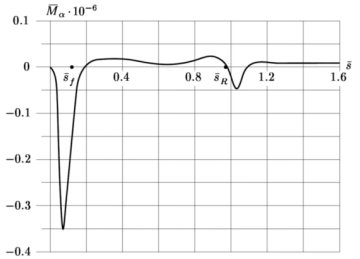

Figure 4.38 Distribution of the Normalized Meridional Bending Moment, $\bar{M}_\alpha = M_\alpha/(pR^2)$, over the Shell Meridian

RESEARCH ACTIVITIES:

1. Literature review on the analytical.
2. Model build up: Analytical → Numerical (Simple → FEM)
3. Detailing of distinguishing characteristics of each modelling approach for stress analysis accuracy, and critical judgement.

$$B_{11} = \sum_{i=1}^{k} \bar{h}_i \left(\bar{E}_1 \cos^4\varphi_i + \bar{E}_2 \sin^4\varphi_i + 2\bar{E}_{12} \sin^2\varphi_i \cos^2\varphi_i \right)$$

$$B_{12} = \sum_{i=1}^{k} \bar{h}_i \left[\bar{E}_1 \nu_{12} + (\bar{E}_1 + \bar{E}_2 - 2E_{12}) \sin^2\varphi_i \cos^2\varphi_i \right]$$

$$B_{22} = \sum_{i=1}^{k} \bar{h}_i \left(\bar{E}_1 \sin^4\varphi_i + \bar{E}_2 \cos^4\varphi_i + 2\bar{E}_{12} \sin^2\varphi_i \cos^2\varphi_i \right)$$

$$\bar{E}_{1,2} = \frac{E_{1,2}}{1 - \nu_{12}\nu_{21}} \qquad E_{12} = 2G_{12} + \bar{E}_1\nu_{12}$$

$$\sigma_1 = \bar{E}_1 \frac{pR}{2Bh} \left[(B_{22} - 2B_{11})(\cos^2\varphi + \nu_{12}\sin^2\varphi) + (2B_{11} - B_{12})(\sin^2\varphi + \nu_{21}\cos^2\varphi) \right]$$

$$\sigma_2 = \bar{E}_2 \frac{pR}{2Bh} \left[(B_{22} - 2B_{11})(\sin^2\varphi + \nu_{21}\cos^2\varphi) + (2B_{11} - B_{12})(\cos^2\varphi + \nu_{21}\sin^2\varphi) \right]$$

$$\tau_{12} = G_{12} \frac{pR}{2Bh} (2B_{11} + B_{12} - B_{22}) \sin 2\varphi$$

METHODOLOGY: Numerical - Analytical

DURATION: 6-9 months

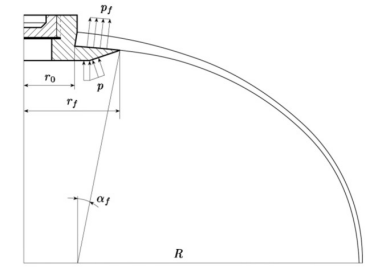

Figure 4.18 Metal Fitting Working in Contact with a Composite Shell

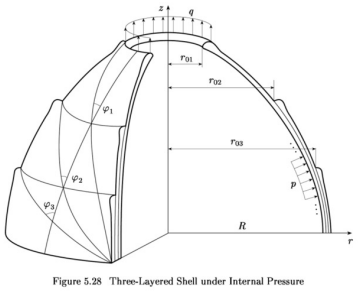

Figure 5.28 Three-Layered Shell under Internal Pressure

CONTACTS:

andrea.manes@polimi.it
marco.giglio@polimi.it