Analytical Solution for the Design of Spoolable Composite Tubing

J. Michael Starbuck, Ph.D.
Oak Ridge National Laboratory*
Oak Ridge, Tennessee 37831

Abstract

In oilfield spoolable tubing applications, polymer composite materials offer advantages over traditional tubing materials in terms of reduced weight and improved fatigue life. The many different loading scenarios that spoolable tubing is designed to withstand include bending strain, axial force, internal and external pressure, elevated temperature, and combinations of these loads. For the most part, these loads can be treated as axisymmetric with the exception of the bending strains. The bending strains are induced when wrapping the tubing around a large diameter spool, hence the terminology spoolable tubing. Design trade-offs occur because of the multitude of load cases and resulting multi-axial stress states promoting the need for efficient and accurate design tools. Solutions based on classical laminated shell theory are accurate for thin-wall cylinders but solutions for the three-dimensional stresses in thick-wall cylinders are needed for the typical tube diameters and wall thicknesses being considered for spoolable tubing. A closed-form solution is presented for determining the layer-by-layer stresses, strains, displacements, and first-ply failure in thick laminated composite cylinders subjected to axisymmetric and non-axisymmetric loads. The formulation is based on the theory of anisotropic elasticity and a state of generalized plane deformation along the axis of the cylinder. Parametric design trade studies can be easily and quickly computed using this closed-form solution, and a computer program that was developed for performing the numerical calculations is described.

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