

## **Closed - form expressions for the optimum winding angles of fibres in laminated cylindrical pressure vessels subjected to internal pressure, axial force and torque**

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The present paper aims at deriving closed-form expressions for the optimum winding angles of fibres in laminated cylindrical pressure vessels subjected to internal pressure, axial load and torque. To achieve this goal, the state of the stress on the surface of the vessel is represented by a composite layered element subjected to general in-plane loading.

The symbolic software Mathematica is used to formulate, solve the optimization problem and to generate the data of optimum fibre angles for different loading combinations. The generated data is fitted with simple polynomial expressions capable of accurately predicting the optimum winding angles.

The optimization is performed for three candidate composite materials: graphite/epoxy, glass/epoxy, and Aramid/epoxy laminates.