Failure analysis and optimal design of thick-walled composite pipes under combined loading

M. Menshykova[1*], T. Wang[1], O. Menshykov[1]

[1] School of Engineering, University of Aberdeen, King's College, AB24 3UE, Aberdeen, Scotland UK, m.menshykova@abdn.ac.uk

The main advantages of composite materials are their high stiffness, good strength-to-weight ratio, and excellent corrosion resistance. However, the disadvantages of lower performance data, regulatory requirements, complex design procedures limit the industrial implementation of composites.

In the current study we present a comprehensive failure analysis of thick-walled multi-layered filament wound pipes subjected to combined loading that includes bending.

The finite element model is developed to carry out the stress and failure analysis, and the model is validated by the comparison with the three-dimensional elasticity solution, and the results obtained using the laminated plate theory for different modes of the loading (internal and external pressure, axial and shear loading, torsion and bending) [1–5] .

It is worth noting that the analysis shows the applicability of the laminated plate theory approach for composite pipes under bending with 0^0 and 90^0 degrees winding angles only (with some additional limitations).

It could be concluded that the developed finite element model and three dimensional elasticity solution (taking the extensional shear couplings into account) shall be used for failure analysis and optimal design of multi-layered composite pipes under pure bending and consequently under combined loading.

The detailed parametric analysis (including effects of fibres orientation, stacking sequence, magnitude of loading and layer thickness on the structural performance of the pipe) is given, and it is followed by the failure analysis and optimal design recommendations based on the modified Tsai-Hill failure coefficients.

In addition, to find the suitable fibre angles for the multi-layered pipes under loading the safety zones were introduced. Safety zones show the allowable angles for the particular lay-up and magnitude and direction of the loading, providing a wider range of options, making the design process of the filament wound pipe faster and more reliable [6].

References

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