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COUPLED THERMOMECHANICAL ANALYSIS OF THERMOPLASTIC COMPOSITE PIPE BY FEM SIMULATIONS

Igor A. Guz[1]*, James C. Hastie[2] and Maria Kashtalyan[3]

[1] School of Engineering, University of Aberdeen, Scotland, AB24 3UE, i.guz@abdn.ac.uk
[2] School of Engineering, University of Aberdeen, Scotland, AB24 33UE, r03jh15@abdn.ac.uk
[3] School of Engineering, University of Aberdeen, Scotland, AB24 3UE, m.kashtalyan@abdn.ac.uk

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Thermoplastic composite pipe (TCP), consisting of fibre-reinforced thermoplastic laminate with inner and outer thermoplastic liners, is a lightweight spoolable pipe solution on the cusp of deployment in deepwater riser applications. During operation the pipe is subjected to pressure and tension in combination with large through-wall thermal gradient arising from the mismatch between temperatures of the pipe contents and surrounding ocean [1]. In this work, a 3D finite element (FE) model is developed to analyse stress-based failure of TCP subjected to load combinations representative of deepwater operation. Temperature-dependent material properties are considered for homogeneous plastic and composite. Special attention is paid to increasing internal temperature, which may vary drastically while the surrounding ocean temperature will remain near constant. Different laminate stacking sequences are analysed and a multi-angle stack is shown to be effective for both pressure- and tension-dominated scenarios. The inner plastic liner exhibits a marked rise in failure coefficient with increasing temperature but becomes less temperature-sensitive under sufficient mechanical loading.

TCP is subjected to large bending moments when wound on its storage spool, potentially in different thermal environments. The bending of TCP at reduced and elevated temperatures is also investigated by FE modelling. Temperature change causes deviation from the symmetry expected between stresses at top and bottom of the pipe. The results reveal that TCP can be optimised for spooling by orientating unidirectional layers at an ‘intermediate’ angle that avoids excessive fibre and transverse stresses that develop in low and high angle layers respectively. Practical benefits are demonstrated by quantifying minimum bending radii for optimal and sub-optimal configurations in line with the industry TCP design standard [2].

It is clear that optimising the laminate for operation will adversely affect spooling capacity and vice-versa, i.e. TCP intended for extreme in-service conditions will require large spools. Future work can be aimed at scrutinising the physical accuracy of lamina failure criteria with a view to reducing the required safety factors specified in current design guidelines.

REFERENCES

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