STRESS ANALYSIS OF NON-CONVENTIONAL CROSS-SECTIONAL COMPOSITE PIPES

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ABSTRACT

Composite materials such as fiberglass reinforced thermoset plastics have been used in piping systems for over 40 years now for their advantage in lower weight with high strength and stiffness values. Most composite pipes are manufactured by filament winding. Filament winding is the process by which fibers are layered onto a rotating mandrel, building the wall of the pipe layer-by-layer. This is an effective means to produce a pipe with good mechanical properties because the fibers are in tension as they are layered onto the pipe, and the operator is able to control the angle they are layered at, and can therefore optimize the final product. However, current methods of filament winding are not conducive to manufacture a pipe with a non-circular cross-section. Components, such as these are produced by the hand lay-up method, in which sheets of fabric are wetted with resin and wrapped by hand, layer-by-layer. This method is time consuming, labor intensive, and does not produce an end-product with the same mechanical quality as does filament winding.

Filament winding can produce components of unconventional shape, but the process requires specialized equipment and is typically reserved for high-cost aerospace components. The major obstacle to filament winding of the pipes of nonconventional cross-sectional shapes is the impracticality of winding large flat faces and the uncontrollable curing stresses arising due to the curing process of the composite pipe. Convex structures are ideal for winding because the tension and the winding angle of the fiber are kept relatively constant by the uniform convex shape of the mandrel onto which the fibers are drawn. In order to incorporate the same level of confidence in the winding of pipes with flat faces, the kinematics for rotating bodies of the nonconventional shapes must be evaluated and the filament winding process must be mechanically controlled to overcome the hindrances inherent with winding flat-faced structures. In this research new methods have been developed to construct composite pipes of unconventional shapes, which can adequately support design loads and remain cost effective for industrial use.

The objective of selecting such non-conventional cross-sections is to increase the utility of pipes where space is a constraint. The analysis has been performed keeping in mind, the usefulness and the necessity of using pipe-bundles. This allows for the use of multiple pipes within the available space resulting in versatility and economy.

An analytic and numerical study was also conducted to investigate the elastic and failure behavior of composite laminated pipes of non-conventional cross-sectional pipes under internal pressure and torsion. Glass fibers reinforced in an epoxy resin matrix have been used for this analysis. The modeling was performed with Shell-99 element type, which has been used in similar work. [1] The various material properties such as the modulus of elasticity, shear modulus in the axial and hoop directions, and the Poisson’s ratio are obtained from the typical material properties and are used in the analysis. In our overall analysis the dependence of these material properties on the piping’s geometrical configurations have been taken into account. [2,3] The distribution of circumferential (hoop) stress and the variation of the peak hoop stress for different shapes such as triangular, rectangular, square, and circular have been studied. The concentration of the hoop-stress around the corners and the effects of fillet radii on the peak hoop stress have been studied. The variation of shear stress due to torsional loading has also been investigated for the above mentioned cross-sectional profiles of the pipe. [4]

Novel simulation techniques for the pipe loading processes are developed based on the Finite Element Method (FEM) of generally, a linear axi-symmetric problem for composite pipes. In this study, the established finite element software, namely ANSYS was used to predict the stresses arising in the pipes. The relationship between the applied internal pressure and peak hoop stress, torque and maximum shear stresses were obtained by numerical method. The analytical
model was developed based on the mechanics of composite materials and thin shell criteria. [5, 6]

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REFERENCES