AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
Design and Production Engineering

Modeling of Polymer Matrix Composite Pipes using Finite Element Analysis

A Thesis submitted in partial fulfillment of the requirements of the degree of

Master of Science in Mechanical Engineering

(Design and Production Engineering)

by

Ahmed Wagdy El-Desouki Abdel-Ghany

Bachelor of Science in Mechanical Engineering
(Design and Production Engineering)
Faculty of Engineering, Ain Shams University, 2010

Supervised By

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Cairo - (2016)

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Date: 01 June 2016

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Statement

This thesis is submitted as a partial fulfillment of Master of Science in Mechanical Engineering, Faculty of Engineering, Ain shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or a qualification at any other scientific entity.

Signature

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Ahmed W. Abdel-Ghany

Date: 01 June 2016

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Thesis Summary

Structural failure of Polymer Matrix composite pipes is investigated. The present work shows a numerical study for fiber reinforced polymer pipes produced by filament winding technique. The used combination of winding angles and type of reinforcement directly affect the strength of the pipe and consequently its performance. A progressive structural failure analysis is done for a four thin layered pipes oriented anti-symmetrically $[\pm Ø°]_2$ subjected to internal pressure using Finite Element Analysis. Three different composite structures are investigated in this study: E-glass fiber/epoxy, carbon fiber/epoxy and aramid fiber/epoxy. The implemented methodology can be further applied to other structure types.

Three different criteria are selected for the analysis: Tsai-Hill, Tsai-WU and Hoffman criteria. Finite Element Analysis results are verified using published experimental results for E-glass/epoxy for the range of winding angles from $[\pm 45°]_2$ to $[\pm 90°]_2$ using ANSYS Composite PrepPost. Boundary conditions are defined for the model, and further analysis is done to select the optimum element size for reasonable computational cost. The last ply failure technique is applied to determine the structural failure of pipes. Finite Element model shows a good correlation for experimental burst pressure values with an average error of 6.8%, 2.9% and -2.6% using Hoffman, Tsai-Wu and Tsai-Hill criteria respectively.

Analysis is done for the full range of winding angles from $[\pm 0°]_2$ to $[\pm 90°]_2$ for the three different selected types of composites. The optimum winding angle for the three types of composites is realized at $[\pm 55°]_2$ and a lowest value of burst pressure at $[\pm 0°]_2$. Analysis results show that the maximum burst pressure values for the three materials as 10.9, 25.5 and 29.4 MPa for E-glass/epoxy, aramid/epoxy and carbon/epoxy respectively. At a winding lay up

of $[\pm 0°]_2$ no significant effect is observed for changing the composite type where the three types show a burst pressure range from 0.6 to 1.3 MPa

Finally, recommended effective range of winding angles for E-glass fiber/epoxy are between $[\pm 15°]_2$ to $[\pm 90°]_2$ where the range of angles from $[\pm 0°]_2$ to $[\pm 15°]_2$ shows a drop in the burst pressure values compared with other winding angles. For carbon fiber/epoxy the recommended range exist between $[\pm 35°]_2$ to $[\pm 90°]_2$ and aramid fiber/epoxy between $[\pm 20°]_2$ to $[\pm 90°]_2$. The achieved Finite Element provides accurate predictions which allow the optimization of the composite pipe lay-up.

Key words: Burst pressure, Filament winding, Finite Element Analysis, Polymer matrix composites, Structural failure.

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