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Parametric Study on Stress Concentration Factors in Reinforced Tubular X-Joints Under Out-of-Plane Bending

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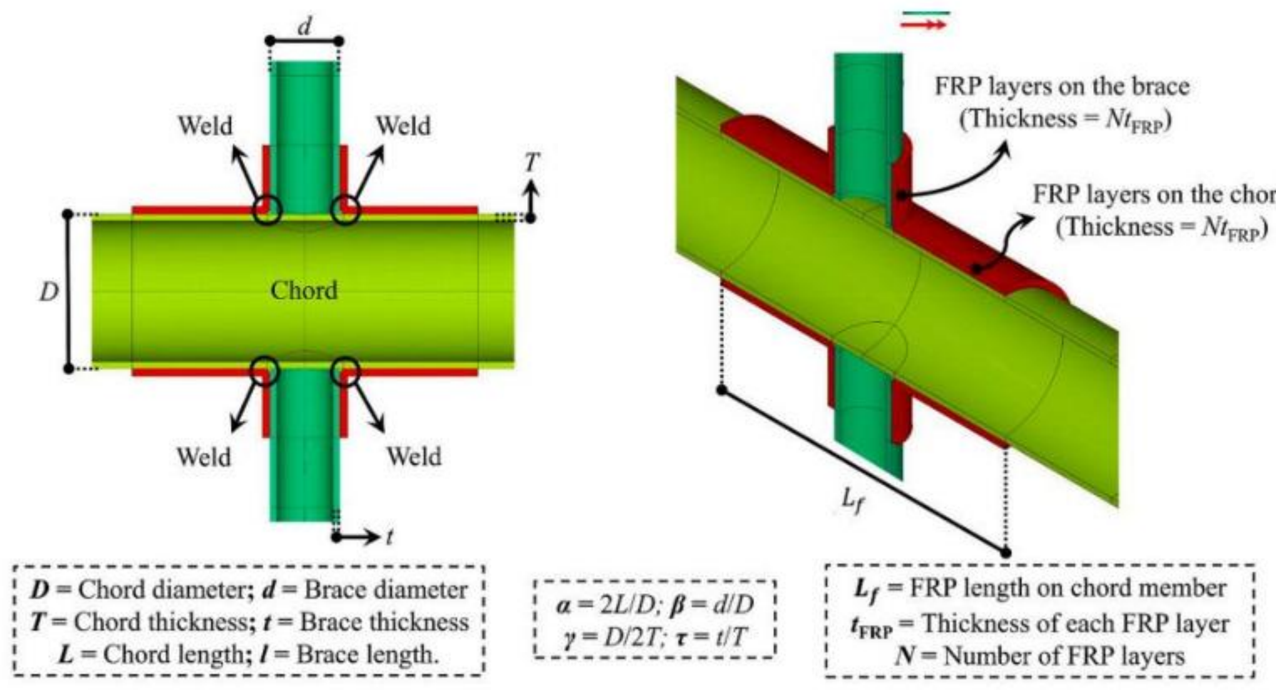
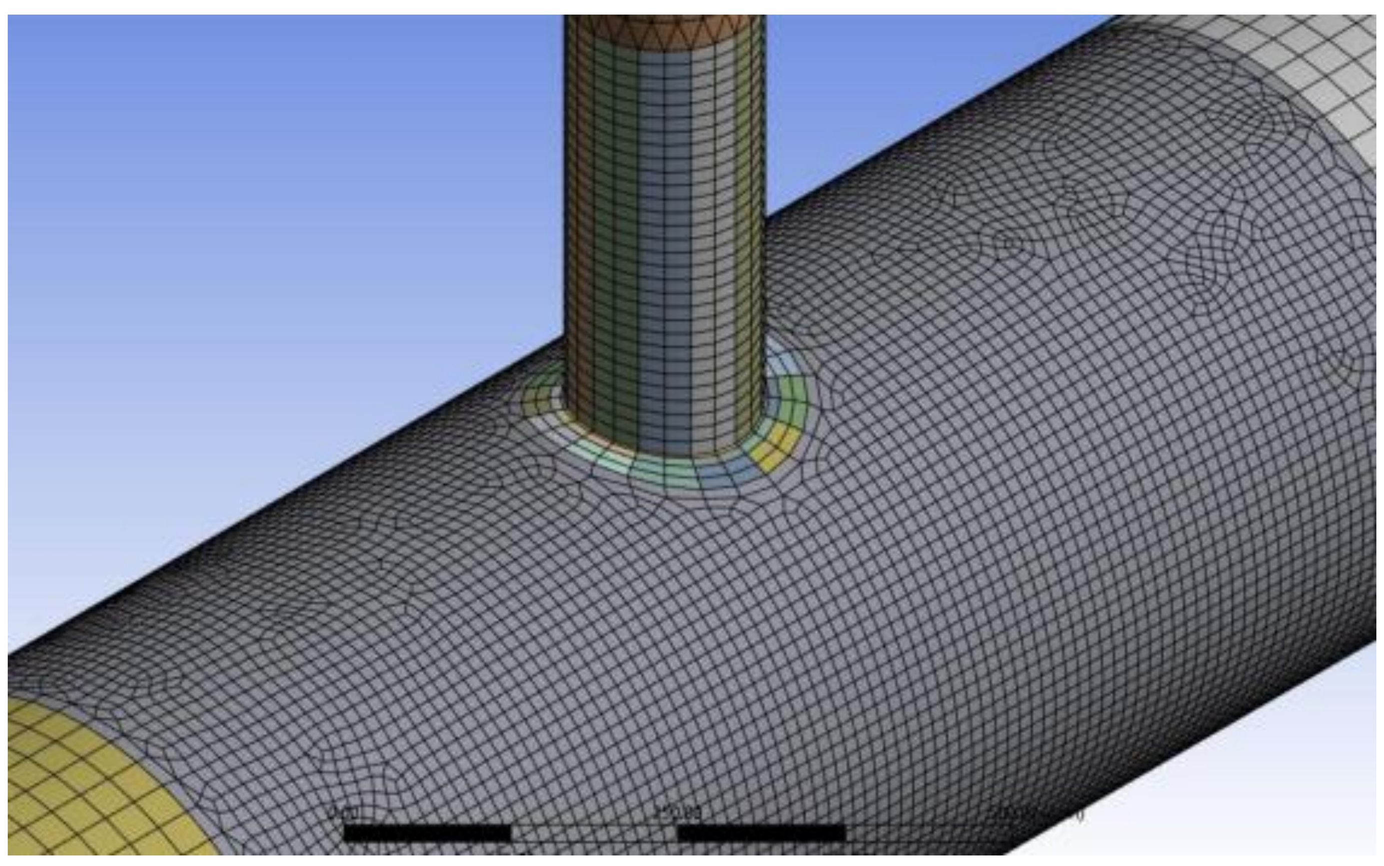
INTRODUCTION & AIM

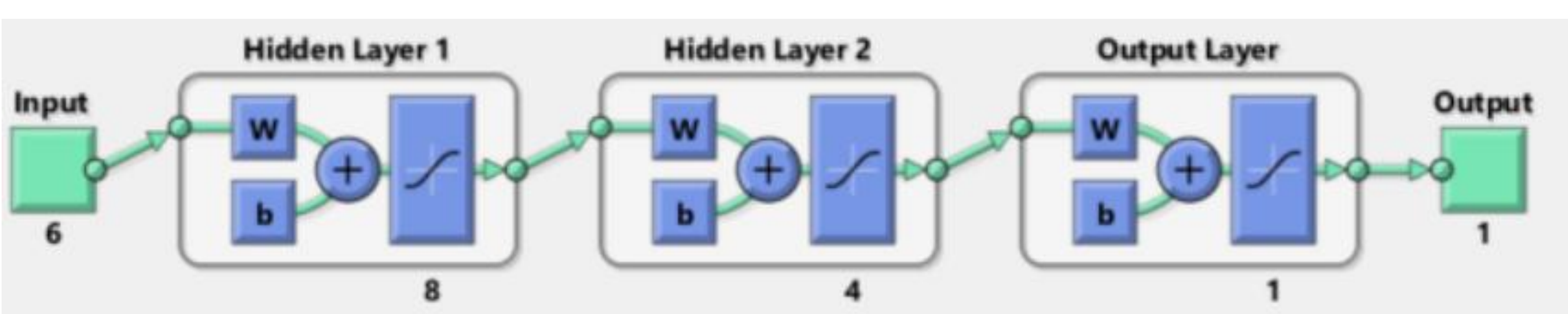
Offshore jacket-type platforms rely on tubular connections that are prone to fatigue failure due to localized stress intensities. While Fibre Reinforced Polymer (FRP) retrofitting improves fatigue life, existing prediction models often overlook the critical influence of the brace-chord intersection angle (θ). This project aims to bridge that gap by developing an Artificial Neural Network (ANN) model to accurately predict Stress Concentration Factors (SCFs) in FRP-reinforced X-joints under Out-of-Plane Bending (OPB), explicitly incorporating θ as a parameter.



METHOD

A validated Finite Element Analysis (FEA) model was developed in ANSYS Workbench 2024 R1. The study employed the IIW-recommended linear extrapolation method to extract Hot Spot Stresses (HSS). A full parametric study of 127 models was conducted, varying geometric parameters (β, γ, τ, θ) and reinforcement parameters (N, ζ). These datasets were used to train a Feed-Forward ANN in MATLAB (Levenberg-Marquardt algorithm) to map input parameters to SCF outputs.

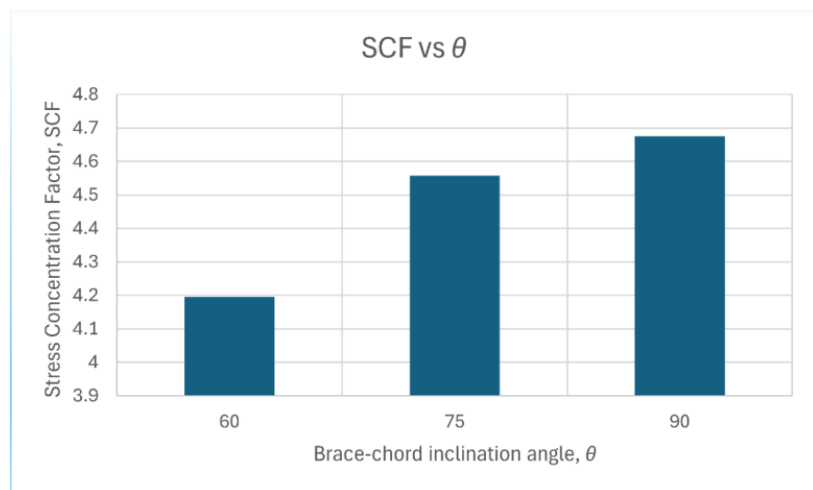


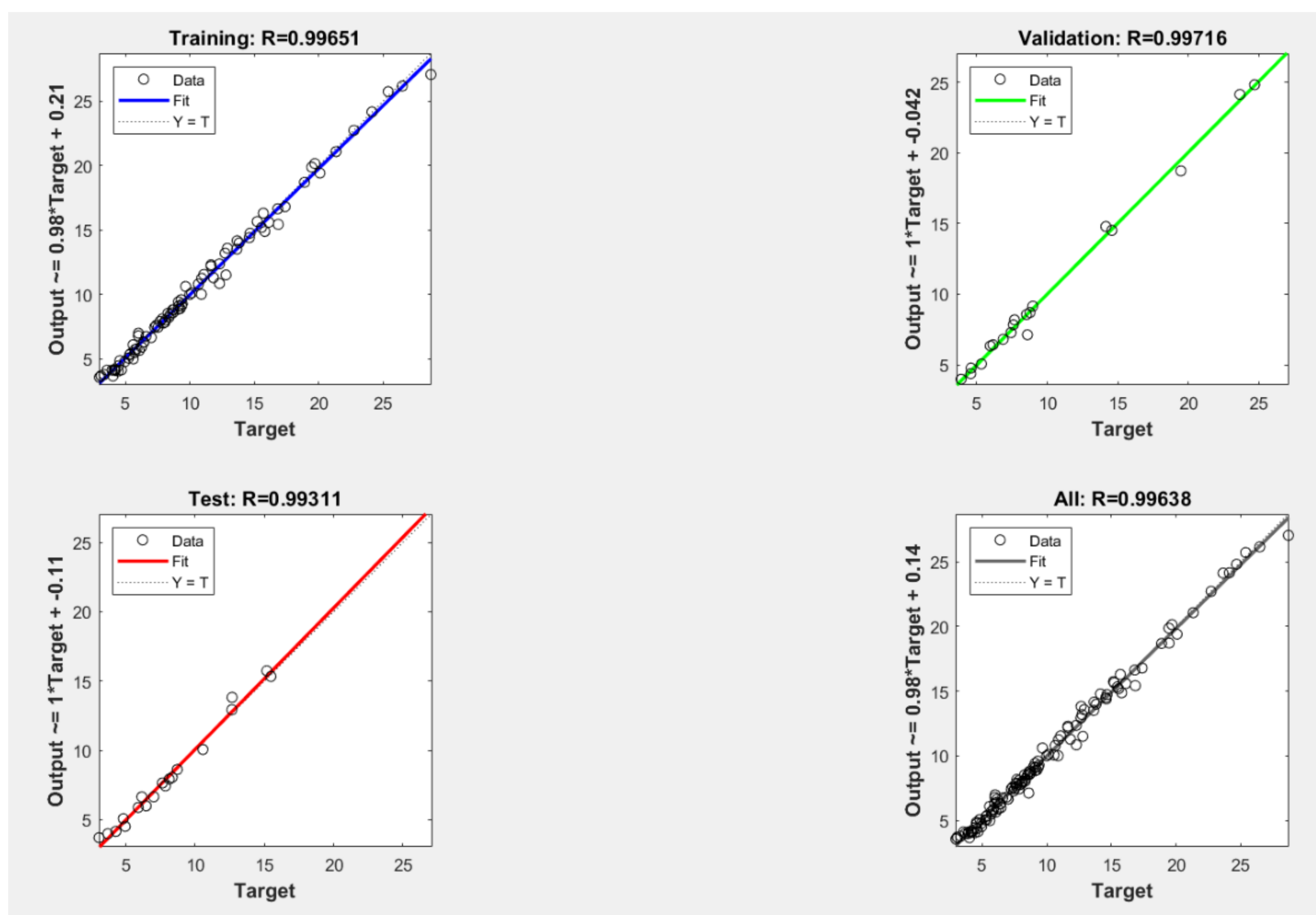


RESULTS & DISCUSSION

The parametric analysis revealed that geometric parameters significantly dictate stress distribution. Increasing the brace-to-chord diameter ratio (β) and chord slenderness (γ) raised the SCF by 84.14% and 61.15%, respectively. Conversely, FRP reinforcement proved highly effective; increasing the number of FRP layers (N) from 4 to 12 reduced the SCF by 38.29%.

Crucially, the study confirmed that steeper brace inclination angles (θ) resulted in a 10.25% reduction in SCF, validating the need to include this parameter in prediction models. The developed ANN model (6-8-4-1 architecture) achieved a regression coefficient R^2 of 0.996. External validation confirmed the model's robustness, with all predicted values falling within a ±10% deviation from FEA results.





CONCLUSION

This study successfully delivers a reliable, angle-inclusive SCF prediction model for FRP-reinforced X-joints. The results demonstrate that the brace-chord intersection angle (θ) is a significant parameter that should not be ignored in fatigue design. The developed ANN model offers a computationally efficient alternative to complex FEA simulations, providing a practical tool for optimizing the fatigue life of offshore structures.