Artificial Intelligence Based Prediction of Residual Stress Relief in Thick Aluminum Alloy Plates

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Abstract:
Thick 7000 series aluminum plates are widely used in aerospace and structural applications, but quenching can induce significant residual stresses, leading to distortion, cracking, and dimensional instability. Tensile stretching is an effective stress-relief method; however, conventional finite element method (FEM) simulations are computationally expensive for real-time manufacturing applications. This study investigates residual stress relief in thick 7055 aluminum alloy plates using FEM simulations and machine learning (ML). An extended FEM framework was employed to simulate water quenching and tensile stretching for plate thicknesses of 10–250 mm and stretching ratios of 1.0–4.5%. More than 9 million FEM-derived data points were used to develop Random Forest and XGBoost regression models for residual stress prediction. Results showed that plate thickness strongly affects residual stress, with intermediate thicknesses exhibiting the highest stress levels. Tensile stretching effectively reduced residual stresses, particularly at 2.0–2.5% strain. Random Forest achieved an R^2 of 0.9995 and RMSE of 1.3252 MPa, while XGBoost demonstrated strong generalization with an R^2 of 0.9783 and RMSE of 8.7259 MPa. The proposed FEM–ML framework provides an efficient approach for residual stress prediction and stress-relief optimization.

Keywords:
Aluminum alloy plates, Residual stress relief, Machine learning.