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GRAPH CONVOLUTIONAL NETWORKS FOR MODELING ELASTIC-PLASTIC STRESS AND STRAIN FIELDS NEAR CRACKS

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ABSTRACT

Predicting elastic-plastic stress and strain fields near cracks is a critical challenge in structural mechanics, particularly for nonlinear hardening material behaviors and diverse crack geometries. Graph Convolutional Networks (GCNs) have recently demonstrated significant potential in tackling complex problems in mechanics by effectively capturing spatial dependencies within mesh structures. In this study, a novel application of GCNs is presented for accurately predicting elastic-plastic stress and strain distributions using elastic stress fields as input. Finite element (FE) mesh of a cracked body of SAE 1070 steel is represented as a graph, where nodes correspond to mesh nodal points and edges capture the connectivity of elements. Elastic stress fields under different load levels are provided as input features, while the corresponding elastic-plastic stress fields serve as outputs. By utilizing the FE elastic stress field as input, the GCN model is trained to estimate corresponding elastic-plastic stress and strain fields, thereby overcoming the limitations of traditional FE methods that require incremental non-linear computations. The GCN is designed to capture the intricate relationships between the elastic stress and the elastic-plastic deformation fields around the crack tip. The model accurately predicts the elastic-plastic stress and strain fields compared to reference solutions from FE analysis. The GCN model demonstrates its capability to generalize across different crack configurations and loading conditions by providing results with significantly reduced computational cost. These findings are significant for advancing predictive modeling of crack propagation behavior in metallic materials, offering a computationally efficient alternative to traditional FE methods. This approach opens new avenues for integrating advanced machine learning method(s) with material deformation modeling in fatigue and fracture damage analysis. Thus, the framework allows rapid assessment of material performance under various loading and geometric conditions across a wide range of engineering applications.