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Investigation of Ductile Failure Mechanisms in SA508 Grade 3 Steel via X-Ray Computed Tomography and Fractography Analysis

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Abstract : SA508 Grade 3 steel is widely used in the construction of nuclear pressure vessels, where its fracture toughness plays a critical role in ensuring operational safety and reliability. Understanding the ductile failure mechanisms in this steel grade is crucial for designing robust pressure vessels that can withstand severe nuclear environment conditions. In the present study, round bar specimens of SA508 Grade 3 steel with four distinct notch geometries were subjected to tensile loading while capturing continuous 2D images at 5-second intervals in order to monitor any alterations in their geometries to construct true stress-strain curves of the specimens. 3D reconstructions of X-ray computed tomography (CT) images at high-resolution (a spatial resolution of 0.82 μm) allowed for a comprehensive assessment of the influences of second-phase particles (i.e., manganese sulfide inclusions and cementite particles) on ductile failure initiation as a function of applied plastic strain. Additionally, based on 2D and 3D images, plasticity modeling was executed, and the results were compared to experimental data. A specific 'two-parameter criterion' was established and calibrated based on the correlation between stress triaxiality and equivalent plastic strain at failure initiation. The proposed criterion demonstrated substantial agreement with the experimental results, thus enhancing our knowledge of ductile fracture behavior in this steel grade. The implementation of X-ray CT and fractography analysis provided new insights into the diverse roles played by different populations of second-phase particles in fracture initiation under varying stress triaxiality conditions.

Keywords : ductile fracture, two-parameter criterion, x-ray computed tomography, stress triaxiality
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