Strain Concentration around Geometric Features in Welding

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Abstract. In the study of structural integrity, the strain distribution around different geometric features has a strong impact on the fatigue performance of materials, especially in areas where strain concentration may occur. Accurately measuring the strain in these areas is important for assessing the safety of structures. This research focuses on the strain behaviour near typical geometric features in tensile components, such as transitions, notches, and weld reinforcements, under cyclic loading. It also investigates the potential for strain singularities in these regions.

Introduction. Dog-bone shaped specimens were used for low-cycle tensile fatigue (LCF) tests. These specimens are widely adopted for studying strain development under axial tension, particularly in the presence of geometric discontinuities. In our experiment, cyclic tensile loads were applied, and strain control was achieved using strain gauges attached to the surface of the specimen, either at the centre or near critical geometric features. The strain gauges ensured that the target strain amplitude was accurately reached in each cycle, enabling consistent loading conditions across all tests.

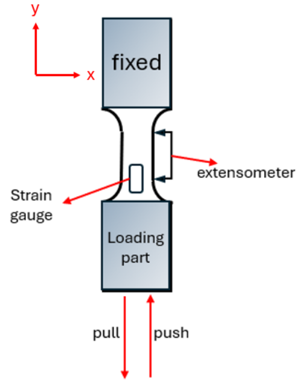

Figure 1Schematic diagram of the experimental setup.

Figure 1 illustrates the experimental setup, including the placement of strain gauges, grips, and the loading direction.

To investigate the influence of weld-like geometries, different features were introduced in the middle section of the specimens, such as weld caps, transitions, or grooves. These discontinuities are representative of real welded structures and allow assessment of their impact on local strain concentration.

Figure 2 shows the actual dog-bone specimens with various geometric features introduced.

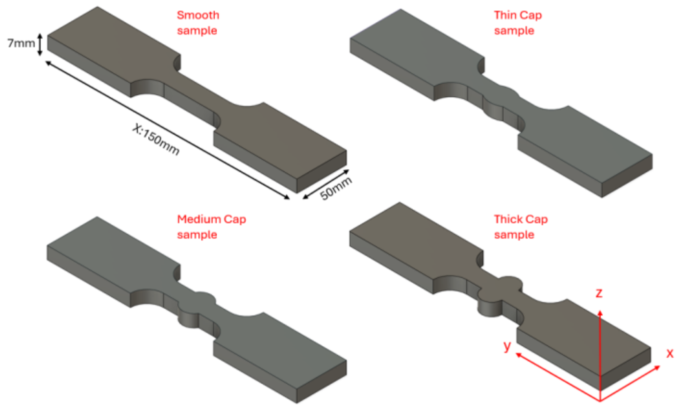

Figure 2 Dog bone fatigue specimens with different geometric features.

In addition to strain gauges, Digital Image Correlation (DIC) was employed to capture full-field strain distributions on the specimen surface. This technique provided further insight into strain localisation, especially around the geometric discontinuities.

Digital Image Correlation (DIC) (as shows in figure 3) was employed during the fatigue tests to capture full-field strain distributions on the specimen surface. This non-contact optical technique allowed visualisation of strain localisation near weld-like features, especially around areas with abrupt geometry changes. By recording images at maximum and minimum load levels in each cycle, DIC provided additional insight into how strain concentrations evolved throughout the loading history.

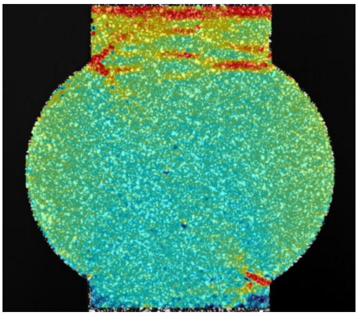

Figure 3 stress concentration around the cap edge in DIC image

To complement the experimental study, purely elastic finite element simulations were conducted using Abaqus. The aim was to estimate the local strain magnification caused by different geometric features under nominal strain loading. Since the objective was to evaluate **Weld Strain Enhancement Factors (WSEF)** as defined in the R5 procedure, plasticity effects were not included; instead, elastic simulations were used to isolate the geometric amplification of strain.

By comparing the experimental strain measurements with the elastic simulation results, the strain enhancement effects of different geometries were quantified, forming the basis for evaluating the conservativeness and applicability of WSEF values specified in R5 for welded joints.