PREDICTION OF DUCTILE FRACTURE IN NOTCHED STEEL PLATES USING SMCS METHOD

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Fracture occurs in steel beam-column connections when they are subjected to ultimate loadings in extreme conditions, such as earthquake. This event is the major concern of structural engineers. Since ductile crack initiation often controls the onset of fracture in mild steels, employing an appropriate model based on the mechanical properties of material for prediction of this phenomenon is of major interest (Deierlein and Kanvinde, 2004 and 2006). Therefore, employing health monitoring systems in critical points of steel structures can reduce the risk of their brittle and sudden collapse during such events. In this study, with the aid of the Stress Modified Critical Strain (SMCS) model and piezoelectric sensors, a crack growth prediction system for steel beam-column connections is addressed. SMCS model is a new and efficient micromechanical based fracture model which works on the concept of void growth in ductile crack formation. The SMCS crack initiation criterion needs determination of plastic strain and stress triaxiality (ratio of mean stress to effective stress) at the vicinity of critical regions like bolts, welds, etc.

The SMCS criterion is simply states that fracture will occur when the SMCS exceeds zero, i.e. (Deierlein and Kanvinde, 2006).

$$SMCS = \varepsilon_p - \alpha \exp\left(-1.5\frac{\sigma_m}{\sigma_e}\right) \qquad r > l^* \qquad (1)$$

Where ε_p= equivalent plastic strain; σ_m and σ_e= mean and the effective stress; α= material- dependent constant; and l^* = characteristic length.

In this study piezoelectric sensors near the notch are utilized in order to convert the mechanical response fields to electric ones to enable crack status prediction with the naked eye. Based on the piezoelectric sensors orientation and properties, a strain-voltage relation is provided. A steel plate with an edge notch which is an ideal local model of bolted beam-column connections is considered. The uniaxial uniform far-field load is applied at the remote boundary normal to the notch plane. The multilinear isotropic strain-stress curve with kinematic hardening is considered to model the steel material. A large deformation nonlinear analysis is utilized to obtain response fields of the model near the notch.

Owing to the symmetry of the problem, only one quarter of the plate with dimensions 20×100×6 mm including an 8mm-diameter notch at its center is modeled utilizing the ANSYS software (ANSYS Inc., 2010). The element sizes in the vicinity of notch are about 0.1 mm, which is sufficient to capture the SMCS gradients in this area. The material of plate is steel A572-Grade 50 with yield stress of 390 MPa, and ultimate stress of 590 MPa (Deierlein, and Kanvinde, 2006). The material-dependent α , and l^* parameters of the SMCS criterion are 1.18 and 0.20 mm, respectively (Deierlein and Kanvinde, 2006).

FEM simulations show that the most localized region of plastic strain locates on the interface of plate and notch. Figure 1 shows the SMCS criterion for different levels of applied stress. It is observed that ductile crack formation, which is equivalent to SMCS=0, begins at the stress level of 480 MPa. This value is 23% greater than the yield stress of the steel plate. The fracture occurred when the applied stress level reached about 86% of the ultimate stress, i.e. 510 MPa. This analysis is easily conducted for any notch sizes and the fracture behavior is each case is investigated. This study shows that the SMCS criterion is an effective and simple method for predicting the fracture initiation in steel connections. The results of this study can be used in the assessment of existing connections and preparing health monitoring systems for them.

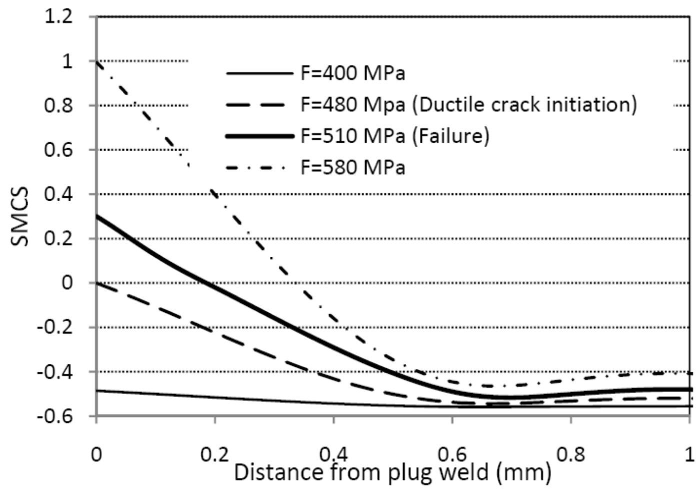

Figure 1. SMCS distribution along the edge notch

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