A NODE RELEASE APPROACH TO CALIBRATE COHESIVE PROPERTIES FOR FRACTURE SPECIMENS AND WELDED PLATE CONNECTIONS

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Abstract

Calibration of the cohesive zone models reqires determination of a number of critical parameters in the traction-separateion law. This paper introduces an approach to determine the traction-separation law, namely the Park-Paulino-Roesler model, through the node-release analysis implemented in the finite element research code WARP3D. The validation of the proposed approach utilizes results from the single-edge-notched bend, SE(B), specimens with varying levels of crack-front constraints and welded plate specimens.

1. Introduction

The cohesive zone model describes the material separation process during ductile tearing of metallic materials and provides a convenient approach to analyze the fracture failure in engineering structures. The calibration of the cohesive traction-separation law often entails a trial-and-error process to minimize the difference between the numerically computed and experimentally measured load-deformation responses. However, such a process may not yield a close representation of the constraint-dependent, material fracture resistance over the fracture process zone. To overcome this, the present study presents an approach to calibrate the cohesive parameters from the local stress-deformation relationship ahead of a growing crack tip. By releasing the crack-front nodes at deformation levels corresponding to the crack extension observed during a fracture test, the stress-deformation in the material ahead of the crack tip provides a natural representation of the traction-separation relationship required in the cohesive zone model. By translating this traction-separation relationship into a cohesive zone model with a compatible near-tip mesh, the cohesive analyses reproduce the load-deformation reponse of the specimen observed in the experiment.

2. Results

Figure 1 illustrates the three different stages in a crack-tip element in a node-release process. Stage A represents the material deformation prior to releasing the crack-tip nodes. Stage B corresponds to the redistribution of the residual nodal forces after the node release. In Stage C, the residual nodal force continues to redistribute, while releasing the nodes in the adjacent crack-tip element. The three different stages correspond to the different regimes in the traction-separation law, as shown in Fig. 1.

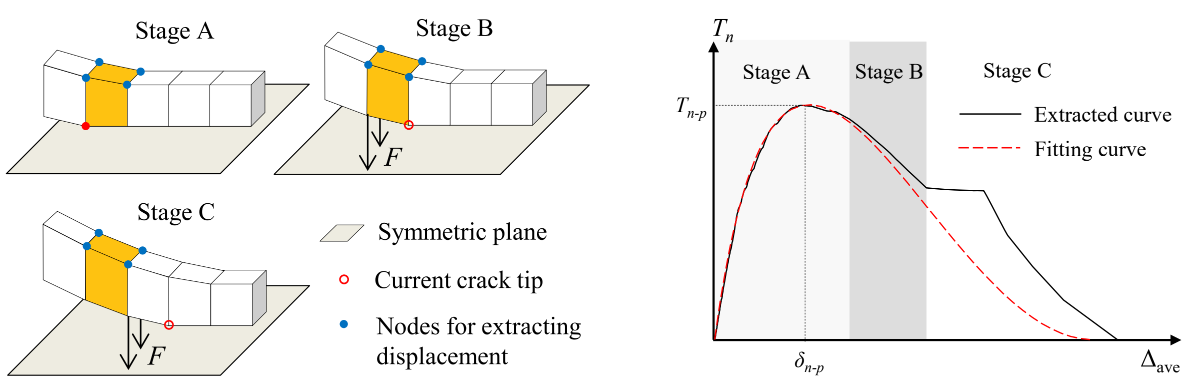

Fig.1 – Different stages in the node release and the corresponding traction-separation relationship.

The current study adopts the Park-Paulino-Roesler (PPR) model [1], implemented in WARP3D [2], to describe the traction-spearation law in the cohesive zone model. Figure 2 compares the traction-separation extracted from the node-release analyses for a series of SE(B) specimens made of HY80 steels [3] with different crack-depth ratios. The SE(B) specimens used to generate the traction-separation law includes four different crack sizes in Fig. 2a, which represent different crack-front constraint conditions. Figure 2b shows the good agreement between the cohesive model analysis and the experimental results for an SE(B) specimen, which was not included in generating the traction-separation law.

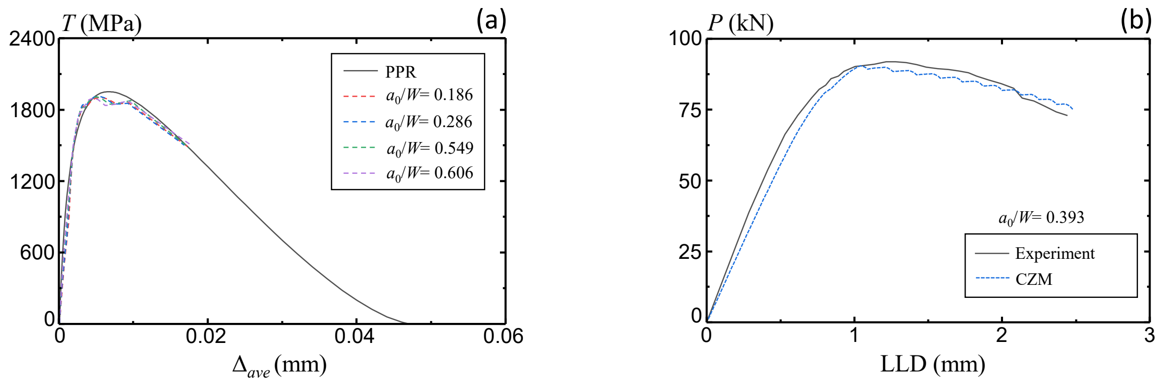

Fig.2 – Comparison of: (a) traction-separation law; and (b) load-deformation curves for SE(B) specimen.

Figure 3 demonstrates the application of the application of the cohesive zone model in estimating the fracture failure in a fatigue-cracked, welded cruciform joints with crack extension at the weld toe.

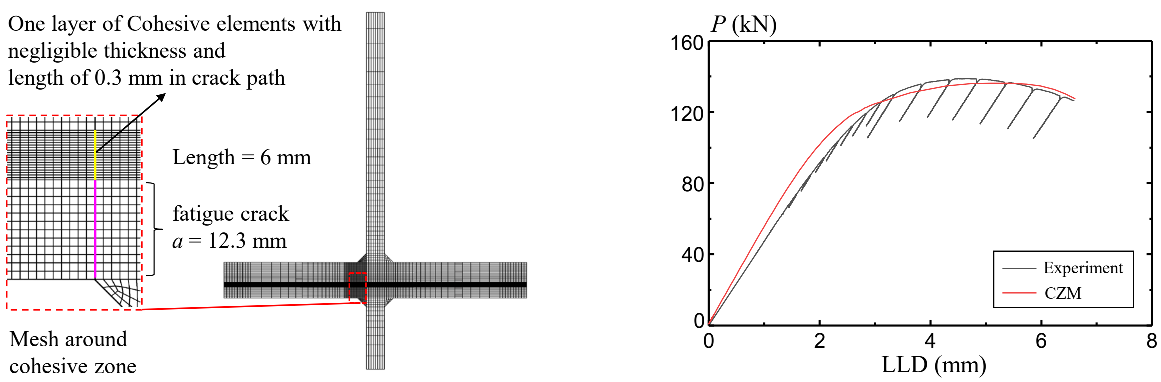

Fig.3 – Application of the cohesive zone model in a welded plate connection.

3. Conclusions

The node-release method demonstrates to be a feasible approach to calibrate the traction separation law in the cohesive zone model, as evidenced by the good agreement between the experimentally measured load-deformation responses and those computed from the cohesive zone model. The current approach remains applicable to other types of traction-separation law beyond the PPR model presented above.

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References

[1] Park K, Paulino GH, Roesler JR. J Mech Phys Solids 2009; 57:891-908.

[2] Gullerud AS, et al. WARP3D Release 15 manual. 2004.

[3] Zhu XK, Joyce JA. Eng Fract Mech 2007; 74: 2263-81.