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Crack propagation analysis using elastic-plastic FEM in torsional loading

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Crack growth under the elastic-plastic fracture is an important issue of the structural integrity, because seismic wave causes low cycle fatigue in the engineering structure. Many researchers have worked for many experiments and numerical analyses, however obvious and general criterion cannot be found until now. In order to develop a three-dimensional fracture criterion, the fully automated and state-of-the-art FE crack growth simulation should be realized. In the numerical simulation system, there are three important processes which are generation of the model with crack, stable and accurate FE analysis and post-processing for fracture evaluation. Crack growth simulation requires each process to be stable and connected each other in the one system. On the other hand, experiment should be conducted to determine material properties such as cyclic stress strain curve, crack tip opening displacement, J integral and so on. In particular, determination of parameters for appropriate cyclic stress strain curve is very important to actual evaluation of seismic loading.

We developed automated FEM analysis framework for elastic-plastic crack growth simulation. The framework consists of 4 major modules. The first module is the determination of the parameters for constitutive equation. The second module is the mesh generation with cracks. Crack tips move to the direction which is determined by three-dimensional fracture criterion. According to crack tip movement, the mesh also is regenerated by the automatic mesh generator. The third module is nonlinear finite element application. In this study we employ ANSYS 11. Of course, we define the data structures between each module and specifications of the framework. Therefore, the framework can accept the other FE codes for elastic-plastic crack growth simulation. The last module is the evaluation of fracture parameters to evaluate crack growth direction and rate. In this work, we employ crack tip opening displacement (CTOD) and crack tip opening angle (CTOA) which are the geometrical parameters to be defined near the crack tip.

The present work is applied to the cyclic loading analysis of a pipe with a single notch at the low cycles. In order to show the effectiveness of CTOD and CTOA parameters in the pipe, the conventional generation phase and application phase analyses are conducted in the work. The work shows comparisons between the experimental result and the numerical simulation results. The automated mesh generation capability and fracture mechanics parameters can evaluate crack growth criterion for the pipe under torsional cyclic loading.

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