Crack propagation in a pressurized stiffened cylindrical shells by XFEM

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Key Words: CTOA, XFEM, shell crack tip enrichments, crack propagation.

ABSTRACT

Shell and plate elements have been extensively used in modeling of tubular structures, such as natural gas transmission and pressurized pipes. The presence of cracks decreases the load-bearing capacity of a structure and may even lead to its collapse. Generally, occurrence of three types of cracks is more likely: longitudinal crack in pipes whose diameter is large, circumferential crack in pipes which bending is dominant and their combination. Since in a longitudinal crack, unstable crack can likely occur when the load reaches a critical value, lateral stiffeners are employed to prevent crack propagation in axial direction. Although the J integral is commonly used to calculate fracture parameters such as the stress intensity factor, but in pressurized thin-walled structures modeled by shell elements, this method is less efficient and problematic due to the presence of pressure on cracked elements. The alternative criterion to assess the crack propagation is the Crack Tip Opening Angle (CTOA). In addition to mesh dependency, the need for remeshing, and inability to estimate the singular stress field in fracture problems, the mesh dependency of CTOA criterion is an extra problem in the conventional FEM simulations. Alternatively, the extended finite element method (XFEM) which enriches the solution around the crack affected fields, avoids the mesh dependency and remeshing, while captures the displacement discontinuity across a crack and reduces the crack tip stress singularity near the crack tip. This also leads to accurate estimation of CTOA and substantial decrease of mesh dependency of this criterion.

In this paper, crack propagation in stiffened pressurized cylindrical shells are investigated by the CTOA criterion. For this purpose, XFEM has been extended to model crack in shells by considering crack tip enrichments in shear-deformable shell elements. Then, the effect of crack tip enrichments on estimation of CTOA and the number of required elements to model have been studied for several problems.