Summary of Dissertation

Fracture Mechanics Analysis of Shell Structures employing Ordinary State-Based Peridynamics

(Ordinary State-Based Peridynamics を用いたシェル構造物の破壊解析)

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Thin-walled structures are widely used in the naval architecture and ocean engineering industries owing to their high strength-to-weight ratios. Fracture mechanics regarded as one of the branches of mechanical science plays a critical role to ensure the safety of marine structures. Peridynamic (PD) theory that consists of integro-differential equations without any spatial derivatives has been recently developed to be an alternative powerful numerical method for treating complicated fracture mechanics problems.

In the present thesis, an ordinary state-based peridynamic (OSPD) shell model is introduced to deal with different kinds of fracture mechanics problems for shell structures. However, a lower accuracy phenomenon in the PD theory, called the PD surface effect, arises in the vicinity of domain boundaries or crack surfaces. A novel PD surface effect correction with arbitrary horizon domains is proposed to minimize the influence of the PD surface effect. Static and dynamic mechanical behaviors near crack surfaces are examined to demonstrate the effectiveness of the proposed surface effect correction.

Moreover, static fracture parameters are evaluated to verify fracture behaviors around crack surfaces by employing the domain form of J-integral. To further confirm fracture behaviors near the crack tip, dynamic fracture parameters are assessed by adopting the crack surface displacement extrapolation method. It is found that the proposed OSPD shell model can successfully predict static and dynamic fracture behaviors near crack surfaces under in-plane and out-of-plane loadings.

Dynamic crack propagation problems are subsequently investigated. A novel stretch-based failure criterion for cracked shell structures is presented in the proposed OSPD framework. For in-plane and out-of-plane loading conditions, several classical benchmark problems are simulated, including crack branching, Kalthoff-Winkler experiment, biaxially loaded plate, diagonally loaded plate, three-point bending test, etc. It reveals that the proposed OSPD shell model can well simulate dynamic crack extension under in-plane and out-of-plane loadings.

Finally, a series of dynamic fracture responses of float annealed glass plates subjected to blast loading is implemented. A convergence analysis of the fracture pattern is performed. Meanwhile, the influence of explosive scales, plate thicknesses, and aspect ratios for tested glass plates is conducted. It indicates that the proposed OSPD shell model can capture overall blast-loaded fracture patterns.