An efficient 3D crack propagation model using the total Lagrangian smoothed particle hydrodynamics with a frame of reference update

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The total Lagrangian version of the smoothed particle hydrodynamics (TLSPH) offers many advantages over the classical updated Lagrangian version. The TLSPH provides better stability, and computational-time cost, which the tensile instability is vanished using TLSPH, and the neighbour search is only once at the first time step, making the computational time shorter. However, in the application of fatigue crack propagation with the presence of geometry change, a pure total Lagrangian formulation is not capable of handling the problem. The interaction pairs of the particle, especially near the crack tip, must be updated. On the other hand, if the updated Lagrangian formulation is used, this problem can be handled well with the consequence of higher computational time costs. Therefore, an efficient 3D crack growth modelling using the total Lagrangian smoothed particle hydrodynamics with an update of the frame of reference is proposed.

The development of the SPH method for fatigue crack propagation still becomes an interesting research area. One of the latest publications is the pseudo-spring based SPH for fatigue crack simulation [1]. In our previous research, the TLSPH is proposed for 2D fatigue crack growth simulation [2]. To handle the geometry change in the crack growth problems, the interaction pairs at the crack tip are deactivated when the crack propagates, and the stress distribution is returned to zero. The direct deactivation of the interaction pairs when the crack propagates yields the kernel gradient of its neighbour remaining the same with the initial value without a new correction when the geometry change. This problem will affect the completeness of the SPH approximation at the crack tip. Therefore, a further improvement for TLSPH is required in the application of crack propagation simulation. In this research, the previous crack growth model for TLSPH is improved using an update of the frame of reference every time the crack propagates. The interaction pairs are deactivated when the crack propagate, which is similar to the previous research. In order to maintain consistency and completeness, kernel gradient correction using the update of the frame of reference is proposed. On the newly geometry with a crack extension, the particle's coordinate is transformed to the undeformed configuration. Then, the kernel gradient is recorrected on the new updated frame of reference. Then, the simulation is continued to obtain a new stress distribution.

The proposed crack model in this research is applied for 3D fatigue crack growth simulation. The crack is modeled using a surface that propagates through the particle interaction. An efficient procedure to calculate 3D J-integral for SPH is presented. Then, the stress intensity factor can be calculated using the relation of energy release rate and J-integral in LEFM problem. The maximum normal stress or maximum shear stress criteria can be used to determine the orientation of the new crack plane, depending on the material properties, load configuration, and the dominating crack mode during the propagation process. Finally, the results are compared with available data in the literature.

References

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