MESHLESS DISCRETIZATION OF STRESS-SPACE AND STRAIN-SPACE GRADIENT MODELS

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Meshless methods have been proposed during recent years to overcome some of the disadvantages of finite element methods. These disadvantages include mesh generation in two or three dimensions, locking phenomena, extensive remeshing in case of propagating discontinuities and restricted continuity of the shape functions. The research on meshless methods has initiated a renewed look on finite element formulations, and more recently improved finite element methods such as those based on Partions of Unity have been developed. The latter finite element methods overcome many of the disadvantages mentioned earlier. However, arbitrary continuity of the shape functions is still difficult, if not impossible, to obtain with finite elements. In contrast, arbritrary continuity is natural and straightforward when a meshless formulation is chosen.

One field of application in which higher-order continuity is desired is the discretization of higher-order gradient theories, as for instance gradient elasticity, gradient plasticity or gradient damage. Additional gradients of state variables are added to the governing equations, which in most cases increases the required continuity of the shape functions. The continuity requirements complicate the implementation and comparison between different gradient models when finite elements are used. In contrast, implementation and comparison are straightforward when a meshless discretization is applied.

The Element-Free Galerkin (EFG) method has been used successfully in the discretization of various gradient elasticity and gradient damage models. Also, EFG simulations with gradient plasticity models have been performed, although with different levels of success. A discrepancy exists between the considered strain-space gradient plasticity and stress-space gradient plasticity. Whereas EFG simulations with the former can be done without difficulties, EFG analyses of the latter show severe stress oscillations. One of the reasons is that the weak enforcement of the gradient-enhanced yield function with EFG shape functions prohibits a pointwise satisfaction of the yield function, which results in a violation of the equilibrium condition. Moreover, sub-quadratic convergence is caused by the longe-range interactions of the EFG shape functions which blurs the distinction between elastic and plastic points. It has been found that stress oscillations in the elastic region are eliminated and convergence behavior is improved if the number of integration points per integration cell is increased.

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