Particle Simulation of Modern Mechanical Fastening Processes and Their Failure Analyses in Automotive Applications

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Abstract

Numerical study of modern mechanical fastening processes for connecting metal parts in lightweight car structures has been an important research topic for automotive industry. Finite element simulation of various mechanical fastening methods and their failure analyses probably is one of the biggest challenges for CAE engineers in automotive applications. This is mainly because finite element methods inevitably encounter utmost numerical difficulties associated with meshing issues in modeling the extensive plastic deformation and material failure taking place during the joining operation and post failure analysis.

This paper presents a mechanical fastening simulation and material failure analysis using a new particle method based on authors' recent work [1]. Different from other particle stabilization methods which are obtained by modification of the variational equation using either residual or non-residual stabilization terms, the present method introduces a novel velocity smoothing algorithm to achieve the stabilization effect. It is shown that the semi-discrete equation based on the smoothed velocity field is consistently fulfilling the conservation of linear and angular momentum. Since the new method does not require stabilization terms, it avoids the fundamental difficulty inherent in the stabilization stress computation, thus computationally more efficient. Finally, the stabilized formulation is supplemented with the adaptive anisotropic Lagrangian kernel and bond-based failure criterion to extend the application in severe deformation and material failure analysis. Several modern mechanical fastening methods including Flow Drill Screwing (FDS) and Self-Pierce Riveting (SPR) are utilized to demonstrate the effectiveness of the new approach.

[1] Pan X, Wu CT, Hu W, Wu YC (2019) A momentum-consistent stabilization algorithm for Lagrangian particle methods in the thermo-mechanical friction drilling analysis. *Comput Mech*, in press.

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