The 8th European Congress on Computational Methods in Applied Sciences and Engineering
ECCOMAS Congress 2022
5-9 June 2022, Oslo, Norway

Model Reduction for Explicit Finite Elements in Crash Applications

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Keywords: *Model Order Reduction, Operator Inference, Explicit Finite Elements, Crashworthiness*

In passive safety, Finite Element (FE) simulations support engineers in making design decisions. However, these computational models include assumptions which have to be verified and validated and they idealize the crash load cases. Since physical crash tests introduce additional uncertainties, hardware testing of a FE-based design is associated with considerable risk of failure.To gain more confidence in a new design, robustness analysis are increasingly performed which require numerous simulation evaluations. During the development process, simulation results accumulate and can be used to accelerate future simulation. To learn from previous simulations in order to accelerate future ones is the main idea of model reduction. Model Order Reduction (MOR) using linear subspace and Energy Conserving Sampling and Weighting (ECSW) [1] has proven to effectively accelerate future simulations [2]. However, using a linear subspace is a major limitation as the inter - and extrapolation capabilities are limited. To tackle this problem basis interpolation methods [3] have been proposed and nonlinear reduction methods are becoming increasingly popular [4]. This is challenging because commercial software provides limited access to the source code. This often limits the applicability to real world problems and reduces the theoretical speed up. New approaches have to be developed here.
Operator Inference [5] aims to approximate the reduced operators arising in an intrusive projection scheme. This method tries to combine the best of the physical and data-driven world as there is no more solver-dependency, however, still equations are obtained and may be interpreted. Until now, only applications to rather academical problems, problems with prior known structure or fluid problems were considered so far. Application to nonlinear FE models is lacking and the influence of contact, plasticity and high deformations has to be assessed.
Currently, we have found that the reduced internal force operator can be approximated using polynomials. However, the obtained model does not yield stable behavior when time integration is applied. Current research focuses on investigating the stability problems by introducing hysteresis models or using different optimization strategies like regularization or semidefinite programming [6] to obtain stable reduced order models.
We present a critical reflection of intrusive MOR techniques together with current findings in operator inference and other modeling techniques applied to a crashbox model.

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