Penalty-coupled trimmed NURBS shell structures in explicit dynamic analysis: Explicit IBRA, time step size and stabilization

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ABSTRACT

We explore Isogeometric Analysis with the aim to speed up the virtual (vehicle) development process, still dominated by FE model generation and error-prone data transfer between CAD and analysis. Our approach is to perform structural analysis directly on trimmed NURBS-based B-Rep CAD models without or with a minimum number of modifications. This requires that we can (i) handle the numerical integration of trimmed elements and (ii) apply boundary and coupling conditions on trimmed NURBS patches. Isogeometric B-Rep Analysis (IBRA) [1] covers all these capabilities and allows for a completely new feature-based analysis paradigm as the analysis model directly inherits the CAD data structure including trimming and topology information. That is, CAD features like cut-outs, beadings or trimmed edges are also identified as such in the analysis model. This allows assigning analysis related information like material properties or boundary, coupling and loading conditions directly to features instead of individual nodes/elements as in FEA. Based on the same consistent data structure, design modifications on the CAD model (e.g. change of position or size of a hole) are automatically updated in the analysis model. Through this tight CAD/analysis connection, IBRA has the potential to significantly cut down model generation efforts and to facilitate data synchronization between design and analysis within the product development process.

Our main focus in this contribution is on explicit dynamic isogeometric analysis of shell structures for crash-type applications. First, we provide a brief overview on Explicit IBRA [2], the recently developed extension of IBRA to explicit dynamic problems in LS-DYNA [3]. We demonstrate the effectiveness of Explicit IBRA by means of nonlinear dynamic elasto-plastic benchmark problems and real-world BMW vehicle component models. Second, we discuss the influence of penalty-coupling and trimming on the critical time step size in an Explicit IBRA setting of penalty-coupled trimmed NURBS patches in explicit analysis. Although we found that high penalty factors indeed reduce the critical time step size, we obtained accurate results already with penalty factors that have no or only a minor influence on the time step [2]. We furthermore found that trimming does not have a negative effect on the stable time step size. Quite the contrary, trimming can even be used to increase the time step size by removing unfavorable elements on the patch boundaries, which have a smaller critical time step size compared to interior elements, see [4]. However, trimming can lead to small trimmed elements with control points of very low mass and stiffness which tend to show unstable behavior in explicit dynamic analysis. Therefore, we finally discuss a novel penalty-based stabilization method particularly suitable for explicit dynamic isogeometric analysis.

REFERENCES

[1] M. Breitenberger, A. Apostolatos, B. Philipp, R. Wüchner, K.-U. Bletzinger, Analysis in computer aided design: Nonlinear isogeometric B-Rep analysis of shell structures, *Comput. Methods Appl. Mech. Engrg.*, Vol. **284**, pp. 401-457 (2015), https://doi.org/10.1016/j.cma.2014.09.033.

[2] L.F. Leidinger, M. Breitenberger, A.M. Bauer, S. Hartmann, R. Wüchner, K.-U. Bletzinger, F. Duddeck, L. Song, Explicit dynamic isogeometric B-Rep analysis of penalty-coupled trimmed NURBS shells, *Comput. Methods Appl. Mech. Engrg.*, Vol. **351**, pp. 891-927 (2019), https://doi.org/10.1016/j.cma.2019.04.016.

[3] D.J. Benson, A.P. Nagy, L. Li, S. Hartmann, Recent developments in isogeometric analysis for LS-DYNA, in: *Proceedings of the 15th International LS-DYNA Users Conference*, (2018).

[4] C. Adam,, S. Bouabdallah, M. Zarroug, H. Maitournam, Stable time step estimates for NURBS-based explicit dynamics, *Comput. Methods Appl. Mech. Engrg.*, Vol. **295**, pp. 581-605 (2015), https://doi.org/10.1016/j.cma.2015.03.017.