Isogeometric Analysis in LS-DYNA: Using CAD-Geometry for Numerical Simulation

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1 Introduction

In the last decade numerous research has been done in the area of *Isogeometric Analysis* (IGA). The intention of this rather new technology is the wish to have a stronger integration of *Computer Aided Design* (CAD) and *Finite Element Analysis* (FEA). Its basic idea is to use the same mathematical description for the geometry as well in the design process (CAD) as in the later analysis (FEA). One of the wide spread geometry description methodology in CAD-systems is the usage of *Non-Uniform Rational B-Splines* (NURBS) as basis functions. NURBS-based finite elements have been proven to be very well suited for computational analysis leading to qualitatively more accurate results in comparison with standard finite elements based on Lagrange polynomials. Therefore continuous development of Isogeometric Analysis has been added to LS-DYNA in the last years. The present contribution will give an overview about the current possibilities in LS-DYNA to use NURBS-based CAD-geometry description for numerical simulation and outline future plans for their enhancements.

2 NURBS-based shells

Up to now, the main focus of the IGA development in LS-DYNA is set on the implementation of NURBS-based shell elements.

2.1 Shell formulations

Basically three different shell formulations are available in LS-DYNA:
- A Reissner-Mindlin shear deformable isogeometric shell [1]
- A large deformation, rotation-free isogeometric shell [2]
- A hybrid version of the first two formulations, called blended isogeometric shell [3]

2.2 Regular NURBS-patches

At present, the analysis capability of isogeometric shells in LS-DYNA is limited to the use of so-called regular NURBS-patches. A regular NURBS-patch is represented as a rectangular grid of control-points in the parameter space. Despite this rather crucial restriction it is possible to join various patches within a multi-patch analysis.

2.2.1 Multi-patch analysis: Joining of matching patches

A set of individual NURBS-patch definitions can be easily joined together once they use the same approximation space along their common boundary. This implies equal number and identical positions of control point pairs in the physical space and similar knot-vectors along the common boundaries. Given this requirement, the identical control points of either patch can be merged together.

2.2.2 Multi-patch analysis: Joining non-matching patches

Given the case that two patches should be joined together without having the requirements given in the previous section, a special type of tied contact is currently implemented.

2.3 Application of boundary conditions

In NURBS-based finite element, the degrees-of-freedom (DOFs) are located at so-called control points, which are not necessarily part of the actual physical geometry. Therefore special attention is needed for the application of certain boundary conditions.

2.3.1 Contact conditions

For the treatment of contact boundary conditions two possibilities are available in LS-DYNA:

- Standard contact via interpolation elements:
  An additional bi-linear quadrilateral mesh is constructed on the physical surface of either NURBS-patch. This can be thought of something similar to NULL-shells. These so-called interpolation elements do not take part in the actual computation and thus have no contribution to the stiffness of the shell, but their displacements are constrained to the displacements of the underlying NURBS-patch. Basically every standard contact type is available via this concept, so the contact acts between the interpolation shells and the contact forces acting on the interpolation nodes are then transferred to the actual degrees of freedom at the control points of the respective NURBS-patch.
- NURBS-contact:
  A new contact type has been implemented which uses the actual smooth NURBS-surface as the master segment in the contact formulation. With this a natural smooth contact type is available.

2.3.2 Nodal forces on the surface

For the application of concentrated nodal force-type boundary conditions, a new keyword has been implemented, which allows to add a massless node at any specific location of a NURBS-surface. The motion of this node is then constrained to the underlying NURBS-patch and the nodal forces applied at this node are distributed to the appropriate degrees of freedom at the control points of the NURBS-patch.

2.4 Analysis capabilities

Many of the standard analysis capabilities in LS-DYNA are also available for isogeometric shells
- Implicit and explicit analysis
- Eigenvalue analysis
- Comprehensive material model library
- Conventional mass scaling [4].

2.5 Trimmed NURBS

Most of the CAD geometries are so-called trimmed NURBS surfaces. In addition to an underlying regular NURBS-patch (see section 2.2), various trimming curves are defined to further specify if any areas shall be excluded from the actual surface geometry. Various research has been done to find a way to do the analysis on trimmed surfaces. Currently, an approach presented in [5] is being implemented into LS-DYNA.

3 NURBS-based solids

The implementation of NURBS-based solid elements has started and preliminary results will be shown in the presentation.

4 Pre- and Post-Processing with LS-PrePost

LS-PrePost is capable to read in IGES and STEP geometry files and convert them into an appropriate keyword format for LS-DYNA. Currently work is done to add the trimming capability. For the postprocessing a basic IGA file is already available but additional work is needed in the display of solution variables.

5 Summary

The present contribution gives an overview about the present capabilities in the area of isogeometric analysis in LS-DYNA and indicates future effort planned in this field.

6 Literature

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