A One Step Simulation Approach Using Isogeometric Shells in LS-DYNA®

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1. Introduction

The isogeometric paradigm employs basis functions from computer-aided design (CAD) for numerical analysis. The actual geometry of the CAD parts is preserved which is in sharp contrast to finite element analysis (FEA) where the geometry is approximated with, potentially higher-order, polynomials. Isogeometric analysis (IGA) has been extensively studied in the past few years in order to (1) reduce the effort of moving between design and analysis representations and (2) obtain higher-order accuracy through the higher-order interelement continuity of the spline basis functions used in CAD. LS-DYNA is the first commercial code to support IGA through the implementation of generalized elements and then keywords supporting non-uniform rational B-splines (NURBS). Many of the standard FEA capabilities, such as contact, spot-weld models, anisotropic constitutive laws, or frequency domain analysis, are readily available in LS-DYNA with new features added steadily.

Owing to the direct use of the CAD representation and its accuracy, IGA has been gaining more attention and has been already utilized for critical components in car crash simulations. However, there are many parts that are manufactured from flat sheet metals in a car design. After plastic deformation, the mechanical properties of these sheet metals may change significantly and hence may affect the prediction of the crash simulation. Consequently, the accuracy in the crash model can be improved by incorporating forming history information. As forming tools are developed as part of a parallel design process, forming information is not readily available for the crash simulation. To overcome this difficulty, the one step method is proposed. The one step method only requires the final geometry of the part and its material properties. Subsequently an assumed initial blank is optimized for minimum energy. In essence, the part is assumed to deform from the optimized initial flat blank to its final shape within one step. The one step approach provides the analyst with a rough approximation of the forming data, e.g. blank thinning or effective strain, which can be easily incorporated into the crash model.

Studies of the one step simulation using finite element models conducted at car companies, e.g. General Motors, Fiat Chrysler, and others, have shown that the accuracy of the prediction can be improved using the forming information obtained through the one step method. This paper will demonstrate the one step method for IGA and highlight its applicability.

2. Keywords

A non-uniform rational B-spline is a piecewise polynomial that can efficiently represent complex geometries including conics, e.g. a circle or an ellipsis. The most common form of an isogeometric shell is a NURBS surface which can be represented as a tensor product of two NURBS in local r- and s- directions. For more details, the reader is referred to the *ELEMENT_SHELL_NURBS_PATCH keyword in the keyword manual.

The one step analysis for metal stamping now supports IGA. The one step analysis can be activated using the *CONTROL_FORMING_ONESTEP keyword, setting the option to 7, and leaving the second line blank, i.e.

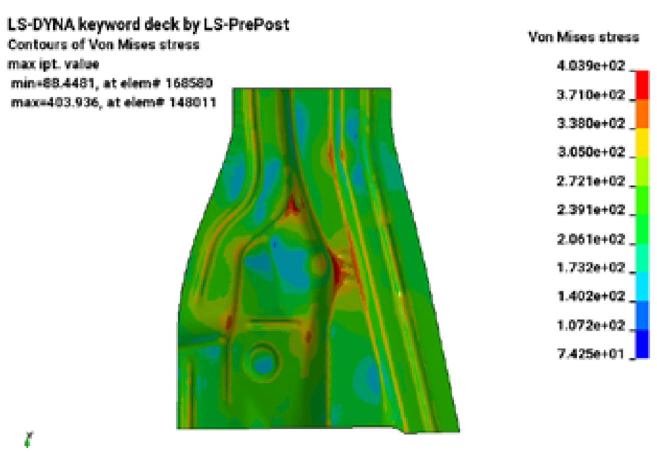
```
*CONTROL_FORMING_ONESTEP
$#  option  maxthick    autobd   thinmin    epsmax
         7
```

The output results are written to the *igaonestepresult* file which may be used in exactly the same manner as the standard *dynain* file.

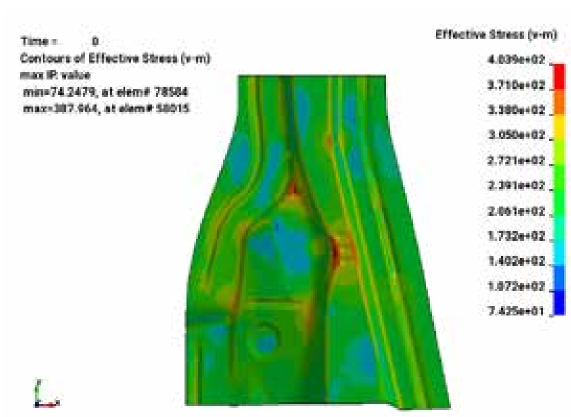
3. Simulation Results

The IGA one step approach is demonstrated and compared to its FEA counterpart in a couple of examples. The first example uses a single untrimmed NURBS patch to define isogeometric shells while the second uses a trimmed NURBS patch.

A comparison of the von Mises stresses in the FEA and the untrimmed IGA models is shown in Figure 1. The stress distribution looks very similar for these models; however, the maximum stresses slightly differ which is best explained by localization. The comparison of the effective plastic strain fields is shown in Figure 2.

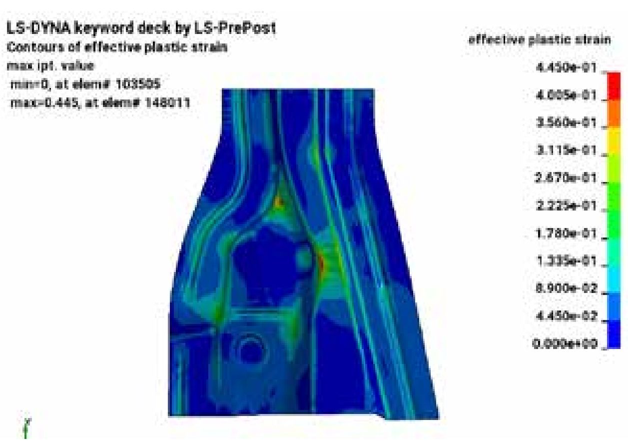


(1) FEA

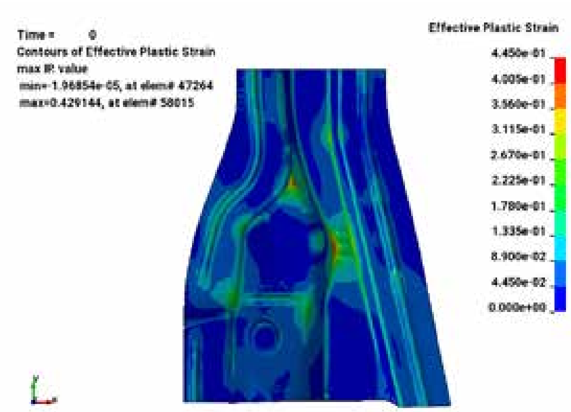


(2) IGA

Figure 1: Von Mises stresses as a result of the one step analysis using (1) FEA and (2) untrimmed NURBS-based IGA



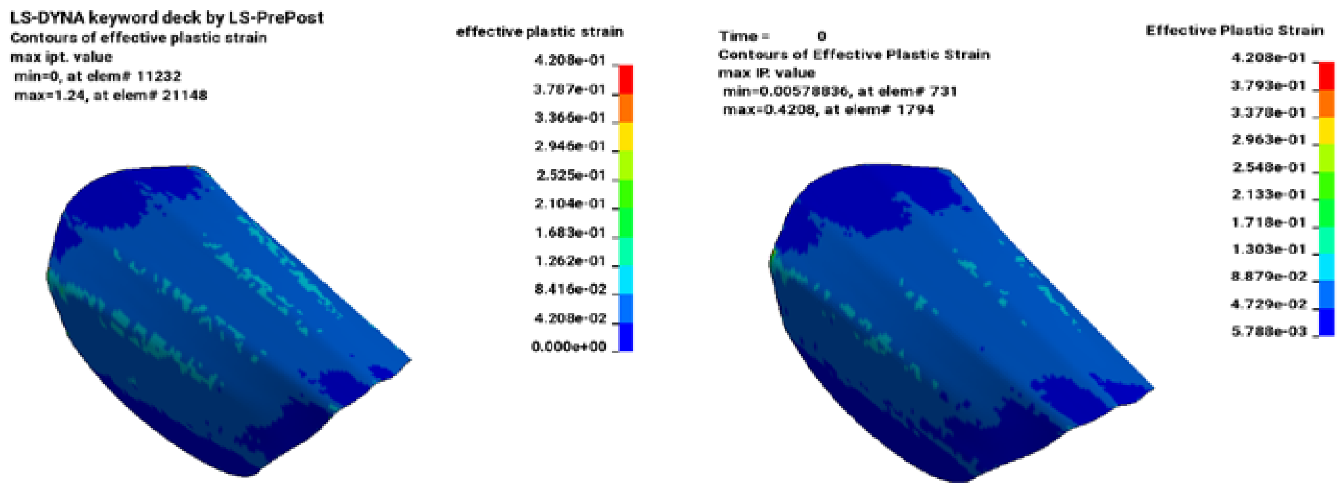
(1) FEA



(2) IGA

Figure 2: Effective plastic strains obtained via the one step approach using (1) FEA and (2) trimmed NURBS-based IGA.

The effective plastic strain of the finite element and trimmed isogeometric element models are compared in Figure 3. Due to localization the maximum strains are slightly different in the finite element model as shown in Figure 4.



(1) FEA (2) IGA

Figure 3: Effective plastic strains obtained via the one step approach using (1) FEA and (2) trimmed NURBS-based IGA.

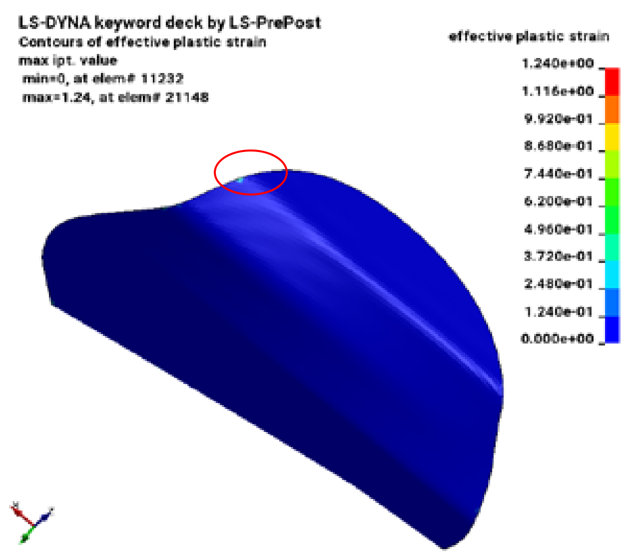


Figure 4: Localized effective plastic strain in the FEA model.

4. Conclusions

The one step method has been extended to include isogeometric models. As a result of some numerical benchmarks, we found the overall results to be similar with respect to the equivalent FEA models. The one step IGA approach is available to improve the prediction accuracy in car crash simulation of IGA parts and consequently the entire model.