

# Metal Forming Automation using LS-OPT<sup>®</sup>

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## Abstract

*The principal objective of this paper is to demonstrate the Metal Forming automation setup using LS-OPT, in which CREO (CAD software), Hypermesh (FE pre-processor), LS-DYNA<sup>®</sup> (FE Solver) and LS-PrePost<sup>®</sup> (FE post-processor) are integrated. Metal Forming simulations are performed to check the formability of an intended geometry for various process settings like different draw bead retention forces, friction coefficient, blank dimensions, material properties, etc. In case of formability issues, geometry modifications are implemented in the necessary areas. Automation in any process will help to reduce the manual effort in running various combinations, saves time and gives more accurate results.*

*Automation workflow is developed with reference to general metal forming simulation approach. To modify the geometries at concerned areas, CAD software is required. FE –preprocessor is required to create new mesh for modified geometry. LS-DYNA and LS-PrePost is used for solving and post processing respectively. In this work, Design of experiments (DOE) are performed to understand the effects of process parameters and critical dimensions of geometry on formability (Maximum thickness reduction, Crack elements, Risk of Crack elements, Wrinkles, etc). Critical process parameters and affecting areas in the geometry are indentified. Affecting areas are made parametric and significant process parameters which have significant effect on formability are considered. From data analysis of DOE results, a relation can be obtained between geometric dimensions, process parameters and formability responses. The knowledge obtained is shared with Design team and Tool makers. The Automation setup will be used for Optimization, Monte Carlo simulations, etc based on the requirement.*

## Introduction

Metal Forming simulations are performed to check the formability of an intended geometry for various process settings (like different draw bead retention forces, friction coefficient, blank dimensions, material properties, etc) and control options (adaptive levels, element type, element size, etc). In case of formability issues, geometry modifications are implemented in the necessary areas. In our regular work, we check for formability of a part either which is already in production with some design modifications or completely new design. In former case, most of the process settings will be kept constant except draw bead retention forces. In later case, formability has to be checked for different process settings and control options. The ultimate goal is to have a robust design which can sustain variation.

Performing manual iterations will be quite cumbersome. Process automation - automatically do what users needs to get done. Automation will help us to save time, eliminate manual errors, create a reusable knowledge, check for various parameters and also helps to perform DOEs, optimization tasks, Monte Carlo studies, etc.

LS-OPT [1] developed by Livermore Software Technology Corp. (LSTC), is an optimization tool that can be linked to most of simulation software, in which some of them are directly linked such as LS-DYNA, Excel, LS-PrePost, etc and other software can be linked through batch mode like CREO, Hypermesh, etc. LS-OPT allow the user to structure the design process, explore the design space and compute optimal designs according to specified constraints and objectives.

### General Approach

Metal Forming simulations can be carried out in many ways. Different methodologies are being used globally based on one’s need and availability of resources (like software, licensing, computer architecture, etc). In our work, the general simulation work flow is shown in Figure 1 for manual iterations.

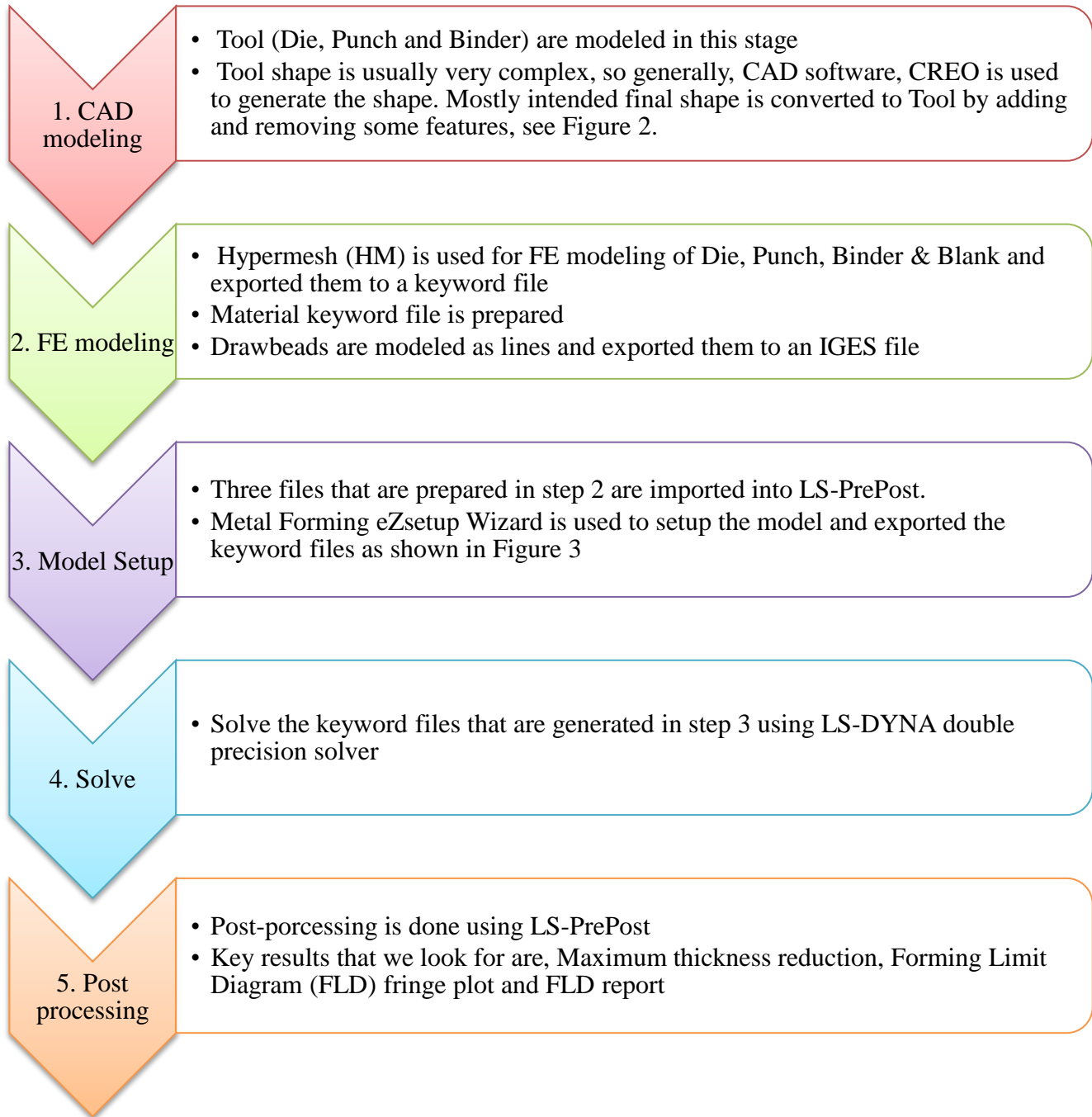


Figure 1: Work flow for Metal Forming simulations

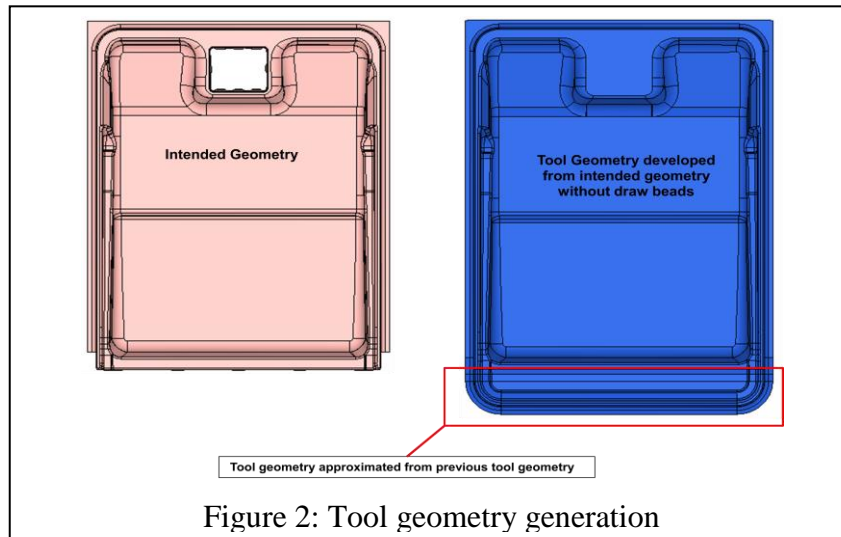


Figure 2: Tool geometry generation

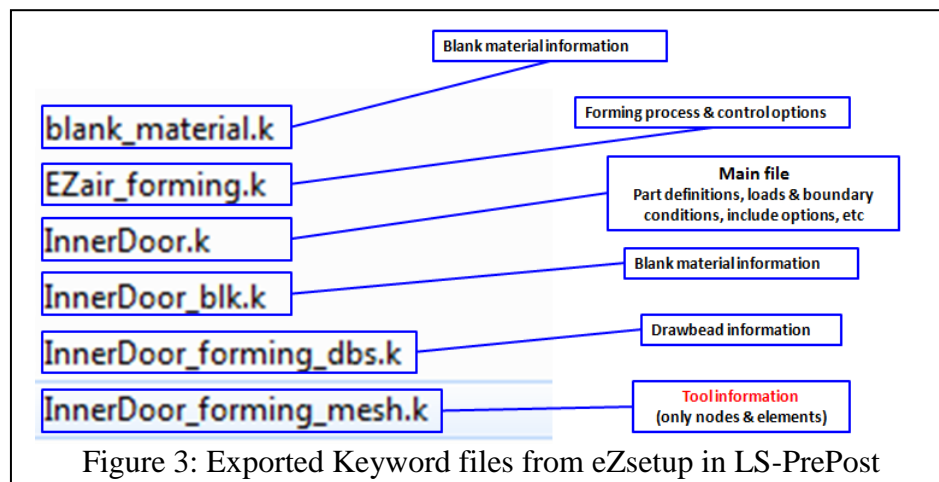


Figure 3: Exported Keyword files from eZsetup in LS-PrePost

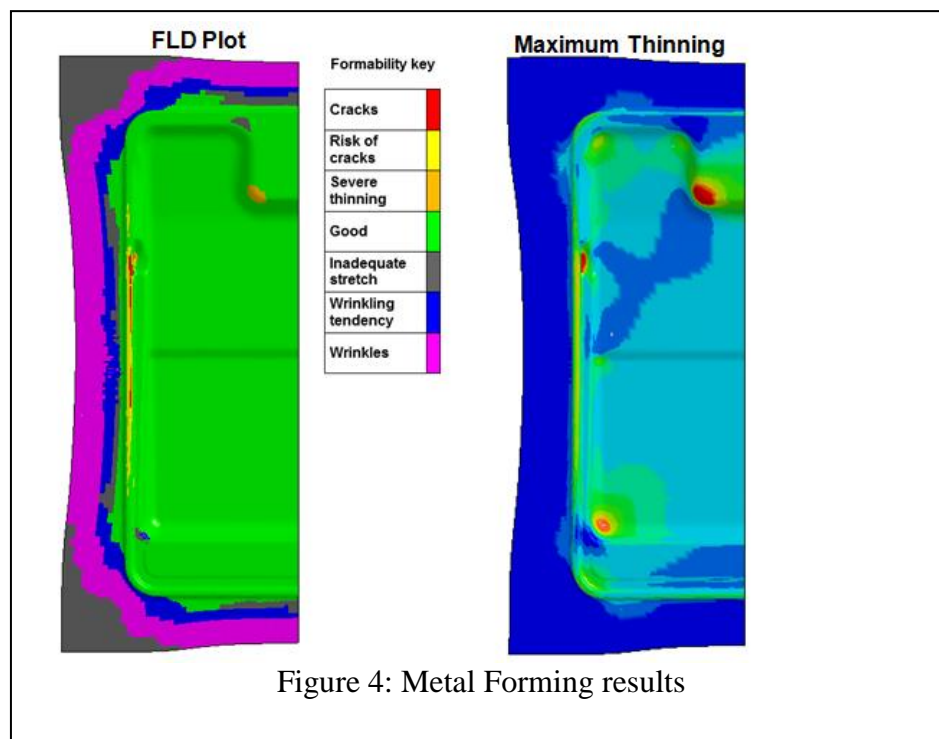


Figure 4: Metal Forming results

From initial runs, concerns will be identified such as cracks, severe thinning, inadequate stretch, wrinkles, etc then one have to improve the formability by changing the process settings and control options, and simulations are repeated from step 3. If there are still concerns in formability after checked with feasible process settings and control options, then geometry must be modified in the affected areas. For geometric modifications, simulations are repeated from step 1. Finally, a formable geometry is achieved which can sustain variation in process settings.

With increasing number of iterations, manual repetition is quite cumbersome and post-processing will be complicated. Identifying feasible solutions is also difficult. To overcome these hurdles, automation is identified as a solution.

### Metal Forming Automation

The general approach is automated using LS-OPT as shown in Figure 5. This process automation is developed to overcome the difficulties in manual iterations and also help us to perform DOE studies, Optimization tasks, Monte Carlo studies, etc.

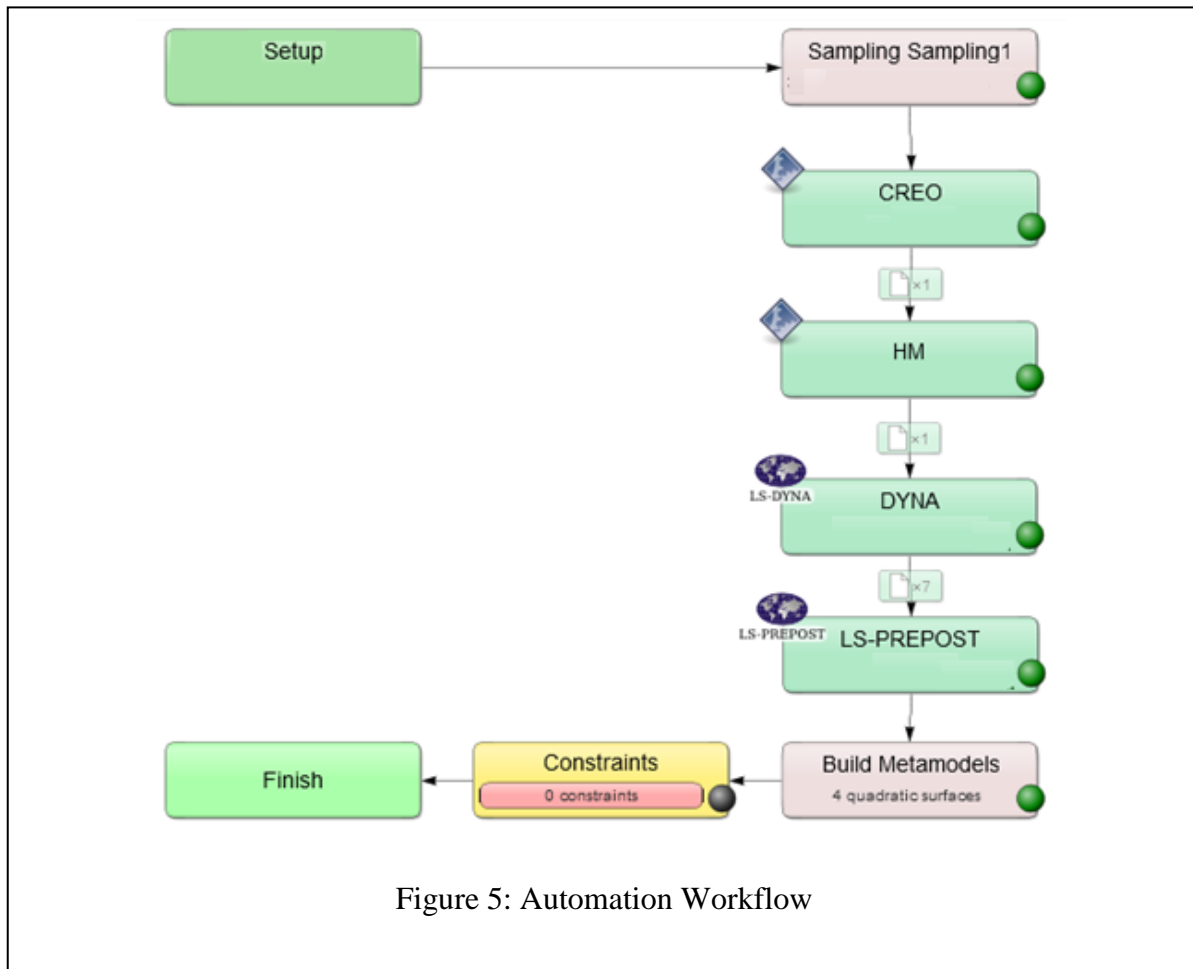


Figure 5: Automation Workflow

LS-OPT is a user-friendly software, most of CAD and CAE software can be integrated. There are two ways of software integration in LS-OPTui, one is direct and other is indirect. Software like LS-DYNA, LS-PrePost, Excel, etc can be directly integrated to LS-OPTui and other software (like CREO, Hypermesh, ANSYS, etc) are indirectly integrated.

For indirect integration, user-defined solver or preprocessor can be specified by selecting User-defined in LS-OPTui. The command can either execute a command, or a script. The substituted input file UserOpt.inp will automatically be appended to the command or script. The specification of an input file is optional. If the own solver does not generate a 'Normal' termination command to standard output, the solver command must execute a script that has as its last statement the command: `echo 'Normal' [1]`.

#### Indirect Integration:

CREO (CAD software) and HM (FE-preprocessor) are not available in LS-OPTui. Figure 6 shows indirect integration of CREO in LS-OPTui. CREO is used to open the parametric geometry, modify the critical dimensions as per the sampling and export the modified geometry. A script is used to perform these steps. HM is used to import the modified geometry, mesh all Tool parts (Die, Punch & Binder) and export the Tool nodes and elements which will replace the tool information file, refer Figure 3. CREO and HM are executed in batch mode.

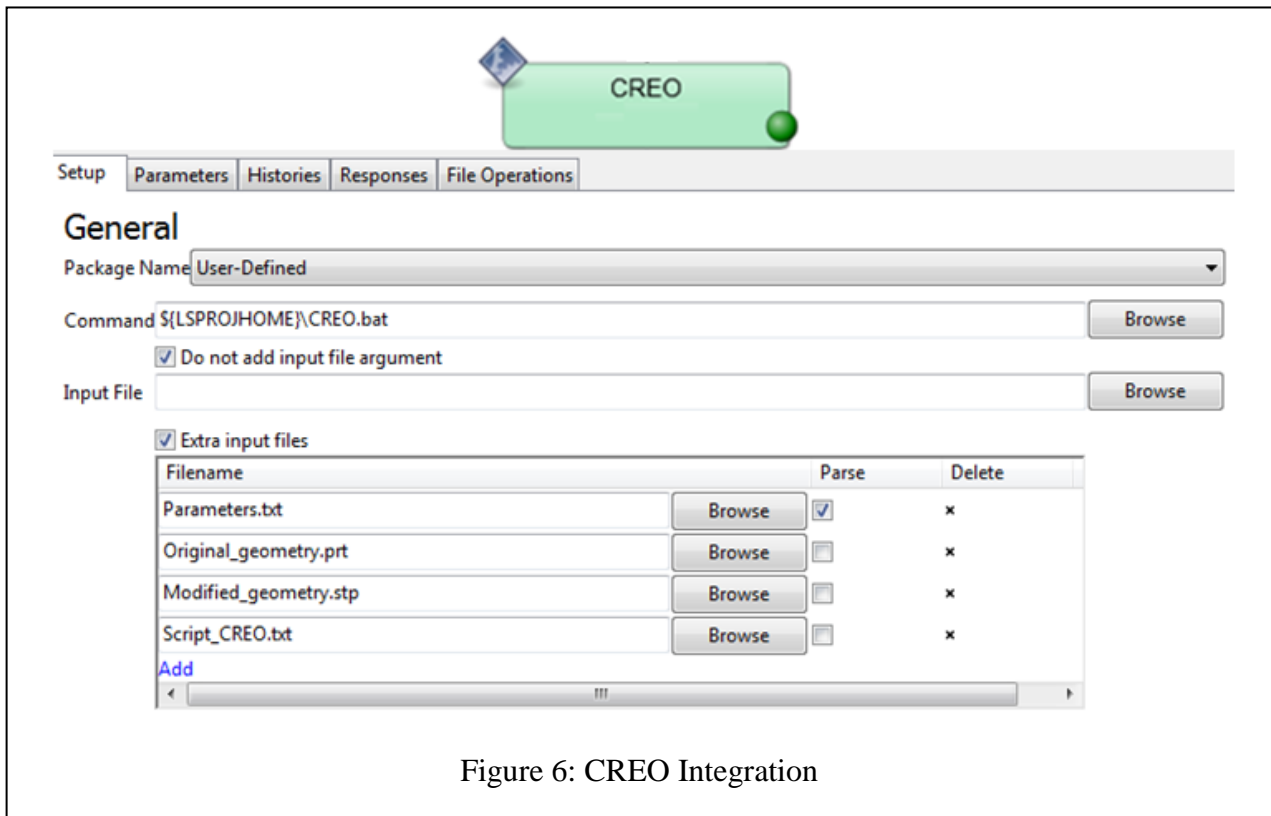


Figure 6: CREO Integration

#### Direct Integration:

LS-DYNA (solver) & LS-PrePost (FE-postprocessor) can be directly integrated in LS-OPTui. Intended versions are used through command option. In DYNA stage, Main file (refer Figure 3) is selected as an input file and all include files are detected automatically. For post-processing, a script is used to generate the FLD report.

## DOE Study

In this paper, Metamodel [3] based DOE studies are performed. Multiple algorithms, different point selection methods, etc are available in *Sampling* stage. Polynomial based response surface method is used with higher order approximation, i.e. quadratic. D-optimal method is used for point selection.

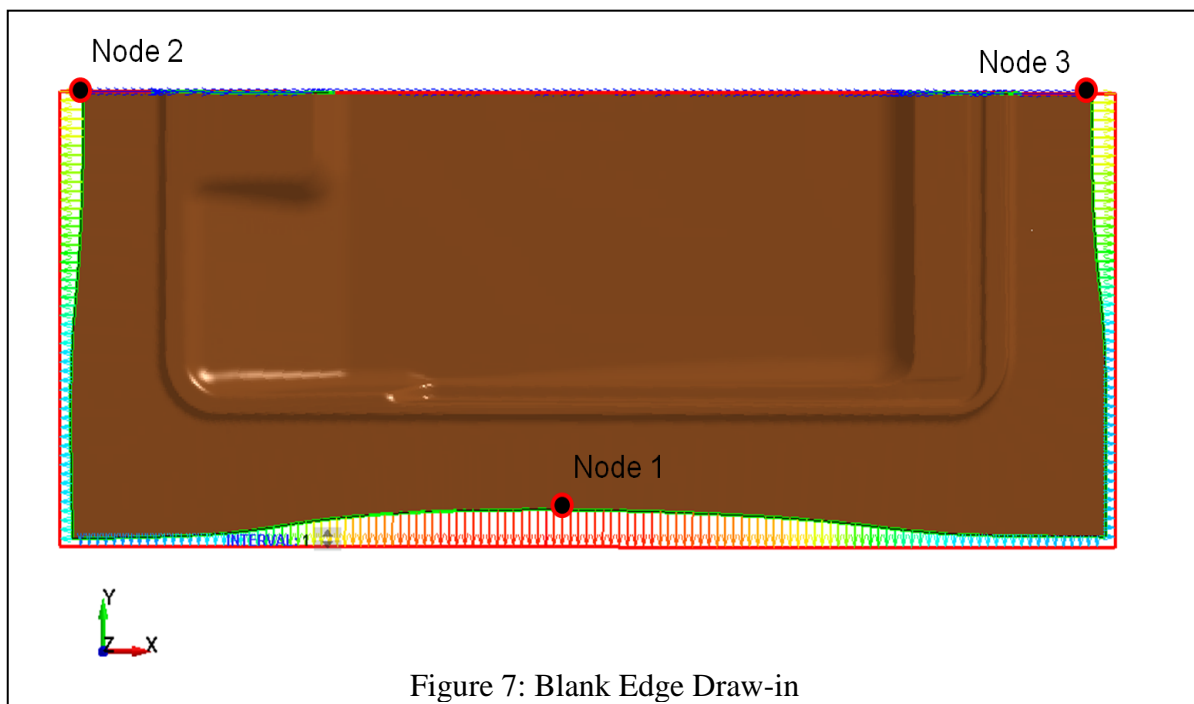
Factors of DOE:

All parameters are identified and displayed in *Setup* stage. User can choose parameters that are important as continuous with minimum & maximum values and the remaining is kept constant with nominal value.

Critical dimensions of the geometry are parameters from *CAD* stage. Drawbead retention force scaling factors (DFSCCL, [2]), friction, material parameters, process and control settings, etc can be the factors in *DYNA* stage. In this paper, critical dimensions and DFSCCL are only factors considered for DOE study.

Responses of DOE:

Maximum thickness reduction (from *DYNA* stage), FLD report entities (Cracks, Risk of cracks, Inadequate stretch, Wrinkle tendency, Wrinkles and Safe are from *PrePost* stage) and Blank edge draw-in (tracked by nodal displacements from NODOUT) are the responses. GenEx, the LS-OPT Generic Extractor provides features for extracting entities from text files. Responses are created using GenEx [1].



### DOE Results

Generally, DOE or Optimization results will be huge. Data analysis and visualization is a challenging task. Data analyzing tools are great assistant for scientists and engineers in terms of data visualization. Signifcant factors, trade offs, dependencies, response surfaces, individual and interaction effects, etc can be visualize with Data analyzing tools.

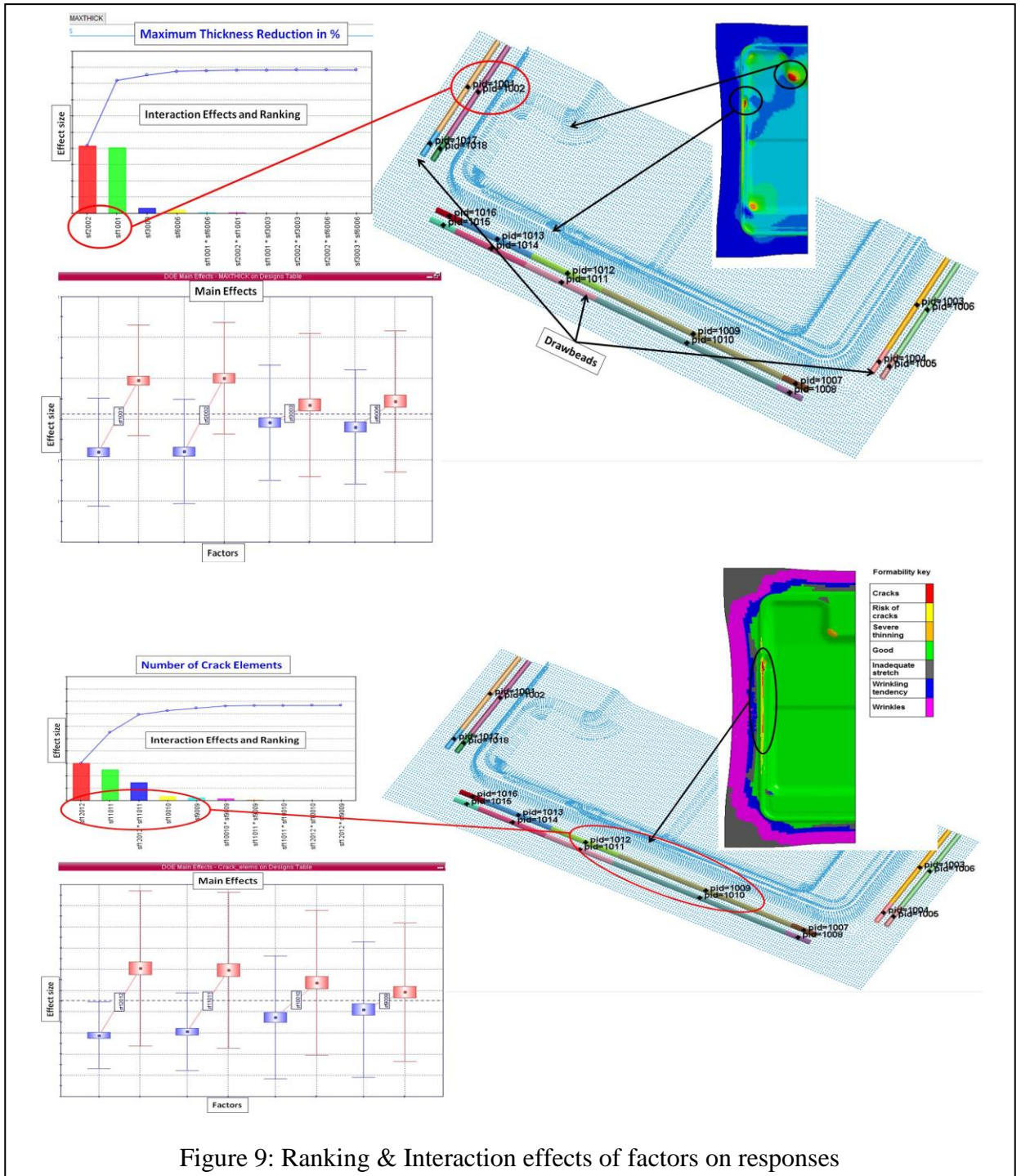


Figure 9: Ranking & Interaction effects of factors on responses

Influence of Drawbead retention forces on Maximum thinning and Number of Crack elements is shown in Figure 11. Ranking of significant factors with their individual and interaction effects also shown in respective plots. From data analysis of DOE results, a relation can be obtained between geometric dimensions, process parameters and formability responses.

### **Conclusion**

Metal Forming Automation is developed using LS-OPT with reference to general approach. This automation setup helps to overcome the difficulties in manual repetitions of metal forming simulations. The Automation setup will be used for DOE studies, Optimization tasks, Monte Carlo simulations, etc based on the requirement. In this paper, DOE studies are performed to understand the significance of drawbead retention forces on formability. From DOE results, a relation is obtained between factors and responses of DOE. Process automation will help us to save time, eliminate manual errors, check for vast design space, create a reusable knowledge, etc. The knowledge obtained is shared with Design team and Tool makers.

### **References**

1. LS-OPT User's Manual, A Design Optimization and Probabilistic Analysis Tool for the Engineering Analyst
2. LS-DYNA Keyword User's Manual
3. Metamodel-based Multidisciplinary Design Optimization for Automotive Applications by Ann-Britt Ryberg, Rebecka Domeji Bæckryd, Larsgunnar Nilsson