An Innovative Approach to Sheet Metal Forming Simulation for Higher Accuracy, Using 3D Solid Elements in Simufact.forming

A.J. Buijk
Simufact-Americas LLC
(arjaan.buijk@simufact-americas.com)

Keywords: Sheet Metal Forming, Stamping, Roll Forming, Finite Element, Simufact.forming, Hex Re-Meshing.

ABSTRACT

The most common issues in sheet metal stamping are progression design, transfer design, thickness control, wrinkling, thinning, tearing, spring-back and die-wear. An innovative methodology has been developed to analyze these aspects using a non-linear finite element approach with 3D Solid elements instead of the more traditional Shell elements. This leads to the most accurate result, and allows a fully transparent implementation in the metal forming simulation package Simufact.forming. The method takes 3D STL-data or CAD data as input, and fully automatically creates a 3D Solid mesh that is optimized for sheet metal forming, using a '2½ D sheet mesher'. During the simulation, the mesh is constantly updated to enable tracking of the large deformations. Parallel processing further reduces the CPU times.

INTRODUCTION

For many years, the implicit Finite Element method using 3D Solid Elements has been successfully applied to many bulk forming processes, in particular cold heading and hot forging. An example for each is given in figure 1 and 2. A recent development in meshing technology extends the applicability of this method to sheet metal forming. A typical example is shown in Figure 3.

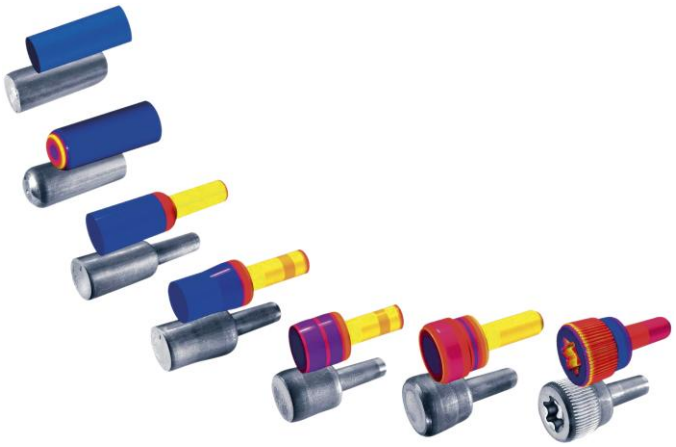

Figure 1: Bulk Forming Example – Cold Heading

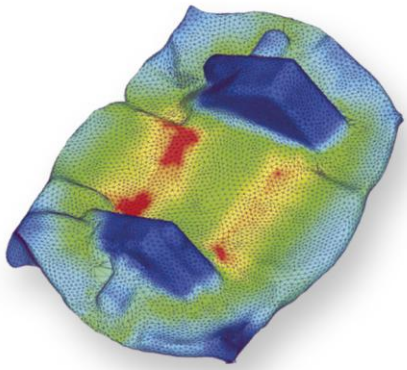

Figure 2: Bulk Forming Example – Hot Forging

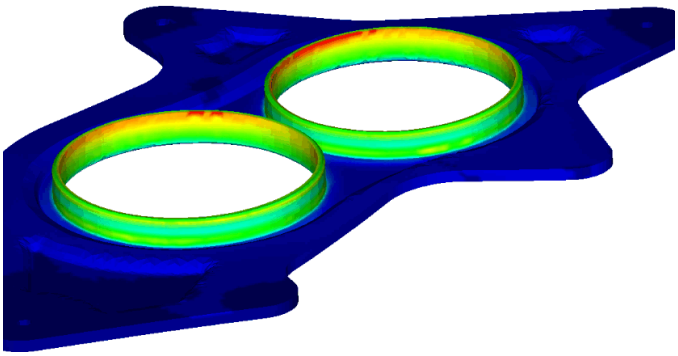

Figure 3: Sheet Metal Forming

In this paper we will summarize the typical modeling steps for a Sheet Metal forming simulation. These steps are demonstrated by means of a relatively simple example. After this, more complex simulation results will be given.

MULTI-STATION PROCESS DEFINITION

A simulation session always starts with the selection of the type of metal forming process to be modeled. A special dialog guides the user with this choice. Based on the choice, a tree structure will be created with place-holders for the dies, work-piece and all process parameters.

A progression design to be evaluated is always defined by a sequence of 3D die models, created in a 3D CAD system. The die models of each station are imported directly from the CAD files, and organized in a tree structure, as shown in figure 4. Each station has its own collapsible tree-structure with place holders for the dies and other process parameters.

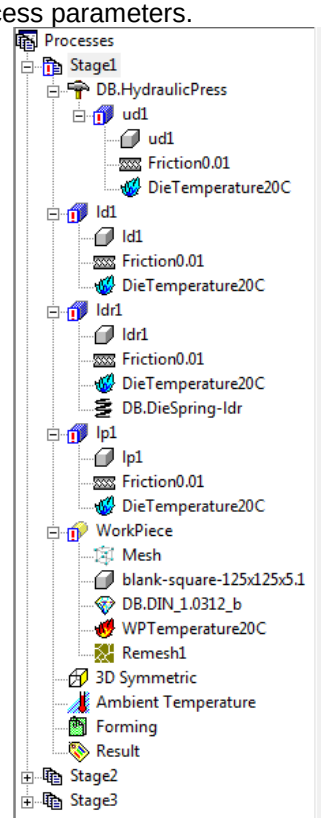

Figure 4: Typical Tree Structure for Multi-Station Process

PRESS

A press can be defined manually by assigning characteristic parameters. For instance, a Hydraulic press definition is shown in figure 5.

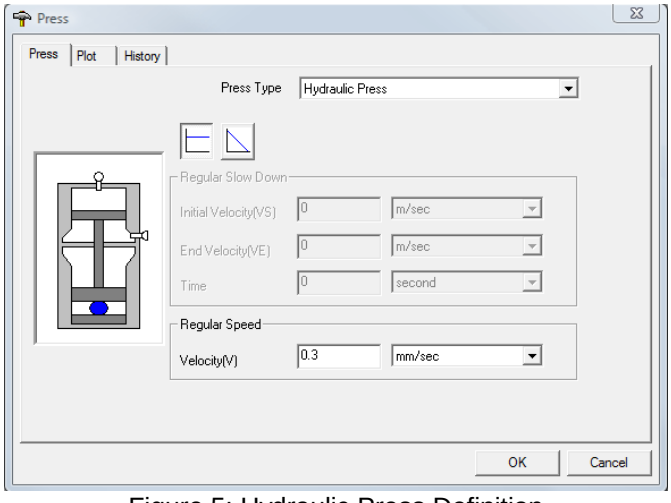

Figure 5: Hydraulic Press Definition

The Hydraulic Press is drag/dropped into the process tree, and the appropriate die assigned to it, as shown in Figure 4.

SPRINGS

Often, one or more dies are supported by springs, which can be either released or pre-loaded. The spring is defined as shown in Figure 5.

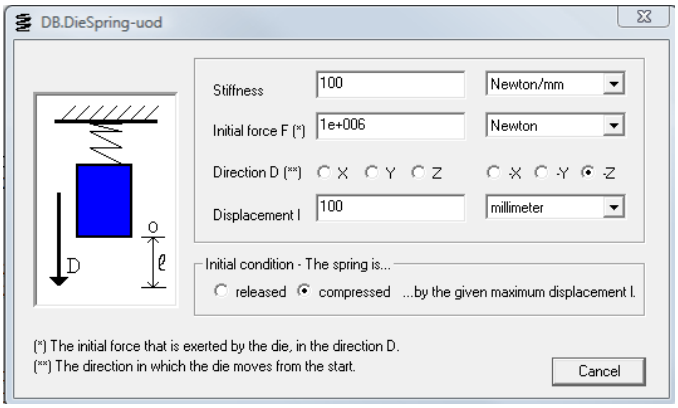

Figure 5: Spring Definition

The spring is then drag/dropped on the appropriate die in the process tree, as shown in Figure 4.

MATERIAL DATABASE

It is extremely important to use accurate material data for the work-piece. The data must define the flow stress as a function of strain, strain-rate and temperature. Especially when studying warm- or hot-forming processes, the temperature dependency is critical. The material is selected from an extensive material database, and assigned to the work-piece.

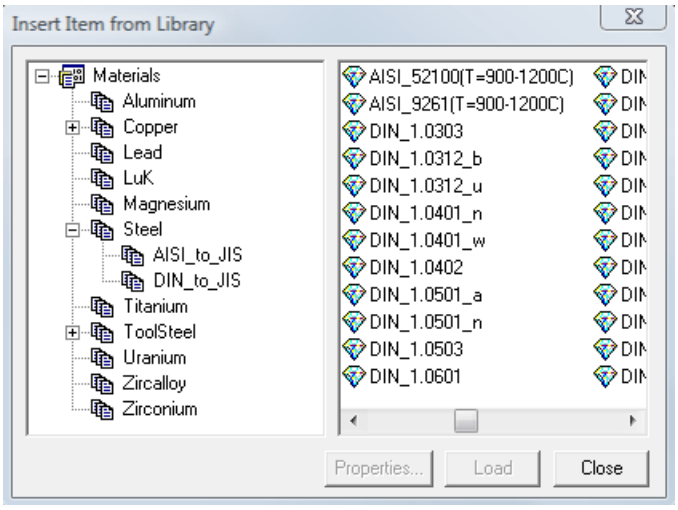

Figure 6: Material Selection from Data-Base

LUBRICATION

The lubrication is modeled by assigning an appropriate friction coefficient to each die. To assist with this choice,

a lubrication option can be chosen from a friction library, as shown in figure 7.

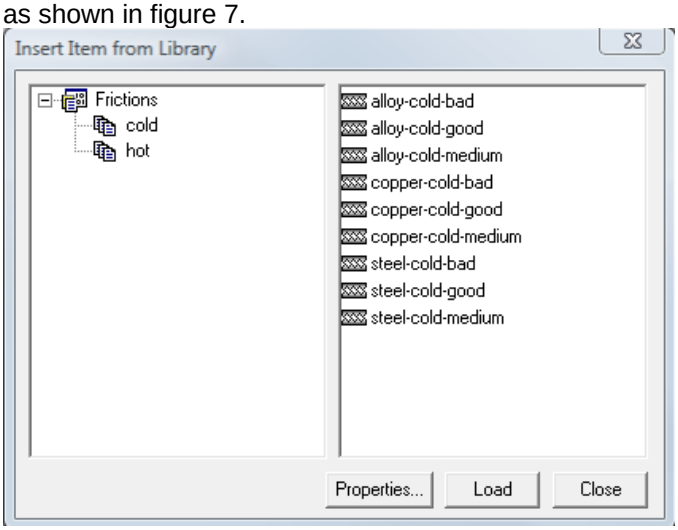

Figure 7: Friction Selection from Data-Base

2½-D SHEET MESHING WITH HEX ELEMENTS

The blank, or work-piece, is defined as a 3D shape. A 2½-D sheet meshing algorithm will automatically detect the thickness direction of the sheet, and create an optimized mesh of 3D Solid Elements, also referred to as HEX elements. The ability to use HEX elements is unique, and provides the most accurate results possible. It is especially good for predicting thickness variations, spring-back and residual stresses.

The initial and deformed Hex sheet-mesh representations are shown in figure 8.

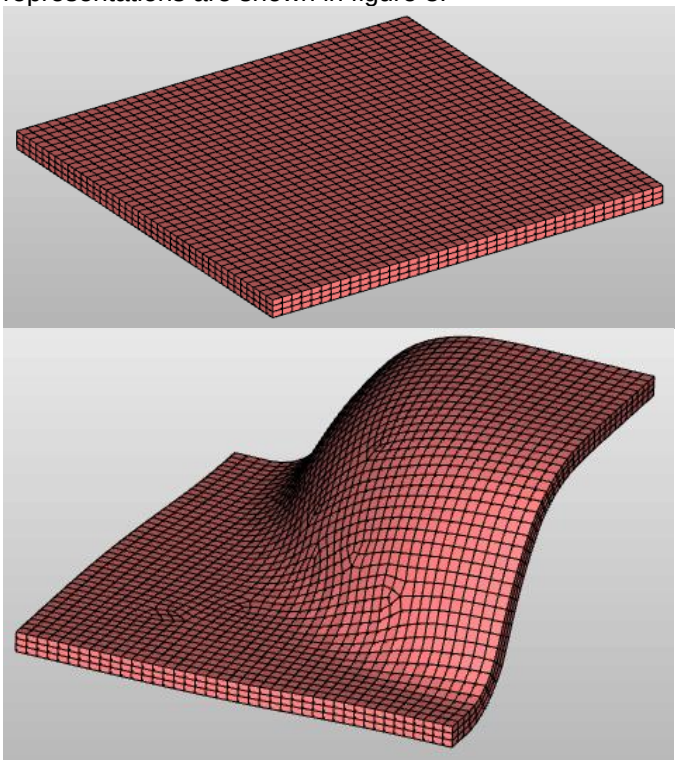

Figure 8: HEX re-meshing for Sheet Metal example

MULTI-STATION

The above description describes the modeling steps for the first station in a sheet metal forming process. Most parts are formed with a sequence of forming steps. After each forming step, a spring-back calculation will be performed automatically. During the simulation of the next station, the shape, thickness, stress, strain, and temperature of the previous station are automatically carried over. This process is demonstrated in figure 9.

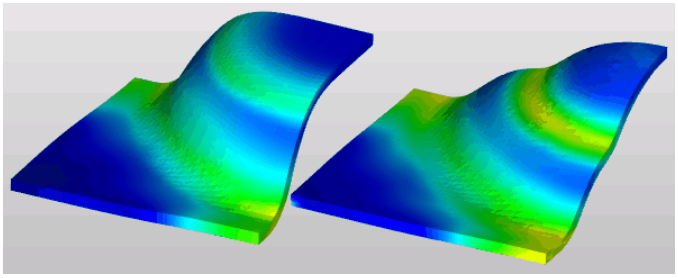

Figure 9: Multi-Station example with automatic transfer of all properties – Example Showing Plastic Strain

ADDITIONAL CAPABILITIES

Additional capabilities, which will be demonstrated in a next paper include:

- **Die-Wear** - the Archard wear model is available to predict wear of the die during the forming process [1].
- **Trimming** - after the final forming step, typically a trimming of the part takes place. After the trimming step, a spring-back calculation will give the final shape, with residual stresses & strains
- **Part Performance** - It is possible to take the final result and use it in a structural stress analysis to study for instance fatigue life or resistance against external loads the part might encounter during operation in the final product.

MORE EXAMPLES

The examples shown here high-light the capabilities of the 2½-D sheet meshing algorithm, which is the key enabling technology to make it a possible to efficiently apply 3D Solid Elements to Sheet Metal forming simulation.

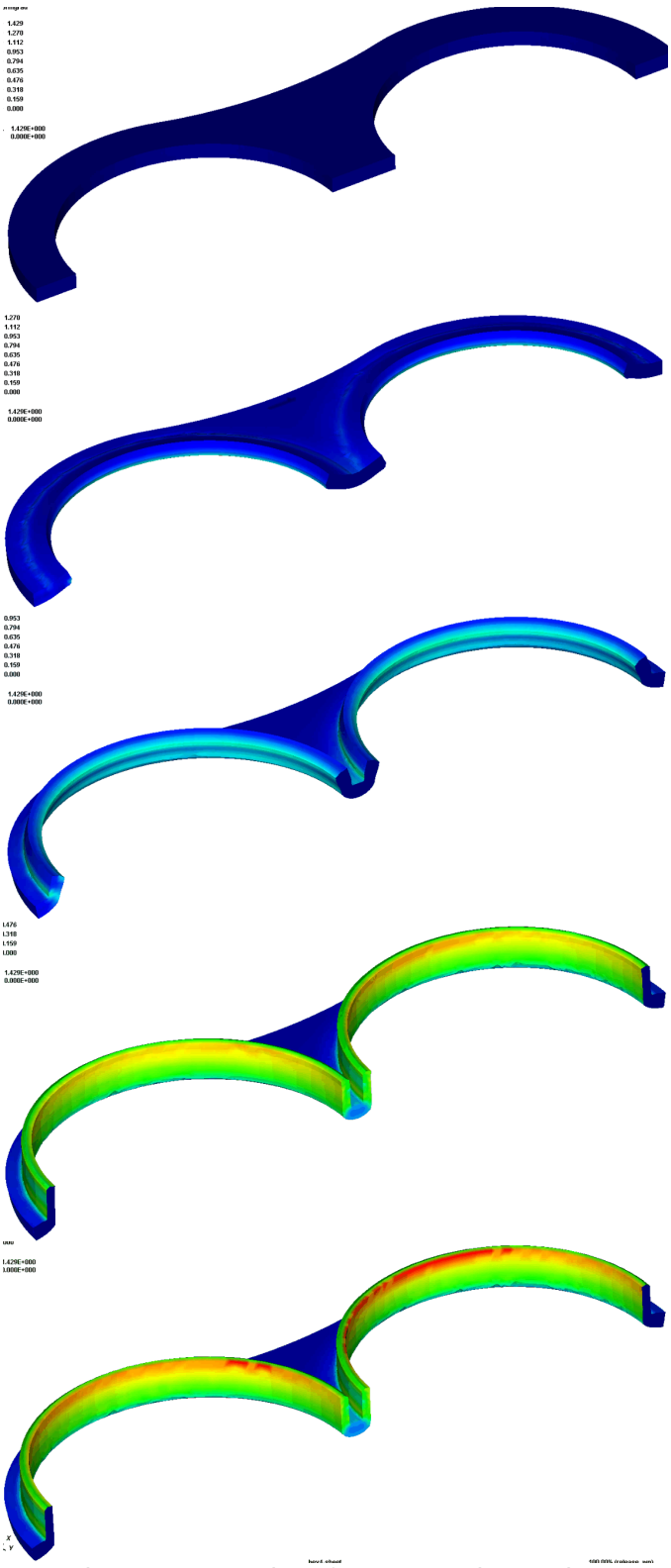

Figure 10: Stamping of an Automotive Gasket

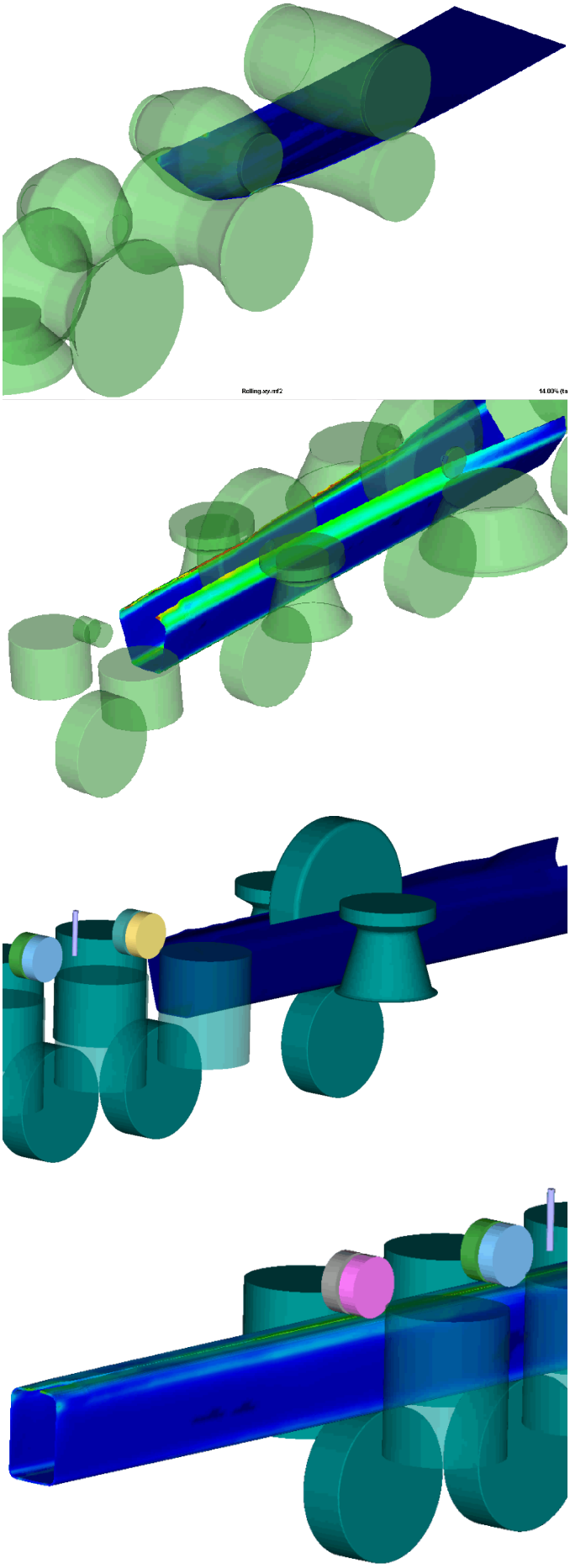

Figure 11: Roll Forming of Profile from Flat Sheet

CONCLUSION

A new sheet meshing technology has been developed, using 3D solid elements (HEX). The technology is seamlessly integrated into the proven, easy to use metal forming simulation software package Simufact.forming.

The results of a sheet metal forming simulation using 3D solid elements allows an accurate prediction and study of through the thickness stresses & strains, resulting in a correct spring-back prediction.

REFERENCES

(1) J. F. Archard, 1953, "Contact and rubbing of flat Surfaces", J. Applied Sciences vol. 24, Pg. 981-988

CONTACT INFORMATION

For further details about this work, the author can be contacted at the following e-mail address:

Arjaan Buijk: arjaan.buijk@simufact-americas.com

For further details about the 2½-D sheet meshing algorithm, the developer can be contacted at the following e-mail address:

Peter Kraft: peter.kraft@simufact.de