Simulation of Sheet Metal Forming – New Developments

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1 Introduction

The use of finite element (FE [12], [16]) simulations to conduct a virtual validation of the forming process for sheet metal parts has been introduced in the mid 1990s and is state of the art in the automotive industry today. Two challenging tasks for determination of feasibility of a tool design and its process parameters [17] are the prediction of the material behavior during the forming process and the springback of the final part [2,3,4].

In order to improve the predictive accuracy of the forming simulation, the level of detail has increased steadily regarding many aspects of the simulation model. For example, the material behavior during drawing is influenced by the preceding trimming operation as the latter causes damage at the trimmed edge. Furthermore, during the drawing the pressure distribution between the blank and the blankholder may vary significantly due to the deflection of the tool and the press. This can result in a disadvantageous restraining behavior. Considering these effects may lead to a further improvement of the simulation's accuracy.

As a result, the increase in data size and level of detail of the FE models poses a challenge for the future simulation systems and their application [5].

2 Forming simulation at the BMW Group – State of the art

Since the mid of the 1990s, forming simulation is state of the art in the tool development process and there are a lot of use cases today.

2.1 Simulation in the tool development process

The design process of a deep drawing tool is supported by FE simulation systems in many applications.

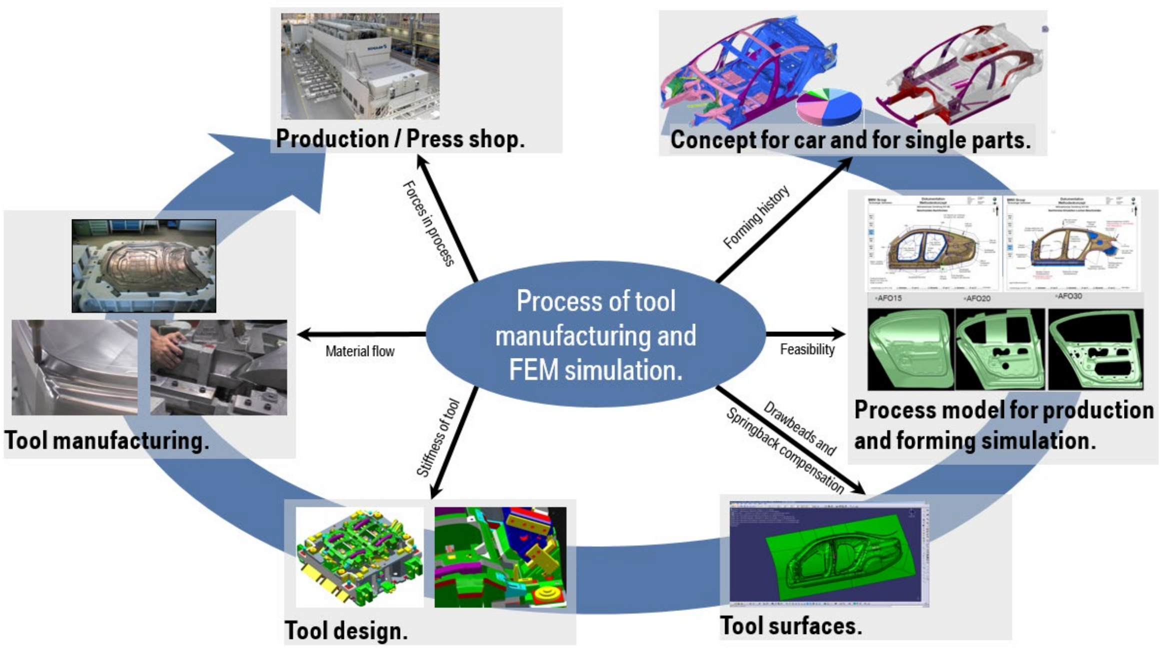

Fig.1: Application of simulation in the tool development process – [5].

In the design process of the car body, the forming simulation supports the simulation of passive safety with the material history from the production process to give a better prediction of the structural behavior of the car body in crash simulations. The main usage of the forming simulation is to model the production process itself and to conduct design studies for feasibility. When a good geometrical design for the forming tools is found, the next step is the springback simulation and its geometrical compensation. One more use case for the simulation is the prediction of stiffness of the tool to support the CAD engineer. More key results from the forming simulation are the forces that occur in the production process in the press line and the material flow during the deep drawing. All these applications of the FE simulation support the engineers in the design process.

2.2 Software concept

To deal with all the challenges in the design process, a general software setup is used for forming simulation. The input consists of geometries, material data and process parameters. These are all part of the classical pre-processing. The application was realized with BMW's own software systems to provide a process orientation to the forming process in graphical user interfaces [2,3,4].
This approach enables every user to setup a metal forming simulation with the FE solver LS-DYNA [1,9]. In the next step, the solution is computed by the solver and the results can be analyzed.

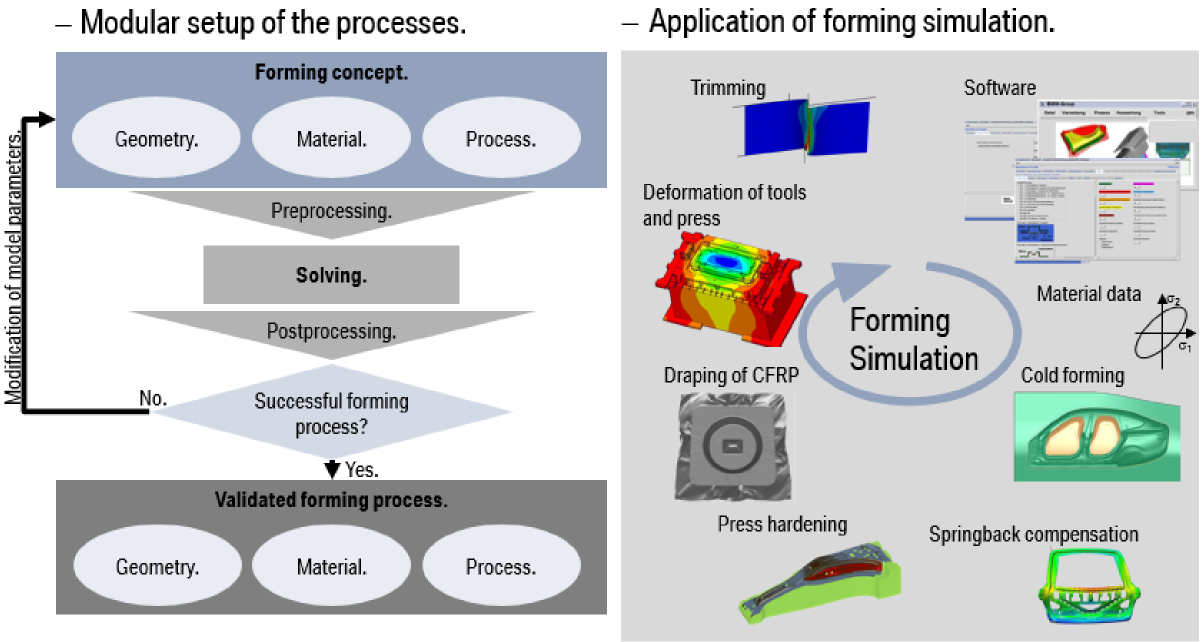

Fig.2: Software concept – [5].

This kind of simulation is used in a lot of cases in the engineering process, whereas cold forming simulation of automotive body parts is fundamental. After the cold forming simulation, the tools are springback compensated to reduce the final deviation from the target geometry. Further applications are indirect press hardening [13], draping of CFRP [14,15], calculation of the deformation of tools and the press at the end of the forming operation and the trimming.

2.3 Assumptions and limitations

The state-of-the-art simulation models for sheet metal forming have a lot of assumptions and restrictions [15]. For example, assuming all the tool surfaces as well as the whole press as a rigid body, the simplification of the displacement curve for the punch, the evaluation of necking and fracture with the FLD – limited to linear strain paths and flat geometries, etc.

One big point is the assumption on the behavior of the sheet metal blank as a shell body and the implementation of the FE shell elements with linear strain tensors through thickness with constant volume.

3 New developments

In the following, a short overview of why we need new shell elements with the capability to use 3D material models is given.

In classical deep drawing operations for body parts of a car, the usage of drawbeads is common. In some cases, two drawbeads are used in combination. Then, we've got six radii and then the draw in radius of the die.
All these radii are relatively small compared to the thickness of the blank, so that the assumption of a linear strain tensor in the shell elements is not valid.
Because of this the state of stress is not calculated in a correct way and in consequence, the prediction of spingback is not accurate.

The demand for a new shell element, with a nonlinear strain tensor over thickness is shown.

The EFB-Project "3D-Blechmodellierung" developed new shell Elements. The results on springback of a fender from a prototype deep drawing tool is shown, by using the new 3DBM13 Element in combination of a 3D yield model.

4 Summary

Shell element, rigid tools and the FLD have been state of the art for more than 10 years in evaluation of the forming simulation for the sheet metal blanks. In this presentation, the results of a new shell element in combination of 3D yield models are shown.

5 Literature

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