Process optimised FEA- Calculation for Hydroforming Components

Authors:

Michael Keigler, Herbert Bauer
University of Applied Sciences, Aalen, Germany

Richard Hall
University of Wolverhampton, UK

Prof. Musa Mihsein
De Montfort University – Leicester, UK

Correspondence:

Michael Keigler
University of Applied Sciences Aalen
Beethovenstraße 1
73430 Aalen – Germany

Tel: +49 – (0)7361 / 576-290
Fax: +49 – (0)7361 / 576-214
e-mail: michael.keigler@fh-aalen.de

Keywords:

Finite Element Analysis, Forming Simulation, Optimisation Concept

1 Introduction

Since the beginning of the 90s Finite Element Analysis (FEA) Forming Simulation has gained importance in design and realization of hydroformed components [1]. It has been used in process design from the first layout to serial production [2]. There are now many installations of appropriate software systems in forming technology companies as well as numerous publications on this topic.

The possibilities of further reduction of costs, increased returns during simultaneous development-time reduction are largely exhausted without the optimized application of FEA Forming Simulation. At the same time however the pressure of global competition to reduce development costs, time and improvements in quality has arisen. Based on these facts it has to be searched for new rationalization concepts in the surrounding field of the FEA Forming Simulation.

This contribution pursues the principal purpose: to present a new simulation concept for the reduction of costs and time of component feasibility studies. This new concept gives enterprises suggestions to re-organize FEA Forming Simulation. In addition to that, the difference between the “classical FEA simulation approach” and the "new approach" will be shown in order to present the improvement.

2 Classical FEA- Simulation Concept

Due to its various shaping and design possibilities, the hydroforming process is used for more than 10 years in the automotive industry for the production of complex carrier structure units. Thereby deemed the since 1994 at BMW in series manufactured rear axle construction, consisting out of 4 hydroformed units, as a precursor for this new production technology. The requirements e.g. the shaping possibility respectively the design space of unit geometry, the expansion relationship as well as the maximum plastic deformation possibility are risen constantly since that time. This requires ever larger efforts to fulfill these requirements under compliance of the fixed time and cost goals.

Figure 1 shows the principle proceeding of the development of a hydroformed part based on the design data of the unit [3]. In a first step of the component analysis, it is necessary to evaluate the part quality based on correctness of circumferences and radii as well as the run of the part centerline. Based on the expert knowledge of the process planner, the first and deciding definitions will be done regarding the technique compatible adjustments of certain geometry parameters. On the basis of the component analysis results, the definition of the initial tube diameter and the layout of additional manufacturing steps such as bending, preforming, hydroforming and punching as well as, if necessary, the end trimming take place.

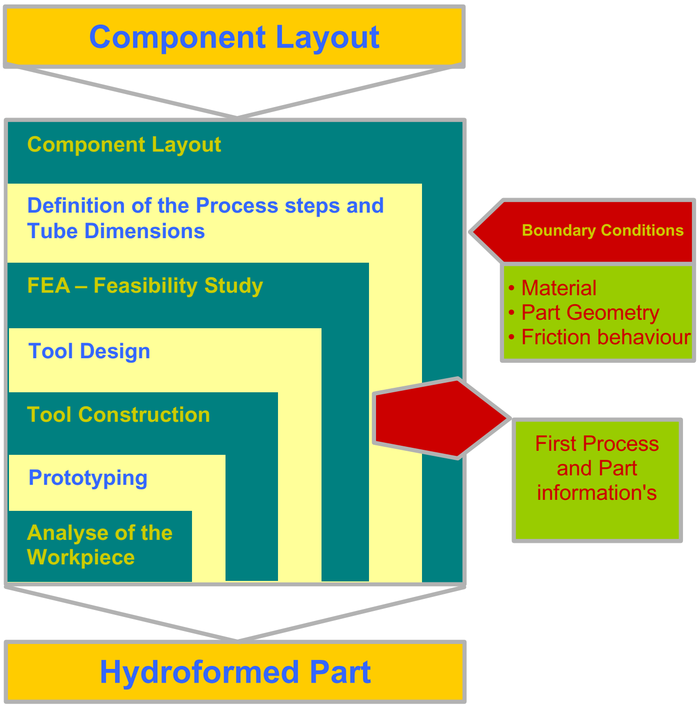

Figure 1: Principle proceeding at the development of a hydroforming component

The task of the following FEA simulation of the hydroforming process consists in a general feasibility study for the forming behaviour of the semi-finished product and/or the tools. Due to the complex connections of the process influence parameters the method of the non-linear finite elements offers the condition to fulfill these requirements in particular regarding plausibility check, general feasibility as well as adjusting quality and tolerance field promises (formation of wrinkles, springback, form and position tolerances). A quality increase can additionally be derived accompanying the increase of manufacturing security for series production by the evaluation of the manufacturing simulation.

In the feasibility study beside the forecast from any failure modes (breaks, bursting and formation of wrinkles) also an analysis of sensitivity of the process influence parameters (semi-finished material, transforming pressure and axial force as function of time) will take place. Additionally in the virtual prototyping the optimisation of the process will be started by a meaningful variation of the important process influence parameters. A further substantial task of the manufacturing simulation is, to get early statements concerning the resulting product properties (wall thickness distribution, stress and/or strain distribution, work hardening). Therefore the progression of the forming process is very importance. The calculation of the influence of any elastic deformations on the springback behaviour of the hydroformed component is important regarding dimensional- and form tolerance. Crucial starting points for the optimisation of time, costs and quality of the process layout lie in the early stages of the component development. In this phase it is possible to change the process parameters without time and cost-intensive measures e.g. tool modifications.

With incremental non-linear 3D-FE-Systems, e.g. LS-DYNA, very good results have been obtained in comparison to experimental results, which make physical prototyping no longer necessary. Deficits are still in the time-effective realization of the FEA forming simulation in continuous shortened development cycles.

Five years ago the development time of a hydroforming prototyping tool, i.e. the time period of the feasibility check of the design information regarding the used forming method, the tool design and the production of 50 samples, required on average 22 weeks. This period has been reduced nowadays to 11-13 weeks. Consequentially there is a demand for the FEA forming simulation, to realize solutions and process chains within reduced time intervals.

3 New FEA- Simulation Concept

Mainly in the development phase, but also during the production planning of hydroformed components, the implementation of modern analysis techniques can take a key position in order to get producible components in less time. CAD/CAM and FEM techniques allow the dimensional definition, final product geometry definition and the determination of production technologies in a virtual environment [4]. However in addition to the already addressed integration of these support tools also the specific time-optimised realisation must take place.

By the use of method- planing- tools, so-called virtual planning systems, an analysis of the product geometry can be accomplished. This serves the process engineers but also the tool designer during the design of the process (manufacturing sequence, tube diameter, tube wall thickness etc.) and tool design (separation plane definition). For that purpose the intuitively accomplished design of the hydroforming tools will be replaced by structured process specific CAD planing algorithms. Thereby the mutually coupled design steps are controlled. As result of this planning-methodology an associative parameterised tube geometry is available, which offers now the possibility, apart from the already usual process parameters (flow pressure, calibration pressure), to include the geometry variance into the process optimisation. Thus not only the quality of planning can be increased substantially, but also the planning expenditure can be reduced up to 70%.

On the basis of the results of the above addressed planning systems it is possible to define the manufacturing sequences and the used tube geometry in order to determine the actual feasibility of the process and the condition of the formed component before the tool manufacturing. The FEA forming simulation must take place as efficient and fast as possible. For this e.g. the calculation software AutoForm is suitable. Such a system offers the advantage, that the manufacturing (prefabrication) of the tools can begin very early in the process design. An estimation of the strain and wall thickness distribution after the hydroforming process, in addition, a view of the hydroforming process preceding bending process, can be done with this FEA- tool. This only takes a few CPU minutes and thus proves suitability for this kind of application.

Numerous industrial projects have shown in the past that the accuracy, which can be achieved, is sufficient for the first estimations during the planning phase. Different optimisation loops and variations can be accomplished quickly. Thus, at a relative early stage time-intensive tools can be manufactured, during still existing critical ranges will be examined with time-intensive, explicit FEM systems and optimised if necessary.

The University of Applied Sciences Aalen uses such a system (figure 2) of a closed process chain since the year 2001. The substantial effect is that a further time reduction can be reached during the realization from the design to the manufacture of a real hydroformed prototype. Thereby the addressed demand of the market to produce prototyping tools for the hydroforming process within 10-12 weeks can be obtained.

4. Conclusion

In order to get very fast results for the feasibility of a hydroforming component, the software AutoForm suits very well in combination with the HydroDesigner. In a few steps the bend line and the tool geometry are specified from the component geometry as well as a first circumferential analysis is accomplished with a selected diameter. The quality of the results of the forming simulation shows the handicap of the Software. Here are the advantages of LS-DYNA. The quality of the obtained results is still unequalled so far. In the meantime an analogy with the reality is reached which is under the dimensional tolerance of the semi-finished material. Because of the fast development of the computer systems the calculation time is no longer a criterion for the comparison. The optimal solution for the users would be a combination between the excellent pre-processing of AutoForm and the reliable and high- precision solver of LS-DYNA.

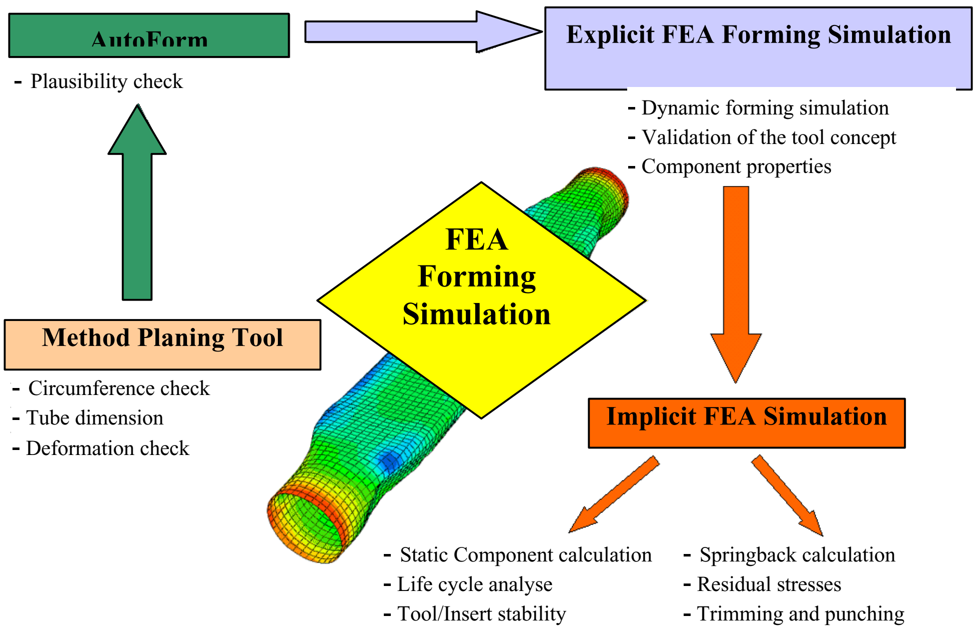

Figure 2: Process chain for the "New" FEM simulation concept

References:

[1] H. Bauer, A. Haas, R. Hall, M. Mihsein “Production Safety for Hydroforming Products by using FEA.Techniques”, NAFEMS World Congress 99, Vol1. p. 475- 484, Newport, USA

[2] A.Haas, H. Bauer, R. Hall, M. Mihsein “State of the Art in the use of (LS-DYNA) forming simulation in hydroforming and preceding processes”, Third European LS-DYNA Conference 2001,Paris, France

[3] M. Keigler, I. Lerch, H.Bauer, A. Böhm “Möglichkeiten und Grenzen der FE- Simulation bei der Innenhochdruckumformung“, 19th CAD-FEM Users´Meeting 2001, Berlin, Germany

[4] T. Pepelmjak, G. Gantar, K. Kurzman ”Numerical Simulation in Optimisation of Product and Forming Processes”, SheMet ´99, pp. 203-210, Erlangen, Germany