Process Simulation of closed profiles by chaining of forming and welding simulations, using Simufact.forming & Simufact.welding

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Summary

Manufacturing process simulation is becoming a standard tool in design and development departments. Better parts can be manufactured at lower cost and in less time. The range of manufacturing processes that can be analyzed with simulation tools has increased rapidly in recent years. This is the result of a combination of factors. Computer hardware has continued to evolve with faster CPUs and lower cost cluster configurations, while software developers, like SIMUFACT, have created very efficient solvers that benefit from today's hardware capabilities by using parallel computational algorithms. In addition, the graphical user interface (GUI) technology has evolved to an intuitive and extreme ease-of-use, enabling process design engineers to prepare in little time a realistic, 3D simulation model that captures the underlying physics of the manufacturing process. The fast, ease-of-use modeling capability is critical to enable manufacturing process designer engineers to rapidly evaluate a series of possible process variations, prior to any physical trials.

This paper will ilustrate the process simulation of closed profiles by the chaining of forming and welding simulations, using the **Simufact.forming** and **Simufact.welding** software.

Keywords: *Simulation; Roll-Forming; Welding; Closed profiles; Simufact.*

1. Introduction

Prediction of parts or entire assemblies properties by virtual process design is gaining more and more relevance. Of particular interest is the modeling of the manufacturing process to determine machine parameters, and to determine the properties of the formed product.

One of the strengths of simulations is the possibility to try out ideas and validate concepts, to examine a large number of variants and to carry out sensitivity studies. For this purpose, **Simufact.forming** provides special automatic optimization algorithms and allows the user to easily organize a large number of variants, carry out the required simulations, evaluate them and finally describe the results in a format that any process design engineer can understand. This considerably unburdens the user.

A new trend in the simulation is the consideration of the manufacturing history in subsequent manufacturing processes targeting the precise prediction on the properties of individual parts and assemblies of components. These results can then be used for subsequent more accurate structural and fatigue simulations.

A challenge for the simulation of entire process chains and their individual aspects is the usability of the applied programs, which must be user-friendly, praxis-oriented and interpretable. In this paper, some recent developments of Simufact Engineering GmbH, from now on referred simply as Simufact, will be presented and discussed. These developments are carried out in close cooperation with customers and research organizations from different disciplines.

A large number of material models (fully elastic-plastic, isotropic, anisotropic, kinematic hardening, Bauschinger effect, etc.), powerful contact algorithms with friction models, heat conduction, dynamic effects, complex kinematics of the tools (load-controlled or revolving, spring-loaded) and rigid-body-mode for the work-piece are available. Furthermore, the program design is open, allowing for fast adaptation to customer requirements and quick implementation of new functionalities.

2. Process Chain

The term "process chain" is being used in different fields, from business processes to factory layout. In the context of this paper, the focus is placed on process chain analysis of selected metal forming & welding processes.

The aim of a holistic modeling approach is the combination of a series of manufacturing steps to include part-properties from start of the manufacturing process to the finished product. The complexity of these processes can no longer be efficiently handled without simulation techniques.

The industrial competition forces enterprises to develop new products faster, leaving less time for iterative trial and error experiments. This often leads to expensive corrections, if the process window is not large enough. An example is the short life of the tools, which can handicap the start of mass production, even if the process is principally ok. Also, variations of material properties or production conditions may result in a disrupted process.

The objective of a process chain examination is to increase reliability and discover possible serious disruptions. In addition, more knowledge about the properties of the final product is generated, allowing further product and process optimizations.

Figure 1 shows an example process chain, which can be arbitrarily extended or shortened.

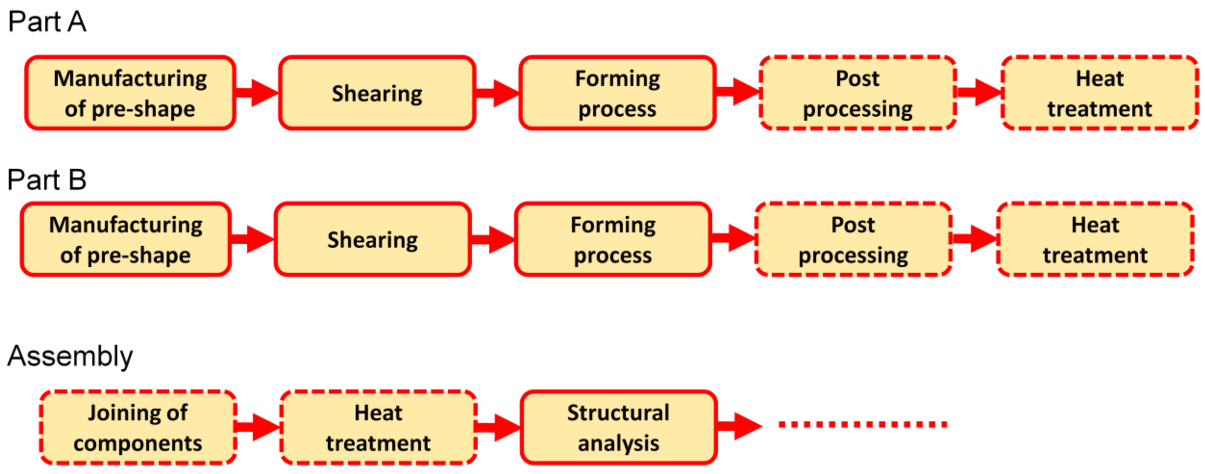

Figure 1.Schematic representation of a process chain

In this example, production of two parts is investigated, which are assembled to a finished product e.g. by mechanical or thermal joining. The properties of the assembly can be subjected to external loads and also analyzed. The inclusion of the full history of the part gives a deeper understanding of the complete manufacturing process and allows for specific adjustments to reach an optimal final product.

The philosophy of Simufact is to connect the best technologies available. This is carried out in two ways. Either the methods are directly implemented in the software or interfaces to external modules are provided.

3. Welding simulation

A large number of metal products are joined by welding after being formed. In addition to its purpose of thermally joining the formed parts, the welding process has important side-effects that must be controlled:

- The material properties are partially altered
- Distortion is added
- Stresses are added, which are superimposed to the residual stresses of the preceding forming processes.

Simulation of metal forming processes is well established at many companies and used by manufacturing process design engineers. In contrast, the simulation of welding processes is relatively new, and has not been adopted by many industrial companies. In those companies that do perform welding simulation, it is typically carried out by researchers in separate departments specialized in fundamental analysis. The reason is that welding simulations were always very time consuming and complex to set up.

Due to the impact on the manufacturing process, welding simulations have recently received a larger focus in the manufacturing industry. For this reason, Simufact was assigned 6 years ago with the development of a new simulation program, called **Simufact.welding**. This new simulation program focuses on the requirements of the research-group *"Welding Simulation"* of the German automotive industry. This new software program has been released and is being used alongside with **Simufact.forming**. Both software are consistent in their user-interface, and incorporate the latest developments and modern concepts. Both software can also be merged to allow process simulations of entire manufacturing process chains.

Besides the prediction of the structural properties of the assembly, the welding simulation is applied to determine the best sequence of welding steps, the required heat and to define suitable clamps to minimize the distortion.

In the remainder of this paper, an example will be presented highlighting important aspects of the simulation of the complete manufacturing process of a closed profile, composed initially by a roll-forming operation followed by welding

4. Process Simulation of Closed profiles by chaining of forming and welding simulations

The complete process chain of this examples consists of the following steps:

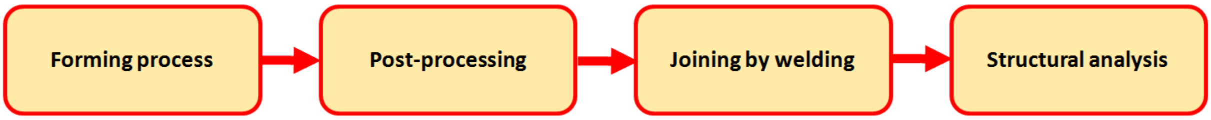

Figure 2.Schematic representation of a process chain forming and welding

Metal Forming Process and Post-processing

The metal forming process of the component starts with a roll forming process that transforms a plane metal sheet into a closed profile. The geometry of the initial blank is given by its CAD-geometry with a constant sheet thickness, and the tools are defined by solid 3D geometries, also modeled in the CAD system. Figure 3 shows the forming sequence as simulated by **Simufact.forming**.

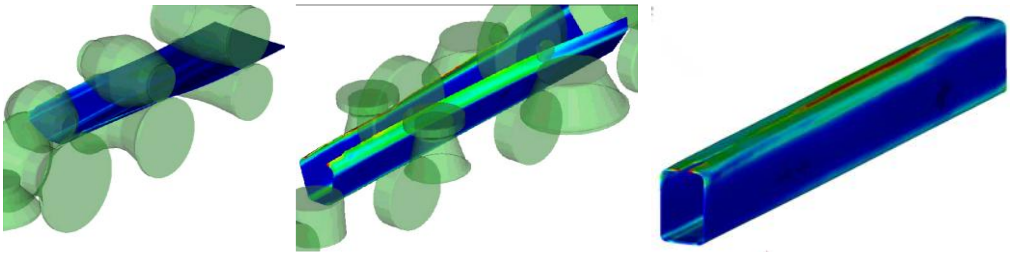

Figure 3.Metal forming simulation of roll-forming process

After the forming simulation is completed, the component is now available in its final shape with simulated sheet thickness distribution and all other properties, e.g. strain hardening and residual stresses to name the most important.

Joining by Welding

Next, the final geometry and all other associated properties and results obtained in the forming simulation are imported into **Simufact.welding**. Welding boundary conditions and all relevant welding process properties are then assigned to create a new model to simulate the welding process. This includes the specification of the welding heat source, for which a Gaussian Volume Model was used, as shown in Figure 4.

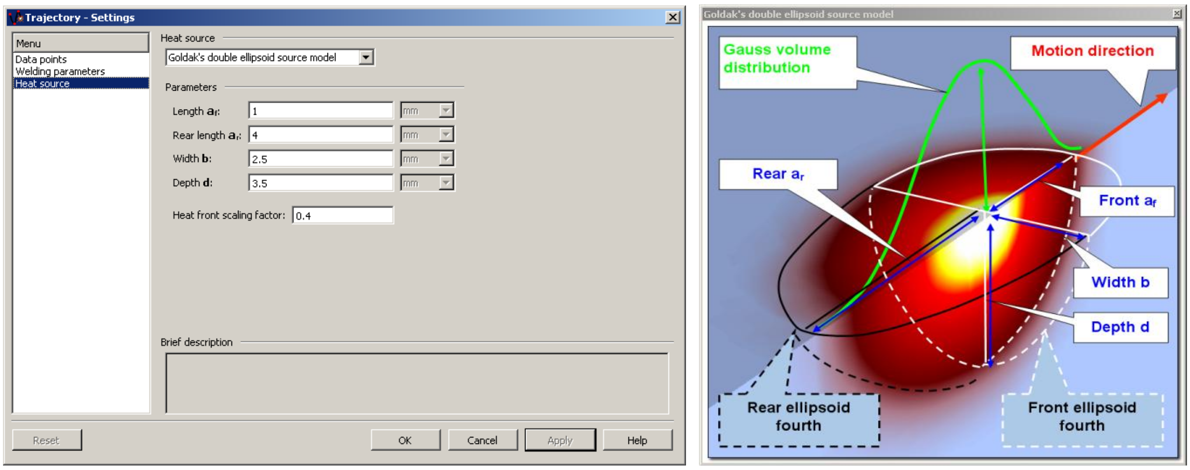

Figure 4.Definition of the heat-source of the welding process

Once all process parameters are defined, the simulation of the welding process is carried out. As the heat source is moving along the weld-path, the finite element mesh automatically adapts itself, allowing for an accurate prediction of the heat flux, heat conduction and calculation of distortion and residual stresses. This adaptive meshing is visualized in Figure 5, showing the temperature along the weld-path and in the cross-section of the sheet.

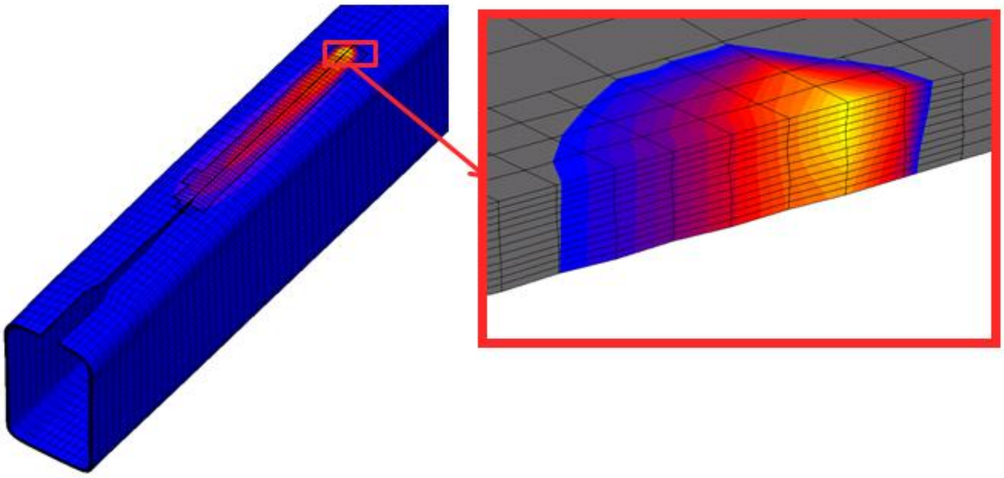

Figure 5.Automatic adaptive mesh refinement as heat source moves along the weld-path

As can be seen in Figure 5, the element type used for simulation of the welding process is a solid hexahedral element.

During the welding process, it is important to take into account side-rollers that push the profile shut, so the welding process can indeed close the profile. This model setup is shown in Figure 6.

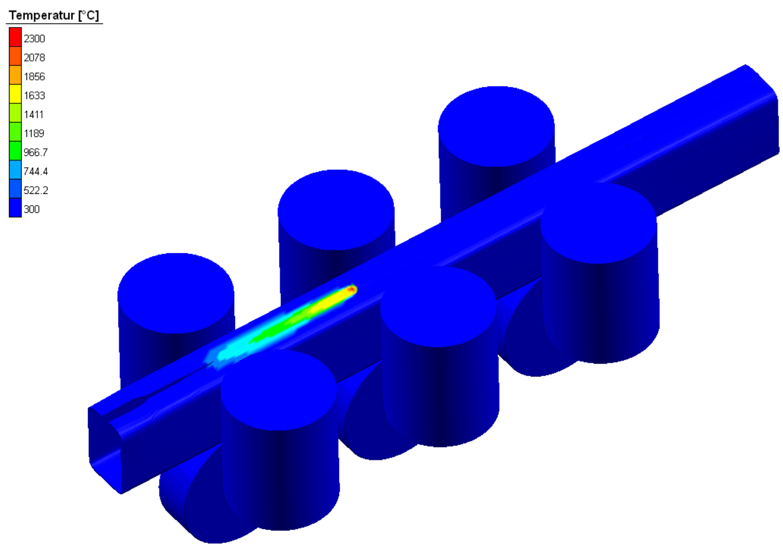

Figure 6.Model setup, including side-rollers that push the profile shut

Following the welding simulation, the assembly is cooled and the clamps are released, followed by a possible heat treatment and structural analysis. All these type of simulations can be carried out through a new model assembled and executed by **Simufact.forming** or by other third party FE software to which an interface is available.

4. Conclusion

In this paper an example illustrated the simulating of a the complete manufacturing process of a closed profile through the chaining of roll-forming and welding using the **Simufact.forming** and **Simufact.welding** software

For more realistic and accurate predictions, it is important to consider the process history of a component until it is assembled to a complex product. Integrated simulation of the complete chain of manufacturing processes is therefore receiving an ever growing interest from the metal forming industry.

With the Simufact software family (**Simufact.forming** and **Simufact.welding** , complemented by the implementation of interfaces to other third party simulation software, the process and product design engineers have an extremely powerful and trendsetting concept at their disposal.

Simufact continuously develops the software in tight cooperation with its customers based on their requirements and suggestions, ensuring that future capabilities implemented into the software are in accordance with customer requirements, providing them with a competitive advantage. Because of the proven and robust underlying solver technologies employed in both software, many possibilities for future advancements can be rapidly provided. The open concept of the software assures faster development and integration of further technologies.

5. References

[1] Barth, C. Optimierung von Fertigungsprozessen mit simufact.forming. Neue Möglichkeiten der Kaltumform-Simulation. Tagungsband 12. Round Table "Simulation in der Massivumformung", Bamberg, 2010. ISBN 978-3-9813814-0-5.