Sheet Metal Forming: Spring-back of hydro mechanical deep drawn parts

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ABSTRACT

Active hydro mechanical forming (AHMF) has been developed in order to meet the demand of the automotive industry for economical production of sheet metal parts with more individuality in small lot sizes. Conventional deep drawing of automobile parts which have large outer surface areas (such as roofs, doors and hoods) leaves them with a very small dent resistance. This is caused by the low deformation degree in the middle of the part. This low component stiffness has a negative effect on the crash resistance of vehicles. By using the AHMF technology a consistent plastic strain distribution can be brought into the part and therefore its stability will be improved. Within the design of conventional deep drawing tools the spring-back of a part is well understood because of the long experience with the process and its influence on the stress distribution inside the deformed part. In AHMF, as with any new process, the spring-back phenomenon is still under investigation. There are a considerable number of parameters to control in order to regulate the stress distribution and the shell thickness, which leads to more spring-back possibilities. This paper presents a simulation of spring-back in AHMF to find an efficient method of tool design and to generate the optimum process parameters, in the prototyping or later production. The FEM simulation is based firstly on the validation of the results of the AHFM process given by the mathematical calculation with the computer generated model. Secondly, spring-back simulation is introduced to see the influence of pressure curves and the blank holder forces or the parameters of the pre-bulging step. The quality of the FEM simulation is verified using practical applications in the automotive industry.

INTRODUCTION – Basics

Today hydro mechanical deep drawing is a good solution to produce parts for a low number of units or in the field of prototypes. The range of parts which are manufactured in this technology is very wide: including parts from the chassis made of high strength steel up to large outer surface parts in aluminum [1].
In the first steps of the rediscovery of this technology (developed in the late 1960's), the simulation was calibrated and all necessary tool features were integrated in the virtual model. A scaling was also done from small cups to larger parts which take place in the automobile industry today. The technology was developed for the requirements of the automotive customers in those days and for the needs of the future.
In this phase a lot of tests were done to improve the friction parameter for the simulation, also the tribology of hydro mechanical drawing was studied. The result of this work was significent and is illustrated in Figure 1. The display of the wrinkles over the complete manufacturing process is very accurate and precise. In the first process step the pre-forming, this accuracy is very useful for the optimization of the tool design and for the machine parameters which will be used in the prototyping [2].
All this previous research builds the basis for new and faster developments in the area of forming with working media. Today the timescale for early prototypes is 12-14 weeks from the first CAD data, the forming simulation, a tool (material: zamak) to the first part. This short time is seen as a result of the virtual prototyping and the advantages of the AHMF technology.

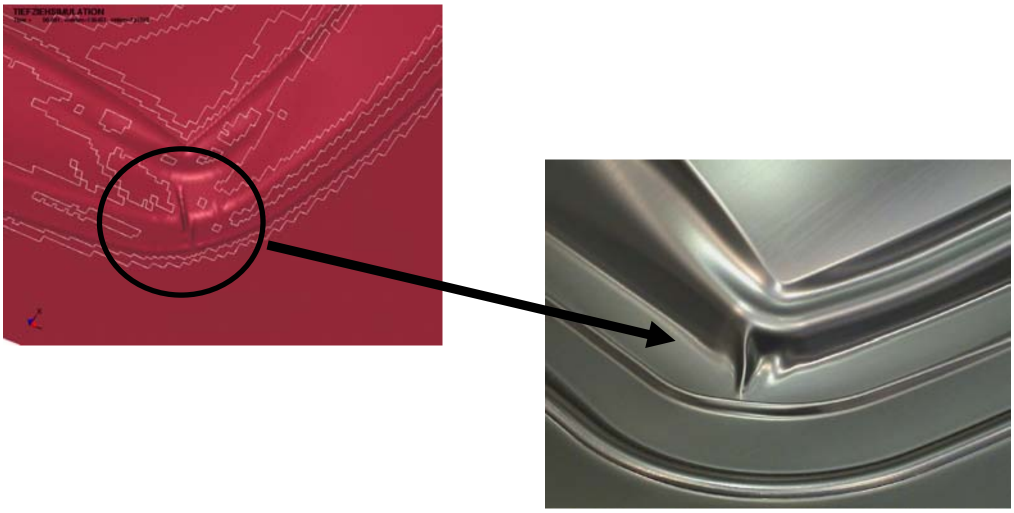

Figure 1: Wrinkles in the simulation (left) and on the real part (right)

Experimental Investigations

For the AHMF process the pre-forming step is very important: in this phase 80% of the part properties and nearly all parameters which are necessary for the tool design take place. This step has, on the one hand, a good influence on the plastic strain distribution in the part but at the same time length and width of the sheet grows. For example a blank of a car roof has the output size of 2500mm x 1700mm, and around this rectangle there is a further 250mm for the blank holder area on each side. The resulting area on which the pressure reacts is 2000mmx1200mm, after the pre-forming step a bubble has been formed as shown in Figure 2.

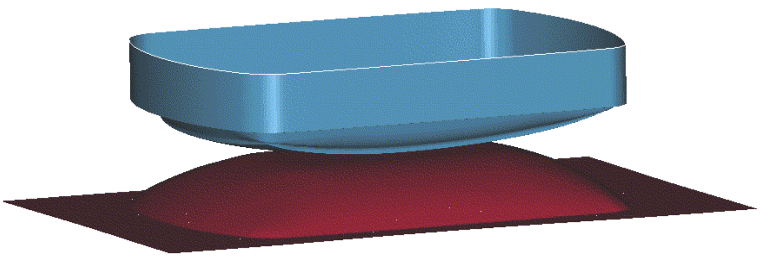

Figure 2: Simulation of the pre-forming operation and the resultant formed bubble of material

In the normal pre-forming step, plastic strain of up to 6 % can be achieved, depending on the shape of the water chamber and the distance between the blank and punch. The developed length of the bubble with 5% plastic strain, based on the example before, is then 2100mm x 1260mm [3]. The following reverse drawing of this bubble brings even more plastic strain. The outcome of this is still more material. A section through an AHMF simulation shows these characteristics of the process very well.

In the starting phase of a new project the simulation is a good tool to calculate the material flow and to optimize the shape of the punch surfaces. The goal is to use all material that occurs during the drawing process in order to get a smooth blank surface on the punch without wrinkles.

An optimization of such a complex process with many parameters takes a long time, but the advantage of this work is a fast prototype phase and a stable process.

The following investigation shows the connection between the pre-forming parameters and the expected spring-back of the part. In the following chart parameters like pressure, punch position and blank holder force are listed to visualize most of the influential parameters.

During the simulations which were focused on the pre-forming step many parameter variants were tested. The goal for the simulation was a constant plastic strain distribution with 3%,4%,5% and 6% in the middle of the part after the first step. In this research the test part was a car roof. One restriction for the reverse drawing step, for the parts with 5 and 6% plastic strain, was the reduction of the material flow. In the calculations above, it is obvious that the developed length rises with increasing plastic strain rates. In addition to a normal process that follows, too much material is present. This surplus of material is too much in comparison to the available punch area: wrinkles appear on the punch area and are considerable on the transition from the punch to the blank holder.

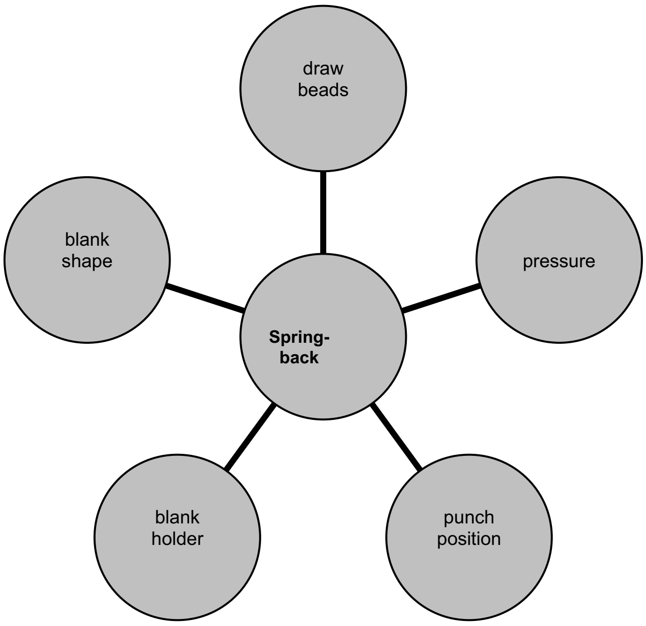

Figure 3: Parameters which influence the spring-back behaviour

In this case the spring-back simulations are not comparable; the different geometrical shapes of the drawn parts provoked by wrinkles falsify the results. The basis for the implicit spring-back calculation should be drawn parts with the same quantity of wrinkles but different plastic strain rates in the middle of the part. In the case study of the car roof it was possible to achieve this goal with one punch design. It is not possible to use one punch for different pre-forming operations as the tool surfaces must be changed to achieve comparable results. A new construction of the punch is very time-consuming but in this case, necessary.

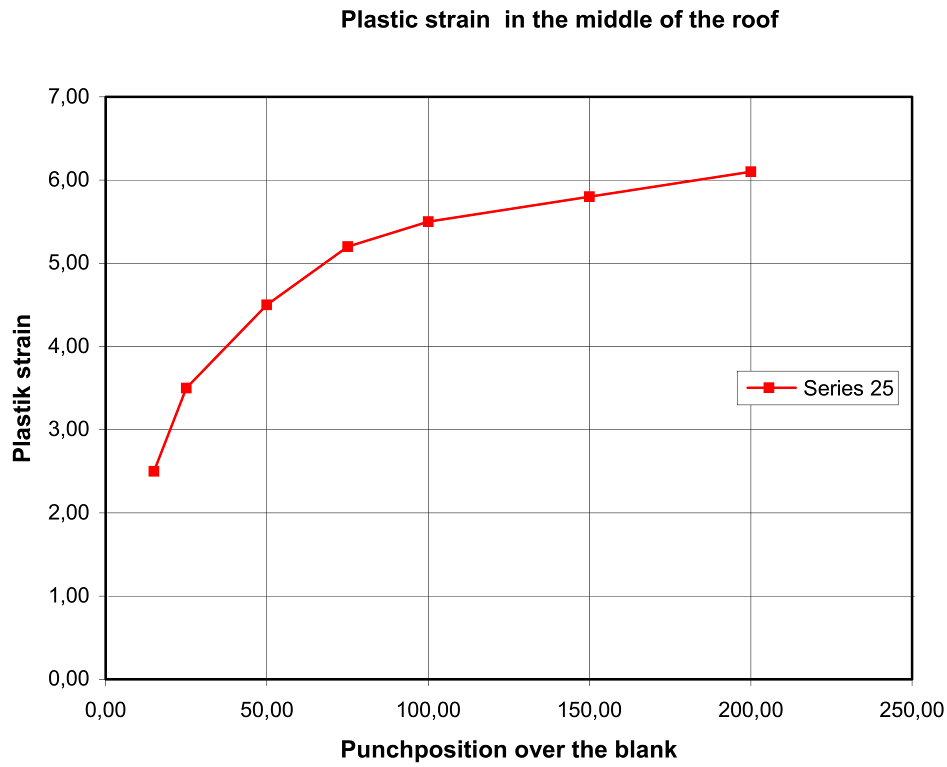

Figure 4 Diagram of the plastic strain in the middle of the roof (y-axis) in correlation to the punch position (x- axis)

The two main parameters to control the material flow during the drawing are the pressure curve in relation to the punch position and the blank holder force. In the interaction of this parameter a good result can be found. In the future, this may be achieved with an optimizing tool. The open parameters should be pressure and blank holder force and the target is a part without, or with less, wrinkles. One wrinkle criterion can be the ratio between the first and the second main strain to get the new input for the next simulation step in the optimizing tool [4]. The result after this step should be the pressure and blank holder parameters for a stable process.

In the test execution for the implicit spring-back calculation the roof is placed in the normal position. The black points define the support of the roof and the geometrical position of the measuring rack for later tests on real parts. For each spring-back simulation the support was newly defined over the geometrical position of the points and the nodes in this area. In the simulation and also in the prototyping, the part is measured with the complete material around the active surfaces. Cutting operations and the behaviour of the trimmed part will follow in a new investigation. Figure 5 shows the roof after the drawing with the position of the support.

Figure 5: The roof component with the black spots showing the support in the simulation

The measuring points on the roof are placed in the edges. The idea is to measure the maximum of the displacement when the spring-back appears. In the analysis of the results only the z-displacement is measured, where the z-axis is vertical to the normal position of the roof.

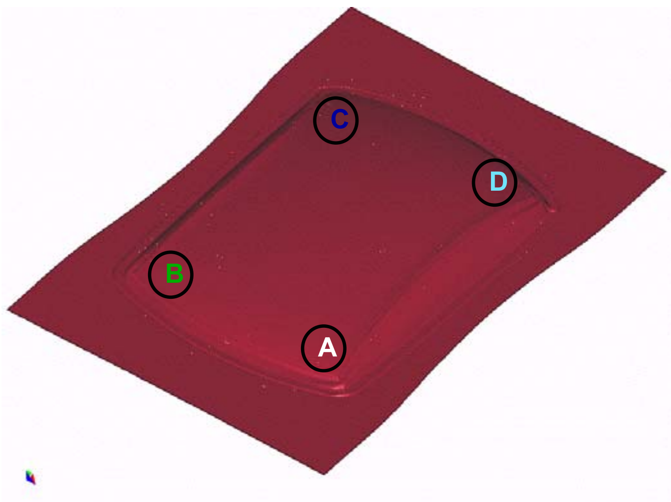

Figure 6: Measuring points on the roof after the spring-back simulation

The input for the spring-back simulation comes from the AHMF simulation, the net on the blank is uniform with 90000 elements; element type 16 (full integrated shell) with 7 integration points. The calculation on a HP B2000 workstation needs 70h for this explicit solution and 19 min for the implicit spring-back simulation. In the case of the explicit solution the 70h refer to the simulation of the part with 6% plastic strain. This solution needs more time because of the larger distance between the punch and the blank and leads to a higher drawing depth and to the highest calculation time.
For the optimization of the drawing process, described previously, less elements with the element type 2 are used to save calculation time [5]. Only the last simulations are done with the fine net and the fully integrated shell.
The evaluation of the spring-back results shows a decrease of z-displacement when the plastic strain in the middle of the part increases. In the areas of parts such as roofs or engine hoods this result shows that the spring-back can be adjusted in a small range when the AHMF process is used. The key to influence the spring-back is the pre-forming operation in addition to the drawing. In the following diagram (Figure 7) the displacement from measure points A and D are shown in the cases of 3%-6% of plastic strain in the middle of the part. All curves of the displacement are off-peak and show a good tendency to less spring-back.

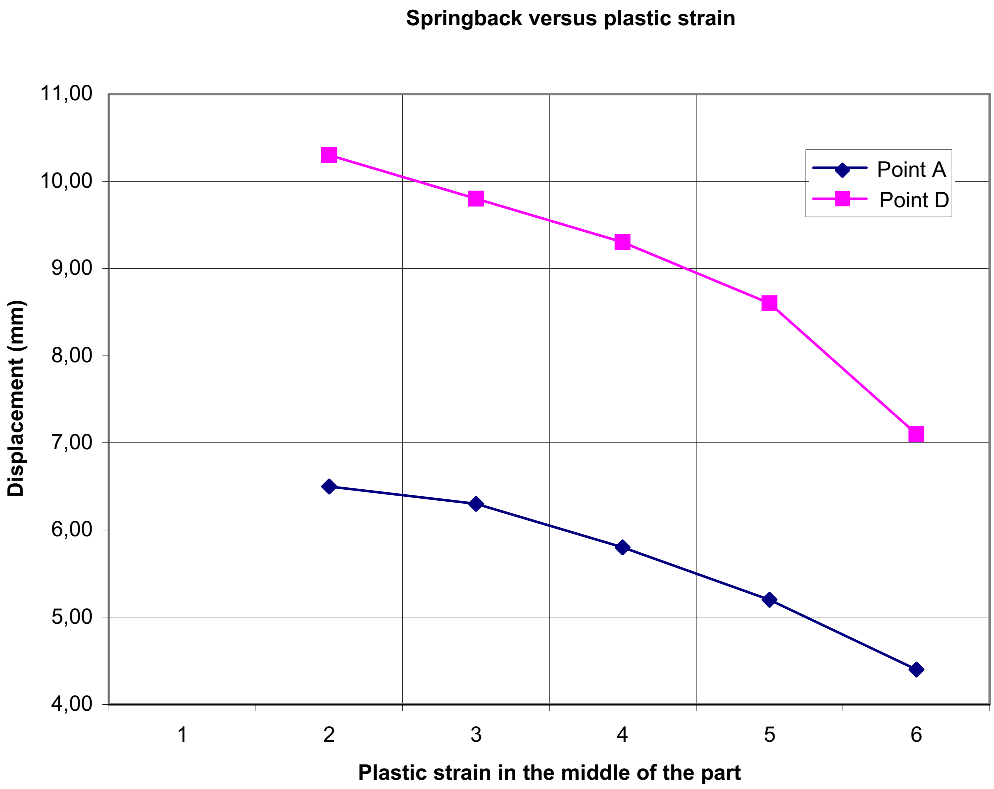

Figure 7: Spring-back tendency in connection with different plastic strain rates

Summary and Conclusions

The simulation in LS-DYNA gives a good prediction of the spring-back behaviour of AHMF produced parts. In Figure 8 a comparison between simulation and reality is shown in the case of 2% plastic strain in the middle of the part. In reality the displacements are higher than in the simulation calculated but the direction and the quality are good [6]. In the finished investigation a drawn roof was simulated without a cutting operation, but further work has to be done to analyse the behaviour of a finished roof once the surplus material is removed. Also new investigations are required in the area of complex parts, such as. fenders or structural parts. LS-DYNA can assist the designer in the layout phase of a new forming tool to avoid later changes in the tools being necessary.

Spring-back at the point of 2% plastic strain		
Measuring points	Simulation (mm)	Reality (mm)
A	**6,5**	**8,1**
B	**6,1**	**7,5**
C	**11,3**	**14,1**
D	**10,2**	**12,9**

Figure 8: Comparison of the spring-back at the point of 2% plastic strain

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