METHODOLOGY OF THE SPRINGBACK COMPENSATION IN SHEET METAL STAMPING PROCESSES

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Abstract

In the stamping process, springback causes geometrical inaccuracies in the final shape of metal stampings. Springback behavior is highly influenced by mechanical properties of the material, by the geometrical complexity of the shape and also by stamping process itself. In reality, it is very difficult to predict to which extent springback occurs. That is the reason, why numerical simulations are used more commonly nowadays (AutoForm, PAM-STAMP, etc.). This research focuses on the creation and application of the springback compensation strategy with the goal of minimalize the springback phenomenon in the field of stamping processes. Especially in automotive (in the production of car body parts) where springback became an often debatable and significant topic. For the verification and validation of the strategy, car body parts from VW Group were used, namely SEAT Ateca inner and outer fifth doors and ŠKODA Superb fender. Proposed strategy was designed in the cooperation with the Pressing tools design department in ŠKODA AUTO.

Keywords: Springback, numerical simulation, AutoForm, forming, deep drawing

1. INTRODUCTION

During the deep drawing process, the punch is pushed into the die cavity, the blank is plastically deformed and the specific shape of the punch and the die is transferred to it. As soon as the loads are removed, the elastically driven change of the product occurs. At that moment the final shape of the pressed part is affected only by plastic deformation, elastic deformation "returns" while causing a shift in the shape of the material. This shift in the material results in the change of geometry and the phenomenon is called springback. Springback results in geometrical shape inaccuracies of the obtained product. In order to compensate the springback, it is important to carefully consider all factors prior to the stamping process, otherwise a reject product occurs. Apart from the geometric error, springback leads to increase in the costs in pre-production tool design. Tool design and tool construction is one of the most time consuming step in new car type developing process. Therefore, to find an effective and reliable method for springback prediction and its compensation is very important. Nowadays numerical methods for process simulation and evaluation are commonly used. Software like AutoForm, PAM-STAMP, DynaForm, LS Dyna and others are a powerful tool in the pre-production. The problem with numerical simulations and springback is still in its accuracy which is still far from exact. In terms of springback, approximate accuracy of the numerical simulations is up to 75%, depending on the simulation settings (type and size of elements, nodes, number of iterations, etc.) [1, 2].

The main target of this research is to design methodology of the springback compensation and later integrate it into the process of the methodical planning and pre-production phase of the tools production. If the current experimental trial and error process were replaced by a reliable numerical procedure, the pre-production time and costs of tools production would be decreased dramatically [2].

2. METHODOLOGY OF THE SPRINGBACK COMPENSATION

In order to resolve the springback phenomenon, primarily, stable and accurate analysis of the springback must be carried out. With use of the numerical simulations, possibilities in the springback analysis are enormous. Use of the numerical simulations for springback analysis has mostly advantages, nevertheless some drawbacks are also present (besides the lower accuracy as was mentioned in the introduction). The advantages are mainly in the analysis itself, where all kinds of comparison can be used, such as evaluation in the various directions, comparison with the reference geometry and many more. On the contrary, when it comes to the springback analysis, parameters and settings play a great role in the final accuracy. For example, one can choose from evaluation as a free springback (no gravity), constrained springback (with gravity), real measurement, etc. The results between each analysis always vary. Furthermore, settings of initial numerical simulation also influences the final results of the springback analysis. For instance the settings of finite element method (type and size of elements, nodes, number of iterations, etc.), process parameters (pressure of binder, drawbead type, trimming with or without tools, pressure and velocity dependency, etc.). The possibilities in the combination of settings in the numerical simulation are very comprehensive. The aim is to reach stable and accurate results that can be achieved through unified methodology [3].

2.1. Methodology of the Springback Analysis

Even though the overall accuracy of the numerical simulation outputs is very high, use of the numerical simulation in springback prediction and compensation is not optimal yet. When the springback analysis or compensation is expected, numerical simulation must be carefully designed from the very beginning of the process. The reason is that the overall accuracy of the springback analysis (in comparison with the reference geometry) is highly influenced by the initial settings. That is also a reason why a checklist for the springback analysis and compensation had to be designed foremost. Use of the checklist results into more stable numerical simulations throughout the team of tool designers. The checklist focuses on initial settings of the numerical simulation and on setting the stamping process. Key parts are listed below:

- Settings of imported geometry - meshing tolerance, stitching distance, max side length, etc.
- FEM calculation - use of elastic plastic shell elements instead of membrane cells
- Stamping process - use of the 3D or adaptive drawbeads, pressure and velocity dependency, etc.
- Process in numerical simulation corresponds with the productive press line
- Trimming and cutting operations with complete tool geometry
- Radius and thickness ratio $R / t < 2$
- Use of pilots due to the centering of blank position

Above are listed only the key steps and major parts of the checklist. The whole checklist comprises of 6 pages focused on every part of numerical simulations. The best options for the settings of numerical simulations were obtained through various tests.

In the springback methodology, aim is to get the numerical simulation as much close to the reality as possible. The following scheme (**Figure 1**) shows the designed methodology of the springback analysis with a focus on a stamping process of car body parts such as fender, sideboard, inner and outer doors, etc. Free springback between individual operations should simulate the segment of the stamping process, where drawn part is taken out of the previous operation and is placed into the following one. At that moment, almost all the tensions and elastic strain in the part are released (as in the process in the press line). The criterion for springback compensation vary from the geometry and from the part (in **Figure 1** it is 0.8 mm).

In the software, one can choose from various springback analysis. The major difference is in the gravity and how the part is clamped into the fixture during the dimensional measuring. Since the outer car body parts are often made of low carbon steels and the stiffness of the parts is very low, gravity substantially influences the analysis. That is the reason, why free springback cannot be applied in the final analysis. Instead, constrained springback offers all the necessary requirements for the meaningful analysis. For example, constrained springback in the software AutoForm uses defined points of contact as a real clamps (one-sided and double-sided clamps). In addition, pilots can be defined in order to adjust and control the position of parts of the assembly. The problem with the real dimensional analysis is that the part is oftentimes clamped in all the defined RPS points (reference point system). When the part is clamped around its whole circumference, tensions causing springback are later not able to release properly and substantial part of the tensions is locked in the part. In order to analyze the springback accurately, the part must be partially free and thus released from the majority of the tensions. The ideal amount of clamps is 3 to 5 according to the geometry of the part [4].

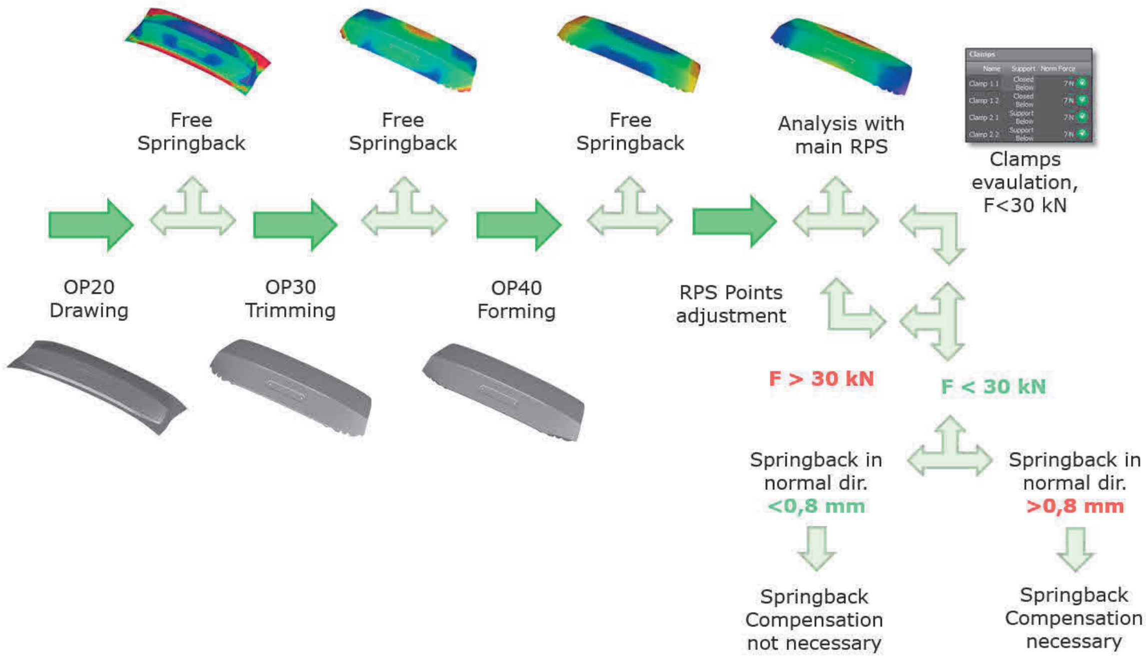

Figure 1 Draft scheme of the methodology of the springback analysis

2.2. Methodology of the Springback Compensation

When it comes to the springback compensation, two approaches are known. First approach focuses on the manual geometry compensation with the use of one of the CAD software. This approach, oftentimes spring-forward method (**Figure 2**), requires a lot of experience in the field of forming and the method is time consuming due to the manual surface modeling. The more effective approach is the use of special computational modules, e.g. AutoForm Compensator or PAM-STAMP Die Compensation module. These modules focus on the geometry correction after the springback results from the previous iteration. Principe is similar as with the manual correction, that is, to create compensated tool geometries in order to optimize dimensional fit after the springback. However, to get accurate results from the compensation, very consistent fundamental simulation with the appropriate compensation strategy must be used [5].

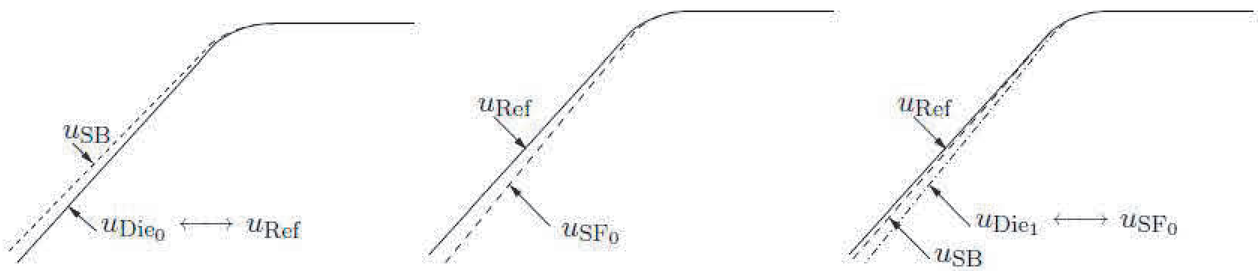

Figure 2 Spring-forward compensational method, a) Springback, b) Spring-forward compensation, c) 1st iteration of the compensation [6]

Various results have been discovered throughout the research, depending on the selection of the compensation strategy. **Figure 3** shows some compensation strategies, which are:

A) Compensation of the OP20 drawing operation
B) Compensation of the OP20 drawing operation and the last forming operation
C) Full compensation - OP20 drawing, OP30+OP40 trimming and OP50 last forming operation

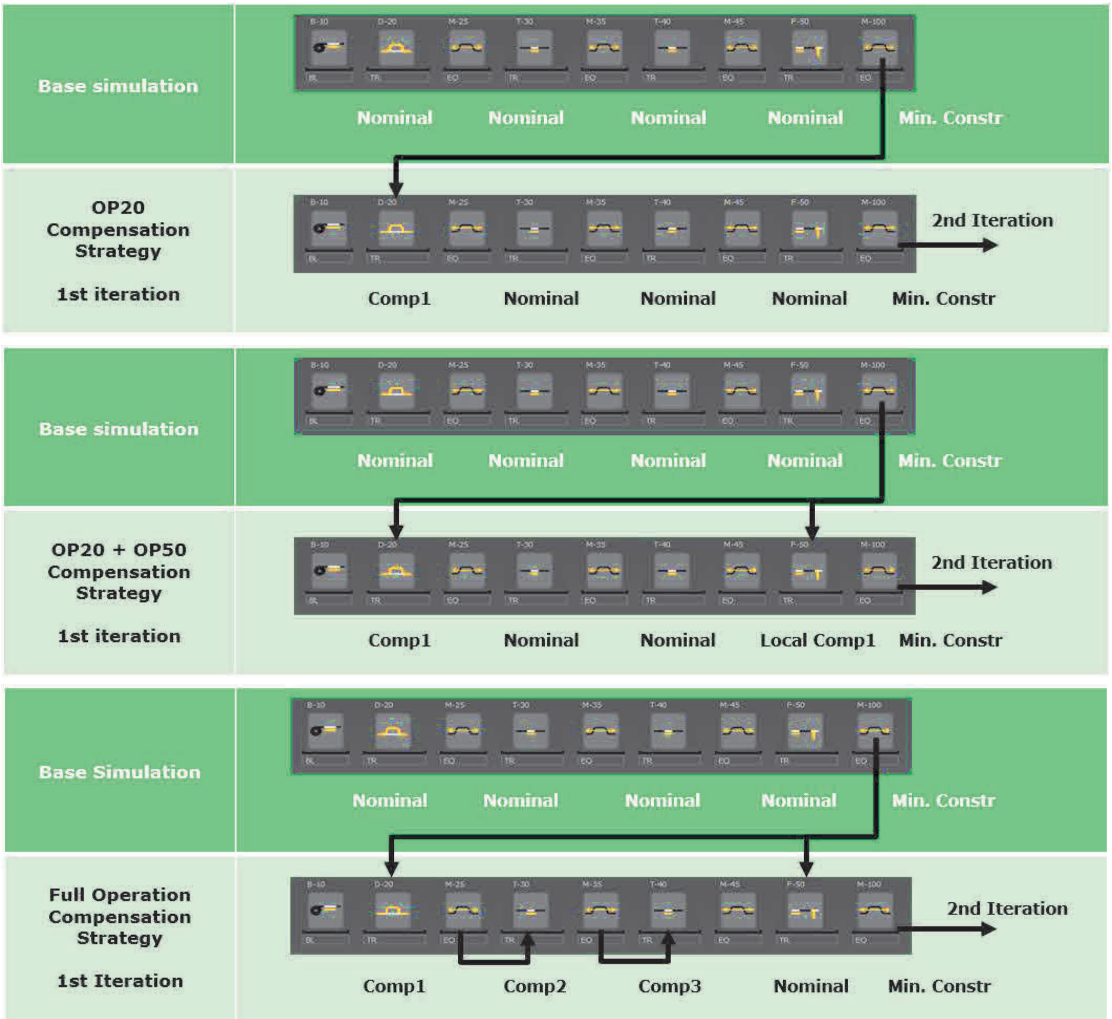

Figure 3 Potential strategies of the springback compensation

3. APPLICATION OF THE SPRINGBACK COMPENSATION METHODOLOGY

The methodology has been carried out on few outer and inner car body parts, for example fender of ŠKODA Superb, inner fifth doors and outer fifth doors of Seat Ateca. In this research, results from application of the fifth door outer panel from Seat Ateca are shown. **Figure 4** shows the process of initial springback analysis and application of compensation strategy in 3 individual iterations. In this case, from 3 strategies, only the first strategy (drawing operation OP20 is compensated) showed gradual and positive progress in each iteration. 3rd and final iterations still revealed some springback in the center of the fifth door panel. Specifically, springback in this area showed approximately 0.5 mm hollowing. In addition, 4th and 5th iterations showed worsening of the springback in all the strategies. Therefore, the ideal number of compensation iterations is from 3 to 5, based on this experience.

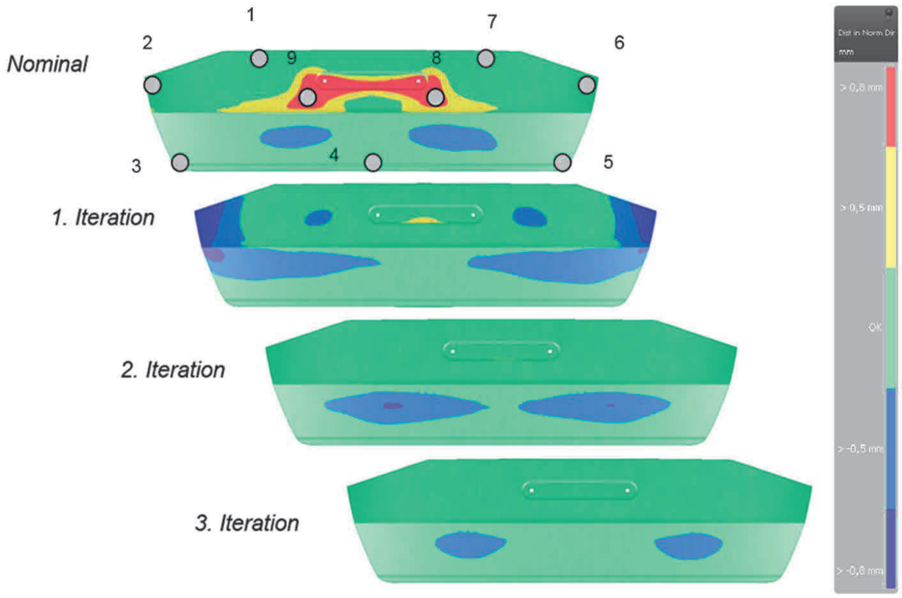

Figure 4 Application of the springback compensation strategy with use of the AutoForm Compensator

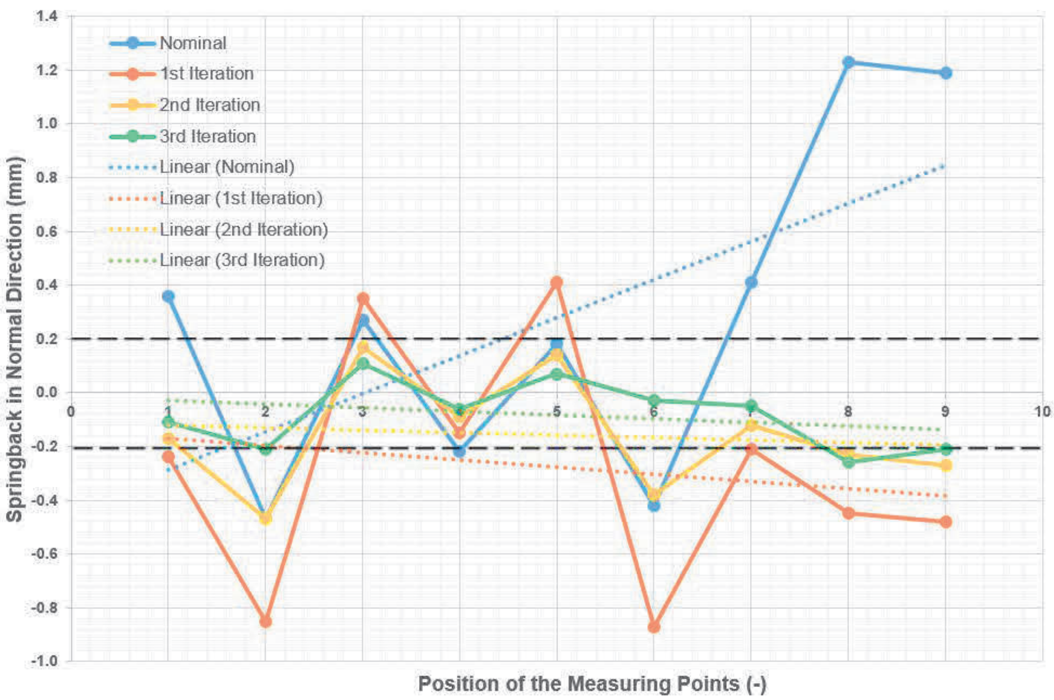

Figure 5 Sequential springback compensation and its elimination in course of 3 iterations

The progress of each of the iterations is represented in the **Figure 5**. Virtual dimensional measuring has been carried out in every iteration. The position of the measuring points is given by the nominal simulation in the **Figure 4**. Diagram (**Figure 5**) clearly points out the gradual compensation of the springback. The 3rd iteration (in the diagram marked as a green line) showed the best result in comparison with the reference geometry (in the diagram represented as a zero value). Unfortunately, the AutoForm module Compensator has not been able to find the optimal solution of the springback compensation in any of the strategies.

4. CONCLUSION

The research showed that elaborate methodology for the springback analysis and compensation had to be designed. This research describes both methodologies and the checklist which is needed to set up a stable numerical simulation which can be compared with the real stamping process. The designed methodology was applied on various car body parts. In this research, the application on the Seat Ateca outer fifth door panel was briefly described. As seen in the chapter 3, the designed strategy with use of the AutoForm Compensator module showed positive results. In the 3rd and final iteration, springback rapidly decreased, only one area still revealed some springback (approximately 0.5 mm). To get the perfect results, compensated geometry should have springback in maximum range of 0.2 mm (in **Figure 5** marked as a black dashed line).

In a further research, verification of simulation and reality must be carried out, e.g. as a comparison with the scanned part or with the results from dimensional measuring. In both cases, the analysis of the springback must be carried out under the same conditions as in reality. Otherwise the results of the analysis will be different and it will not be possible to verify the methodology and compensation strategy. In addition to that, the problem with the final geometry after the compensation needs to be dealt with. The curvature of the surface is usually uneven and wavy due to the local compensation. Such surface is very complicated to produce with the metal machining and later fit bottom and upper tools perfectly together. Therefore, after the local springback compensation, the surface has to be smoothened.

ACKNOWLEDGEMENTS

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