Evaluation of all Springback Aspects through a Success Story on Ford Cargo Truck Door Opening Part

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Abstract. Springback remains as a challenge in the automotive stamping industry. Use of different new materials for lightweighting purposes like aluminium, HSS and AHSS increase studies on that subject. Moreover, constraint timings and cost reduction targets require robust strategies on springback prediction and its compensation. In this paper, the industrial approach to this issue is told through a successful large scale case study where various applied methods are mentioned for accurate springback prediction and effective compensation. On the prediction side, this includes hardening curve, yield criteria, FLC, friction, drawbeads, spacers, blankholder model, blank properties, thickness, material grade, clamping concepts, mesh parameters. On the compensation side, strategies are playing an important role and also certainly validation. For the validation, so called, full cycle simulations are performed. Full cycle simulations must be carefully evaluated due to many noise factors.

1. Introduction
Springback is the most important issue in the automotive stamping industry. It is the only reason of form deviations for the stamped parts. Thus, parts can’t reach the desired surface tolerances which cause extra cost and time. All other issues are slightly easy to solve.

In this context, engineering becomes more and more effective in the industry. Die manufacturing costs and delivery times must be decreased where at the same time higher quality level is targeted for the parts.

2. Industrial Approach
Industrial approach to springback differs from academic view. The main concept in the industry is customer satisfaction. It can be external or internal. A stamping die manufacturing project consists of two buyoff phase. One is die buyoff and the other one is part buyoff. PIST (Percentage of Inspection points Satisfying Tolerances) is the key item of part buyoff. Form tolerance for mating surfaces is +/- 0.5 mm. and +/- 1.0 mm. for non-mating surfaces. A percentage of min. 90% is expected as the PIST value at this time but it will be revised as 95% for the upcoming projects.

Expectation from engineering is to master springback. In this context, compensation is not the only unique way of solution. Minimizing and determining suitable clamping concepts are also playing a significant role. For the outer A-Class surface parts, hemming must be taken into account. Robustness in the serial production is another item, which must be also considered.
3. Elements of springback and case studies
As shown in the figure 1 there are several elements of springback in the engineering. Accurate prediction of springback behaviour of a part is the basic issue and the most difficult one. Used FEA software and its characteristic is very important but the main difficulty comes from complexity level of geometry, material grade, thickness, number and type of operations required for the production of a part.

![Figure 1. Elements of springback in the stamping engineering](image)

3.1. Prediction
For the prediction of springback, FEA softwares are used. In the stamping engineering, global predictions are taken into account. Global prediction includes everything within the production line of an automotive part from draw operation to the measurement on the checking fixture.

Below a large scale case study from the Ford Cargo truck project is explained as an example. The name of the part is Door Opening Panel which is called shortly as DOP in the industry.

![Figure 2. Dimensions of Door Opening Panel](image)

Autoform is used as the FEA software for calculations. Some of the key factors of prediction such as material model, layers (integration points through thickness), contact between tools and sheet are depending directly on the software capability. Key factors such as drawbead model, blankholder model, mesh size, friction, convergence criteria, refinement level, spacer, pilot usage and certainly clamping concept are input parameters for the FEA software which are depending on the user choices.
Springback is calculated through stress tensor. Stress distribution and level are determining the springback result.

As seen in the figure 3 for the production of a DOP panel you need four stamping operations in the press line. Measurement of the final part on the checking fixture is also considered as an operation. In the figure 5 design of the die-set for DOP is given. It is double unattached type so one of the biggest size in the industry. There are some prerequisites for the validity of springback results. Formability must be free of split, free of heavy wrinkle. Thinning distribution must be within the tolerance limit. Wrinkling behaviour must be checked 1 mm., 5 mm. and 10 mm. before the end of stroke to ensure that there is no geometrical wrinkling on the part surface.

In figure 4 you see the formability results of the full process simulation showing free of split and free of heavy wrinkle conditions. In figure 6 input parameters of the full process simulation for DOP are given. We prefer to use 12 mm. for the initial mesh size because we think that it is an optimum value for accurate results. Max. side length is a tool mesh parameter which should be lower than initial mesh size for good contact. General meshing rule is that a 90-degree radius of tools must have min. 8 elements on it. In response to this for a sheet radius under same condition 5-6 elements are enough.
Combined isotropic and kinematic hardening is used even for mild steel. In figure 7 you see the used hardening curve and yield criteria in Autoform.

Figure 6. Input parameters of full process simulation of DOP

| Material Grade   | DX56D+Z         |
|------------------|-----------------|
| Hardening Curve Type | Swift         |
| Kinematic Hardening Model | Autoform (Krasovsky) |
| Yield Criteria   | BBC 2008       |
| FLC              | Arcelor        |
| r-value          | 0,2            |
| \( f_0 : f_50 : f_{15} \) (anisotropy coefficients) | 1,96; 2,1; 1,45 |
| thickness        | 0,8 mm.        |
| initial mesh size | 12 mm.         |
| layers           | 11             |
| max. side length (tool) | 10 mm.       |
| radius penetration | 0,16 mm.     |
| refinement level | 6              |

Figure 7. Hardening Curve and Yield Criteria

FLC (forming limit curve) is taken directly from the sheet supplier Arcelor. In addition to mesh and material input, there is a lot of other parameter to consider such as convergence, drawbead model, blankholder force. If many times no convergence is reached that will indicate a problem in the simulation. Using 3D profile drawbeads is a must. Especially where part-on-binder structures are in question. You can’t catch stresses without using 3D profile drawbeads. And finally blank dimension
and shape, drawbead forces and blankholder force must be optimized to minimize the amount of springback. Drawbeads can be very effective on the springback.

3.2. Robustness
We are talking about robustness of springback. Springback must be seen as a noise factor and its variation has to be investigated. If with slightly changed parameters a big difference and variation occurs between the springback results than we can’t say that it is reliable.

Assume that we are satisfied with the predicted springback result so next comes mastering of springback. Robustness of the process becomes more important in springback point of view. As known, variation in the serial production is an ordinary thing.

Therefore to perform a Sigma study to confirm the robustness of the process will say us that we will get similar springback response even, when some uncontrollable parameters within an interval change. This interval is taken usually as +/- 10%. Yield strength, UTS, r-values, n-value, friction coefficient, thickness (+/- 0,03 mm. tolerance) and blankholder force are incorporated. Normally, blankholder force is not an uncontrollable parameter but due to press window requirements it is also taken into account. A robustness analysis for DOP is performed, too. The results are given below in the figure 8 and 9. We are focused on noise variation level and Cpk. If Cpk >= 1,33 than the process is accepted as capable.

3.3. Control of springback
In the automotive industry there are two main types of parts. Outer and Inner parts. For the outer parts springback compensation is not preferred. Therefore minimizing and determining a suitable clamping concept are the solution ways on which we focus more. Minimizing the springback in the outer parts means to increase stretch level (over 5% plastic strain).Thus, you can also decrease the strength and amount of visual surface defects which is mandatory for outer parts. Only increasing the stretch level works to some degree. Besides that the uniformity of the stress distribution is also very important. That can be checked with mean stress transitions.

In the inner parts, stretching is also effective but PDPD (Process Driven Product Design) becomes very useful tool to decrease springback. By adding extra forms, ribs, swages etc. to the part cad data you can easily keep the springback under control.

You can also study all operational springback behaviours and propose a clamping concept so that springback gets relatively minimum values.

But in this paper we will focus on compensation method which is also applied for DOP. The first and the key issue is to develop a compensation strategy. You have to compare the springback of OP60 (checking fixture) and OP40 to fix the effect of secondary forming on the springback as seen in the
figure 10. If there is no major effect of secondary forming than you can do the compensation according to OP60 result. Draw die surface will be morphed as shown in the figure 10. Springback in OP50 will be compensated in the OP50 die. Compensation must be validated through a full cycle simulation where fitting of sheet on the line dies is also checked. But if secondary forming has a major effect on the overall springback than compensation gets complex.

4. Conclusion
In the figure 11 three PIST values are shown. The first one is the value without any compensation applied. It is 63% and not acceptable. After compensation studies a 99% of PIST value is reached virtually. Virtual PIST values are the values obtained from FEA. On right side you see the actual PIST value of the real stamped part. It is for mating surfaces 92% and for non-mating surfaces 100%. A really impressive result has been reached.