Bridging the gap between engineering and tryout of sheet metal forming parts by a smart solution

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Abstract. When a good simulation solution is found by an engineering department the challenge is to transfer this knowledge properly to the tryout process, because in an ideal process, the tryout would reproduce engineered results in a minimum time. But very often this knowledge transfer exists only of handing over printed simulation reports to the tryout team and then it depends on the interpretation of such a document to reproduce all important information to get similar results in reality. A solution to improve this situation would be to connect engineering and tryout with a smart digital solution, which supports tryout to reproduce the results from simulation fast and easy. The draw-in from simulation solution can be used as target to reproduce the same draw-in at tryout, because if draw-in is matching, then also the material flow is matching and the strain distribution too. To do so a sensitivity analysis based on the found simulation solution should be calculated by variation of the drawbead restraining and binder force and then exported to a smart digital tryout solution. Finally this smart digital tryout solution would provide all required information to tryout that they are able to reproduce the draw-in like engineered as fast as possible to speed up the process by avoiding unnecessary tool modifications. Based on this the gap between engineering and tryout can be bridged in a more efficient way.

1. Introduction

Since several years already there is the trend to increase the design language of the cars and it is still ongoing. The design of the car is very important in order to be successful in the market. This leads to more and more complex geometries of the car body. But the car body design is not the only cause that increases the complexity. Also the material suppliers deliver many different grades of material to support different aspects like to reduce the weight of a part by Aluminum or to increase the safety structure of the car by using high strength steels. Thus it becomes more and more challenging to be able to produce sheet metal forming parts in time and the required quality by stamping. To master these challenges simulation software helps a lot to check if all requirements can be fulfilled. If a good simulation solution was found the decision about the tool manufacturing can be done.

But the next challenge is to transfer this engineered solution in a proper way to the tryout process. Ideally the tryout team would reproduce this in a minimum time. It sounds relatively easy to reproduce this simulation solution in reality; but it is not. Today very often printed simulation reports will be used to transfer the engineering knowledge to tryout. Currently we are talking about Industry 4.0 or Internet of Things (IoT), but here in this case the digital connection between engineering and the tryout process mostly does not exist. Thus now it depends on the tryout team on the interpretation of such printed reports to get all relevant information to reproduce similar results on the tryout press. If inquiries would popup the engineering team is not always available to deliver a proper answer in time, e.g. nightshift or on weekend. The engineering team is already working and busy with new projects. They finished the related simulation of this current part at tryout some weeks or months ago and mostly they cannot...
remember about all details and archived the data already [1]. Therefore now it is up to the tryout team to get similar results like engineered mostly based on the printed reports only. Of course every unnecessary or wrong decision about real tool modifications to improve results would increase the costs and takes more time. This could result in very time consuming Trial and Error Approach and this also depends on the person who deals with the job at tryout. How could we bridge the gap between engineering and tryout in a better way to improve this current situation?

2. Current solution and how to improve
First let us analyze the required boundary conditions to define a better way to connect engineering and tryout. The current solution with printed reports can be summarized with the following weaknesses:

- Time consuming job for engineering to create such a report with required details.
- A lot of slides with many different information, which is not always easy to interpret and / or specific information is missing.
- Static and fix report content which cannot be used interactively for specific details.
- No guidance from the report how to reproduce the engineered solution as easy as possible.
- Finally engineering gets no or less feedback about the changes at tryout compared to engineered solution, e.g. to learn from this for the next similar projects. Mostly it is only a one way communication from engineering to tryout.

Therefore what should be improved to avoid or at least to minimize these weaknesses?
- The new solution should simplify data exchange.
- It should guide tryout to be able to reproduce the final engineering simulation result as fast as possible, e.g. by proposals about the most efficient modifications on the real tool.
- The new solution should allow tryout team members an interactive work with engineering data without asking engineering for active support.
- A simplified time shift process between the involved different tryout teams should be possible.
- It should increase communication between engineering and tryout in both directions, e.g. that all changes and final real tool settings from tryout would be accessible for engineering too to learn for the next similar part projects. This would speed up the tryout loops in the future based on better provided solutions from engineering.

What could be a good solution to bridge the current gap between engineering and tryout in a better way to improve this current situation?

3. A smart solution to bridge the gap between engineering and tryout
Based on the trend Industry 4.0 or Internet of Things (IoT) a digital connection of different departments should be enabled. Therefore a digital solution to connect engineering and tryout should be preferred. The engineering data can be available everywhere and anytime based on a software solution. This software should allow having access to the final simulation data from engineering and should guide the tryout team how to get similar results on the tool by proposals as fast as possible.

What should engineering provide to support this new process? First of all engineering should simulate until all required limits would be fulfilled. There should be no issues anymore, because this one would be used as reference to reproduce it as fast as possible in the tryout process. Let us call this final simulation from engineering the Reference simulation. To be able to provide proposals by the tryout support software the Reference simulation from engineering should be expanded by a sensitivity analysis [2]. This means the most important parameters for tryout like binder force and drawbead restraining forces would be defined as variables with a range higher and lower than the Reference simulation. Based on tryout experiences if the tryout draw-in is similar to the Reference simulation the results of the thickness distribution are similar too. This is the key factor to be able to guide the tryout team by providing proposals about real tool modifications to get the similar draw-in in reality like in the Reference simulation.

Why a special software solution? Because the current simulation software and user interfaces are designed for the engineering process. This engineering solution would be too complicate for the tryout,
because they need only a reduced solution focused on their requirements. Also new functions adapted to the tryout process are required, which the engineering does not need. This tryout support software should be always close to the press, therefore a smart mobile solution should be preferred like on a tablet or laptop.

3.1. Tryout workflow
Assumed the tryout people would start the tryout process on a new part and they would have this tryout support software the flow chart should look like to see in Figure 1. The content of these steps along the flow chart will be covered by the following chapters.

3.2. Step 1: Check of basic parameter settings
The objective is to synchronize the tryout basic parameter settings to the reference simulation. Therefore it makes sense to provide such basic parameters from the Reference simulation, which the tryout team could easily compare with real tool settings. This supports to reproduce the settings from the Reference simulation to the current settings in reality. It does not require a stamped part so far. This kind of checklist should contain - amongst others - the following information in this tryout support software:

- The same blank dimension like in Reference simulation should be used at tryout. Because another blank size cannot be used as reference to get similar draw-in like engineered and leads to other results in reality.
- The identical material grade and similar material properties like in Reference simulation should be used at tryout. If the material grade, blank thickness and/or material properties are very different then there should be no surprise that tryout cannot reproduce the Reference result from engineering. It becomes transparent that there is a mismatch. Another typical parameter is the rolling angle. If they are not identical and the process would be sensitive for this it would become very difficult to be able to reproduce the engineered Reference simulation result.
- Display drawbead designs from the Reference simulation to be able to compare these with the real milled drawbead profiles. Also it becomes transparent for the tryout team that the current real drawbead geometries differ from the engineered Reference simulation.
- Used values for binder force and lubrication should be also checked to have same boundary conditions at tryout like simulated.

Table 1 displays an example of such a check list:

| Parameter at tryout like reference simulation? | Yes | No ➔ real settings and why |
|-----------------------------------------------|-----|---------------------------|
| Blank size: 750x500                           | ☐   | ➔                         |
| Material properties: HCT600T, 1.5mm, YS 404MPa, TS 653MPa | ☐   | ➔                         |
| Drawbead design: all Radii 3mm, bead height 5mm | ☐   | ➔                         |
| Binder force: 150t                            | ☐   | ➔                         |

If the tryout settings are different from the Reference simulation they have to be adapted at tryout according to the documented parameter settings in the tryout support software. Only then it is possible to compare simulation results to tryout results and to get similar draw-in like engineered.
3.3. Step 2: Blank positioning

The objective is that the blank position in the tool at the binder closure of stamping is similar to the Reference simulation. Because it is well known that another blank position leads to different results on the real formed part compared to simulation result. Put the blank on the tool at the defined position and close only die and binder to form the drawbeads like to see in Figure 2.

![Image of blank boundaries at the beginning, binder closing and end of drawing](image)

**Figure 2.** Blank boundaries at the beginning, binder closing and end of drawing

Then measure the distance between the formed drawbeads and the outer boundary of the sheet at several locations to enter these distances in the tryout support software. Based on these real measurements the tryout support software can identify the current position in reality and propose required adjustments of the real blank position to get similar position like simulated. The tryout team
can follow this proposal, they would use a new blank with the new modified position and repeat the procedure to form the beads again and then to measure the new distances. Based on this tryout gets new proposals. This approach should be repeated until the real blank position is similar to simulation.

3.4. Step 3: Reproduce simulated draw-in
The objective is to get the same draw-in in tryout like in the Reference simulation. In case if draw-in is matching, then the material flow and finally also the strain distribution is matching. Therefore it is required to start to stamp the deep drawing part. The binder and die should be spotted to at least 80%, which means the geometry between die and binder is adapted to at least 80% of the occurred thickening to get an uniform binder force distribution there. Comparable to the step before several draw-in measurements should be made at specific locations on the stamped part. Again these measured values would be entered in the tryout support software. Based on the sensitivity analysis and the previous documented parameters this tryout support software is able to identify the current corresponding draw-in and their required drawbead- and binder force settings in tryout. Thus it can propose required changes on the real tool like drawbead designs and binder force to get similar draw-in like the Reference simulation result. In case if the draw-in at tryout is different to Reference simulation the following has to happen at tryout like to see in Figure 3:

![Figure 3. Draw-in at tryout related to restraining.](image)

- Draw-in of tryout > draw-in of Reference simulation ⇒ increase restraining (by drawbeads and / or binder force).
- Draw-in of tryout < draw-in of Reference simulation ⇒ decrease restraining (by drawbeads and / or binder force).

It does not matter if the behavior between draw-in at tryout and restraining would be linear or not. Fundamental is that the sensitivity analysis indicates which drawbead(s) and / or binder force should be modified and how much. Thus proposals about required real tool modifications are possible. Also important is that the tryout people can configure their preferences if the proposals should prefer to propose drawbead profile – and / or binder force modifications first or to exclude some of them which should be kept constant. This procedure should be repeated until the draw-in from reality to Reference simulation would be in a range of ±1mm. These iterations would be stored in the tryout support software for documentation.
This focus on draw-in is important because engineering compensated already the tools to get a part inside of the required springback tolerance. This is a must have to be able to buy off the tools finally. In case tryout would solve all issues, but in another way than simulated, the final springback result will look most probably different compared to the Reference simulation. Therefore the engineered compensation will be obsolete. The tools have to be milled again for the new compensation geometry based on the new different springback behaviour. This leads to avoidable extra costs and time consuming rework.

3.5.  Step 4: Fine tuning
The objective is to be able to react on still open issues like stretching or thickness on the real stamped part which have to be fixed before buying off this tool. Therefore the tryout support software should allow defining the location of these real issues on the simulated sheet and their related issue type. Again the software would propose real tool modifications by trying to keep the draw-in within the ±1mm tolerance to the Reference simulation. Also these iterations would be stored in the tryout support software for documentation.

3.6.  Step 5: Documentation of final real tool settings
The objective is that the tryout team should be able to document the final tool settings in the tryout support software at the end of the complete tryout process. Thus the most important parameters like the final drawbead profiles, the binder force, the lubrication condition and material properties can be stored in the corresponding file for an easier review for engineering. Generally tools shops mill the drawbeads sharper than engineered, because in reality it is much easier to remove material from the drawbeads to make these weaker instead to make it sharper afterwards according to personal communication in tryout shop. Now the engineering team can compare the drawbead design settings at the beginning and at the end of tryout to the provided Reference simulation. If the conclusion would be that the drawbeads were milled always sharper than simulated and at the end the drawbead designs are comparable to the engineered solution the internal processes can be improved to at least reduce the safety margin of sharper drawbead designs. This saves time and money for the next projects.

4.  Summary
Currently the transfer of the engineering knowledge on a specific part to tryout is not easy. Today there are a lot of weaknesses by providing this knowledge on printed reports. Because these are not always easy to interpret and immediate support by engineering is mostly impossible when issues at tryout would occur. But also a feedback from tryout to engineering about helpful and non-helpful modifications and how to improve this next time occurs very seldom. Therefore a new solution is proposed to bridge this gap between engineering and tryout. A digital solution; customized to the tryout process; close to the tryout press is required. The benefit is that the Reference simulation, which fulfills all required limits, will be used as target to support the tryout people to reproduce the simulation reference as fast as possible. For this engineering would expand the Reference simulation to a sensitivity analysis. Now the tryout people would get access to these analyses by a new especially designed user interface for tryout. By reviewing and reproducing the parameter settings, blank position and draw-in the tryout process becomes less time – and money consuming. Also for the different tryout teams it simplifies the work on the same tool because the following team can see the current status of the tool, the already checked and adapted parameters and can continue easily the work at the last documented step by using this new tryout support software. Therefore the current status of the tool becomes transparent, is worldwide and anytime available and guides the tryout people to reproduce the engineered simulation result as fast as possible by getting proposals. Also after finishing the real tools at tryout the engineering is able to review the tryout work much easier, to learn from this and to take over the findings for the next similar parts. This approach helps also a lot to become more efficient. Thus it makes a lot of sense to bridge this gap between engineering and tryout by such a smart solution.

AutoForm developed such kind of software and call this AutoForm-TryoutAssistant [3, 4].
References

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