New Challenges and Requirements in Sheet Metal Stamping and Forming Simulation

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Abstract

Over the past decade, stamping simulation technology has matured considerably. More detailed models have drastically improved the forming analysis capabilities from level of feasibility study to fine tuning and final validation. Simulation technology is providing productivity gain and cost-efficient solutions to sheet metal manufacturers. However, during recent years, new requirements have surged, posing higher challenges to stamping simulation technology, like stringent requirement on quality, springback and tolerance control, integration of the manufacturing effects on product performance such as crashworthiness, etc. The strong time-to-market pressure left a very narrow time frame to perform the forming simulation in order to impact the design decision. Parallel to this, the needs for stamping simulation had also grown drastically in other non-automotive industries such as electronics, aerospace, etc, which has different types of requirements and processes like progressive stamping, stretch forming, flex-forming and super plastic forming.

This paper describe how PAM-STAMP2G, the new generation and state-of-the-art sheet metal stamping simulation tool, meet those new challenges using upgraded features and functionalities with more advance and streamlined approaches.

1.0 Introduction

The rapid and continuous development in computer hardware & software technologies such as DMP parallel computing, sees manufacturing simulation playing an increasingly important role in vehicle development programs, helping to eliminate manufacturing risks, and to compress lead times on ‘critical path’ items such as large press tool manufacturing. This evolution has also resulted in the extended use of simulation, making it no longer the preserve of large companies such as Automotive OEM’s and Tier suppliers, but also finding use in smaller suppliers, and in ‘non automotive’ applications where previously the hardware & software cost, coupled with training & end user resource would have been prohibitive. Increasing competition and cost control in the Aerospace market has seen an increase in the effective use of simulation for the more ‘advanced’ forming processes typically used for metallic aerospace componentry.

2.0 Evolution from Formability check to component validation

The main advances in forming simulation have been the extension of the domain in which the results are considered truly predictive and reliable. Just a few years ago, most of the discussion was about the validity of forming simulation methods, the big discussion about implicit vs explicit solution schemes, and comparison or validation of results based on strains & thickness variations. In a relatively short space of time, we have moved on significantly. Largely the implicit vs explicit debate has gone away, with the realization that both methods have usefulness, and most software vendors are now utilizing both technologies today.

The last few years have seen a real focus and debate on the prediction of distortion due to springback, and the accuracy with which forming simulation software is able to achieve this.

The focus is increasingly on driving simulation methodologies to model the entire forming process chain, cutting costs and time from the overall development process. It is fairly commonplace today for companies to simulate the full ‘die line up’ including re-striking and flanging die operations.

The overall objective of all this work is to arrive at the point, where it is possible to easily perform a predictive virtual panel quality assessment, such an assessment would of course include tolerance control; in respect of springback, ‘fit to gauge’, trim-line accuracy, and in the case of skin panels or visible panels, then also cosmetic surface quality.

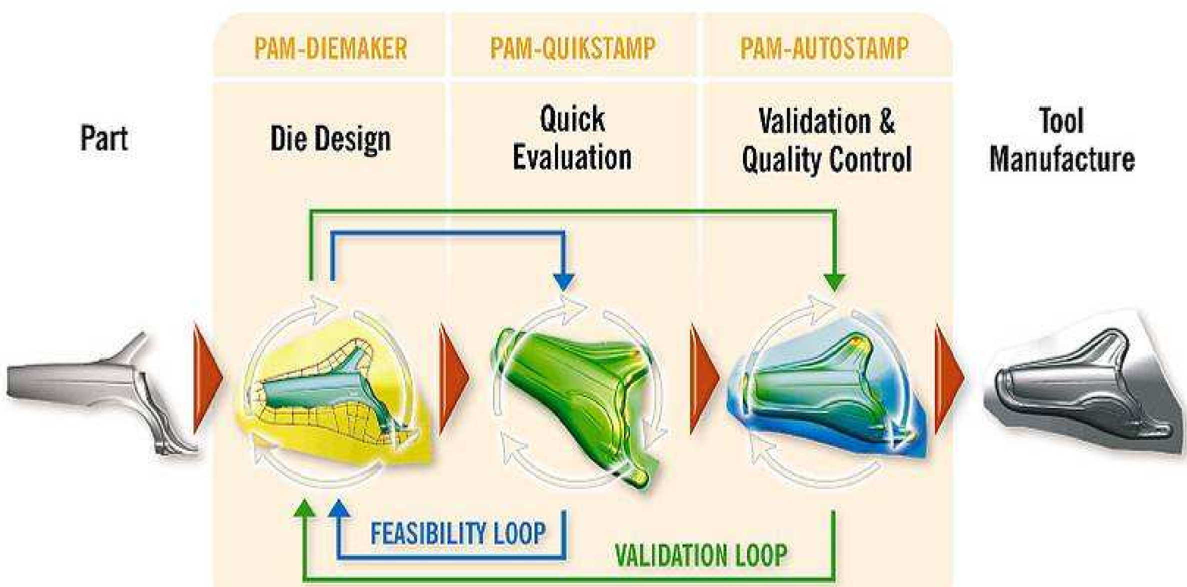

Figure 1: PAM-STAMP 2G ™ Overview

3.0 Springback Prediction & Compensation

The topic of springback prediction and control or compensation is at the forefront in the field of stamping simulation software today. Compensation methods have been discussed at length for some time, but have only found use recently as springback prediction has come of age, and can be considered predictive, without this, even the best compensation methods would be futile.

The question of springback prediction remains complex, with a significant number of factors having influence.

3.1 Materials Evolution

In particular the advent of new material technologies, driven by the pursuit of weight saving and vehicle crash performance, has resulted in innovations such as ‘Dual Phase’, ‘TRIP’, ‘TWIP’, and ‘Complex Phase’ steels. This has rendered a lot of the ‘old school’ or experience based rules for springback control worthless, meaning that there exists now an absolute need to rely on simulation where experience can no longer solve the problems. In order to keep pace, forming simulation softwares have had to respond with developments in material modelling to reliably capture the behaviours of these new materials.

Until the advent of these advanced or ultra high strength steels, many companies did not really make use of springback prediction capabilities, preferring to solve the springback concerns during physical tryout, by process or die geometry adjustments, this however is simply not an option any longer, as the springback magnitudes witnessed from ultrahigh strength steels are very often greater than the thickness of the casting in the die face, this means that it becomes mandatory to *‘engineer a solution’* to the springback control mechanism, rather than to *‘solve the problem’* of springback under the press.

The evolution within material modelling has to cover not only new materials, but also new processes which are used to form these materials.

Cold forming material models have evolved to offer better Yield descriptions such as the Corus Vegter model, and also better hardening models, capturing Kinematic hardening effects such as the Yoshida model. Other advances have been the inclusion of damage and rupture models, though of course this has limited advantages for springback prediction.

Hot forming of Boron steels is becoming increasingly important, one of their major advantages being that they do not suffer with springback, though of course there are a number of other issues related to their forming which limit their use to a few crash critical components. Forming simulation has had to evolve to incorporate not only material models to handle this behaviour, but also to describe accurately the heat transfer.

Other Hot forming processes such as superplastic forming are also successfully modelled using specific material models.

3.2 Integrated Compensation

The last two years have seen all of the major stamping simulation software vendors releasing compensation functionality. The methodologies have evolved in partnership with Automotive OEM's and materials providers. Some significant early success has been seen, particularly in the smaller toolmakers, who have been the first to really embrace this technology and use it to their advantage, in many cases, being able to achieve correct component shape directly in the first tryout, after cutting dies to the predicted compensated shape.

Already in such a short space of time, the state of the art in die compensation is already capable of offering unique automatic, iterative compensation & simulation loops, which seek the minimization of deviation between the final part shape & the desired or target shape, the study being deemed to have converged once a given area (typically 95%) of the part is within the desired tolerance.

3.3 Geometry Integration

The subject of springback compensation has been one of the biggest drivers to highlight the need for closer integration of Geometric data into simulation. Until recently it has been sufficient to begin with CAD definition and to perform forming simulation based on that definition, springback compensation however requires the modification of the geometry and its subsequent incorporation into simulation in an iterative process.

The need for geometry integration is not completely limited to compensation. Drawbeads for example have typically been modelled using equivalent models, these models account for restraining and opening forces, and may also impart changes in plastic strain and thickness to the blank, but they are not perfect, and do not capture all the effects evident with real drawbeads. Notably the flow of material through a drawbead section will inevitably result in some residual curvature in the material.

This residual curvature, or curling effect will have an influence in the springback in reality, in many cases it can be neglected as often the material affected by this phenomenon is removed during part trimming, however in cases where material passing through a drawbead ends up in the component itself, the effect must be considered. In order to capture the effect, it is becoming common practice to incorporate physical drawbeads in stamping simulation for such cases.

3.4 PLM Integration

The natural evolution for this trend toward closer integration of simulation and geometry definition is to eventually embed full simulation systems into CAD, and whilst this is not yet complete, steps in this direction are already well under way. However there will probably be some intermediate steps, with the integration of geometric engine for automatic CAD modifications by the springback compensation schemes.

4.0 Advanced Forming Process Simulation

The extension of the forming simulation domain into a range of forming process outside of the tradition stamping area has been witnessed over the last few years, in low volume automotive applications and also in Aerospace applications, and high speed progressive die forming applications for the electronics industry. The emphasis is perhaps a little different, depending on the context, with Automotive the focus is on the cosmetic quality of the panel and the process time (for efficiency) whereas for Aerospace it is generally more about fine tolerance control.

Progressive die forming simulations have been possible, but rather complex to set up until recently, where advances in the modelling methodologies have made it possible to create multistage simulations with a single input model very easily, this, coupled with the increased accuracy of the springback prediction has enabled an increase in the adoption of simulation based design methodologies in the high volume electronics component manufacture industry.

People have been modelling stretch forming processes for a number of years, but in the last few years we have observed an increase in this activity, as a result of pressure to reduce scrap rates (which remain significantly higher than in Automotive). Simulation of Stretch forming of sheets has been at an industrial level for years, as generally it is a formability related problem, focused on forming within the limits of the material, and avoiding wrinkles. Simulation of stretch bending of ‘profiles’ has been a common process in Aerospace forming, but has recently been adopted in some automotive applications such as bumper beams, and roof reinforcement bars. The simulation of this process is in many ways similar to tube bending problems, the main challenge is in defining the input data to incorporate the evolution of the stretching force with respect to the bending angle.

Rubber pad, (also known as flex-forming) simulation has also increased over the last years, taking advantage of the increased accuracy and dependability of springback prediction. In this process springback compensation is often easier than with conventional tooling, as there is no restriction in terms of undercutting.

Superplastic forming has seen an increase in popularity within the automotive industry over the last 5 years, with some attempts to use the process in a mainstream vehicle, though recently it seems to have settled back into a niche for low volume vehicles, but the manufacturers are exploiting the capabilities of this process to produce very challenging geometries in a single operation, and they are increasingly relying on simulation to improve the part quality and reduce costs, by assessing the formability, final thickness distribution, and to optimize the cycle time for the process.

5.0 Conclusions

In this paper, the authors have set out to illustrate some key areas where the application of sound methodologies delivers state of the art predictive simulations in a variety of metal forming processes, offering an insight into the trends and directions currently visible.

The use of metal forming simulation has evolved dramatically over the past decade, and customer requirements continue to push the boundaries of what is possible, driving the software from tryout validation, through die design, virtual component quality assessments, process optimization, and towards virtual production, and this pace of evolution shows no signs of slowing down.

The increasing use of forming simulation in industry is reflected by the fact that it is now included in the syllabus of many Academic programs, with the provision of a specific educational version of PAM-STAMP 2G™ to support this.

Innovation in the metal forming domain remains high, this is supported by PAM-STAMP 2G™ via an open architecture, which allows both industrial and academic researchers to test and develop their own innovations such as user's material or friction models, shell element formulation, or application coupling.

The big discussion today is now the concept of integrating the manufacturing history into 'Assembly modelling', and making allowances and corrections for assembly deviations in the component manufacturing stages, this of course requires a significant change in the current engineering process, but the potential benefits are very significant.

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