HYDROFORMING SIMULATIONS AND APPLICATIONS IN PRODUCT DESIGN, DIE DEVELOPMENT, AND PRODUCTION TROUBLE SHOOTING

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Abstract. Since late 1990s, GM Manufacturing Engineering - Die Center has been developing and implementing tube hydroforming simulation technology to GM hydroforming operations. Through successful development and implementation of hydroforming simulation technology, the efficiency and quality of die engineering, tryout, and production have been dramatically improved. This paper presents the critical issues in hydroforming, and the applications of tube hydroforming simulations in the areas of product development, die development, springback and compensation and trouble shooting in tube hydroforming production. Finally, the latest developments in sheet hydroforming and simulation technology will be discussed.

INTRODUCTION

Hydroformed parts have been increasing steadily in GM vehicles due to their advantages on weight and structural performances. GM hydroforming die engineering, tryout, and production efficiency have been dramatically improved through successful applications of hydroforming simulation technology. Table 1 shows the reductions in hydroforming tryout time. This paper presents the applications of hydroforming simulation on GM hydroforming activities in the areas of product development, die development, springback and compensation, production trouble shooting, and sheet hydroforming development.

PRODUCT DEVELOPMENT

Formability problems occurred in hydroforming mainly come from non-manufacturable product design. At early product development stage, formability analysis must be performed to detect all potential formability problems and solutions are provided to product community for product revisions. As a result, the final released part is much closer to being manufacturability. Fig. 1 shows an example for an engine cradle side rail.
TABLE 1. Hydroforming Tryout Time Reduction

<table>
<thead>
<tr>
<th>Parts</th>
<th>Elapsed Time in Press</th>
<th>Work Time in Press</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roof Rail X</td>
<td>30 days</td>
<td>10 days</td>
<td>without CAE Validation</td>
</tr>
<tr>
<td>Roof Rail* Y</td>
<td>80 days</td>
<td>10 days</td>
<td>without CAE Validation</td>
</tr>
<tr>
<td>NGEN Part</td>
<td>2 days</td>
<td>2 hours</td>
<td>with CAE Validation</td>
</tr>
<tr>
<td>Roof Rail</td>
<td>2 days</td>
<td>6 hours</td>
<td>with CAE Validation</td>
</tr>
<tr>
<td>Lower</td>
<td>2 days</td>
<td>2 hours</td>
<td>with CAE Validation</td>
</tr>
<tr>
<td>Upright</td>
<td>1 day</td>
<td>2 hours</td>
<td>with CAE Validation</td>
</tr>
<tr>
<td>Upper</td>
<td>2 days</td>
<td>2 hours</td>
<td>with CAE Validation</td>
</tr>
</tbody>
</table>

HYDOFORMING DIE DEVELOPMENT

During die development, simulation is performed to detect problems such as pinching, buckling, bursting, and under-fill conditions for piercing. These problems are resolved by arranging lead walls, adjusting tube bending and morphing the product. In the end, final die face, tube bending, pre-fill and forming pressure are determined to ensure a robust process that produce parts without any defects. Fig. 2 illustrates line die analysis tube bending and forming for a roof rail.

SPRINGBACK AND COMPENSATION

For hydroformed parts made of high strength steels and aluminum tubes, springback becomes an increasing dimensional quality concern. Due to the rigidity of the tube structure, it is extremely difficult to correct the springback in die tryout and assembly process.

Fig. 2. GMX295 Roof Rail
Springback must be resolved in hydroforming die development phase to reduce the time and cost and ensure the GD&T. Fig. 3 shows an example of springback prediction, compensation, and correlations for a roof rail. The springback analysis is performed to predict the behavior of the tube springback. Then the die is compensated and morphed to the opposite direction of predicted springback to ensure the sprung shape to be the nominal product shape. From Fig. 3, the net springback after compensation is within 0.3mm that meets tolerance requirement.

PRODUCTION TROUBLE SHOOTING

One of the major applications of stamping CAE is for production trouble shooting for the dies were engineered previously without CAE validations. When problems occur in production, formability analysis is performed to reproduce the problems, find the root causes, and then to deliver an analysis validated solutions to resolve the problems. Fig. 4 is an example for using hydroforming analysis to resolve pressure leak in piercing operation on a roof rail. The pressure leak caused piercing problem Hydroforming simulation detected the existing voids between the die and part. The hydro-piercing simulations discovered that the voids after hydroforming were forced to close by pressure during piercing punch indentation. Then the perimeter of the piercing hole of the part is move away from the piercing punch. This caused the pressure drop when the water leak from the perimeter. The problem was resolved by revise product to eliminate the voids in forming.

SHEET HYDROFORMING

Sheet hydroforming capability is being developed to GM Body Manufacturing due to the belief that it is capable of forming more complex parts than conventional stamping. It is a punch driven process with water in the lower cavity assisting drawing. Sheet hydroforming simulation technology and process has been developed in GM Die Center. For this new forming process where there is no reliable experience and knowledge existing in the workforce, forming simulation and CAE validation become more critical. The simulations are intensively being utilized to gain understanding and provide formability support for die tryout. Fig. 5 illustrates a working example for a deep drawn hood inner.
Fig. 4. GMX270 Roof Rail

Fig. 5. Sheet Hydroformed Hood Inner
SUMMARY

Hydroforming simulation technology has been successfully developed and applied to meet increasing production needs of hydroforming activities including product design support, die engineering, die tryout and hydroforming production trouble shooting, and new process development. It has helped GM improve efficiency dramatically in tube hydroforming operations and is providing understanding for sheet hydroforming development and productionization.

ACKNOWLEDGMENTS

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