T. High-Strength Steel Stamping Project (ASP 050[i])

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Objectives

Determine how to accurately predict and control the amount of springback and other deviations from the desired stamping geometry for parts made from high strength steel (HSS) and Advanced High Strength Steel (AHSS) prior to construction of production tooling.

Develop part design and manufacturing process guidelines that can be recommended to automotive design and manufacturing engineers for the purpose of reducing springback and other part distortions.

Approach

The approach of HSS Stamping Project is twofold:

1. AHSS stamping springback predictability through finite element analysis (FEA).
2. AHSS stamping springback control by developing knowledge of part design geometries that affect flange springback and die processes that control springback.

Several different types of dies have been constructed or are on loan to the Auto/Steel Partnership for the stamping process development.

Accomplishments

Identified additional processes to control springback, sidewall curl and panel twist.

Modified tooling for stretch-forming processes of AHSS auto body structural components to neutralize the residual stresses that cause springback and sidewall curl. Predictable results have been shown for HSLA 350 and DP600 MPa. The tooling was additionally modified for DP780 MPa and DP980 MPa. Panel measurements and data analysis are completed.

Modified panel geometry to show an alternative approach to control springback. Effective use of stiffening beads and other part shape modifications are being recommended to product designers for control of twist, undercrown and springback.

Built new Multi-Process Master Shoe Die and Sub-Die inserts that are capable of a variety of part shapes and processes. The master shoe has a high-pressure hydraulic cushion that can be programmed for various process control features. Sub-die inserts for two Underbody Longitudinal Rails, a Cowl Cross Bar and Body Center Pillar were either built or modified and run in tryout.

Completed three case studies of AHSS part developments by working through the OEMs. Applications guidelines studies were completed on a DaimlerChrysler roof rail reinforcement and on a General Motors and on a Ford Motor Company "B" pillar reinforcement.

Future Direction

Partner companies have observed fractures in parts subjected to stretch flanging or stretching over a die radius. This phenomenon is not currently predictable. For this reason, the project team has solicited, received and evaluated proposals for work in the area of fracture analysis to support future formability analysis in dies. Project work is scheduled for the 2007 fiscal year.

Die trials with the new Multi-Process Die and programmable hydraulic cushion are also continuing. This die is designed as a master die set and pressure system that will accept sub-die inserts to produce a variety of structural parts, such as underbody rails, cross bars and body side-structure pillars. Stamping processes for draw or form die actions can be developed with this tool.

Additional applications guidelines case studies are planned to be completed at the rate of three per quarter by obtaining one study from each OEM per quarter.

Introduction

Owing to the mechanical properties of Advanced High-Strength Steel (AHSS), the springback after forming and the geometric dimensional control of the stamped parts has been a critical issue in stamping tool construction and in stamping production. Because the actual dimensions of AHSS stampings off the tooling are unpredictable with current tools and technology, the average die face re-machining may be four to six times normal and result in two to three months of lost tryout time.

Computer simulation technology has been widely applied in the stamping industry and has been recognized as a virtual stamping tool to identify formability issues and evaluate solutions before the actual stamping dies are made. Although computer simulation provides an accurate prediction for splits and buckles, experience has shown that computer simulation data has not been totally reliable in predicting the amounts and modes of the springback, twist or sidewall curl. These distortions must be controlled if the AHSS is to be used successfully for lightweight body structures. Innovative stamping processes that neutralize residual stresses resulting from the metal deformation may control springback and other distortions in high strength steel stampings. These processes will involve some type of stretch forming in order to give the stamping "shape set". The work of this project group is to determine the most effective means of researching and applying these "shape set" processes. Computer simulation is also being analyzed to improve the data input for accurate formability prediction.

Benchmarks Toward Meeting Deliverables

Fender Rail Die

To assess the accuracy of the current forming/springback control theories, a full-scale fender rail-stamping die was used (Figure 1). A lockstep was added to the die to provide sidewall stretch and the potential for splits. For this reason, the project team has solicited, received and evaluated proposals for work in the area of fracture analysis to support future formability analysis in dies.

Several different AHSS materials, including Dual Phase 600, 780 and 980 were used to stamp fender rails and the finished panels were measured by laser scan. Springback control experiments were conducted using tooling designed to replicate actual production stamping die processes. These experiments confirmed the importance of stretching the sidewalls during the stamping process in order to reduce residual stress, flange springback and part-to-part variation. However, DP600 MPa and lower strength materials were the only materials that could be stretched with a two-break lockstep. Higher strength material (DP780 MPa and DP 980 MPa) required a four-break lock step for effective stretch results (Figures 2 and 3).

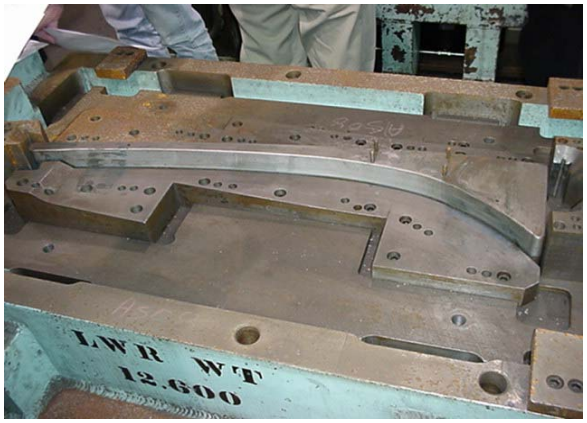

Figure 1. Fender Rail Die – Lower Half.

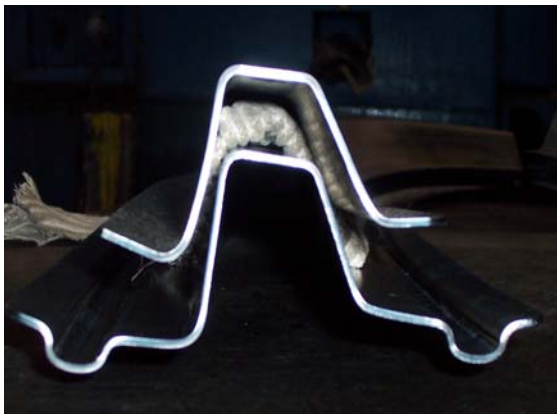

Figure 2. Effect of stretch with four-break lock step. Note that top section was not stretched.

Multi-Process Master Shoe Die

The Project Group is focused on experimenting with a multi-process research die with sub-die inserts (Figure 3) to produce various automotive structural components by a variety of processes. This die has the necessary higher holding pressures and controlled processes required for working the higher strength materials.

A programmable hydraulic pressure cushion is the main component of this system that provides the means of stretch forming the metal and controlling springback. Four sub-die inserts were built for this tool by the end of 2006.

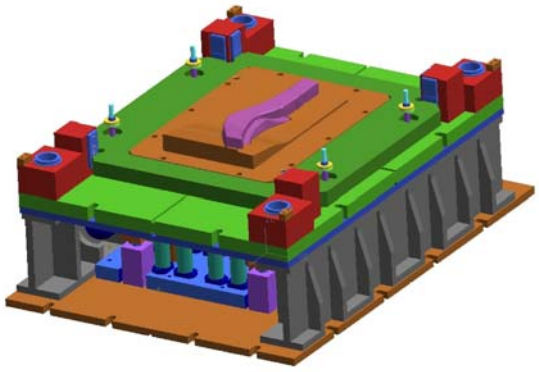

Figure 3. Lower Half of Multi-Process Die.

Sub-die inserts in the multi-process master shoe die enable stamping of underbody, cross-car and body side structural components with a variety of stamping processes.

Rear Longitudinal Rail Sub-Dies

Tryout of the three different stamping processes and with 1.6 mm and 2.2 mm DP600 MPa steel and 1.6 mm DP780 MPa and DP980 MPa steel have shown that the higher strength materials tend to split when drawn and are more readily formed than drawn. Press loads were monitored and lower press loads were noted when using the forming process. Material utilization was also much more efficient when using the forming process (Figure 4). Future efforts will feature continued work with the higher strength grades to improve the springback control with "shape set" features, such as lock steps, added to the forming process.

Figure 4. Rail Stampings Three Processes.

Cowl Cross Member Sub-Die

A Cowl Cross Member sub-die is part of the program. This stamping tryout also shows that the higher strength steels are more easily formed than drawn for some panel configurations (Figure 5). Additional stampings will be produced with DP600, 780 and 980 MPa materials using various blank configurations. These stampings have been laser scanned and the dimensional data has been recorded and analyzed to determine the effectiveness of each process.

Figure 5. Cowl Cross-Bar Two Processes.

Additional Work

Body Side Center Pillar Sub-Die

Another sub-die for a Body Center Pillar has been completed in December of 2005 (Figure 6).

Figure 6. Body Side Center Pillar.

This part is crucial to the body side structure for meeting side impact requirements. It is also typically difficult to stamp in medium strength grades due to springback, twist and undercrown. The higher strength grades will increase the manufacturing difficulties.

By recording the results of innovative forming processes, case studies for specific structural parts will be presented, along with product design and stamping process guidelines for industry reference, when making product applications of the AHSS materials.

In addition, stamping press tonnages are being recorded, along with, impact loads, press signature analysis and die cushion pressure requirements for the stamping industry's information. This will aid in better understanding the machine and equipment requirements for manufacturing components from this material.

Further stamping tryouts of DP600, DP780, and DP980 will be conducted on typical automotive underbody, cross–car and side structural members with new tooling and multiple processes. These materials, in lighter gauges than currently employed, will assist the weight reduction and structural performance goals of the Future Generation Passenger Compartment and other light weighting project groups in the Auto/Steel Partnership.

Conclusions

The dual phase steels of 600 MPa to 980 MPa can be formed more readily than drawn. Product should be designed to allow a form die process for structural parts in the higher strength grades.

Draw die processes and stretch-form processes will be required for large outer "skin" panels of 500 MPa and lower. Product design modifications may be required to use these materials instead of lower strength grades.

When AHSS is formed, a "shape set" stretch should be added at the bottom of the press stroke for springback compensation.

Stretch flanges are very susceptible to edge cracking and flange edge stretch may be minimized by product design. Trim edge quality will be critical.

Presentations and Publications

1. "Product and Process Effects on Stamping Performance of Advanced High Strength Steels." *Presented at the March 8, 2006 seminar* "Great Designs in Steel" in Livonia, Michigan.

2. *"Product and Process Effects on Stamping Performance of Advanced High Strength Steels."* Presented at the September 19, 2006 International Auto Body Congress in Novi, Michigan.

[i] Denotes project 050 of the Auto/Steel Partnership (A/SP), the automotive-focus arm of the American Iron and Steel Institute. See www.a-sp.org. The A/SP co-funds projects with DOE through a Cooperative Agreement between DOE and the United Sates Automotive Materials Partnership (USAMP), one of the formal consortia of the United States Council for Automotive Research (USCAR), set up by the "Big Three" traditionally USA-based automakers to conduct joint pre-competitive research and development. See www.uscar.org.