

By AutoForm Engineering USA, Inc.

Hemming of Thin Gauge Advanced High-Strength Steel



A recent project of the Auto/Steel Partnership demonstrates that thin-gauge AHSS is viable for automotive closure outer panels.

Lightweight construction plays an important role in the automotive industry, particularly in the reduction of fuel consumption and CO₂ emissions. In today's car-body engineering, the primary materials are high and advanced high-strength steels, as well as aluminum. They let car manufacturers design lighter cars that fulfill increasingly more stringent safety requirements. However, the application of these

materials poses additional challenges, and for each automotive stamped part, the material selected must be suitable for its particular requirements.

While advanced high-strength steels, or AHSS, are used extensively in the body-in-white, applications for the exterior "Class-A" panels have been limited to mild and dent-resistant steels. The formability of AHSS is considered insufficient for

the hemmed outer panel of automotive closures. This poses limits in the development of design concepts that use strong lightweight steels. Recently, the Auto/Steel Partnership carried out a project called Hemming of Thin Gauge Advanced High-Strength Steel, which is focused on hemming these steels to achieve weight savings. The main goal of this project was to demonstrate that thin-gauge AHSS is

viable for automotive closure outer panels. AutoForm participated by providing its software, AutoForm-HemPlanner^{plus}, which provides easy definition and optimization of the hemming operation.

PROJECT OBJECTIVES

Formed in 1987, the Auto/Steel Partnership is a consortium of North American automotive companies and the Steel Market Development Institute's Automotive Applications Council. The partnership leverages the resources of the automotive and sheet-steel industries to pursue research, validation and education to support automakers in enhancing vehicle safety, fueling the economy and improving design and manufacturing. This worthwhile project brings new insights into the efficient use of AHSS.

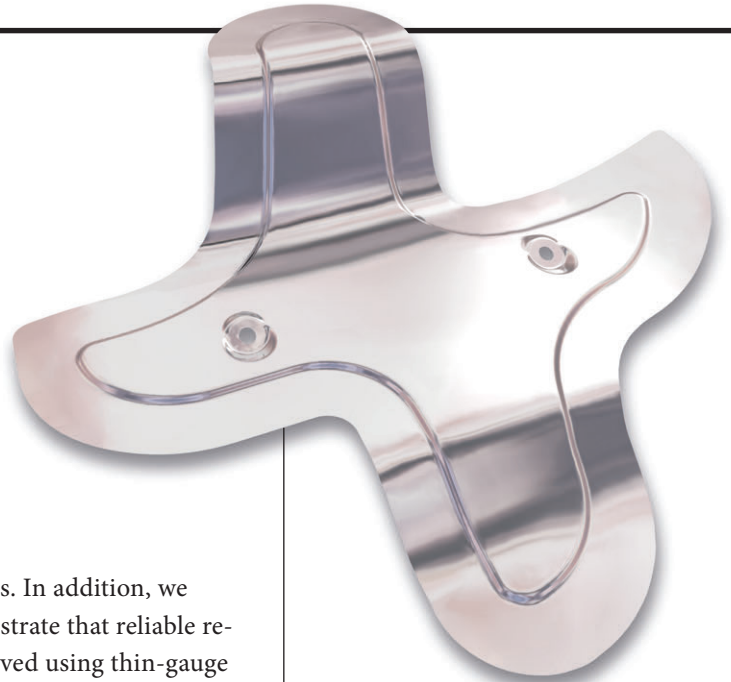
In a first step toward meeting the group's goal, the project team set the main objectives. Giovanni Costa, project leader for the A/SP Hemming of Thin Gauge AHSS team and corporate hemming specialist at FCA US LLC, stated, "We approached this project with great interest and enthusiasm. For us as a team, it was very important to define clear goals. The main goal was to demonstrate that thin-gauge AHSS can be successfully hemmed into shapes typical of those found in automotive-

closure assemblies. In addition, we wanted to demonstrate that reliable results can be achieved using thin-gauge AHSS through the appropriate selection of software that accurately predicts the results of the hemming operation."

He added, "The accuracy of the hemming operation is very important since it affects the surface appearance and surface quality of the panel. Our team at the Auto/Steel partnership selected AutoForm's software AutoForm-HemPlanner^{plus} as our software of choice for this project. With AutoForm-HemPlanner^{plus}, the hemming operation could be planned efficiently, and typical hemming defects that occur during the hemming operation could be successfully addressed."

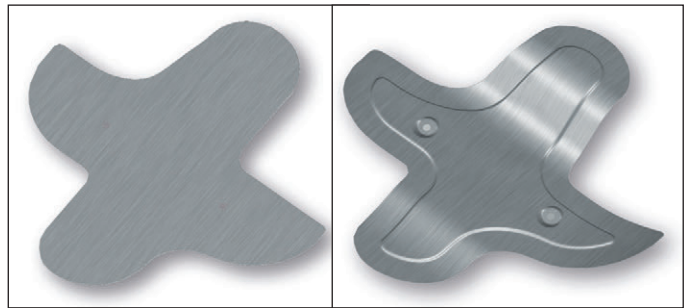
MATERIAL SELECTION

The steel-making partners involved in this project provided three AHSS grades of higher-yield strengths to assess whether they could be used for the production of outer panels of an acceptable quality. The materials and their gauges used were BH 280 gauge 0.55 mm, BH 440 gauge 0.55 mm and DP 490 gauge 0.50 mm. In all three cases, the inner panel was made of mild steel DC04 with gauge 0.7 mm. DC04 is a typical deep-drawn quality steel, which is included in AutoForm's material library. The steels were specially



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FIGURE [1] / Flat and specially designed panels



developed by steelmakers, so it was essential that the simulation captured their true performance. For this reason, the steel suppliers provided the raw tensile-test data that was used to build material cards in order to represent real material behavior.

Three grades of thin-gauge AHSS were formed into 18-inch-by-18-inch test panels, i.e. steel samples, containing shapes and contours that can address many of the challenging issues that might appear in real closure panels during the hemming operation (Figure 1). These newly developed test panels were hemmed into assemblies, which were consequently evaluated for various failure criteria. The test results were then compared with the simulation results obtained using AutoForm^{plus} R6 to verify whether the prediction matched the test results.

FORMING PROCESS

The stamping process was simulated with AutoForm^{plus} R6. Figure 2 shows the forming and flanging operations.

A formability assessment was then carried out as it provides valuable feedback on key stamping-quality issues, such as risks of splitting on the breakline during hemming and excess thinning, as well as the potential for wrinkling. The formability of outer panels showed some minor concerns regarding thinning, but these remained within an acceptable margin of tolerance. The formability of inner panels raised no concerns.

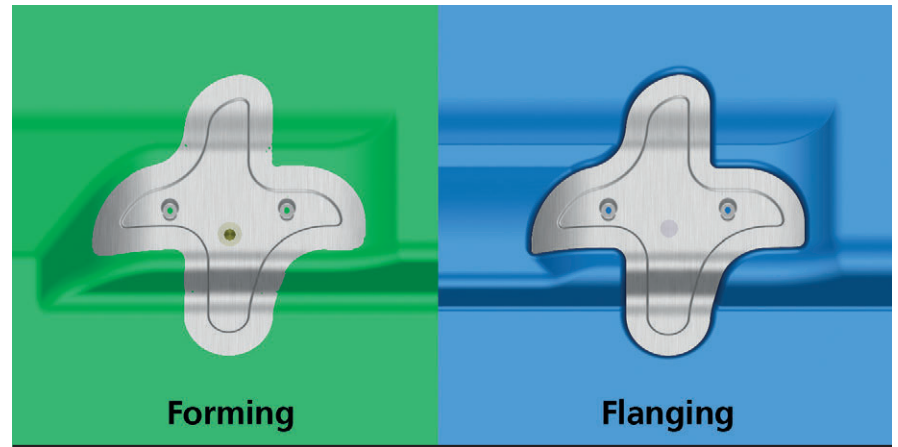


FIGURE [2] / Forming and flanging operations

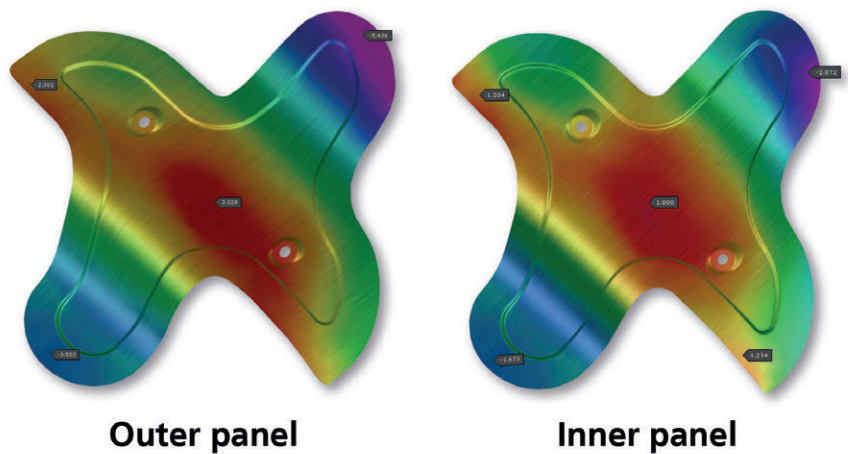


FIGURE [3] / Springback evaluation of outer (deviation from 2 mm to 5 mm) and inner panels (deviation from 1 mm to 3 mm)

SPRINGBACK

Forming parts made from high and AHSS are more affected by springback than parts made from conventional deep-drawn steel. As a result, special attention was given to the springback

analysis of both outer and inner panels. Springback results for these panels are presented in Figure 3. The springback trends were very similar for each of the tested AHSS steel. With all three

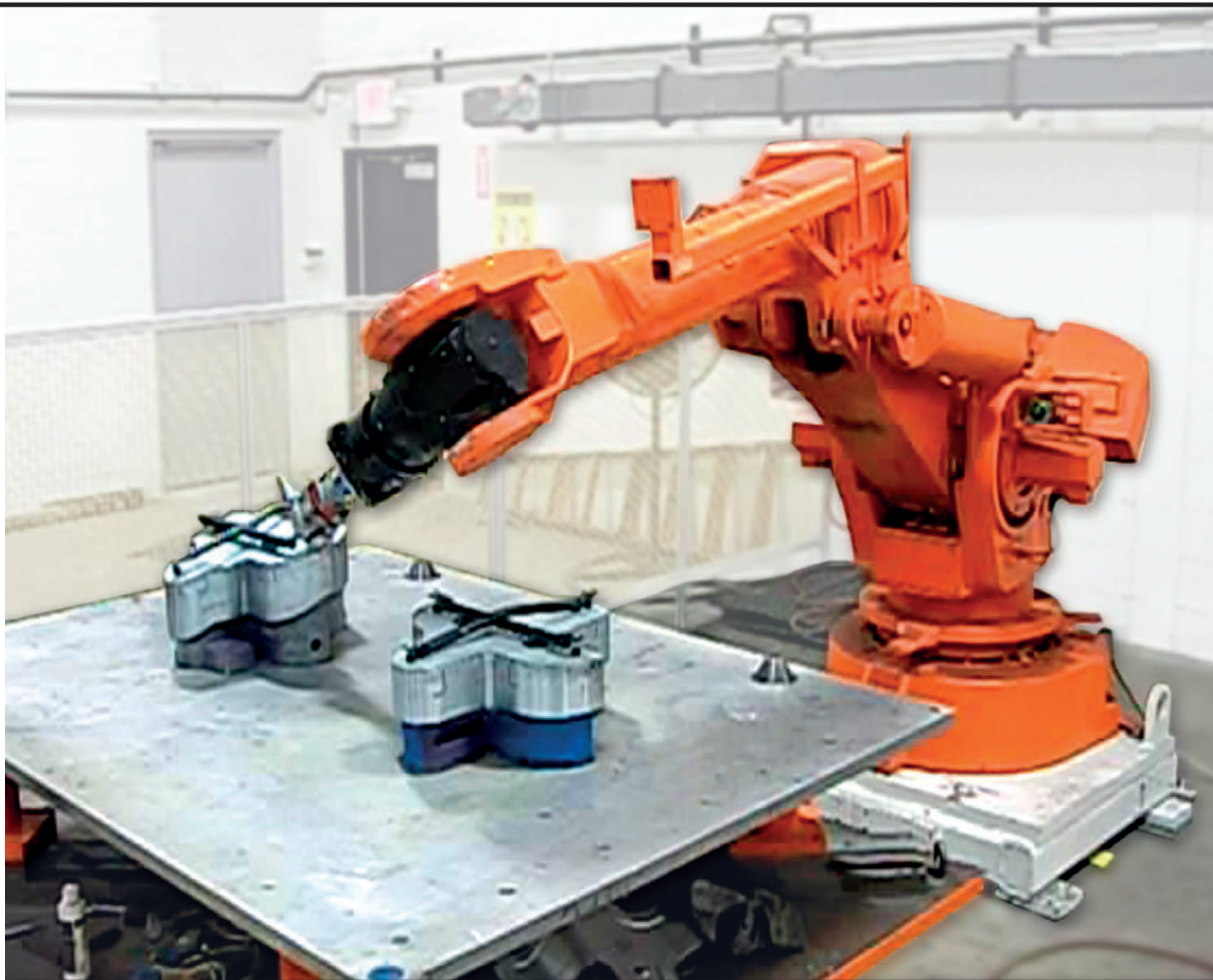


FIGURE [4] / Roll-hemming process

materials, the springback deviation of the outer panels after forming ranged from 2 mm to 5 mm, which matched the advanced simulation. At the same time, the deviation of the inner panel ranged from 1 mm to 3 mm and again was predicted by the AutoForm software. In both cases, no springback compensation was applied.

HEMMING

One of the main concerns of this project was to prove that AHSS materials are formable and capable of being

hemmed. “Class-A” closure panels are visible and scrutinized for surface deformation caused by the forming and hemming processes. They play an important role in attracting the attention of potential customers. For example, part quality and perfect finish are essential for luxury cars, which are produced in small numbers. However, they are also dominant factors for middle-class car models produced in volume. On the other hand, surface appearance, as well as material savings, have a great impact on low-end car

models, where significant cost savings can be achieved with every gram saved in material.

The hemming operation was simulated by AutoForm^{plus} R6. A roller-hemming process on the end of a robot was used for this solution. In this type of hemming, an industrial robot guides the hemming roller and moves the open flange to a closed hem position (*Figure 4*). Roll hemming is a very flexible solution, and tool costs are significantly lower as compared to those of conventional die hemming

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when running multiple models of vehicles.

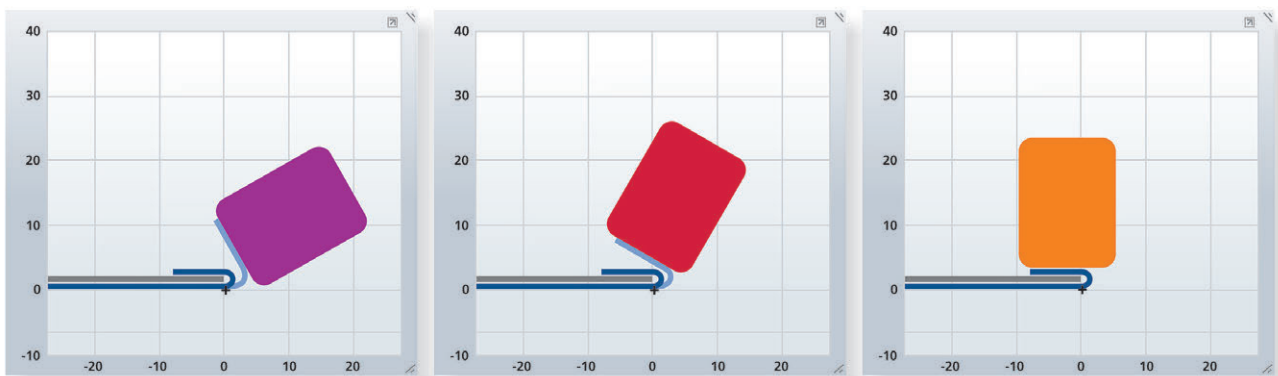
AutoForm-HemPlanner^{plus} supports two use cases, namely quick- and advanced-hemming predictions. Quick-hemming predictions are used in the early stages of product development and production planning when the die layout of the drawing and forming operations is still not available. Advanced hemming is used in advanced process engineering when the detailed definition of a new product and forming operations are only available in design. The accuracy of simulation results is increased by taking into account the history of material deformation accumulated throughout the previous manufacturing operations. With respect to this, Costa explained, “The options provided by AutoForm-HemPlanner^{plus} perfectly suit the needs of this project. Advanced hemming was used to validate the selected hemming concept,

i.e. validate the design, check that the hemming operation would not cause surface deformation or be susceptible to breakline splitting. The software validated the roller path to evaluate the potential hemming defects, as well as predict full assembly springback.”

Both the outer and inner panels were imported with their complete forming history, including thinning and thickening, strains and stresses, and springback deformation prior to the hemming operation. The hemming simulation was performed by three roller passes, the first at a 60-degree open angle, the second at a 30-degree open angle and a final pass completing the hem flange closed (*Figure 5*).

Material deformations, which occur during the hemming process, can lead to dimensional variations and other typical hemming defects, including splits and wrinkles in the flange, material overlaps in the corner areas and material roll-in. Simulation results

FIGURE [5] / Three roller passes — 60-degree angle, 30-degree angle and final pass

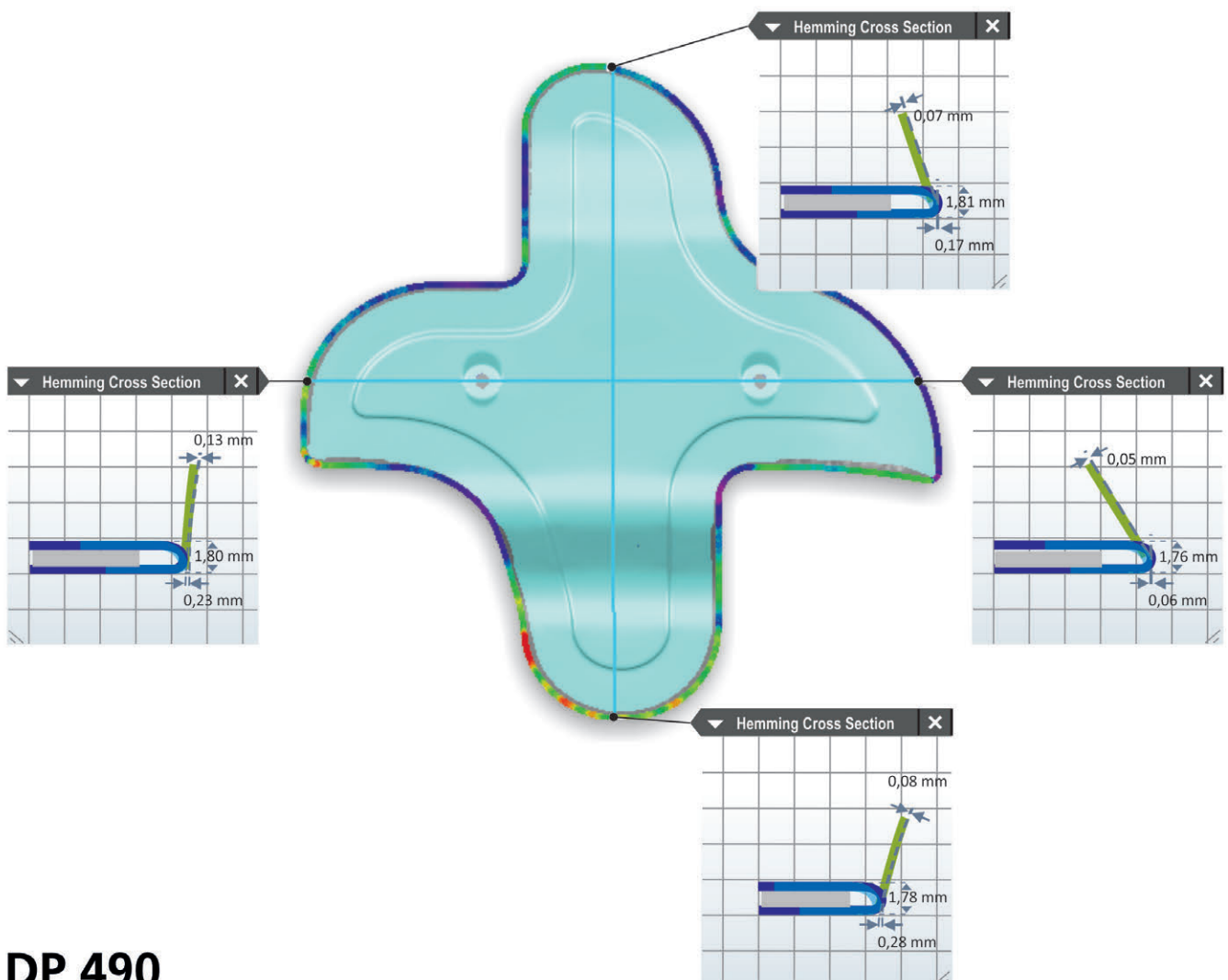


carried out by AutoForm-Hem-Planner^{plus} show roll out, creepage and hem thickness (Figure 6). These values were similar for all three actual tested AHSS steels. Typical issues

were identified in expected locations. Hem-flange wrinkling appears in outer corners where the material tends to gather in compression. Inner corners where the hem

flange is in stretch tend to split. AutoForm^{plus} R6 gave accurate predictions matching the actual hemming-test parts.

FIGURE [6] / Evaluation of hemming defects — results similar for all three actual tested materials



DP 490

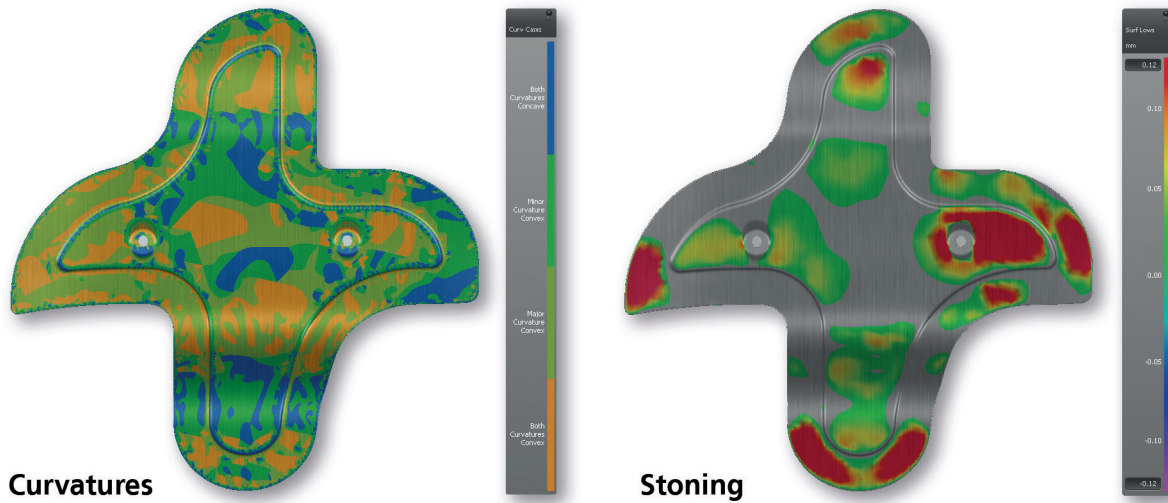


FIGURE [7] | Evaluation of surface quality

SURFACE DEFECTS

By using AutoForm^{plus} R6, surface defects of assembled panels can be easily detected. *Figure 7* shows different curvatures of the panel and digital stoning, allowing for easy visualization of surface imperfections. This method emulates the back and forth scratching of a stone block on a stamped outer panel.

DIMENSIONAL EVALUATION

All test panels were white-light scanned prior to hemming, and this procedure was repeated again on the assemblies after hemming. The before and after scans were then compared to the AutoForm software predictions. Dimensional changes, springback or other issues that may have resulted from the hemming operation were analyzed. The assemblies were visually inspected for cracking, splitting, thinning, compression or any other surface defects.

CONCLUSION

This project demonstrated that thin-gauge AHSS can be successfully hemmed into body-closure outer panels and that it is a viable option for achieving weight savings in automotive-closure assemblies. The hemming of thin-gauge AHSS outer panels did not result in dimensional distortions beyond what would be typical when hemming mild-steel panels with gages commonly used in automotive-closure assemblies.

“The results achieved by the hemming team were exceptional, and AutoForm^{plus} R6 software aligned with our actual results. It proved to be a valuable tool for early product devel-

opment. This project goes beyond the boundaries of common AHSS implementation and gives new insights into their application in hemmed assemblies for automotive closures,” said Giovanni Costa. “We took hemming to new heights and proved it with results. We are pleased to see that AHSS can be successfully implemented in this challenging area of outer-closure panels, and we are confident that its further application will bring tangible benefits in lightweight solutions in weight reduction even up to 30 percent in automotive construction.” **LW**

For more information, contact AutoForm Engineering USA, Inc. www.autoform.com, 888-428-8636

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