Bending for **Braking**

Dynamic simulation reduces the cost of automotive brake pedal design and manufacture.

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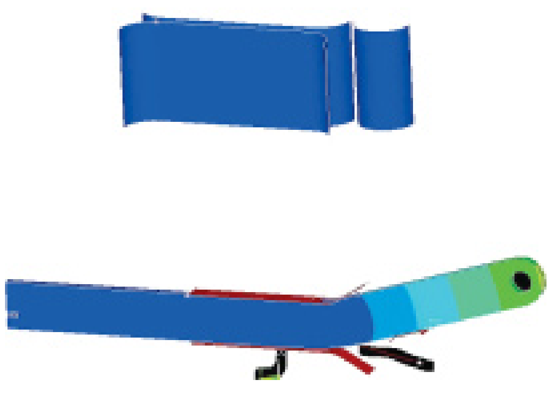
Conventional high-volume pedal beams for automotive applications are manufactured using a progressive stamping operation. The nature of progressive stamping results in a relatively high material scrap rate for many pedal beam designs. GHSP, a company that designs and manufactures driver controls, including shift systems, throttle controls and pedal systems, has modified this process to instead trim and bend, rather than stamp, a narrow strip of steel when manufacturing pedal beams. This change greatly reduces the material scrap rate and production costs.

The bender procedure is a continuous manufacturing process. It consists of a series of machines that perform sequential operations that transform a steel strip into a formed pedal beam. First, a basic stamping, or cutting, action occurs to form the pre-bend outline of the pedal beam. This pre-bend component has no bend in the structure whatsoever. The bending station then deforms the component to its final shape.

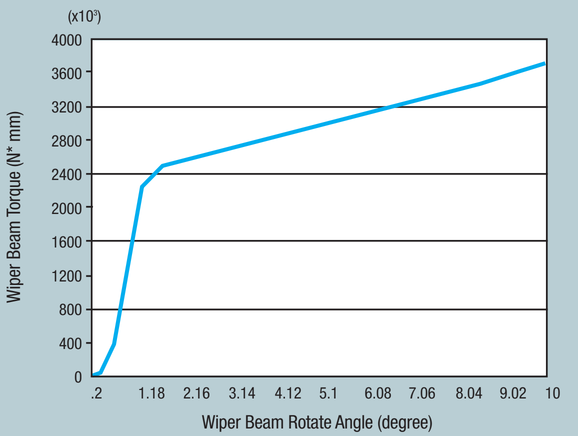
The bending station creates two kinds of bends: hard and easy. “Hard bend” refers to bending the steel strip along its length, against its greatest moment of inertia. An “easy bend” is normal to the hard bend and bends the component to the side, about the steel strip’s lowest moment of inertia. The bending station components that deform the strip to create the bends are called the bend heads and wipers. The bend heads hold the component in place and have guide curves that are designed to locate and guide the formation of the final bend geometry. The wipers press against the component to actually deform the part around the guide curves on the bend heads. In a bending process that requires multiple steps, typically — but not necessarily — the hard bend is performed first. A total bend sequence may consist of one single bend or a combination of many easy and hard bends.

Developing this new process required the design of bend tooling and procedures that would result in bend geometry matching the desired final product. Geometric and strength requirements for both of these components are of great importance. In order to provide a full analysis of the bending process, a dynamic finite element analysis (FEA) of the entire system was implemented.

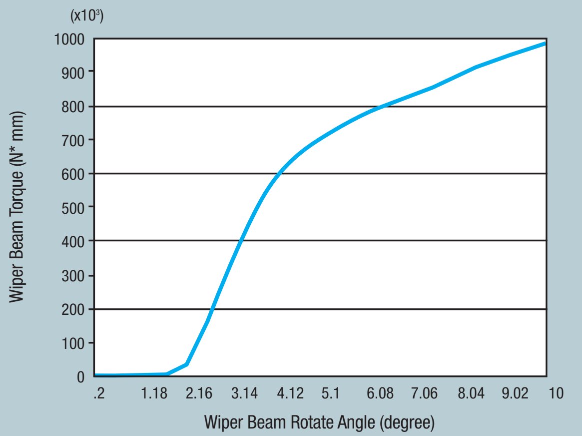
The full simulation included two sequential bend simulations: one hard bend action followed by an easy bend event. The model contained the trimmed steel strip to be bent, a hard bend head and wiper, and an easy bend head and wiper. The steel strip for the model was meshed with 3-D solid elements and modeled with the material properties for SAE950X, a very popular steel in structural automotive components due to its relatively high yield strength. The model, which was analyzed using ANSYS Structural



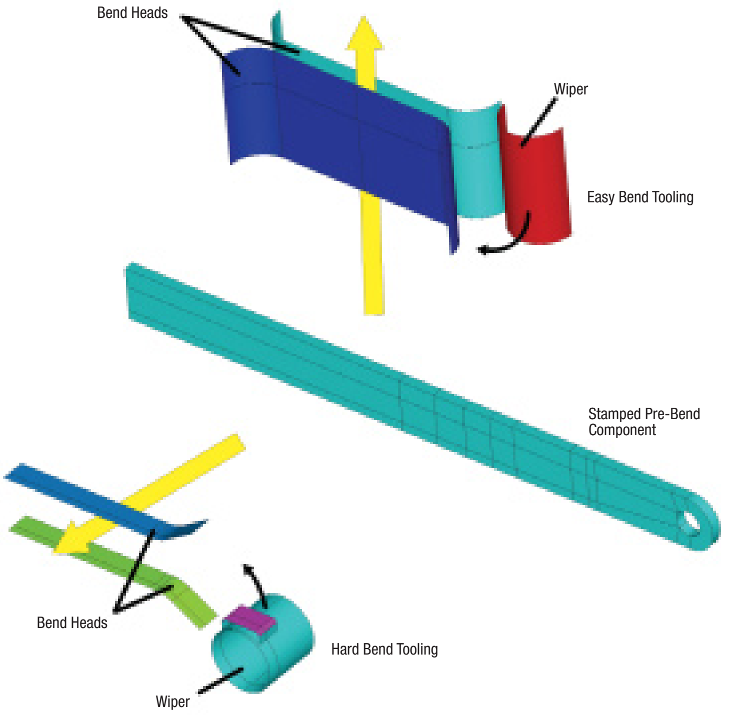
Bend heads (top) and steel strip during hard bend (bottom)



Hard bend torque, as seen by machine tooling, versus sweep angle



Easy bend torque, as seen by machine tooling, versus sweep angle



Components involved in a novel bending process developed by GHSP

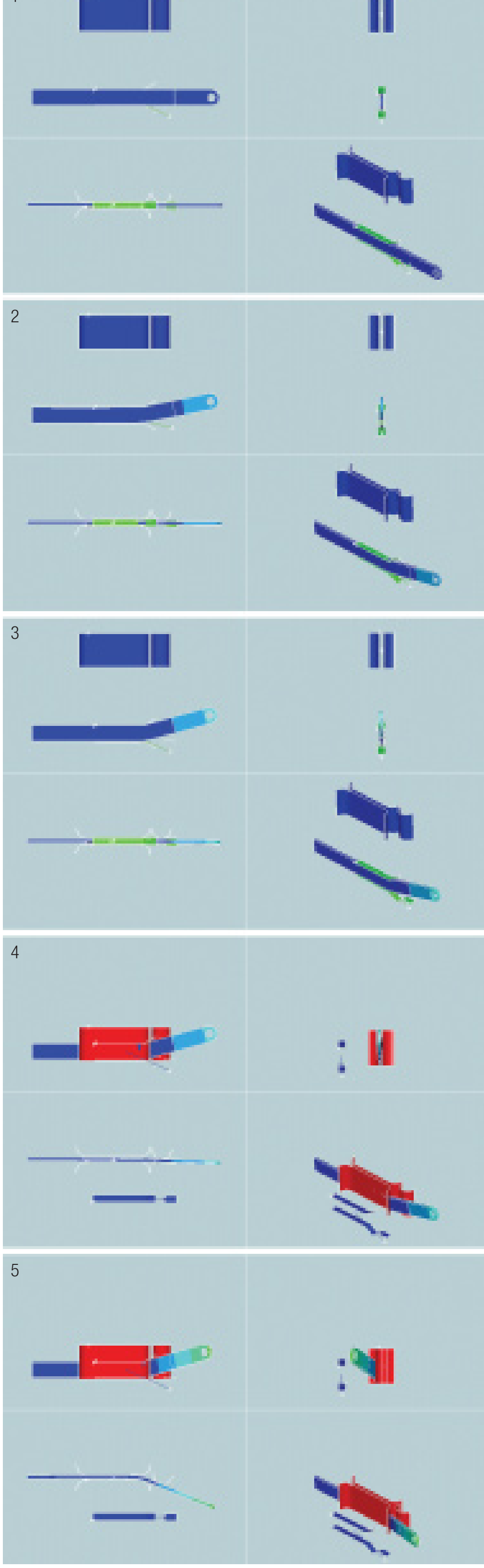
software, included contact, nonlinear material properties, large deformation and large rotation. Contact was defined between the steel strip and both the bend heads and the wipers. Both the bend heads and the wipers were assumed to be rigid. The hard bend wiper was defined with rotation. Both stages of the simulation were modeled as fully dynamic processes.

By using FEA in this way, the bending process could be examined in depth. The simulation results were used to study the final pedal beam geometry and strength properties, as well as the loading experienced by the tooling during the process.

The final bend geometry that resulted from the process was examined and measured to see if it matched the desired outcome. If it didn't, changes were made to the trimmed shape and to the geometry of the tooling and wiper placement, and the analysis was repeated until the process was verified to create the desired final component. The use of this methodology saved time and reduced costs that would otherwise have been expended when utilizing a trial-and-error method to create these components. The final nodal locations of the pedal beam were used to create a solid model of the finished beam geometry. An ANSYS parametric design language (APDL) macro was prepared to develop this geometry creation. This model was then sent back to design engineering to be used in the final pedal beam assembly.

Verifying that the manufacturing tooling was properly designed was equally important and also addressed by GHSP using this simulation. During the simulation, the torques and contact forces on the wipers and bend heads were calculated. By monitoring these values, GHSP ensured that the bender machine limits were not exceeded.

Tooling and time spent in trial, test and error proofing is expensive. Simulation allows GHSP to detect and correct potential problems with hard bend stability, sensitivity to edge conditions, tool wear, beam strain history, beam cracking, etc., before tooling design is finalized. The analysis demonstrated here is used today by GHSP to guide design and manufacturing, reduce cost and shorten the product development cycles. Using APDL, this analysis is being incorporated into end-user software tools to help designers evaluate designs and provide modification guidelines. ■



From top to bottom, these images depict the pedal bending process developed by GHSP. The top three images show the hard bend simulation of the beam advancing with time. The bottom two images display the easy bend process. Each image has four parts, which illustrate the side (top left), front (top right), top (lower left) and orthogonal (lower right) views of the apparatus.