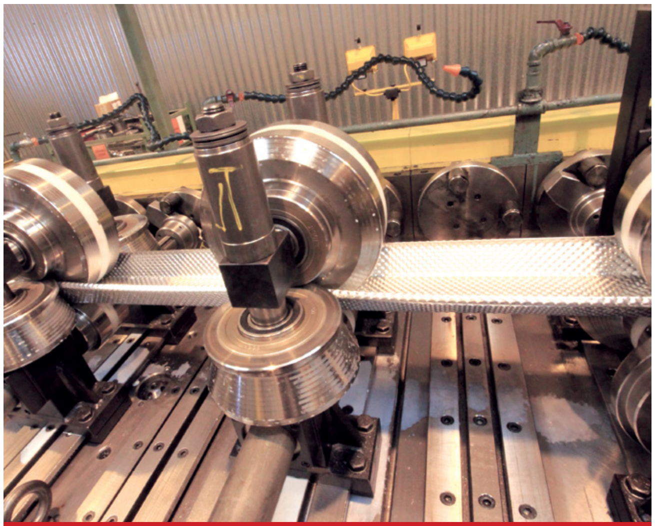
MSC Software

Case Study: **The Hadley Group**

Simulation Increases Sales $4 Million by Validating New Cold Roll Forming Process for Customer Applications

Overview

Hadley Industries PLC's core business is manufacturing cold roll formed products, primarily to the building and construction industries. The company developed and patented a unique cold forming process known as UltraSTEEL® which significantly improves mechanical and structural properties of the strip steel by imparting a dimpling pattern prior to the roll forming operation. The geometry is much too complex to determine the structural properties of the end product based on analytical calculations alone, and it could cost $30,000 to $150,000 for tooling to manufacture the part so its properties could be physically measured.



The reliable and consistent results provided by Marc make it possible to accurately assess applicability in a short time frame at a low cost.

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Dr Martin English, Design and Development Manager, Hadley Industries

Key Highlights:

Product: Marc

Industry: Manufacturing

Benefits:

- Reliable, consistent results that matched experimental measurements
- Reduced physical prototyping for product development cost savings
- Higher accuracy by accounting for forming induced residual stresses in product testing

Hadley addressed this challenge by using Marc nonlinear finite element analysis software to predict the highly nonlinear changes in geometry and material properties that occur during the UltraSTEEL® process, cold roll forming and secondary processes. “Marc overcame problems seen with other finite element software packages such as nonconvergence and provided reliable and consistent results that matched experimental measurements,” said Dr Martin English, Design and Development Manager for Hadley. “The ability to accurately simulate the process and quickly determine its performance in customer applications has been responsible for a substantial increase in sales volume estimated to total over $4 million over the next three years.”

Challenge

Complex Geometry and Process Creates Simulation Challenge

When evaluating any new cold roll forming application, the potential customer needs to accurately investigate the performance of the finished product by estimating section properties such as stiffness and load-carrying capacity in order to make a buying decision. Standard cold roll formed products have a uniform cross sectional geometry, so theoretical calculations can be relatively easily performed to determine their section properties. The geometry formed by the UltraSTEEL® process is much more complicated and the material properties vary over the geometry, so theoretical calculations cannot be used to accurately analyze its performance. “In the past, the only way to fully understand the behavior of a section produced by the UltraSTEEL® process was to invest in a complete set of tooling, produce prototypes and perform physical testing,” English said. “The high cost of this approach was a major obstacle to trying out the new process.”

Hadley has worked for a number of years in developing the capability to simulate the dimpling process as well as the subsequent cold rolling forming and secondary operations with the goal of developing the capability to predict the performance of the finished product. The company tried one popular finite element analysis software package only to discover that the results did not correlate well with physical testing. So Hadley assessed three leading developers of nonlinear finite element analysis software by using them to simulate a complex nonlinear problem involving compression of a thin-walled column. “Marc demonstrated its capabilities to solve applications involving highly nonlinear changes in geometry by providing by far the most accurate results on this difficult problem,” said Bac Nguyen, Research and Development Engineer for Hadley.

Solution

Transferring Geometry and Material Data from One Process to Next

Complex and interrelated nonlinear changes in contact, geometry and material properties occur during the UltraSTEEL® process and subsequent section forming and secondary operations. “The simulation challenge involves both accurately simulating these processes as well as applications under loading,” Nguyen said. “This requires simulations that connect to previous or subsequent simulations to perform continuous processes while taking into account the changes in geometry, material and structural properties of the materials. An important advantage of Marc in this regard is its PRE STATE procedure which can be used to transfer the geometry of the dimpled strip together with its material data including stress/strain data generated from the dimpling process into the subsequent simulations such as the cold roll forming process.”

The ideal approach is to simulate the entire chain of processes as a sequence from start to finish: 1) the dimpling process that deforms a flat steel strip into a dimpled strip, 2) the cold roll forming process that produces the desired section, and 3) additional processes such as shear cutting and applications such as products under tension, bending, compression loads, etc. The geometry and material data of the dimpled strip are transferred from one process to the next in a closed loop. This approach is practical for small sections of dimpled products and optimizing the dimpling process itself. However, the models of the rolls and dimpled strip can contain tens of millions of elements for larger models so transferring the stress/strain data between each of the stages becomes very complicate and time-consuming, resulting in high computational costs.

Hadley Group addresses this challenge by using a simplified method to compute the properties of large dimpled products.

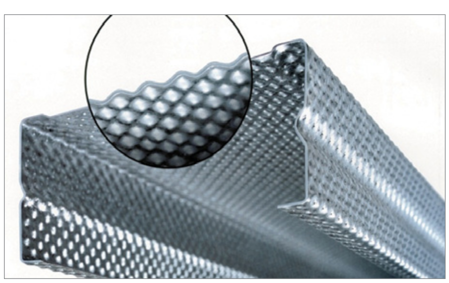

Fig. 1: Typical UltraSTEEL® dimpled steel product

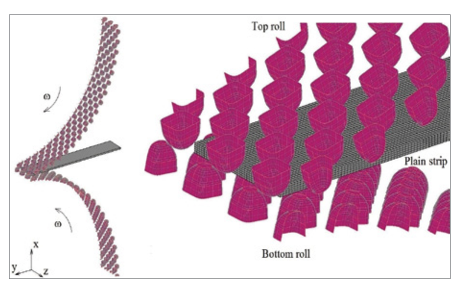

Fig. 2: Model setup in Marc

This approach begins with simulating the deformation of a flat steel plate by producing a single dimple. This general dimple geometry is used to generate a dimpled strip. 3D elements are used for smaller products and shell elements are used for larger products. It's important to note that only the geometry of the dimple is transferred from the dimpling process. The material properties of the dimple are provided from a separate tensile test on a dimpled steel sample. This test can be quickly and inexpensively performed without tooling. The next step is simulating the cold roll forming process that develops the dimpled strip into the desired dimpled product, other processes and applications.

Results/Benefits

Simulation Results Match Experimental Data

"Both simulation approaches have been extensively validated by experimental results and have demonstrated the ability to accurately represent the dimpling, cold forming and secondary processes," Nguyen said. In a typical example, a computer aided design (CAD) model of the top and bottom rolls was imported into Marc for preprocessing. An elastic-plastic material model was used with a Young's modulus of 205 GPa and a Poisson's ratio of 0.30. The top and bottom rolls were modeled as rigid bodies that rotated around their central axes. The plain strip was generated in Marc and placed in a pre-defined position between the two rolls. Five layers of elements were used through the strip thickness to model both bending and stretching phenomena. Two different meshes were evaluated, one with 37,980 solid elements and the other with 149,810 solid elements. The dimpling simulation showed that the maximum plastic strain and stress developed in the two meshes differed by less than 7% and 4% respectively so the coarser mesh was used for the balance of the study.

The top and bottom rolls had an overlapping gap of 0.40 mm between the mating teeth. The sheet was fully fixed at one end and initially fed to the rotating rolls with a velocity equal to the linear velocity at the tip of the roll teeth. When the roll teeth just grasped the strip, the fixed end was released and the strip was deformed by the rotating rolls. The original plain sheet and the dimpled sheet were used in tension and bending simulations. The engineering stress and strain data of the plain steel sheet were obtained from tensile tests. The dimpled sheet was merged into the new model in order to start the new analysis and the PRE STATE option was employed to directly transfer result data from the previous dimpling process into the tensile and bending simulations.

"The simulation was validated by comparing the 3 dimensional geometry of the predicted shape with scanned data of the physical sample," Nguyen said. "The geometry of the predicted dimpled sheet differed from the actual process by less than 1.7%. The distances between adjacent dimples on the simulated sheet also matched the actual dimpled sheet. The predicted plastic strain distribution correlated well with experimental results obtained with micro-hardness tests. In the tensile test the predicted yield and ultimate forces in the plain sheet were 2% and 4% greater than the experimental results and the predicted yield and ultimate force in the dimpled sheet were about 1% and 5% less than the experimental results. The predicted and experimental values for ultimate load in the bending test were also close with a maximum difference of 0.4% and 4% for the plain and the dimpled sheets respectively."

"The reliable and consistent results provided by Marc make it possible to accurately assess the applicability of UltraSTEEL® for existing and new products in a short time frame at a low cost," English concluded. "The accurate simulations have enabled Hadley to make and substantiate technical claims regarding the benefits of the process. As a result the company has increased its sales of UltraSTEEL® products and also generated additional revenue by increasing licensing of the process amounting to an estimated $4 million over the next three years."

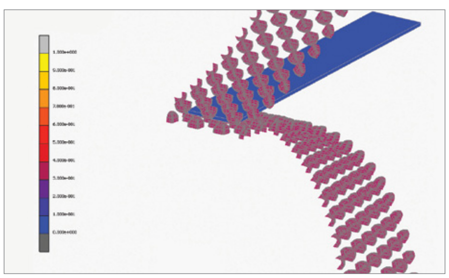

Fig. 3: Simulation results for total equivalent plastic strain

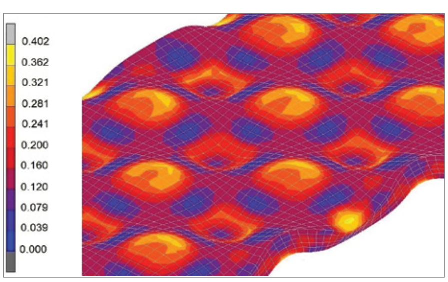

Fig. 4: Close-up of simulation results

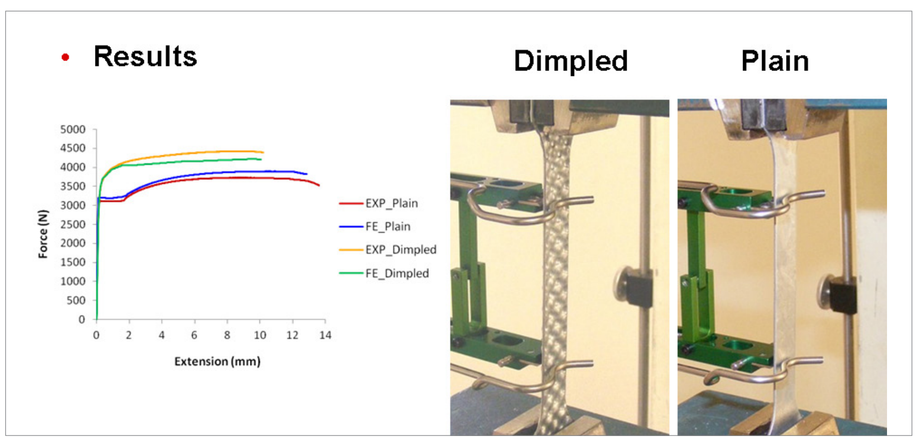

Fig. 5: Tensile test validation

For more information on Marc and for additional Case Studies, please visit **www.mscsoftware.com/marc**

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