Bailey Tool Enhances Structural Component FEA Capability by Seamless Incorporation of Strain Hardening and Thickness Changes during Part Forming

Key Issue

Automotive designers simulate structural and crash performance using structural finite element analysis. It is typical to use the CAD based part shape in the analysis ignoring geometry changes, thickness changes and strength changes that occur during the forming process. It is increasingly being recognized that it is important to include thickness and strength changes in the subsequent structural FEA in order to obtain reliable simulation results.

Example Problem- Buckling of Multi-Stage Deep Drawn Cylindrical Cup Wall

A. Forming Analysis

An interesting example that highlights the importance of including prior forming-induced changes in thickness and hardness is the buckling of a deep drawn cylindrical cup wall. Typically strength increases from forming are associated with thinning, leaving subsequent effects on the structure somewhat unclear. In this case, during the forming process, the material thickens substantially as you go up the cup wall toward the flange. At the same time, the strength developed as a result of the drawing process also increases as you go up the cup wall; this presents a unique situation in forming. Figure 1 shows the thickness change as a result of forming, while Figure 2 shows the change in plastic strain which is a true measure of strength changes.

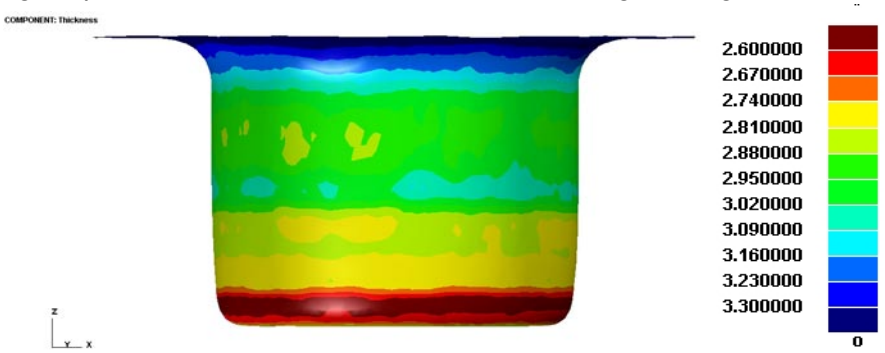

Figure 1: Thickness changes in the cup wall – original material thickness = 3 mm

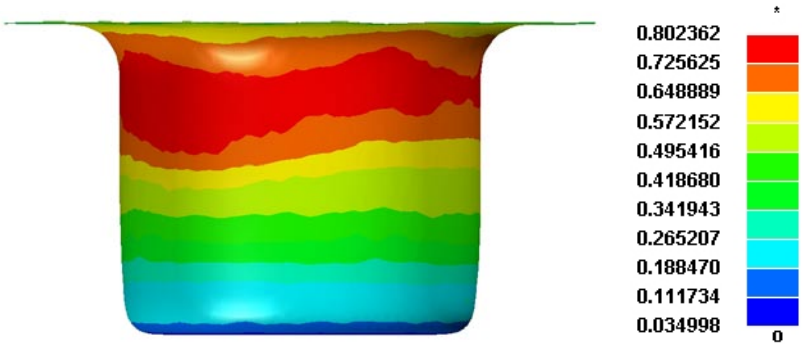

Figure 2: Strain hardening as indicated by accumulation of plastic strain

B. Structural Analysis

I. Typical Structural FEA Analysis

FEA structural analysis is typically conducted using the perfect CAD geometry and does not incorporate thickness or hardness changes. The result from loading the cup wall in compression until the cylindrical column buckles is shown in Figure 3. Note that the collapse is initiated at the top of the column as the base of the column is placed on a horizontal base while the top of the column is subjected to compressive loading.

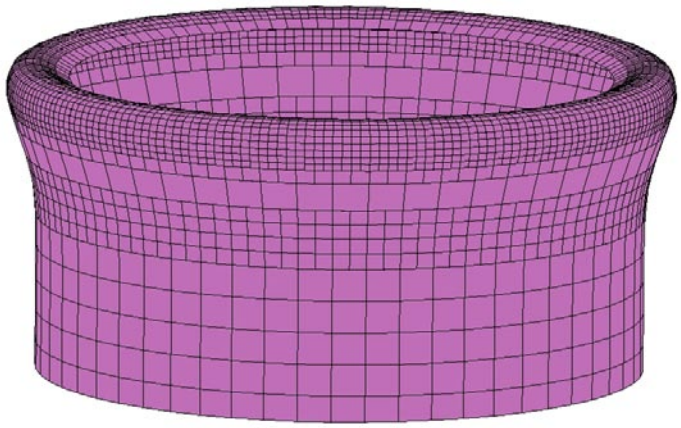

Figure 3: Typical FEA Analysis ignoring prior forming thickness and strength changes in the cup wall.

II. CAD Geometry Incorporating Thickness and Hardness Changes in the Cup Wall

Once you include the thickness and hardness effects, the results are diametrically opposite as seen in Figure 4. Buckling initiates at the bottom of the cup wall since this region is associated with the lowest thickness and strength level.

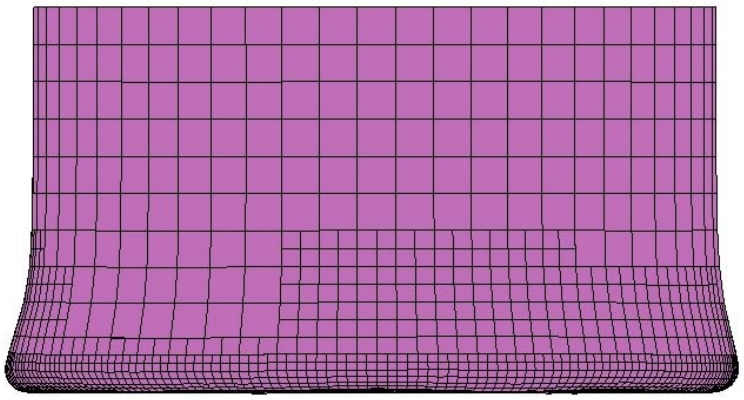

Figure 4: CAD geometry used in the structural analysis but with hardening and thickness changes mapped from the formed part prior to structural analysis

III. Structural analysis using formed part geometry including thickness and hardness changes
The real part geometry after cup drawing shows significant change in shape as well as incorporating the hardness and thickness changes. The initial and final states are shown in Figure 5 – as expected, buckling initiates at the bottom of the cup wall not only because of thickness and hardness changes but also because of shape of the formed part.

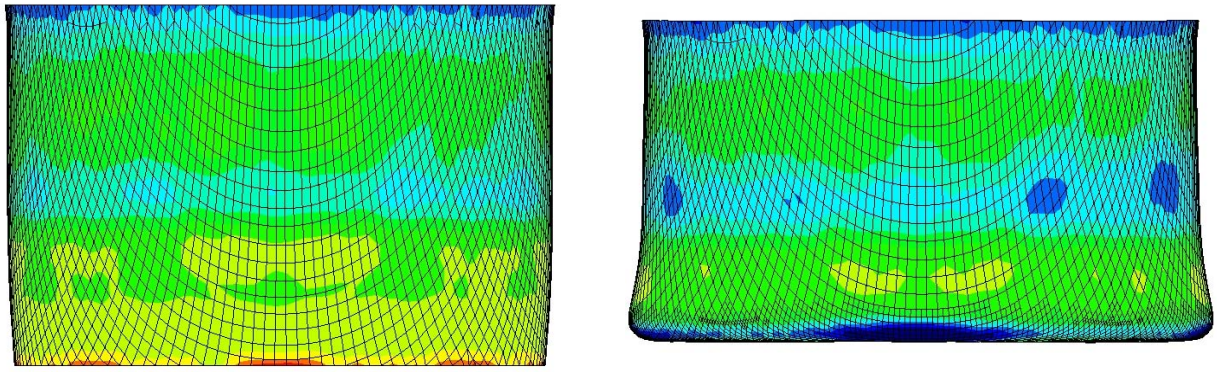

Figure 5: Initial and final states of deep drawn cup wall before and after structural loading

IV. Experimental Results
Verification experiments were conducted by carefully machining the cup wall from the multi-stage drawn can and subjecting the sample to compression. Results are shown in figure 6, which clearly demonstrates the importance of including thickness and hardness changes in structural analysis

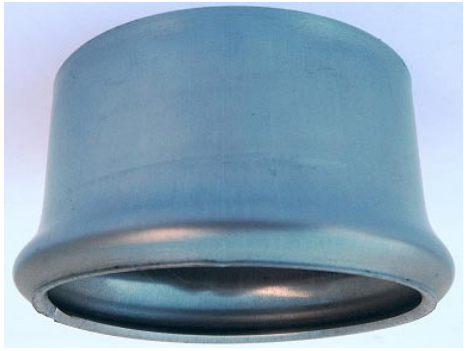

Figure 6: Experimental result showing buckling initiation at the bottom of cup wall.

IMPLICATIONS AND ONGOING WORK

Accuracy in prediction of crash and structural behavior is very important today in light of the increasing dependence on CAE in the design of automotive components and assemblies. Incorporating hardness and thickness changes as we saw demonstrated in this work is critical to achieve reliability in CAE analysis. Bailey Tool is supporting our Tier 1 customers with CAE analysis that is at the forefront of technological advances. The importance of including these forming induced effects becomes even more critical with more widespread applications involving advanced high strength steels (AHSS).

If you have a structure that needs to be optimized in terms of forming and structural performance, please feel free to contact us at Bailey Tool.