GREAT DESIGNS IN STEEL

A NEW TESTING METHOD FOR EVALUATING EDGE CRACKING OF AHSS

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The supplier-to-supplier or batch-to-batch variations of the material properties for the same grade steel exist in advanced high-strength steel (AHSS).

This variation along with edge quality from blank processing can significantly influence the local formability that can lead to edge formability differences.
Background – Prediction and Experimental Evaluation

- Edge cracking is difficult to predict, as well as to accurately evaluate.
- Discrepancy is observed between finite element analysis (FEA) and the actual stamping process.
- The current ISO standard for edge quality evaluation cannot relate edge condition and failure mode in actual production.
• Develop and validate a new test method to evaluate the sheared edge formability considering the production conditions

Expected Benefits:
• Measuring failure strain representing the local formability on the sheared edge
• Prediction of edge cracking in finite element (FE) simulation of stamping
DEVELOPING A NEW TESTING METHOD

1. The Peanut-shaped Hole Punching Test
2. The Peanut-shaped Hole Expansion Test (PS-HET)
3. Finite Element Analysis

Peanut-shaped punches (left) and punching test tooling (right)

Edge cracking predicted at both radius

Uniaxial strain path

Peanut-shaped hole expansion test simulation result and FEM-predicted strain path
PUNCHING TEST VIDEO
STAMPING TEST VIDEO
STAMPING TEST

• A 300-ton AIDA servo press was used for experiments.
• 16 Stroke per minute (SPM) corresponding to the maximum speed of 144mm/sec was used for experiments.
• Measured the load-displacement curve during each test.
• ARGUS tool was used to measure the strains on the tested samples.
COMPARISON OF EXPERIMENTS AND FEM

- Experiment showed the equivalent strain of 0.20 at the cracking.
- The simulation showed the corresponding equivalent strain of 0.195 at 2 mm from the edge of crack location.

GEN3-980 sample punched with 12% clearance
FE SIMULATION RESULTS – STRESS AND THINNING

von-Mises stress contour for 980GEN3 (1.2 mm)

Thinning contour for 980GEN3 (1.2 mm)
LOAD-STROKE CURVE

• Both experiment and FEM showed good correlation for the load-displacement.

• The first load drop corresponds to the edge cracks initiated at the peanut-shape hole.
MATERIAL TESTED

Six different steel suppliers provided the same DP780 materials.

1. Material A: DP780 ($t_0 = 1.5$ mm)
2. Material B: DP780 ($t_0 = 1.4$ mm)
3. Material C: DP780 ($t_0 = 1.5$ mm)
4. Material D: DP780 ($t_0 = 1.5$ mm)
5. Material E: DP780 ($t_0 = 1.5$ mm)
6. Material F: DP780 ($t_0 = 1.5$ mm)

• Three different edge conditions were used:
  • **13% Clearance:** Sheared edge at 13% clearance of the sheet thickness
  • **20% Clearance:** Sheared edge at 20% clearance of the sheet thickness
  • **Machined:** Machined edge
**APPROACH**

1. **Hole Expansion Testing**  ➡ Hole Expansion Ratio (HER)
2. **Half-specimen Dome Testing (HSDT)**  ➡ DIC*-measured strains
3. **Microhardness and microstructure analyses**  ➡ Hardness (work-hardening)
4. **Stamping Test**  ➡ Optically-measured surface strain and failure stroke

*DIC = digital image correlation*
HOLE EXPANSION TEST
ISO-16630 STANDARD

- Hole expansion test is a method to characterize the stretch-flangeability of a material using the hole expansion ratio (HER).
- A conical punch with 60 degrees included angle is used to expand a 10-mm diameter machined hole until a through-thickness crack appears. A sample is fully clamped in the die.
• The machined edge showed a larger HER due to minimal work-hardening.
• The edge formability for the edges sheared at 13% clearance is similar for all the materials, except Material C that shows a slightly higher edge formability compared to the other materials.
• Materials A and B showed no significant difference in edge formability observed between the edges sheared at 13% and 20%.
• Material F gave the maximum difference between the HER for the two sheared edge conditions (13% and 20%).
• Materials A, B and C showed slightly higher edge formability than others.
• HSDT can be used to evaluate sheared edge stretch-ability.
• The major advantage of HSDT is the ability to differentiate between rolling and transverse directions.
• DIC was used to record deformation and provide strain measurements.
• EWI conducted HSDT on the four different edge conditions along the rolling direction:
  o **13% Clearance**: 13% clearance
  o **20% Clearance**: 20% clearance
  o **Machined**: Machined
  o **Rolling**: 13% clearance
The machined edge showed a larger edge formability due to minimal work-hardening.

Material F has the lowest edge formability.

Most materials did not show significant difference in edge formability between the edges sheared at 13% and 20%.

Materials A, B, and C showed a higher sheared edge formability compared to the other materials.

No significant difference was observed between the edge sheared along the rolling and transverse directions.

Note: All the tested samples had the edge parallel to transverse direction.
Hardness measurements were conducted along through-thickness direction.

The first measurement is the highest and critical to edge formability, $HV_{\text{critical}}$.

The work-hardening matrix is defined for both the sheared edge conditions as

$$Work - hardening = \left[ \frac{HV_{\text{critical}} - HV_{\text{base}}}{HV_{\text{base}}} \right]$$
STAMPING TEST

- Measured the load-displacement curve during each test.
- A drop in press load correlates to the onset of edge cracking.
- The die stroke value at the load drop location was compared for the six different DP780 materials.
- A higher stroke value indicates better edge formability.
COMPARISON OF HSDT RESULTS AND STAMPING TEST RESULTS

![Graph showing comparison of HSDT results and stamping test results.](image-url)
CONCLUSIONS

- A new testing method is effective to evaluate edge cracking.
- The stamping test results confirmed the Hole Expansion Test result.
- A higher work-hardening is observed on the sheared edges compared to the machined edges.
- Materials A, B and C showed less sensitive to the variation in sheared edge condition compared to other D, E, and F materials.
- Material C showed the best performance in terms of the minimum damage and work hardening during shearing at 13% and 19% clearances.
FOR MORE INFORMATION

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