Application of Viscous Pressure Bulge (VPB) Test to Predict the Flow Stress of Sheet Materials under Biaxial Deformation Conditions

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Outline

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Introduction

- AHSS and Al alloys are used increasingly in forming automotive structural parts because of safety and lightweight vehicle requirements.

- Some of these alloys have higher strength and low formability compare to conventional draw quality steels.

- One of the problems is the property variations in incoming materials which may not be determined by the tensile test.

- Tensile test is uniaxial and flow stress data is obtained to small strains, while the bulge test is biaxial and data is obtained to higher strains.
Principles of Viscous Pressure Bulge (VPB) Test

Continued downward motion to bulge the sheet

(b) After Forming

Upper die

Test Sample

Potentiometer

Upper die

Lower die

Viscous Medium

Pressure Transducer

Stationary Punch

(a) Before Forming

Downward motion to clamp the sheet

Continued downward motion to bulge the sheet

Viscous Pressure Bulge (VPB) test tooling
Material properties of HSS/AHSS/UHSS

Schematic of viscous pressure bulge test setup at CPF (OSU) and EWI

- Die diameter = 4 inches (~ 100 mm)
- Die corner radius = 0.25 inch (~ 6 mm)

Methodology to estimate material properties from VPB test, developed at CPF (OSU)

**Measurement**
- Pressure (P)
- Dome height (h)

**Material properties**
- Flow stress
- Anisotropy

FEM based inverse technique
Determination of Flow Stress

Tensile Test

Ref: Nasser et al. 2010
Results - Tensile Test

Uniform and Total Elongation of various AHSS grades (Gauge Length: 2 in)

- DP 600: Uniform Elongation 16%, Total Elongation 26%
- DP 780: Uniform Elongation 9%, Total Elongation 17%
- DP 780-CR: Uniform Elongation 10.5%, Total Elongation 18%
- TRIP 780: Uniform Elongation 14.5%, Total Elongation 19%
- DP 780-HY: Uniform Elongation 8%, Total Elongation 17.5%
Results-Tensile Test

UTS and 0.2% Offset Yield Strength of various AHSS grades

Stamping Group
Material properties of HSS/AHSS/UHSS

Bulge test samples

Before bursting

After bursting
Material Properties

Determination of Flow Stress

Bulge Test

Challenges:
1) Tensile test gives a very limited information,
2) Bulge test gives more reliable strain-stress data.

Ref: Nasser et al 2010
### Materials Tested with VPB Test at CPF and EWI

#### Steels and Stainless Steels

<table>
<thead>
<tr>
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<th>Description</th>
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<tbody>
<tr>
<td>St 14</td>
<td>DP 780-CR</td>
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<td>AISI 1018</td>
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<td>DDS</td>
<td>GA DP 780 Y-type V</td>
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<td>BH 210</td>
<td>DQS-270F GA-Phosphate coated</td>
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<tr>
<td>HSS</td>
<td>DQS-270D GA-Phosphate coated</td>
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<td>DP 780</td>
<td>SS 409</td>
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<td>TRIP 780</td>
<td>AMS 5504</td>
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#### Aluminum and Magnesium Alloys

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<td>X626-T4P</td>
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<td>AZ31B</td>
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#### Materials Tested at EWI-FC

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<td>270E</td>
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Evaluation of Formability

Graph shows dome height comparison for SS409 sheet material from eight different batches/coils [10 samples per batch]

Highest formability $\rightarrow$ G, Most consistent $\rightarrow$ F
Lowest formability and inconsistent $\rightarrow$ H
Conclusions

- **Strain values** obtained in the VPB test is **higher** than values obtained in the tensile test. Thus, **VPB test is more suitable** for providing **flow stress input to Finite Element Analysis (FEA)**.

- Some materials **may behave differently** under different states of state. VPB is closer to actual stamping operations than the uniaxial tensile test.

- For some materials, **correcting** the flow stress obtained from the VPB test for **anisotropy** may be important.

- **Dome Height at bursting** in the VPB test is a **quick and reliable** test to check the **quality of incoming raw materials** (different batches, suppliers, …) under biaxial state of stress.

- Large amount of **data may be lost (AHSS)** when ending the VPB before **bursting**. Thus, it is desirable to end the test as close, to the burst pressure, as possible.