Die Design & Simulation Software Experience

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Grand Rapids, MI
Industry Demand for Fuel Efficient Vehicles

- The Obama administration issued the final version of new rules that require automakers to nearly double the average fuel economy of new cars and light trucks by 2025.

- Currently, the CAFE (Corporate Average Fuel Economy) is around 29 MPG.

- New requirements is 36.6 MPG by 2017 / 54.5 MPG by 2025.
Fuel Efficient Vehicles – Possible Solutions

- Develop Small / Mini Cars
  - Not a good solution!
- Develop New / Alternative Energy Cars
  - Cost Increase, possible Weight Increase
- Reduce Vehicle Weight, Raise CAFÉ
  - Vehicle design optimization
  - Vehicle manufacturing optimization
  - Use Super High Strength Steel and/or Light Weight Materials
- Requirements to Develop Simulation Technology to support the overall weight reduction requirements
  - Must resolve Springback issues, in order to use more high strength steel or use higher strength steel
  - Use Hot Forming approach to control Springback concerns in order to use Super High Strength Steel, support 3rd Generation High Strength Steel
  - Implement Die Design Optimization simulation technology to support various issues of die design

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Sheet Metal Forming Simulation Technology
History and Challenges

• 1980s – Global OEMs and Steel / Alumini producers started the development of sheet metal forming simulation technology
  – Using Static Non-Linear FEA approach, Implicit Solution
  – After 10 years R & D, not practical to implement support production

• 1993 – NUMISHEET1993, a international conference with focus on benchmarking sheet metal forming simulation technology
  – Adopted Dynamic Non-Linear FEA approach, Explicit Solution
  – DYNAFORM, PAM/STAMP & AUTOFORM and various commercial software packages were developed on this platform
Sheet Metal Forming Simulation Technology
History and Challenges

• Beginning of 2000s – Global OEM established the Virtual Trial Out process to replace traditional hardware trial out
• Late 2000s – Global tooling Industry adopted Virtual Trial Out process

• New and Future Challenges
  – Springback and Springback Compensation for Super High Strength Steel
  – Support Hot Forming and Alternative Forming Technology
  – Die Face Optimization
  – Accurate Solution using New Computing Platform, Material Utilization, etc.
Virtual Tryout Simulation Methodology

Die Face Engineering and Formability
Die Face Engineering

Product Design

Reverse Trimming

Tip to Stamping Position

Binder Generation

Addendum Calculation

Addendum Generation

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Formability Simulations

Binder Wrap

Draw

Trimming

Flanging

Springback

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Simulation Reliability could be examined per Comparison with hardware Blank Material Draw-in
Tip the part along X axis 80 degrees relative to the automatic tipping center.
DFE - Inner Fill

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DFE - Addendum Profiles Adjustment
DFE - Binder / Addendum Trimming

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Die Face Established – CAD Surfaces

NURBS CAD Surfaces were generated same quality of the Product Design
Generate Mesh for Formability Simulation
Drawbead layout & Simulation Setup

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Simulation Result - FLD

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Simulation Result - Thinning
Simulation Result - Skid Mark
Reliable Springback Simulation
Requirement – Geometry Beads

Geometry Bead Generation and Line
Bead Conversion to Geometry Bead
Geometry Draw Beads – Parametrically Defined

Round Bead

Square Bead

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Line Bead conversion with Geometry Bead

Section cut

Male Bead & Female Bead
Additional discussion on Slide 72

Die Design & Simulation Software Experience
Round Bead

Male side

Female side
Springback Prevention in Product Design Stage
Springback Prevention in Design - Case Study

- Flanging – without darts
- Flanging – with darts

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Section Cut at the Darts

Section cut starts 9mm from edge

Then 54mm interval through the panel

Spring Back – Flange without Darts, Right Side

Blue: Product
Green: Panel with spring back
Springback at Sections

<table>
<thead>
<tr>
<th>Positive deviation (mm)</th>
<th>Section line number</th>
<th>Distance from edge</th>
<th>Positive deviation (mm)</th>
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<tbody>
<tr>
<td>0.172</td>
<td>#1</td>
<td>9mm</td>
<td>0.261</td>
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<tr>
<td>0.391</td>
<td>#2</td>
<td>63mm</td>
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<td>0.159</td>
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<td>117mm</td>
<td>0.196</td>
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<td>#4</td>
<td>171mm</td>
<td>0.221</td>
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<tr>
<td>0.194</td>
<td>#5</td>
<td>225mm</td>
<td>0.141</td>
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<tr>
<td>0.111</td>
<td>#6</td>
<td>279mm</td>
<td>0.090</td>
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<tr>
<td>0.517</td>
<td>#7</td>
<td>333mm</td>
<td>0.417</td>
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<td>0.286</td>
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<td>387mm</td>
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<td>0.792</td>
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<td>549mm</td>
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<tr>
<td>0.120</td>
<td>#12</td>
<td>603mm</td>
<td>0.141</td>
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<tr>
<td>0.159</td>
<td>#13</td>
<td>657mm</td>
<td>0.215</td>
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<tr>
<td>0.773</td>
<td>#14</td>
<td>711mm</td>
<td>0.864</td>
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<tr>
<td>0.376</td>
<td>#15</td>
<td>765mm</td>
<td>0.422</td>
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<tr>
<td>0.908</td>
<td>#16</td>
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<td>0.850</td>
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<tr>
<td>0.389</td>
<td>#18</td>
<td>927mm</td>
<td>0.486</td>
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<tr>
<td>0.150</td>
<td>#19</td>
<td>981mm</td>
<td>0.130</td>
</tr>
<tr>
<td></td>
<td>#20</td>
<td>1035mm</td>
<td></td>
</tr>
</tbody>
</table>
Deviation Comparison – Sums of Both Sides

![Graph showing deviation comparison with and without dart design]

- **Without Dart Design - Green**
- **With Dart Design - Red**
Reduce & Prevent Springback from Product Design Stage

DFE offers tools to generate & manipulate
Diamond Shape Stiffener & Rib Shape Stiffener
Generate “Diamond” Shape Stiffener - Examples

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Generate "Diamond" Shape Stiffener

Generate Diamond Shape Stiffener - Processing Path

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Diamond Parameter

After base point is defined, the program will give a set of parameters.

H1
Height 1 of Diamond

H2
Height 2 of Diamond

W
Diamond Width along center line

R1
Radius1

R2
Radius2
Class A Surface Defect Detection Processing Using Light Strip and Stoning

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Move light strips to detect surface defects over the panel.
To simulate the stoning test for body outer panels in the shop

This function will identify the surface defect (dips, dimples, etc.) on the part surface

Door Panel Simulation Result after Springback
Stoning Test Results from the Shop

Surfaces Defect Identified

Left hand side

Right hand side
Stoning Test Simulation – Example

Result from Stoning function
Very good correlation with testing result
Progressive Tooling Die Face Layout and Multiple Stage Simulations
Methodology –
Product Design & Processing  Data Received

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Methodology –
Unfold the Part Geometry for Tooling Design

Reverse Folding
Reverse Flanging
Reverse Bending

Product Design

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Methodology – Create Tooling

Creating Tools

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Methodology – Layout the Tooling Stations

Tooling station layout using Tool Position function

Material translation consistent with station layout

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DYNAFORM’s Auto Setup – Single Setup & Execution
A 10 - Station Progressive Tooling Simulation
10 Stage Simulation – Movement with Tools
10-Stage Simulation – Formability (FLD)
Optimization – Sheet Metal Forming Applications

• 1D Applications
  – Drawbead Rates, Binder Force, Lubrication, Material and Gage, etc..

• 2D Applications
  – Drawbead Segment, Binder Profiles, Addendum Profiles, PO Line and etc.

• 3D Applications
  – Binder Surface, Addendum Surface
Drawbeads are designed to restrict the blank from wrinkling & splitting in a forming process.

Adjusting Drawbeads layout of a large / complicated drawbead setup can be very challenging, very time consuming to achieve a formable panel/part, take weeks.

Efficiently utilize the optimization technology with modern computing power for Drawbead Forces optimization is practical to achieve a optimum configuration in a reasonable time frame, take days.
Typical Draw Beads – Parametrically Defined

**Round Bead**

- Parameters:
  - Round: 5.50
  - R1: 3.00
  - R2: 3.00
  - R3: 3.50
  - R4: 3.50
  - Wm: 7.00
  - Cl: 0.20
  - Th: 1.00
  - W: 9.20
  - Transition type: Forward
  - Transition length: 25.00
  - Select Male side: Unspecified
  - Female side: Unspecified

**Square Bead**

- Parameters:
  - Round: 5.50
  - R1: 3.00
  - R2: 3.00
  - R3: 3.50
  - R4: 3.50
  - Wm: 7.00
  - Cl: 0.20
  - Th: 1.00
  - W: 9.20
  - Transition type: Forward
  - Transition length: 25.00
  - Select Male side: Unspecified
  - Female side: Unspecified

Additional discussion on Slide 70
Optimization Based on (6) FLD Zones

Define Constrain/Objective function as the ratio of elements in a particular Zone # / total elements
GUI of Optimization Overview

Definition Forming Stages Design Variables

Define Objectives and Constrains

Optimization Solver Status
Case Study: Fender (NUMISHEET02), Stretch Forming

INCSolver Draw Setup Parameters:

- **Material:** HSS_FENE
- **Thickness:** 0.7mm
- **Binder Force:** 1200000N
- **Lower Binder Travel:** 130mm
- **Friction:** 0.125 0.125 0.125 0.125
- **Adapt mesh level:** 2
- **Initial element size:** 16mm
  - 4mm

**Die Design & Simulation Software Experience**
15 Line Beads were setup for optimization: The type of variable is continuous, values are changes from 5% to 80%. The base line of each variable is 60%.

Optimization Objective and Constraint all are “Crack/Split” and “Safe”. Number of Iteration are 185.
Case Study: Fender, Optimization Results

SHERPA returns the best/optimized parameters – 15 Line Bead Rates:

<table>
<thead>
<tr>
<th>Bead ID</th>
<th>Base Line Rate</th>
<th>Optimized</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>60</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>60</td>
<td>70</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
<td>5</td>
</tr>
<tr>
<td>4</td>
<td>60</td>
<td>15</td>
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<td>25</td>
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<tr>
<td>6</td>
<td>60</td>
<td>5</td>
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<tr>
<td>7</td>
<td>60</td>
<td>75</td>
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<tr>
<td>8</td>
<td>60</td>
<td>5</td>
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<td>9</td>
<td>60</td>
<td>5</td>
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<tr>
<td>10</td>
<td>60</td>
<td>5</td>
</tr>
<tr>
<td>11</td>
<td>60</td>
<td>15</td>
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<td>12</td>
<td>60</td>
<td>5</td>
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<td>60</td>
<td>5</td>
</tr>
<tr>
<td>15</td>
<td>60</td>
<td>70</td>
</tr>
</tbody>
</table>
Before Design Optimization

After the Design Optimization, based on FLD presentation, the Crack / Split area is significantly reduced.

Die Design & Simulation Software Experience
<table>
<thead>
<tr>
<th>CASE</th>
<th>Objective and constraint</th>
<th>Iteration</th>
<th>CPU</th>
<th>Calculate Time (Hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fender</td>
<td>Crack, Safe</td>
<td>185</td>
<td>Inter(R) Core(TM) i7-2600 CPU @3.40GHz 3.70 GHz 1 CPU/4 cores/8 threads</td>
<td>45</td>
</tr>
</tbody>
</table>
Hot Forming Simulation
Case Study - A-pillar

A-Pillar with a Local Reinforcement (Patch)
## Part information

<table>
<thead>
<tr>
<th>Part Name</th>
<th>Material</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-pillar</td>
<td>22MnB5_Austenitized_Thermo</td>
<td>1.6 mm</td>
</tr>
<tr>
<td>Patch</td>
<td>22MnB5_Austenitized_Thermo</td>
<td>1.95 mm</td>
</tr>
</tbody>
</table>
Die Face Design
Tooling Setup (3 piece die)

Binder travel 85 mm
Blank Size

Patch Blank

A-Pillar
Outer Blank
Thickness

1.25 mm

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Thickness on Patch Part

2.28 mm
70 mm from home
50 mm from home
45 mm from home
40 mm from home
35 mm from home
30 mm from home
25 mm from home
20 mm from home

Die Design & Simulation Software Experience
20 mm from home
5 mm from home
1 mm from home

Die Design & Simulation Software Experience
Temperature in °C
Temperature in °C
Conclusion

- Thinning of 1.25 mm (21.8%) in one spot (page 8)
- Wrinkles areas observed, one of wrinkle area is located on the trimline
Conclusions and Further Developments

• Springback, Springback Compensation plus Springback Prevention Design

• Optimizations, 1D, 2D and 3D
  – “Black Box” setup enable average tooling users to adopt optimization approach for forming applications
  – SMP & Multiple CPUs / Cores computing is needed for demanding optimization calculations
  – Need to improve Overall Efficiency

• Hot Forming and Other Alternative Forming applications are ready for implementation
  – Hot Stamping, Quenching and Die Structure Cooling
Thanks for your Time and Attention

Q & A