New Features

in eta/DYNAFORM 5.7

J. He (Engineering Technology Associates, Inc.)
DYNAFORM 5.7
Die System Simulation Solution Package

Presentation
Arthur Tang/Jeannie He
September, 2008

Engineering Technology Associates, Inc. (ETA)

- Established 1983
- Engineering Offices
  - Headquarters: Troy, Michigan USA
  - 300 Engineers
- Global offices and network of distributors in 4 continents
- Primary Business – CAE
  - Software Development and Distribution
    - eta/DYNAFORM
    - eta/VPG
  - Engineering Services
    - Tooling Development
    - Full Vehicle Development
    - Virtual Validation

www.eta.com
www.dynaform.com
www.etavpg.com
Brief History of DYNAFORM

• 1983 Coded METALFORM for Ford Science Laboratory
• 1986 Coded C-Form for Chrysler
• 1993 Started the development of DYNAFORM
• 1995 Signed LS-DYNA Bundling Agreement with LSTC
• 1996 Released first version to OEMs and Material Suppliers
• 1999 Released Windows/PC to Tool & Die Industry
• 2000 Started developing Die Face Engineering (DFE) module
• 2001 Unified Windows/Unix/Linux platforms
• 2002 Release first version of DFE module
• 2003 Release BSE (Blank Size Engineering) module and MSTEP
• 2004 Delivered Die Structure Analysis (DSA)
• 2005 Delivered Springback Compensation (SPC) Module
• 2006 Released 5th Generation of DYNAFORM with Auto Setup
• 2008 Releasing DYNAFORM 5.6

DYNAFORM’s Major OEM Users

• Ford Global
  – Ford Brazil, Jaguar and Land Rover
• DCX
  – Used DYNAFORM/LS-DYNA solution for 15+ years
  – Has been a Technology Development Partner since ’90
• GM
  – GMNA
    • BME Die Engineering Analysis (mostly meshing and Springback, joint
development for line die forming simulations, die structure analysis)
    • Body CAE evaluating
  – GME Opel
  – GM Brazil
  – GMAP
    • GMDAT, GM PATEC, GM Wuling (full license)
• Japan - Nissan, Suzuki, ….
• Korea – Daewoo, KIA, Hyundai, SsangYang, POSCO and ….
– BSE (Blank Size Engineering with a One-Step Solution)

– DFE (Die Face Engineering)

– Formability (LS-DYNA Based Forming Simulation Solution)

– DSA (LS-DYNA based Die System Analysis)

– BSE (Blank Size Engineering w/ MSTEP One-Step Solution)
  
  • Full or partially unfold part geometry
  
  • Blanking, nesting, material cost estimation
  
  • Quick trimline development
  
  • One-Step formability analysis
DYNAFORM Unique Capabilities
A LS-DYNA based Die System Simulations

– DFE (Die Face Engineering)

• Product geometry modifications
• Binder generation
• Addendum generation
• NURBS CAD surface based technology
• Associability – binder/addendum profiles
• Re-use existing die face design for new product

– Formability Analysis

• Support extensive material models
• Support quick single stage simulation and multi-stage operation
• Superplastic forming, hot forming, hydroforming, roller hamming etc.
• Parametric geometric Drawbead
• Springback and Springback compensation simulation
DYNAFORM Unique Capabilities
A LS-DYNA based Die System Simulations

– DSA (LS-DYNA based Die System Analysis)
  • Die Structure Strength and Durability
  • Sheet Metal Handling and Transfer
  • Scrap Shedding/Removal and Metal Cutting
  • Draw Simulation with Flexible Dies

BSE
Blanking & Nesting Solutions
for Material Cost Estimation
One Step Application

Blank Size Engineering
- One Step Unfolding
  - Useful for:
    - Specifying Cost & Quoting
    - Blank Development, trimline development, strip lay
    - Result can be export as IGES, VDA etc. CAD files

Partial unfold

Trimline development

Flange unfold to the addendum
Trимлайн разработка

Функция разработки — с или без BC

Полное развертывание модели  
Локальное развертывание
Die Face Engineering (DFE) and Formability

Virtual Tryout - Simulation Methodology
Die Face Engineering and Formability Example – Body Side Panel

DFE - Tipping (Auto and Manual)

Tip the part along X axis 80 degrees relative to the tipping center
DFE - Inner Fill

Binder creation
DFE - Inner Addendum Creation

Inner binder and addendum

DFE - Outer Addendum Creation
Define control profiles

DFE - Addendum Profiles Adjustment

DFE - Binder / Addendum Trimming
Die Face Established – CAD Surfaces

Binder and addendum CAD surface creation

Generate Mesh for Formability Simulation
Drawbead layout & Simulation Setup

Simulation Result - FLD
Simulation Result - Thinning

Simulation Result - Draw In
Simulation Result - Skid Mark

Enhanced “DFE” Features & Functions in DF5.7
Enhanced Function to Fill Up an Open End

Curve Editor allows user to parametrically define an open end shape to be filled.

Alternative Approach to Fill Up an Open End

If desired, multiple arcs could be defined to design the open end shape.
**Fill Up an Open End with Flexible Tools**

Edit Profile to obtain shape, then click Apply to create Side Step.

**Improved Inner Fill Functions**

Fill up trimmed area with the feature shapes being maintained.
Improved Inner Fill Functions

Before Inner Fill  
After Inner Fill

Improved Outer Smooth Functions

Smooth Cutout Region:

Problematic Smooth - Before

Improved Smooth - Improved
Improved Outer Smooth Functions

Challenging area for Outer Smooth Function

• Fill boundary and edit filled surface.
Create Binder – Control Lines

Binder Creation: Control Lines to modify the binder.

Control Lines

Binder Surface Generated

CAD Surfaces Created
When user create Corner addendum, user can toggle on Advanced option and select Create Spline button to create the boundary line for controlling the shape of corner addendum.
Binder Definition for Multiple Stage Tooling Applications

Before Trim

After Trim

Adjustable/Variable Draw Depth Definition

Add radius

New binder

Old Binder
Enhanced Addendum Modifications

Before Modification  After Modification

Benchmark - Fender

- Tipping
- Fill Trimmed Space –Lamp
- Create Binder
- Create Addendum
- Lay-out Drawbead
Benchmark - Fender

- Quick Setup/Guide Pin
- Formability
- Draw-In
- Light Stripe
- Skid Mark

Fender Die Face Design

- NURBS Surface in <.prt> file Format
• Define key profiles as control profiles, addendum can be morphed based on those selected key profiles.
• User could set more controls lines, and modify control profiles to obtain satisfied addendum.

Multi Control Profiles

• Result of addendum by modifying control profiles
Multi Control Profiles

Before Modification  ---  After Modification

Associativity - Binder & Addendum Updates

Binder Design 1- Flat  ---  Binder Design 2 - Curved

Associative Mode -

It is a NURBS Surface Based operation and the newly generated Binder and Addendum Surfaces are ready to be exported to CAD system.

The quality of the new surfaces are as good as the original surfaces in terms of gaps and continuity.
Product replacement and addendum revision for quick and feasible die development using existing die.

Step 1 - Identify Part, Binder/Addendum, etc. on existing reference die face
Step 2 – Establish 3 Sets of Reference

User Defines 3 Reference Points

Step 3 – New Product vs Existing Addendum

Gaps between New Product and Existing Addendum
Step 4. Adopt Addendum and Smooth the Connections

Gap between New Product and Existing Addendum is smoothed & re-connected

Enhanced “Auto Setup” Features & Functions in DF5.7
Auto Setup

Acceleration Time and Thermal Analysis options are available in the **General** page.

Auto Setup - Blank Page

Transformation and constraints (SPC) options are placed in the **Blank** page.
Newly added material model:

103 - *MAT_ANISOTROPIC_VISCOPLASTIC
113 - *MAT_TRIP
122 - *MAT_3-HILL_3R
123 - *MAT_KINEMATIC_HARDENING_TRANSVERSE_ANISOTROPIC
133 - *MAT_BARLAT_YLD2000
106_Elastic_Viscoplastic_Thermal

The Material Axes option is added
When **Import** the FLD curve, the strain type is decided by the flag in the flc file. When **Export** the FLD curve, it saves the current strain type.

```
1 31 'Unnamed' 'FLC_CURVE' 'TRUE'
-3.56673E-001 6.22439E-001
-3.28504E-001 6.50643E-001
-3.02105E-001 6.19831E-001
```

The label of the Reference button is changed to Share, avoiding copying tools between stages.
Guide pin is supported
Default contact is
*CONTACT_FORMING_NODES_TO_SURFACE

Rigid Body Stopper:

U – upper bound
L – lower bound
B – both upper and lower bound

The program will output the displacement curve for the rigid body
The Force vs. Displacement curve is added to simulate the flexible binder wrap.

**Auto Setup - Binder Force Control**

*Binder:* Free Spring element
*Die:* Velocity
*Punch:* Stationary

(4) D3plot Output Control Functions:

- Total number
- List from start
- List from end
- Time interval

It's very convenient to edit the output frames in the edit box, key in the value and hit the Enter key.
Auto Setup - Initial Condition for Gravity

Initial Condition option is placed in the **Process** page

Auto Setup - Load Control Parameters

Allow the user to import the control parameters from the *.dyn file.
Auto Setup

Tools – Display...

When the option is toggled on, only the current stage tools will be displaced

Springback Prevention in Design Stage
**Sensitivity of Springback**

**Material Variations**


![Graph showing sensitivity of springback](image)

**Courtesy of GM**

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**Springback Sensitivity**

**Material Properties**

**CR340 Material**
- **Worst case**
  \[ N=0.13, \text{UTS}=521\text{MPa}, \text{Y}=452\text{MPa} \]
- **Typical case**
  \[ N=0.17, \text{UTS}=495\text{MPa}, \text{Y}=380\text{MPa} \]
- **Best case**
  \[ N=0.19, \text{UTS}=495\text{MPa}, \text{Y}=360\text{MPa} \]

**Courtesy of GM**
Springback Sensitivity

Springback in Die (Z)-Direction

- **Worst Case**
  - Max: 8.8 mm (36% more)
  - Min: -0.06 mm

- **Typical Case**
  - Max Spk: 6.44 mm
  - Min: -0.06 mm

- **Best Case**
  - Max: 6.01 mm (7% less)
  - Min: -0.6 mm

Courtesy of GM

Springback Compensation

Springback Compensation’s Solution:

Reduce design sensitivity!!!
Springback Preventive

Geometry modification options:

1. Offset
2. Stiffing beads
3. Crushed Radii (Darts)

Flanging – without darts

Flanging – with darts

Springback Prevention in Design- Case Study
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

Positive deviation (mm)

<table>
<thead>
<tr>
<th>Section line number</th>
<th>Distance from edge</th>
<th>Positive deviation (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>9mm</td>
<td>0.172</td>
</tr>
<tr>
<td>#2</td>
<td>63mm</td>
<td>0.199</td>
</tr>
<tr>
<td>#3</td>
<td>117mm</td>
<td>0.233</td>
</tr>
<tr>
<td>#4</td>
<td>171mm</td>
<td>0.194</td>
</tr>
<tr>
<td>#5</td>
<td>225mm</td>
<td>0.111</td>
</tr>
<tr>
<td>#6</td>
<td>279mm</td>
<td>0.017</td>
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<tr>
<td>#7</td>
<td>333mm</td>
<td>0.286</td>
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<tr>
<td>#8</td>
<td>387mm</td>
<td>0.792</td>
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<tr>
<td>#9</td>
<td>441mm</td>
<td>0.123</td>
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<tr>
<td>#10</td>
<td>495mm</td>
<td>0.120</td>
</tr>
<tr>
<td>#11</td>
<td>549mm</td>
<td>0.163</td>
</tr>
<tr>
<td>#12</td>
<td>603mm</td>
<td>0.159</td>
</tr>
<tr>
<td>#13</td>
<td>657mm</td>
<td>0.173</td>
</tr>
<tr>
<td>#14</td>
<td>711mm</td>
<td>0.376</td>
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<tr>
<td>#15</td>
<td>765mm</td>
<td>0.908</td>
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<td>#16</td>
<td>819mm</td>
<td>0.809</td>
</tr>
<tr>
<td>#17</td>
<td>873mm</td>
<td>0.389</td>
</tr>
<tr>
<td>#18</td>
<td>927mm</td>
<td>0.150</td>
</tr>
<tr>
<td>#19</td>
<td>981mm</td>
<td></td>
</tr>
<tr>
<td>#20</td>
<td>1035mm</td>
<td></td>
</tr>
</tbody>
</table>

Springback at Sections
Deviation Comparison – Sums of Both Sides

“Best Fitting” Functions to support Springback & Springback Compensation Simulations
Best Fitting Function – Springback

Test data and FEA mesh before Best Fitting

Best Fitting Function -Springback

Define the Source Part and the Targeted Part
Best Fitting Function - Springback

After Best Fitting Overlay

Contour Plot to show the deviation of Springback
Interface for Hot Forming Simulations
### Hot Forming

#### Thermal contact

<table>
<thead>
<tr>
<th>Material</th>
<th>Boundary</th>
<th>Contact</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal conductivity</td>
<td>0.001</td>
<td>Min gap</td>
<td>0.001</td>
</tr>
<tr>
<td>Heat transfer coeff</td>
<td>2.0</td>
<td>Max gap</td>
<td>0.5</td>
</tr>
</tbody>
</table>

- Thermal boundary conditions are off when parts are in contact

#### Thermal friction

- Static friction coeff: 0
- Dynamic friction coeff: 0

#### Thermal analysis

<table>
<thead>
<tr>
<th>Material</th>
<th>Boundary</th>
<th>Contact</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal control parameters</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal analysis type (ATYPE):</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thermal problem type (PTYPE):</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Time step control (TS):</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Time integration parameter (TIP):</td>
<td>0.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. matrix reformation (RFMAX):</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Advanced
NUMISHEET2008 Benchmark BM03

Results after Forming

Temperature
min = 488 C
max = 825 C

Thickness
min = 1.33mm
max = 2.26mm

Forming Limited Diagram (FLD)
Hot Forming – Material

Use material model #106 (viscoplastic-thermal) which allows input of temperature dependent properties. Stress-strain curves can be entered in a table as \((\sigma, \varepsilon, T)\) data points at a strain rate of \(d\varepsilon/dt=0.1\ \text{s}^{-1}\).

*Mat_elastic_visplastic

Isotropic
V-m yield criteria
Tabulated flow rule
Hot Forming - Contact

The contact algorithm allows entry of the thermal contact resistance between the blank and tools as a function of interface pressure.

<table>
<thead>
<tr>
<th>P [MPa]</th>
<th>h [W/m²K]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1300</td>
</tr>
<tr>
<td>20</td>
<td>4000</td>
</tr>
<tr>
<td>35</td>
<td>4500</td>
</tr>
</tbody>
</table>

FE model

Tools: 68,268 rigid shells
Blank: 3,096 deformable shells increasing to 11,682 after adaptivity

Run time:
INTEL Core Quad CPU @ 2.40GHz
1 cpu → 5.10 hr
2 cpu → 3.96 hr
4 cpu → 2.65 hr
Roller Hamming

Using $\text{BOUNDARY\_PRESCRIBED\_ORIENTATION\_RIGID\_VECTOR}$

Progressive Tooling Die Face Layout and Multiple Stage Simulations
Methodology –
Unfold the Part Geometry for Tooling Design

- Reverse Folding
- Reverse Flanging
- Reverse Bending

Methodology – Create Tooling

- Creating Tools
Methodology – Layout the Tooling Stations

Tooling station layout using Tool Position function

Material translation consistent with station layout

Multistage Setup – DYNAFORM AutoSetup

DYNAFORM’s Multistage capability offers convenience of one-time setup from gravity, forming, direct or cam trimming by tool or laser, re-strike or flanging from any direction, etc., or even springback, in any realistic combination and order.
DYNAFORM’s Auto Setup – Single Setup & Execution

A 10 - Station Progressive Tooling Simulation

10 Stage Simulation – Movement with Tools
10 Stage Simulation – Movement w/out Tools

10-Stage Simulation – Formability (FLD)
Progressive Die

DYNAFORM – Production Ready

Progressive Die

DYNAFORM – Production Ready
Draw Bead Geometry Generator

Geometry Draw Beads – Parametrically Defined

Round Bead

Square Bead
**Class A Surface**

Defect Detection Processing

Using

Light Strip

and

Stoning

---

**Door Outer – Light Strip Visualization**

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

Stoning Test Simulation – Example

Door Panel Simulation Result after Springback

Stoning Test Results from the Shop

Surfaces Defect Identified
Stoning Test Simulation – Example

Result from Stoning function

Very good correlation with testing result

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Die System Analysis (DSA)

Simulation Solution for Die System
**Typical Operational Loading for Strength Concerns**

- Operation Loads on Lift Lug Structure

  ![Deflection Contour Plot](image1)

  ![Apply Lifting Loading](image2)

**Typical Stamping Loads for Fatigue Concerns**

ETA-Post to read in “Stamping Force” from the Draw Simulation in D3PLOTINT and export Pressure Mapping on the Die Face

- Extract Pressure Force from Stamping
  - Pressure Force is Mapped on Lower Die Face
**Lower Die Face & Die Shoe Analysis**

- Apply Pressure Load
- Stress & Strain Results
- Fatigue Life Prediction

DSI can Perform Formability and Full Die Structure Analysis using LS-DYNA in DYNAFORM Environment

**DSA - Sheet Metal Transfer/Handling**

The initial Blanking station is shown at left, with the Blank approaching the Draw Station

The stamped liftgate panel is picked up by a robot, then moved it to a Storage Rack for shipping
SMTH GUI and Three main Components of SMTH data:
1. Draw Panel or Blank
2. Suction Cups
3. Motion Curve

Step 1. Define Draw Panel or Blank
Step 2. Define Tools (Suction Cups or Mechanical Fingers)
Step 3. Define Process, read in Motion Curves
Step 4. Setup for Simulation

Note:
The motion Curve is an xls or csv file, to be imported into the simulation.
Hood Inner & Outer - Motion Curve Conversion

- Schuler Designed Motion Curve
  - X-Bar Center Motion Curve Profile
  - Motion Curve for Simulation
  - Y-Direction Velocity
  - Z-Direction Velocity

Hood Inner & Outer – Flexible Body Animation

- Von Mises Stress Animations of 6-Suction Cup Design
SMTH Can Also Calculate Panel Deflection

- Response Comparison – Z Deflection at the Corner of Outer Panel Blank
  Node ID= 72895
  - 6-Suction Cup

Panel Deflection at Specific Time Intervals

- Response Comparison – Max. Z Deflection
  
  **Time** = 0.7614 Angle = 271°
  Max. Z Deflection = 186.831 (mm)

  **Time** = 2.1661 Angle = 18°
  Max. Z Deflection = 178.96 (mm)
Objectives -
Reduce production down time caused by die design process related scrap shedding

What we do -
Using analytical module built in DYNAFORM and LS-DYNA solver

Analyze all trim process before completing die design to avoid extended down time due to scrap shedding & removal related issues
SSR - Trim Line Development

Upper Trim Die Design

Upper Trim Steel/Trim Line

Lower Support Steel

Lower Trim Die Design

Processing Sheet Illustration

Trimming Model Illustration

Blue - Direct Trim
Green - CAM Trim
Purple - Piercing
Chutes & Removal Holes Mesh is Generated

Die System Analysis
Scrap Removal / Shedding Model
Two-Dimensional Trimming Process Simulations

Typical Trim Die Cross-Section

- Upper Shoe
- Trim Steel
- Pad
- Blank

Illustration of Trim Operation

- Trim Steel Velocity = 300 mm/s
- Steel-Post Clearance = 0.056 mm
- Steel Stroke = 6 mm
- Steel and Post Radii = 0.3 mm

Mesh Size:
- Trim Steel: 0.5 mm
- Pad: 1.0 mm
- Blank Shear Zone: 0.1 mm
- Trim Post: 0.5 mm
Two-Dimensional Trimming Process Simulations

Trimming Force and Responses
DYNAFORM Scrap Shedding Module

Example – Trim Die Operation

Trim Die Operation Processing information required for simulation
Import Geometry

Low Trim Die

Draw Panel & Trim Line

Multiple-Stage trimming

Simulation Setup for Trim Die Operations

1. Mesh & Create Scrap
2. Mesh Check, Trim Line Editing
3. Trimming, Lancing
4. Simulation Setup
Dynaform offers the flexibility to perform the scrap creation operation.

Assign Properties and Initial Velocity

Material and thickness is applied to scrap.
Initial Velocity Generated on Scrap

Initial velocity shown on scrap parts

Conduct Simulation/Calculation
Simulation Results

Overall Scrap Shedding Simulation

Unique Results Visualization Capabilities

Transparent View – Scrap Drop off through the Die Structure
Unique Results Visualization Capabilities

White Spots indicate locations where the scraps interact with other scraps, chutes and die structure

Next Generation VPG + DYNAFORM Unified

Will be released 2009
Summary of Brand New Capabilities

• Graphical User Interface (GUI)
  • Configurable, Extensible, Efficient.....
  • Similar "Look & Feel" of VPG, DYNAFORM, FEMB, CATIA, UG/NX........

• Graphic Engine
  • High Performance on Super-Large Models
  • High Quality (texture mapping)

• Geometry & Mesh
  • A full feature/function CAD Engine implemented
  • Topology and Associativity (Mesh with CAD Surfaces)
  • Improve Mesh Quality, a break-through

• Framework
  • Multiple model/view, Plug-in modules, Centralized options

• Script
  • Session Files, Batch Processing, User Functions, Auto QA........
Thanks you!