Simufact 12th Round Table Conference
Bamberg, Germany

Design Robustness & Process Capability
By
Simufact & 6 Sigma

Dr. Kunding Wang/Principal FEA Analyst
Luk USA LLC
Wooster, Ohio, USA
Product Range Automotive

- Engine and Transmission Components
  - Variable valve timing
  - Finger follower with hydraulic pivot element
  - Hydraulic tappet
  - Timing chain drive
  - Overrunning alternator pulley
  - Shifting system
  - Toothed chain for timing drives
  - Drawn needle bearing
  - Ball screw drive

- Clutch and Transmission Systems Components
  - Clutch release system
  - Dual mass flywheel
  - CVT components
  - Torque converter
  - Tapered roller bearing
  - Tandem angular contact ball bearing
  - Deep groove ball bearing
  - Sensor-wheel bearing
  - Strut bearing
  - Dual clutch system dry/wet
  - FAG

- Wheel Modules Components
  - Dual clutch system dry/wet
  - SACHS
Outline

1. Simufact as simulation tool for
   • Manufacturing process.
   • Performance evaluation.
   • Durability life assessment.
   • Robustness and capability prediction.

2. Summary.

3. Q & A.
Automotive Torque Converter
Integrated Product Development

Engineering

Brazing
Stamping
Heat Treatment
Riveting
Welding

Durability Testing
Rapid Process Optimization Demand Growth

- Started Simufact.forming
- Forming
- Tooling
- + Riveting
- + Welding
- + Heat Treatment
- Added Simufact.forming GP

Calendar Year:
- 2006
- 2007
- 2008
- 2009
- 2010

Process Simulation / Total Simulation [%]
### Simulation Classification

<table>
<thead>
<tr>
<th>Total Simulations</th>
<th>Process Simulations</th>
<th>Performance Simulations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Types</td>
<td>Softwares</td>
<td>Users</td>
</tr>
<tr>
<td>Forming</td>
<td>Simufact.forming</td>
<td>CAE Specialists</td>
</tr>
<tr>
<td>Tooling</td>
<td>Simufact.forming</td>
<td>CAE Specialists</td>
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<tr>
<td>Riveting</td>
<td>Simufact.forming</td>
<td>CAE Specialists</td>
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<tr>
<td>Welding</td>
<td>Simufact.forming</td>
<td></td>
</tr>
<tr>
<td>Heat Treatment</td>
<td>Simufact.forming</td>
<td></td>
</tr>
</tbody>
</table>

- Take the model, and use it for further process optimization.
- Take the solution (t16), and use it for performance simulations
Simufact Flange Forming Optimization

Objective:
  • Stamp flange from coil steel instead of machined forging.

Benefits:
  • Reduce overall cost
  • More value added in-house
Simufact Stamp Stator Optimization

Objective:
• Stamp stator instead of die cast aluminum

Benefits:
• Cost reduction potential
• Performance improvement potential
Simufact Blind Riveting Simulation

Objective:
• Design and process optimization

Benefits:
• Reduce develop time
• Reduce prototypes
• Reduce developmental tests
• Drive inventive design and process
Simufact Quenching Process Optimization

Objective:
• Eliminate quenching cracks
• Avoid excessive quenching distortion

Benefits:
• Reduced scraps

Simufact optimized process to eliminate quenching cracks
Simufact Durability Life Assessment Methodology

Forming Simulation

Overbend stress analysis

Pressure cycling stress analysis

Goodman Analysis

\( \Delta \sigma \)

S-N Curve

Cycles

Overbend Piston

Overbend Force
Overbend Piston Durability Assessment

Forming

Overbend

Pressure cycling

Overbend by forming

Pressure Cycling

Permanent Set

Bore Deflection [mm]

Overbend Force

Durability Assessment

100000
1000000
2.2 M
Diaphragm Spring Performance Evaluation

Quenching - Forming

Tempering

Shot peening

Testing
Simufact Performance Evaluation

1st Stroke

2nd Stroke

Testing
Simufact Drives Inventive Process Design

Original Design

Some damages

Multiple patents

No damage
Simufact MIG Weld Joint Durability Assessment

- Back plate
- Drive ring
- Front cover
- Hub

Bolted to the dyno thru. the flex plate

Stress Range [MPa]

Durability [cycles]

P_{Dynamic}
TCC Piston plate rivet joint design

Functions:
• Join the piston and the drive ring
• Transmitting torque

Requirements:
• Durable pressure cycling
• Avoid automatic transmission fluid leakage
Simufact 6σ Rivet Joint Robustness

1. Concurrent Simulation

2. FEA DOE Optimization

Critical Factors

Control Output

3. Robustness & Capability

4. Pre-Screening Feasible Solutions
Simufact Rivet Joint Modeling

- Rigid stripper
- Rigid punch
- Rivet Carbon steel
- Piston plate Carbon steel HR
- Friction paper

Case Hardened Strain limit: < 2%
### 6 σ Rivet Joint DOE Table

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<thead>
<tr>
<th>Critical Factors</th>
<th>Control Output</th>
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<tbody>
<tr>
<td><img src="image1" alt="Diagram" /></td>
<td><img src="image2" alt="Diagram" /></td>
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<table>
<thead>
<tr>
<th>Variation limits</th>
<th>Input factors, 2 levels</th>
<th>Output</th>
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<tbody>
<tr>
<td>3 Sigma</td>
<td>Min. Fmax</td>
<td>380</td>
</tr>
<tr>
<td></td>
<td>Max. Fmin</td>
<td>470</td>
</tr>
<tr>
<td>6 Sigma</td>
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<td></td>
<td>Max. Fmin</td>
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Rivet Joint Robustness & Process Capability
Benefits

<table>
<thead>
<tr>
<th></th>
<th>Prototypes</th>
<th>Lead Time %</th>
<th>Budget %</th>
<th>Design Robustness</th>
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<tbody>
<tr>
<td>DOE</td>
<td>12</td>
<td>100%</td>
<td>100%</td>
<td>▶ Requirement</td>
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<tr>
<td>FEA DOE</td>
<td>3</td>
<td>25%</td>
<td>20%</td>
<td>&gt; Requirement</td>
</tr>
<tr>
<td>Avoidance</td>
<td>9</td>
<td>75%</td>
<td>80%</td>
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Summary

1. Simufact based performance simulation is successfully developed.
2. Process simulation is integrated with product development.
3. Sophisticated technology is used by tool designer.
4. Simufact simulation biomes a strategic tool in product development.
5. Simufact based process and performance simulations.
   - improves accuracy, efficiency, and confidence.
   - reduces developmental tests.
   - shortens development cycles.
   - reduces production cost.
   - increases knowledge retention.
   - drives inventive design and process.

   • multiple patents
   • trade secrets