Design Robustness & Process Capability
By
Simufact & 6 Sigma

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Product Range: Automotive

- **Variable valve timing**
- **Finger follower with hydraulic pivot element**
- **Hydraulic tappet**
- **Clutch release system**
- **Dual mass flywheel**
- **CVT components**
- **Overrunning alternator pulley**
- **Shifting system**
- **Toothed chain for timing drives**
- **Drawn needle bearing**
- **Ball screw drive**
- **Deep groove ball bearing**
- **Sensor-wheel bearing**
- **Tandem angular contact ball bearing**
- **Tapered roller bearing**
- **Torque converter**
- **Strut bearing**

- **Engine and Transmission Components**
- **Clutch release system**
- **CVT components**
- **Dual mass flywheel**
- **Overrunning alternator pulley**
- **Shifting system**
- **Toothed chain for timing drives**
- **Deep groove ball bearing**
- **Sensor-wheel bearing**
- **Tandem angular contact ball bearing**
- **Tapered roller bearing**
- **Torque converter**
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
- Added Simufact.forming GP
- Forming
- + Tooling
- + Riveting
- + Welding
- + Heat Treatment
- 2006
- 2007
- 2008
- 2009
- 2010

Calendar Year

Process Simulation / Total Simulation [%]
Simulation Classification

<table>
<thead>
<tr>
<th>Total Simulations</th>
<th>Process Simulations</th>
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<tr>
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<td>Product durability assessment</td>
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<td>Product robustness prediction</td>
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- 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 Durability Life Assessment Methodology

Forming Simulation

σ ε Geo

Overbend stress analysis

σ ε

Pressure cycling stress analysis

σ ε

Goodman Analysis

Δσ

S-N Curve

Cycles

Overbend Piston
Overbend Piston Durability Assessment

Forming

Overbend

Pressure cycling

Durability Assessment

Overbend by forming

Pressure Cycling

Permanent Set
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

No damage

Multiple patents
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

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

#### Critical Factors

- Stripper force
- Riveting force
- Rivet Height
- Rivet Diameter
- Rivet Hole

#### Control Output

![Diagram of rivet joint]

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<th>Output</th>
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Rivet Joint Robustness & Process Capability

![Diagram showing failure zone, durability, rivet expansion, and process capability with -3σ and +3σ markers.](image-url)
Benefits

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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