Cost- and Quality-prioritized Methodology Towards Robust Stamping Process Solutions

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Troubleshooting Production Crises
Constraints and Pitfalls

• Time is money
  - Loss of production, press downtime, assembly stoppage
• Rush to resolve
  - Quality and cost compromised for time
• What can be changed quickly?
  - Not necessarily what needs to be changed?
• Will the problem stay resolved through life of production?
  - Intuition, experience - important, but sufficient?
Systematic Engineering Towards Balanced Resolution

**Setup**
- Experience, constraints
- Available Countermeasures: "Design"
- Uncontrolled Variations: "Noise"

**Calculation**
- "Simulation cluster" over spectrum of available countermeasures

**Evaluation**
- "Process Window" Potential resolution
- Actionable Countermeasures
- Stability of Resolution
Systematic Engineering

Design parameter 1

Design parameter 2

Process Window

Influence

Thinning

Design parameter
Upfront:
Systematic Engineering of Balanced Process

• Establish critical process elements: number of stations, die rotations, etc.

• Identify all die & process conditions that need to be engineered: ‘Design’
  – Die face shape, Beads, Blank shape, Tonnages, Punch Support, etc.

• Identify conditions that cannot be controlled: ‘Noise’

• Select quality metrics for acceptance

• Generate “simulation cluster”
  – Simulations auto-generated as random combinations of “Design” parameters over meaningful ranges
  – Relationships established between “Design” parameters and quality-critical simulation results

• Identify process window and meaningful resolution

• Validate resolution through Robustness assessment over “Noise”
Troubleshooting: Systematic Engineering for Balanced Resolution

- Baseline / reproduce production condition in simulation
- Identify all potential countermeasures: Design
  - Beads, Blank location, Die face changes
- Identify conditions that cannot be controlled: Noise
- Select quality metrics for acceptance
- Generate “simulation cluster”
  - Simulations auto-generated as random combinations of “Design” parameters within meaningful ranges
  - Relationships established between “Design” parameters and quality-critical simulation results
- Identify process window and meaningful resolution
- Validate resolution through Robustness assessment over Noise
Case Study – F250 Box Side Outer Panel

- Panel splits along lower draw wall at bottom of stroke
- Time consuming bead grinding leads to blank slipping past beads on lower side
  - *Process is unstable*
  - *Challenging to find a balanced solution*
- Constraints
  - *Production material, blank dimensions, draw surfaces cannot be changed*
  - *Bead adjustment is only option*
Baseline – reproduce reported issue

Balanced binderset with even blank outside of beads top and bottom

Simulation panel @ bottom of draw similar to physical panel
Finalize baseline

Convert physical bead to equivalent modeled bead baseline

Original physical beads set up

Modeled beads with parametric sections representing physical beads
Systematic engineering

• Identify all potential countermeasures:
  – Beads identified to be only viable, adjustable countermeasure
  – These are the “Design” parameters

• Quality metrics:
  – Even draw-in top and bottom at end of draw stroke; blank lies outside inner beads
  – Thinning and FLD criteria to judge panel safety
    Thinning Max. = 30%; FLC Safety Margin = 10%
  – Major strain and minimum thinning criteria for panel stretch
    Positive Major / Minor; Required thinning = 0.5%
**Systematic engineering**

- Run simulations spanning ranges of all Design parameters
  
  - *Bead profile parameters (bead height, bead entry/exit radius) were varied over large range to produce wide variation of bead restraint*
  
  - *Wide range of design parameters is important to ensure no potential solution is ignored*
Results – Splits on panel

Worst case result in “simulation-cluster” – identifies all split locations
Results – Splits on panel

Beads that need to be adjusted to mitigate condition

Critical failure Location
Marginal Location

Failure locations identified based on quality metrics
Dependencies derived from “simulation cluster”
Results – Bead influence on splits

Significant bead influence on split condition

“Tlnr” => Top Inner bead

Max. Failure result: notice counterintuitive dependence of lower draw wall splits on top side beads
Results – Bead adjustment to eliminate splits

Review results:

- Automatic resolution for splits and excessive thinning

Resolution of all split issues through automatic, simultaneous adjustment of bead shapes

Leads to inadequate panel stretch
Results – Draw-in

Review results:

- Automatic resolution for splits and excessive thinning

Resolution of all split issues through automatic, simultaneous adjustment of bead shapes

Leads to draw-in violation
Results – Bead adjustment for balanced draw-in

Review results: Alternative resolution based on balanced draw-in
Results – Validation of acceptable panel

Review results:

• Validate that resolution for draw-in is adequate for splitting / thinning

Balanced draw-in condition generates a couple of marginal formability concerns
Results – Validation of acceptable panel

Review results:

- Validate that the resolution for draw-in is adequate for surface metrics

Balanced draw-in condition generates a couple of marginal stretch concerns
Engineered vs. Production panel

Comparison to physical panel

Panel draw-in matches quite well overall, and especially so in the highlighted area where blank edge flows past outer bead.
Is engineered process repeatable?

• Is the validated resolution repeatable?

• A robustness assessment was carried out with following normal variations of “Noise” parameters
  
  – Thickness 0.84 – 0.88 mm (nominal 0.88 mm)
  – Yield 129 – 192 MPa (nominal 183 MPa)
  – Tensile 275 – 337 MPa (nominal 325 MPa)
  – R-bar 1.58 – 1.92 (nominal 1.75)
  – Lube 0.11 – 0.13 (nominal 0.12)
Validation of repeatability

Panel repeatability & acceptability relative to Splits & Thinning
Validation of repeatability

Panel draw-in acceptability & repeatability
Validation of repeatability

Panel draw-in acceptability & repeatability

Very narrow band / range of draw-in variation

Draw-in resolution repeatable and acceptable except in 2 locations
- Draw-in overshoots by 15 mm max.
Summary & Conclusions

Systematic resolution of stamping problems in production / tryout –

- Reproduce problem in simulation
- Prioritize die & process parameters that can be changed to improve panel condition; establish meaningful ranges for these parameters
- Work towards established quality metrics for acceptable panel
- Run simulations over selected parametric ranges – to build relationships between selected parameters and panel quality results
- Leverage these relationships for automatic, or experience-lead resolution
- Validate that resolution is balanced
- Validate that resolution is repeatable

Application to Ford 250 box side outer production issue illustrated in presentation

Balanced, virtual resolution matches production panel achieved after extensive and expensive bead adjustment and tryout.
Thank you.

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