Die Design Software and Simulation Technology Experience

CASE STUDIES

Design, Development, Optimization, and Tooling Validation

Peter Ulintz
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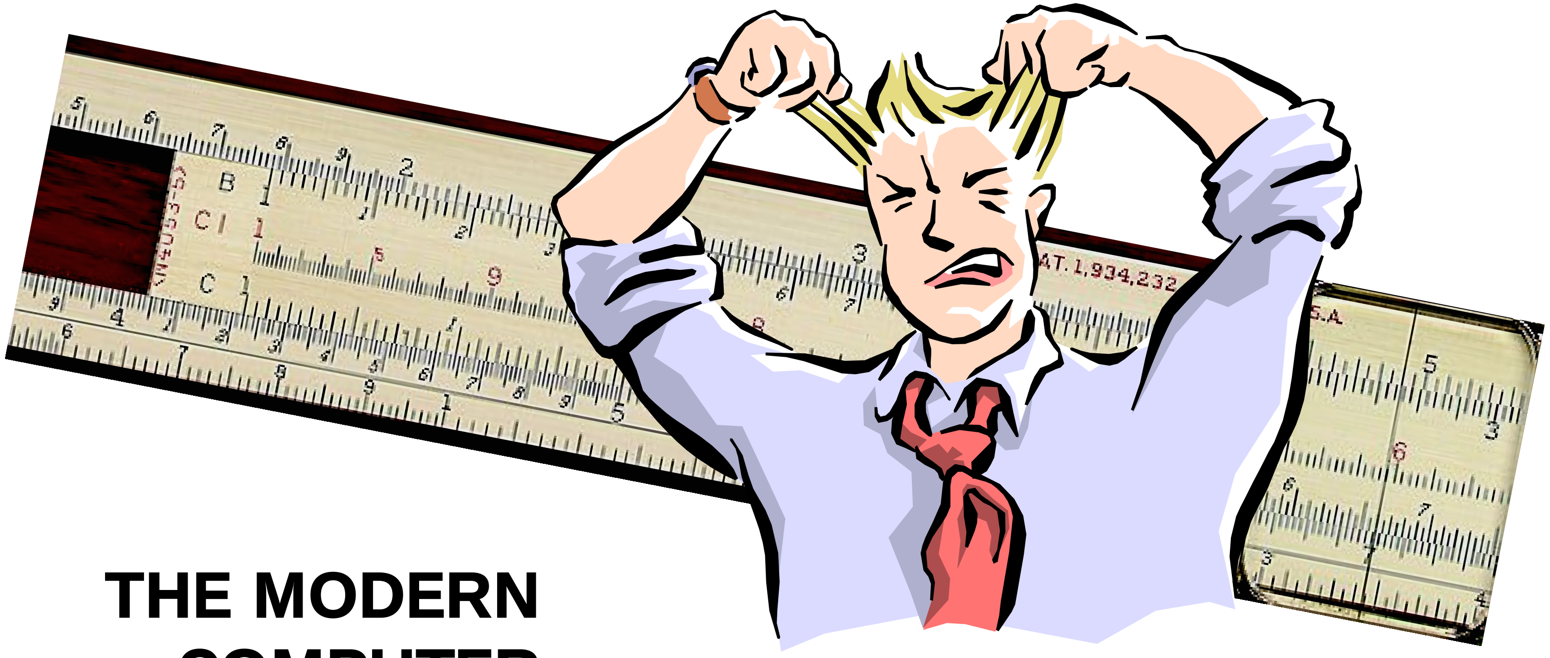
Precision Metalforming Association

Historical Overview

Mathematical modeling for sheet metal formability is generally thought to be a recently developed science

However, a paper written by George Sachs, Director of Metallurgical Research at Syracuse University, provided a mathematical model for deep drawing a cylindrical cup **in 1935!**

Historical Overview



THE MODERN COMPUTER

circa 1935

Historical Overview

- In 1959, Stuart Keeler wrote a machine language code for the huge MIT computer for a one-step simulation of a hemispherical dome
- Although never published, the predicted results correlated with his laboratory tests
- This may have been the first computer simulation & validation of a metal forming problem

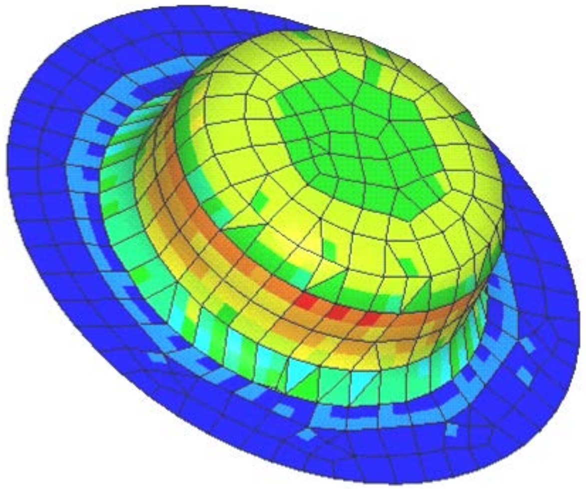
Historical Overview

1970's

By the early 1970's, finite element calculations began to appear

Axis symmetric problems – round domes and cylindrical cups – became standard test problems for finite element developers

By the end of the decade, some 3D applications were being carried out. Due to the limited computing power available only simple geometries were used



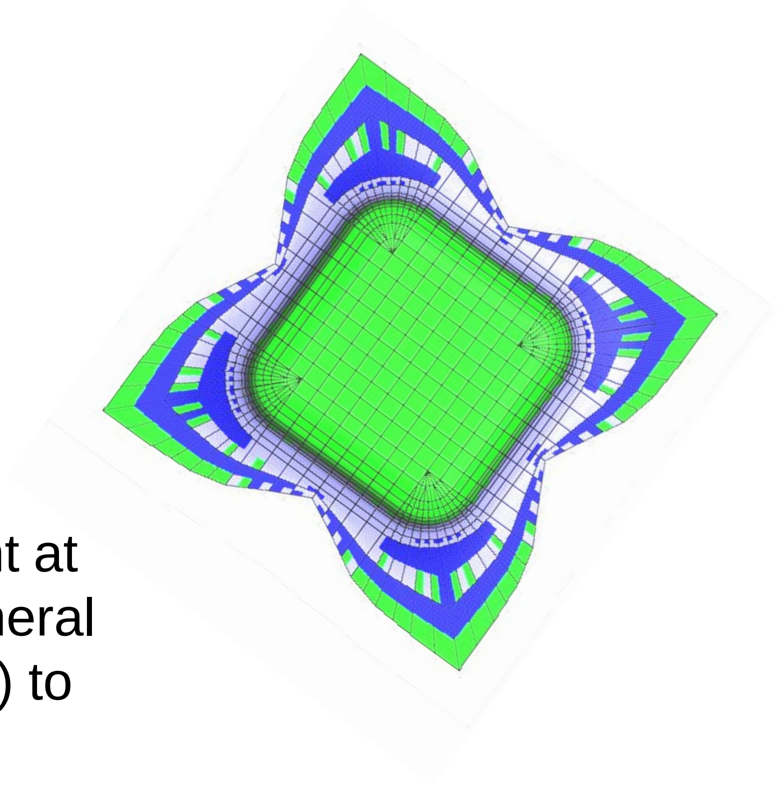
Historical Overview

1980's

Rapid increase in capability as computing power increased

Non-symmetric problems (square and elliptical cups) became more evident

Perhaps the most significant development at the end of the decade was the use of general purpose FEA codes (ABAQUS, DYNA3D) to simulate sheet metal forming



Historical Overview

Early-1990's

By 1990, the capabilities of finite element methods were well understood as were the requirements for good analysis

Industrial panels, such as automotive fenders, could now be analyzed

Advances in CAD and post-processing systems provide the ability to visualize the tool and work piece surfaces as the problem is set up and ability to handle massive amounts of output data

Historical Overview

Mid-1990's

GM and other OEM's made a critical decision to set aside all of the in-house codes that had been developed, and started to use commercially available codes (FastForm 3D, HyperForm, Optris, PamStamp).

This decision simplified the problem of developing and maintaining these codes as technology needs evolved

Historical Overview

By the end of the 1990's

Automotive OEM's reported to be doing metal forming analysis on most every major body panel and many Tier 1 automotive suppliers were conducting forming simulations in-house

Today

Many Tier 2 and 3 stamping suppliers and tool & die shops routinely use simulations to validate tooling design <u>and engineering (process) changes</u>

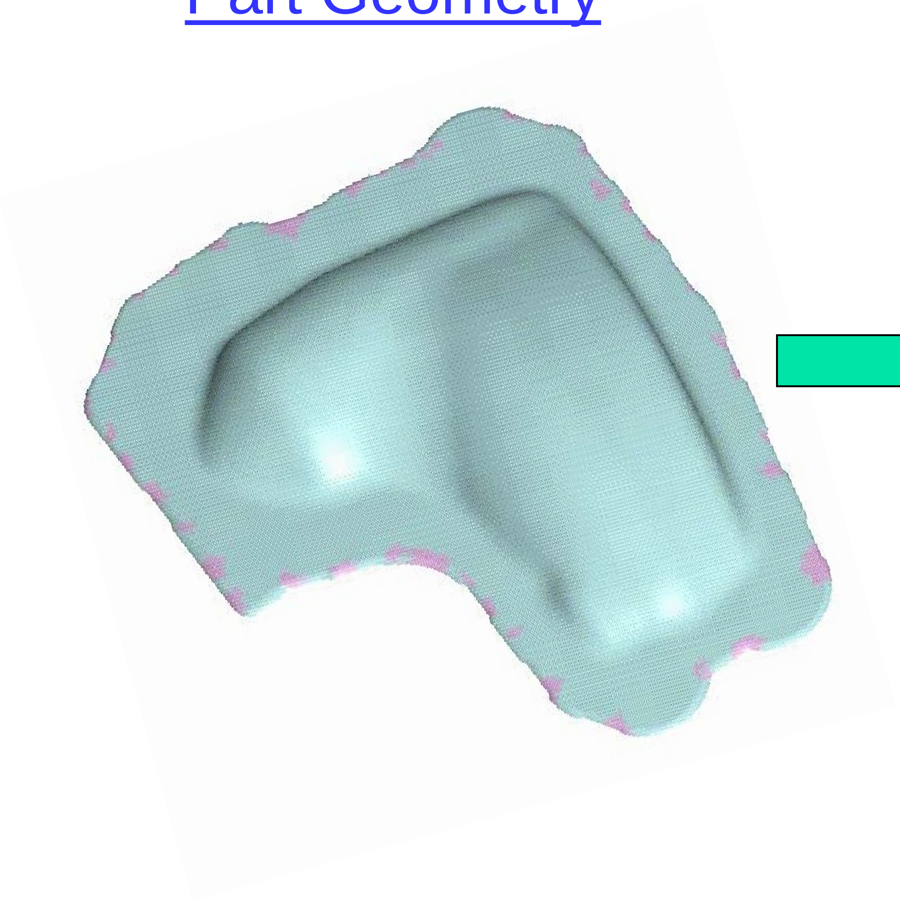
Case Study

Transfer Case Cover Development

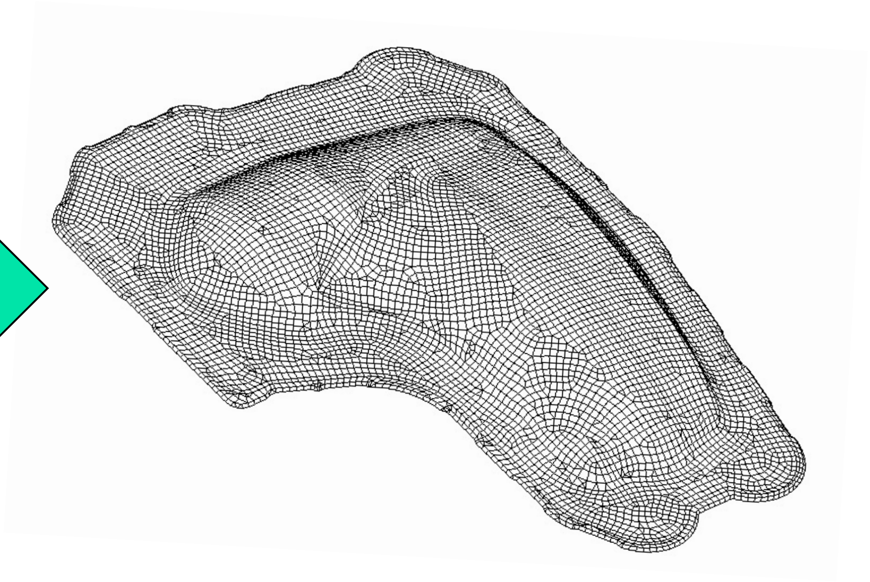
Case Study

Transfer Case Cover

Part Geometry



Finite Element Mesh



The One Step / Inverse Method
Product and Process Validation

Inputs

- Final product geometry
- Minimized material properties

Ignored

- Press
- Tooling
- Lubrication

The One Step / Inverse Method

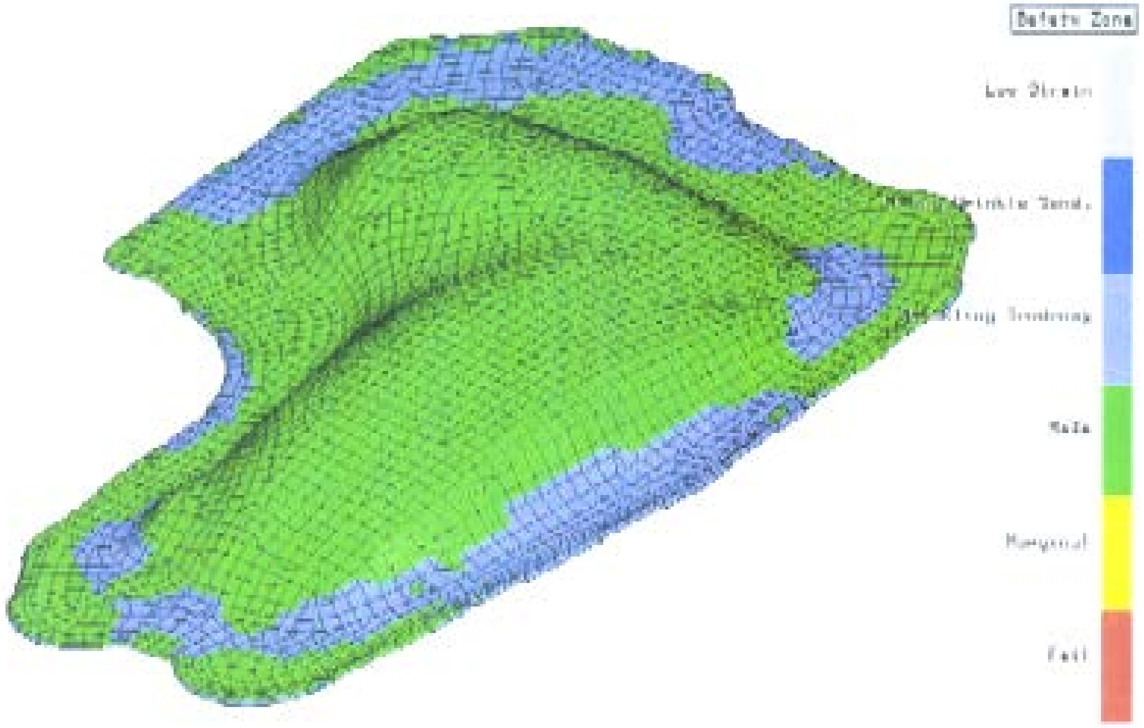
Product and Process Validation

```
C:\Program Files\FAST_FORM3D\GEO\NVG\NVGC2\NVG3-1.fpi

-----------------------------------------------------

Material Table: SAE 1008 CRSDQ

    Thickness = 1.00 mm
    Yield Stress = 179 MPa
    Young's Modulus (E) = 203.4 GPa

    r-Value = 1.700000
    n-Value = 0.230000
    k-Value = 551.58 MPA

-----------------------------------------------------
```

The One Step / Inverse Method

Product and Process Validation

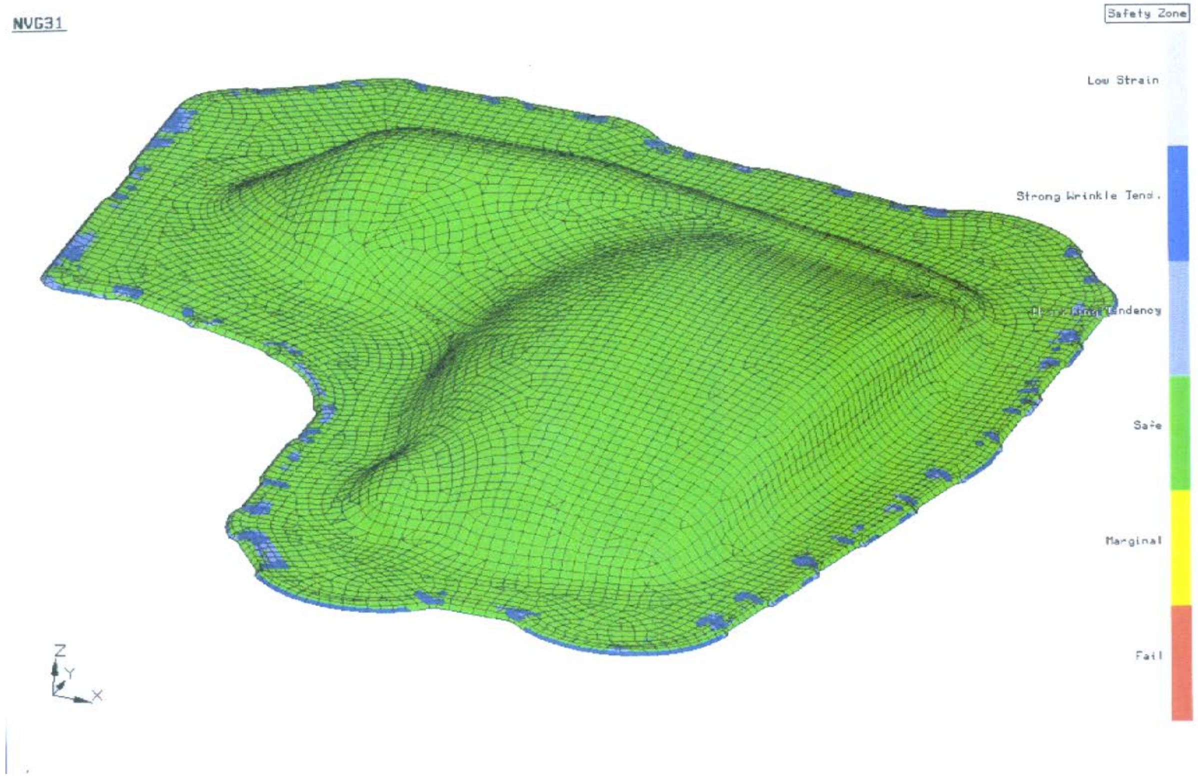
Deep Draw Process – Safety Zones



The One Step / Inverse Method

Product and Process Validation

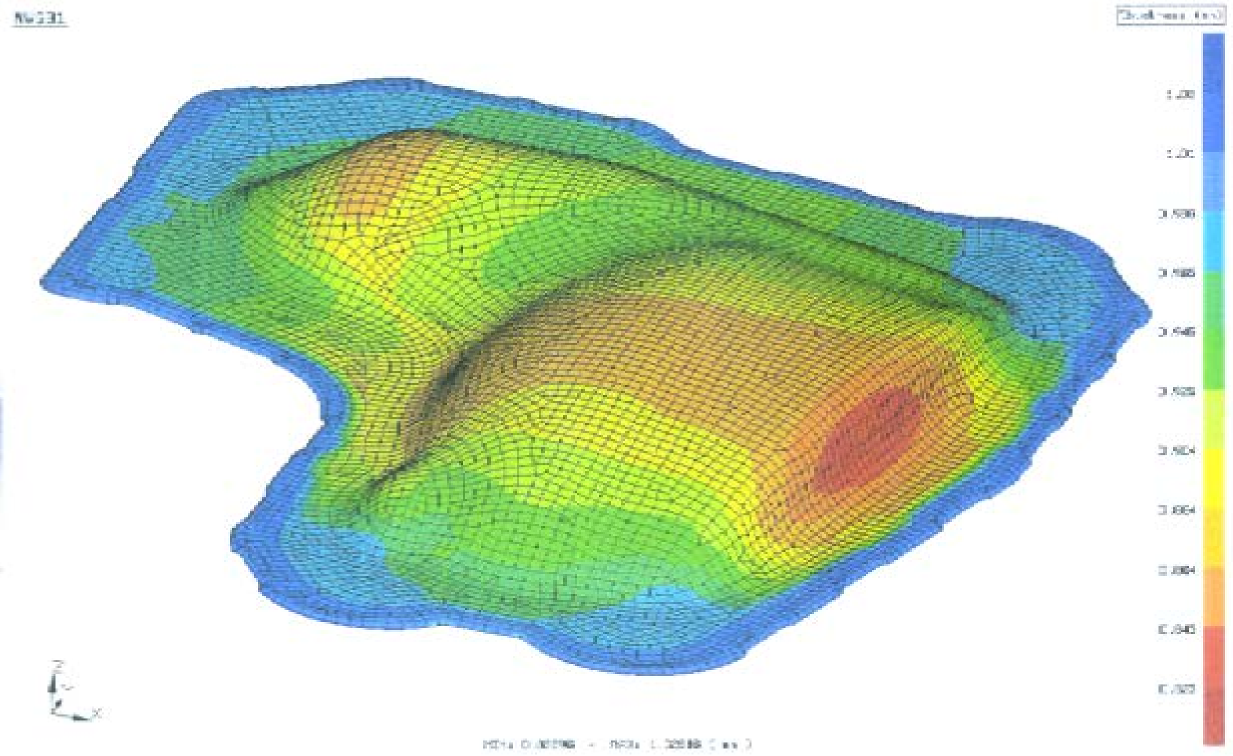
Stretch Process - Safety Zones



The One Step / Inverse Method

Product and Process Validation

Stretch Process – Thinning Strains



The One Step / Inverse Method

Product and Process Validation

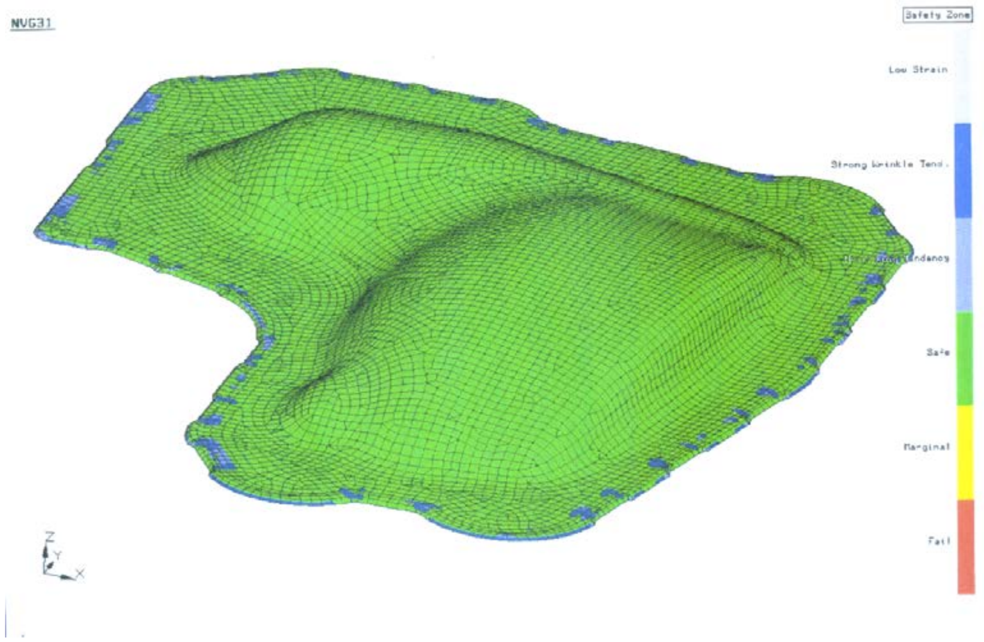
Outputs

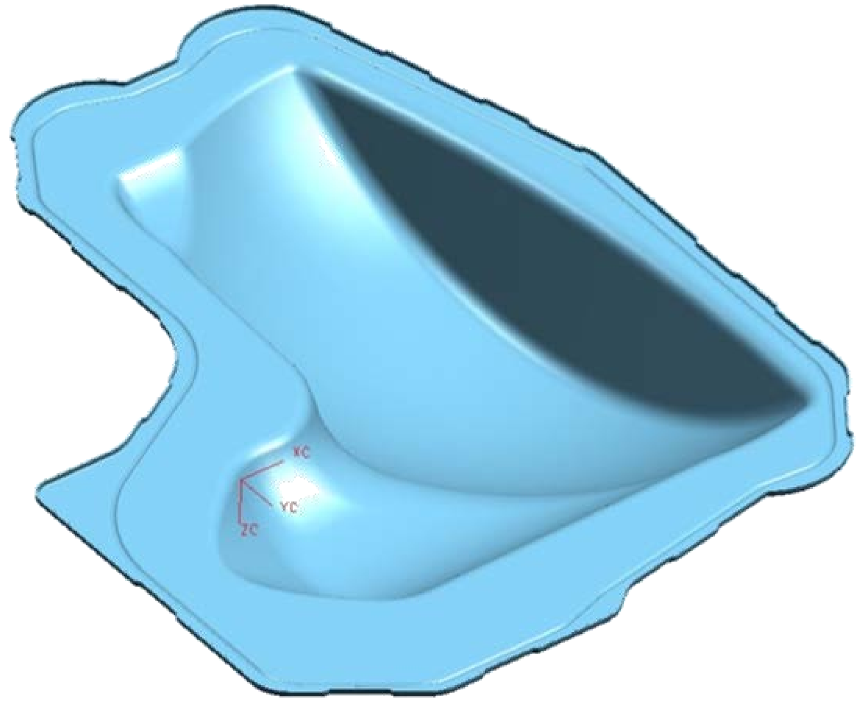
- Circle grid distortion
- FLD forming severity
- Major, minor, thickness strains
- Strain along section lines
- Process signatures
- Trim line to blank plots

The One Step / Inverse Method

Product and Process Validation

DESIGN CHANGE

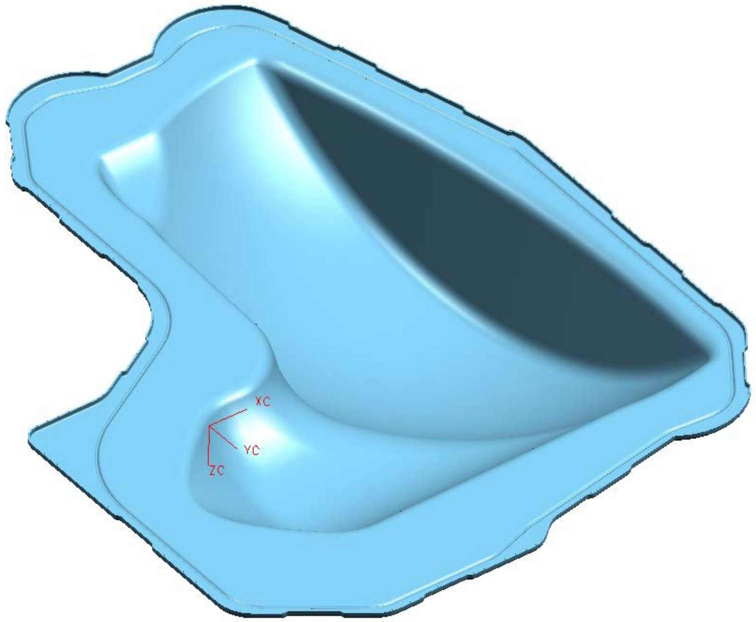


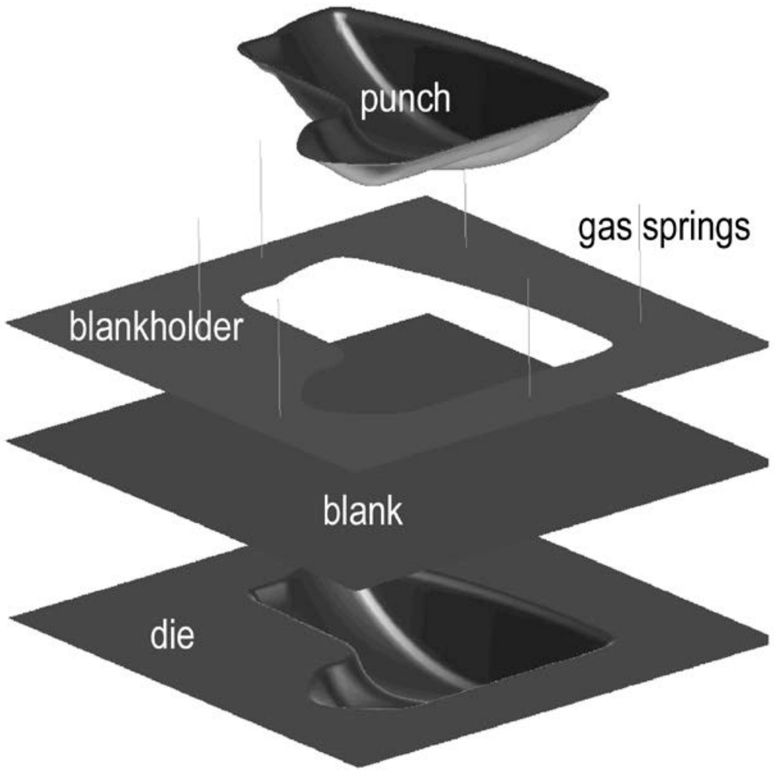


Formation of a Non-Symmetric Part and Blank Optimization Using Finite Element Analysis

From Young Seo and Peter Ulintz

Third North American Conference and Exhibition on Virtual Engineering (2007)



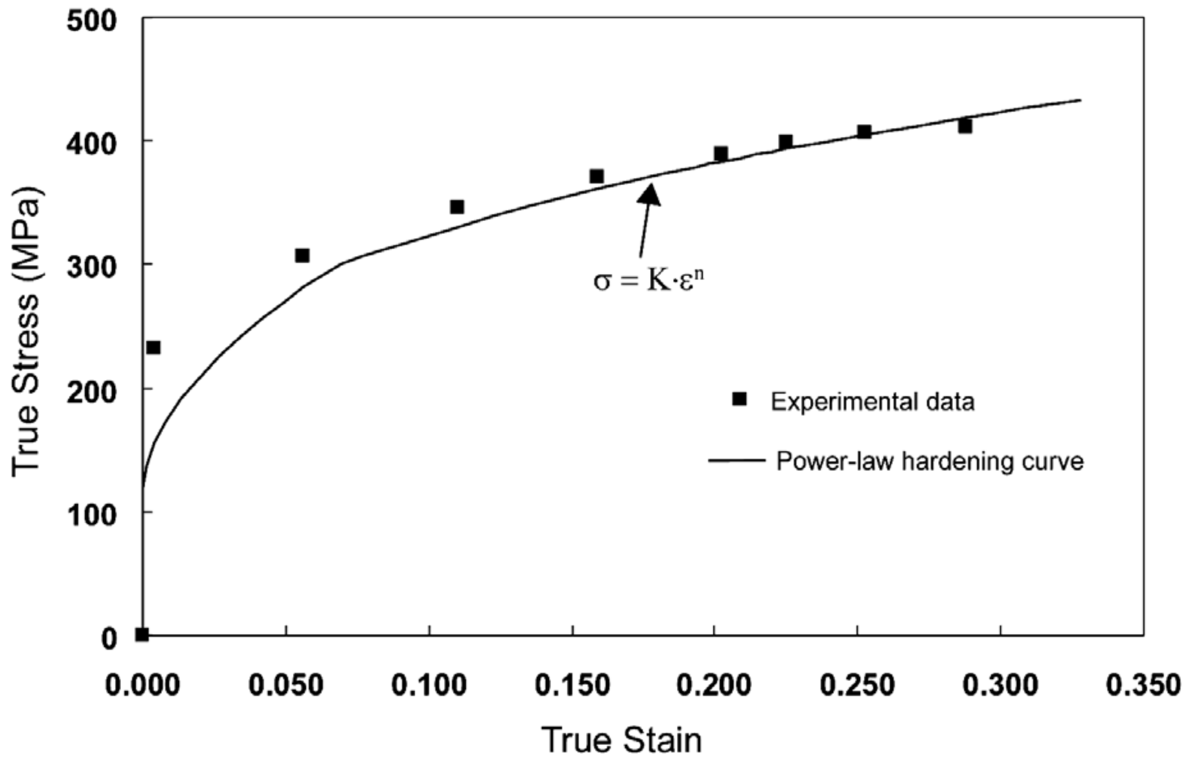


Incremental Method

Material Properties from Tensile Test

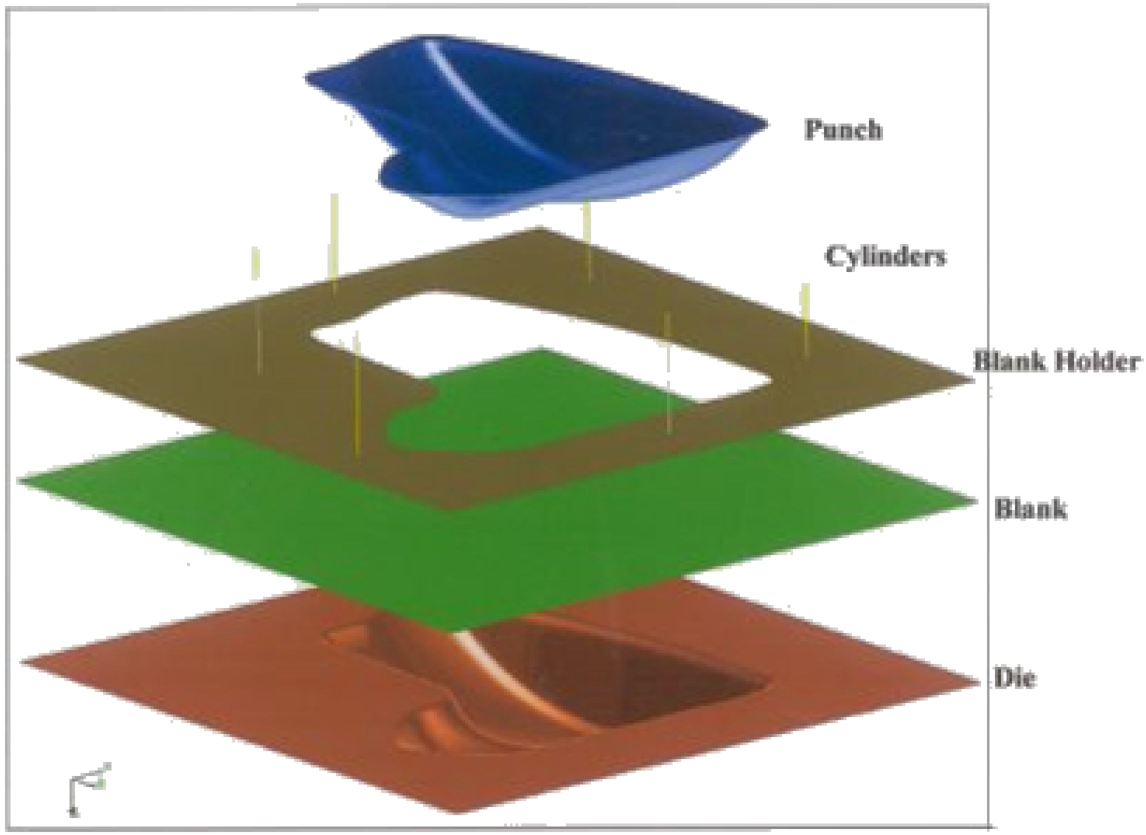
Table 1
Mechanical properties of SAE 1008 cold-rolled steel sheet

Yield stress	Young's Modulus	Poisson's ratio	*r*0	*r*45	*r*90	n-value	K-value
175 MPa	126 GPa	0.3	1.87	1.31	2.13	0.2257	537MPa



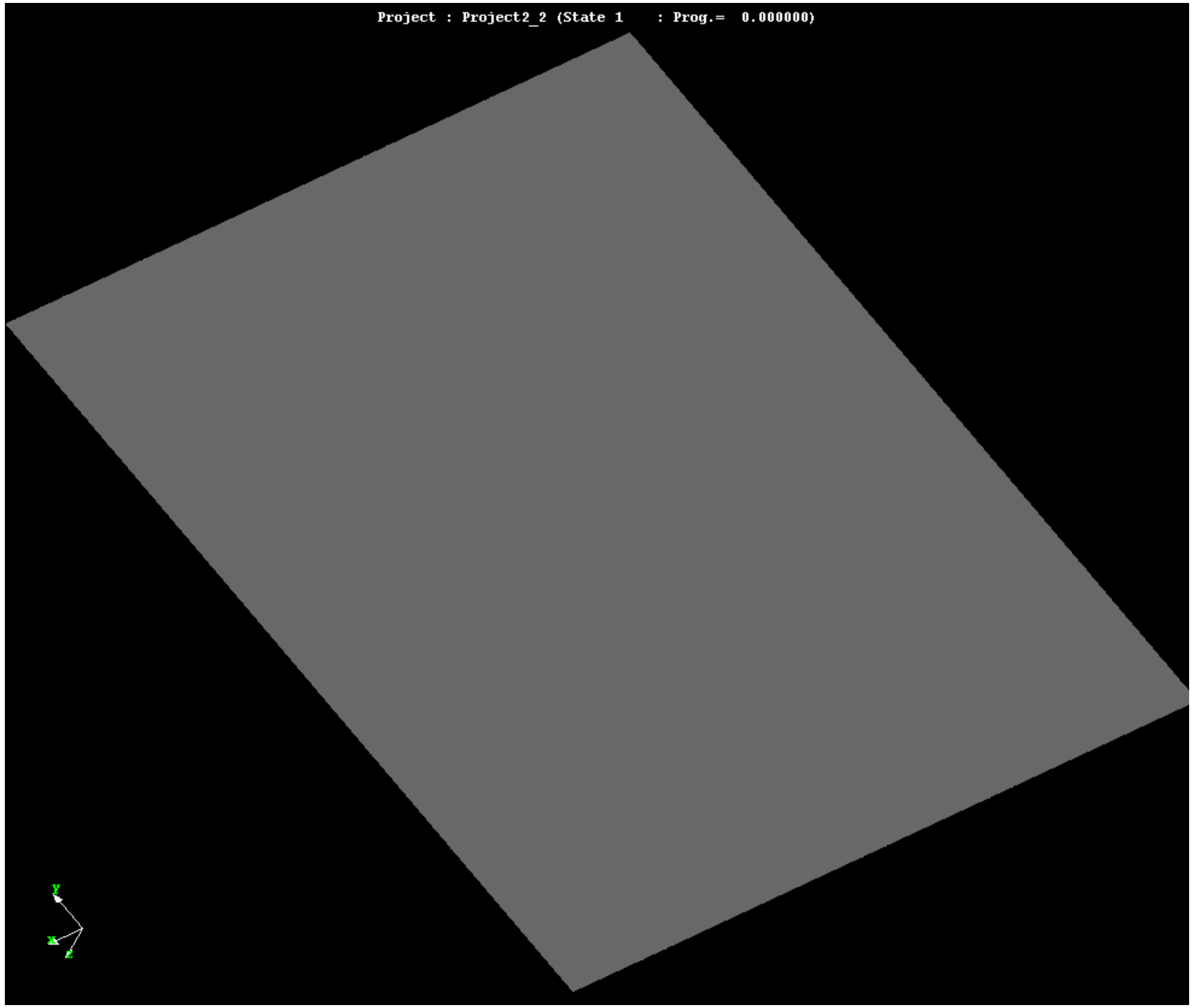
Incremental Method
Tooling Validation and Blank Optimization

Set up the Tooling



Incremental Method

Tooling Validation and Blank Optimization

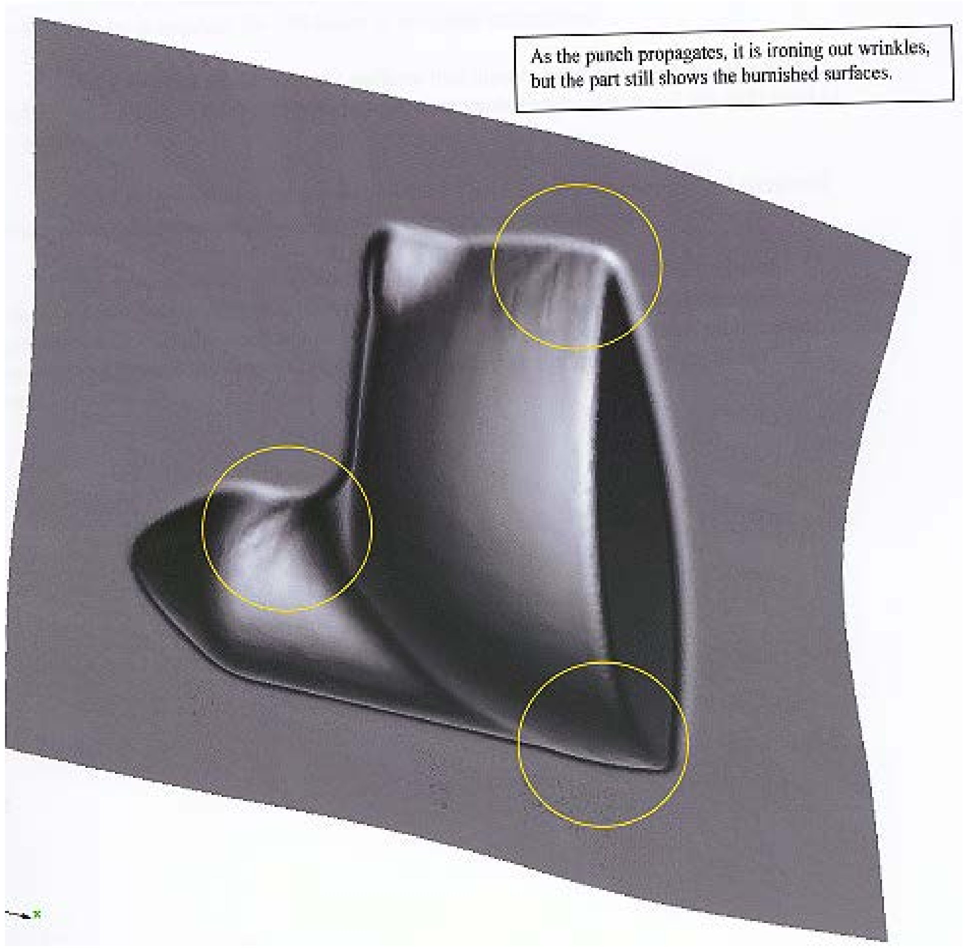


video

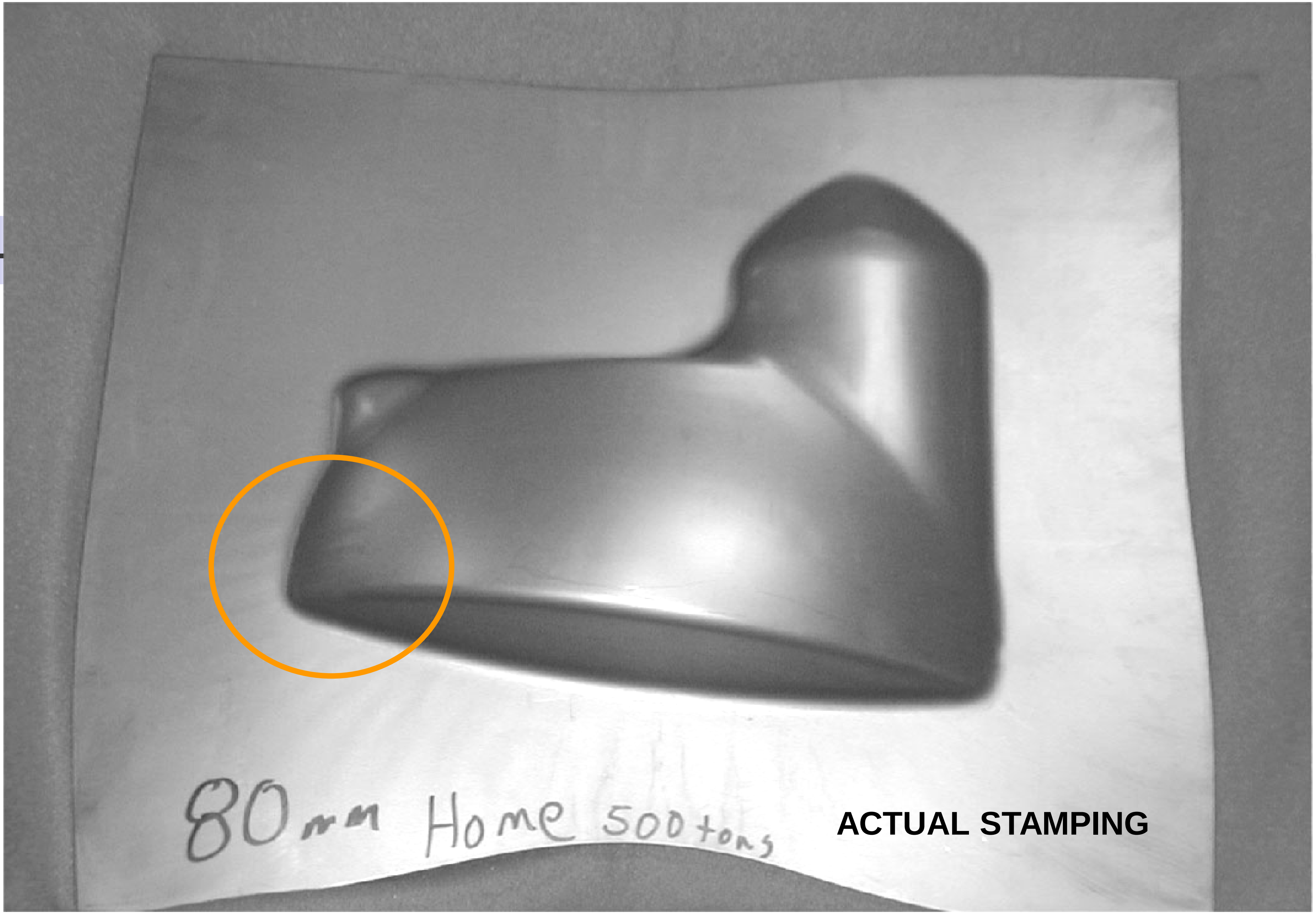
Incremental Method

Tooling Validation and Blank Optimization

Draw Depth 80 mm

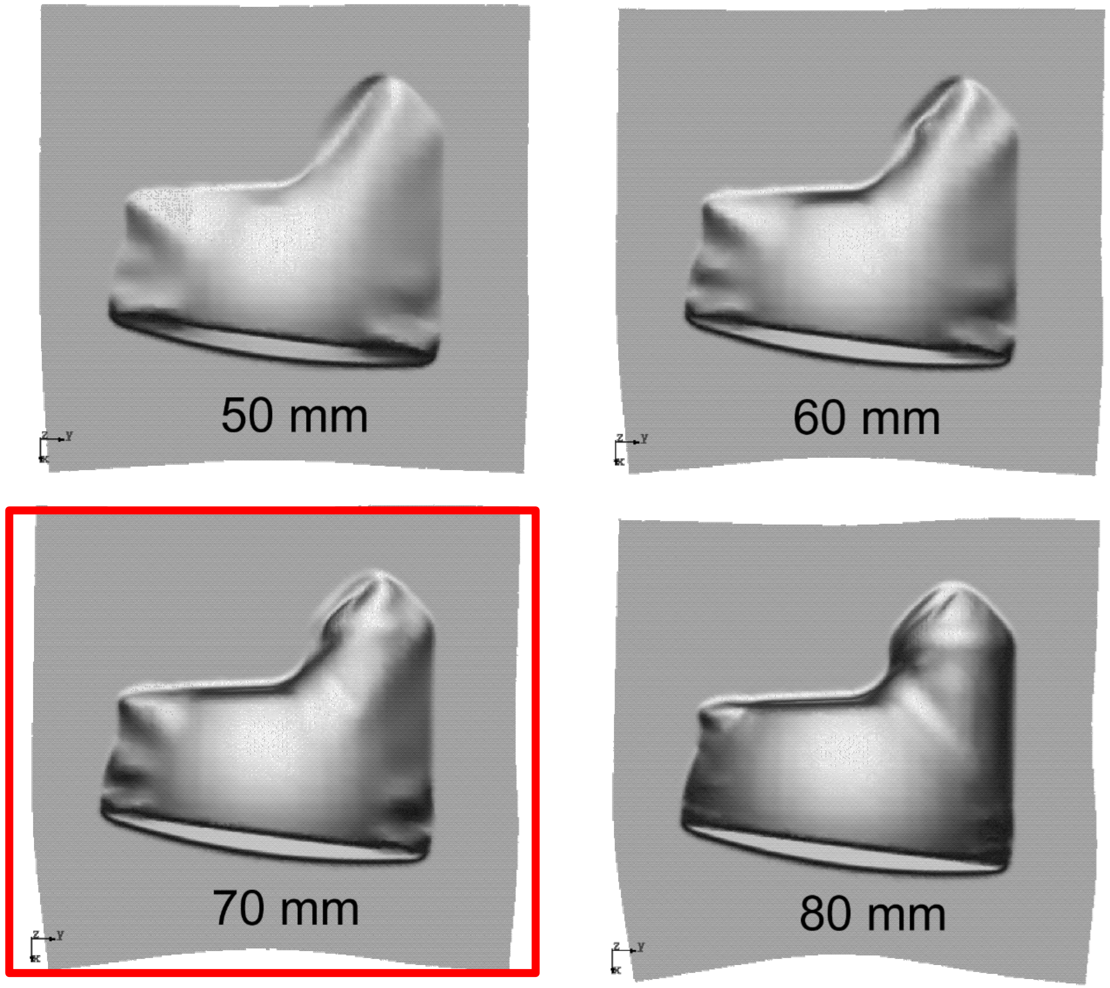


SIMULATION RESULTS


80mm Home 500 tons
ACTUAL STAMPING

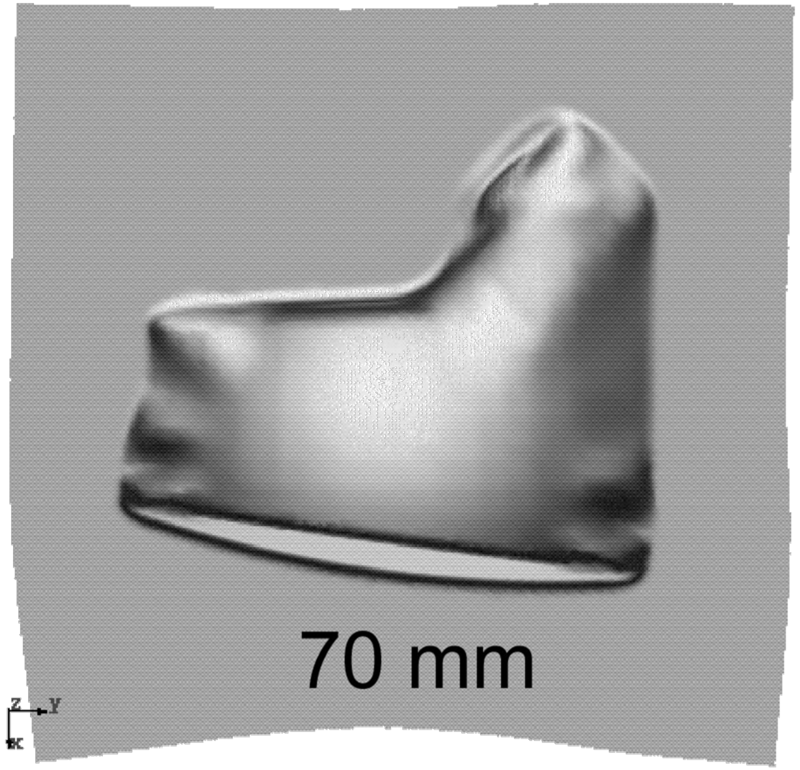
Incremental Method

Tooling Validation and Blank Optimization

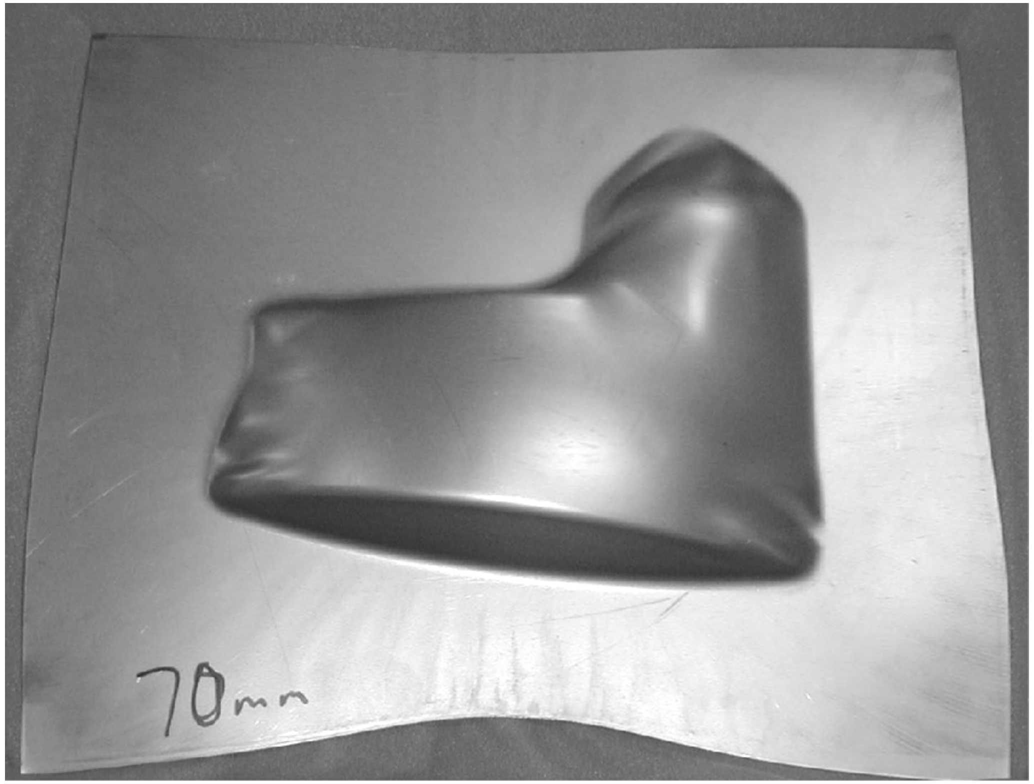


Incremental Method

Tooling Validation and Blank Optimization



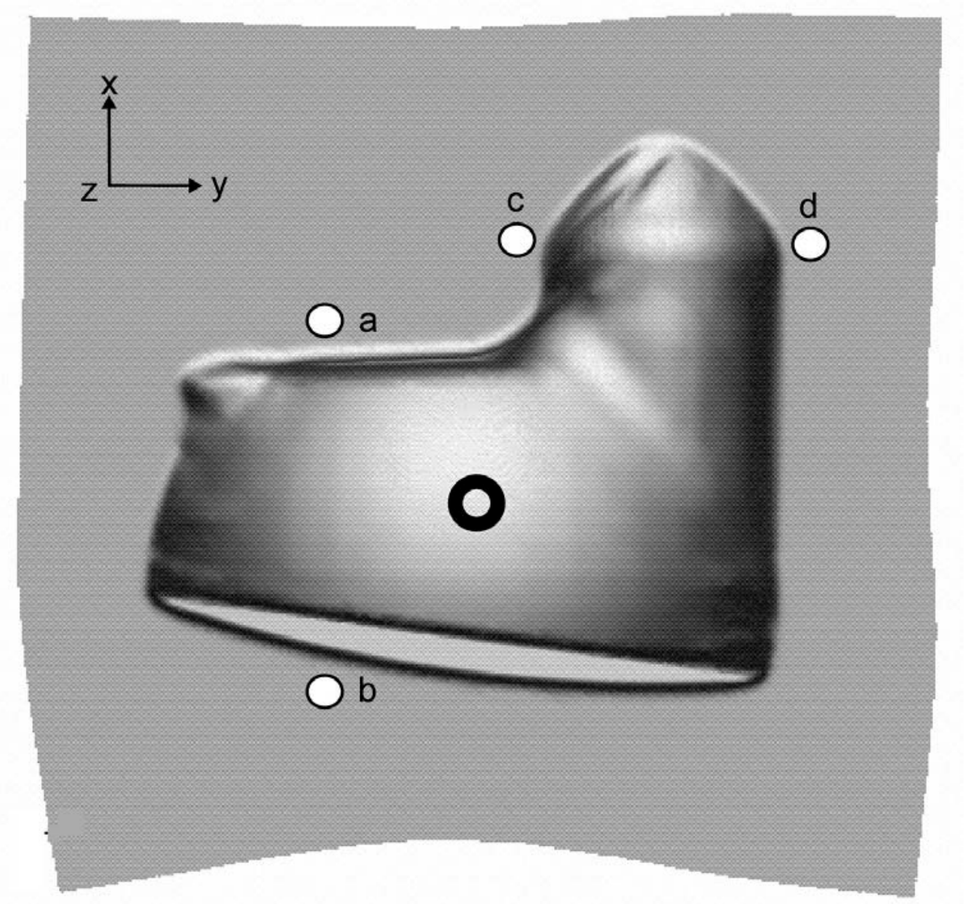
SIMULATION



STAMPING

Incremental Method

Tooling Validation and Blank Optimization



SPRINGBACK

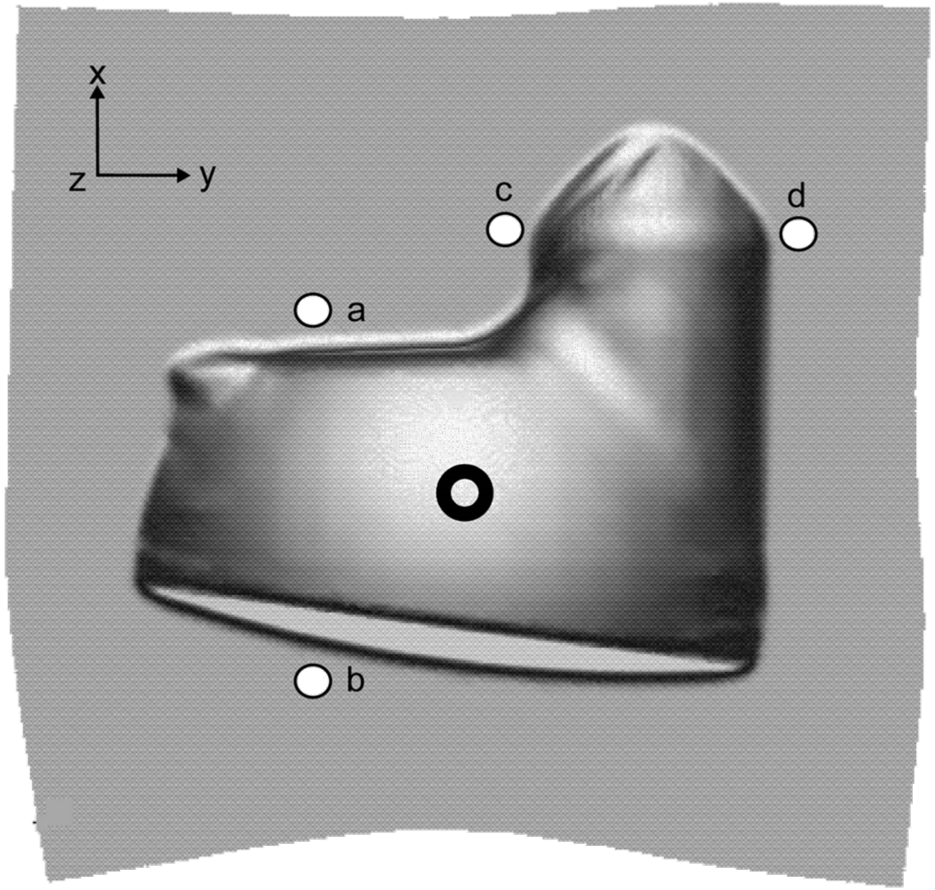
MEASUREMENT METHOD:

Applied hand pressure at O until flange material is flat against layout plate.

Zero indicator at white points. Release pressure and read indicator (springback).

Incremental Method

Tooling Validation and Blank Optimization

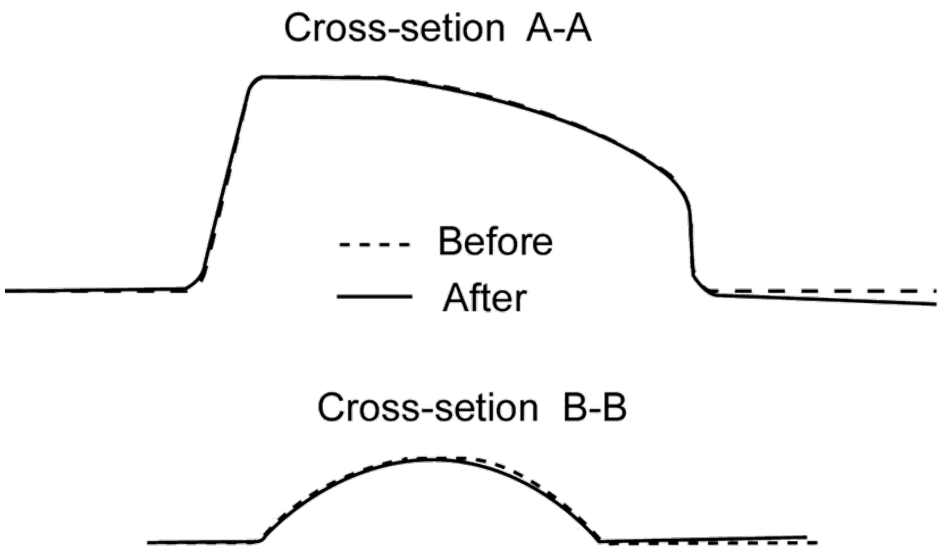


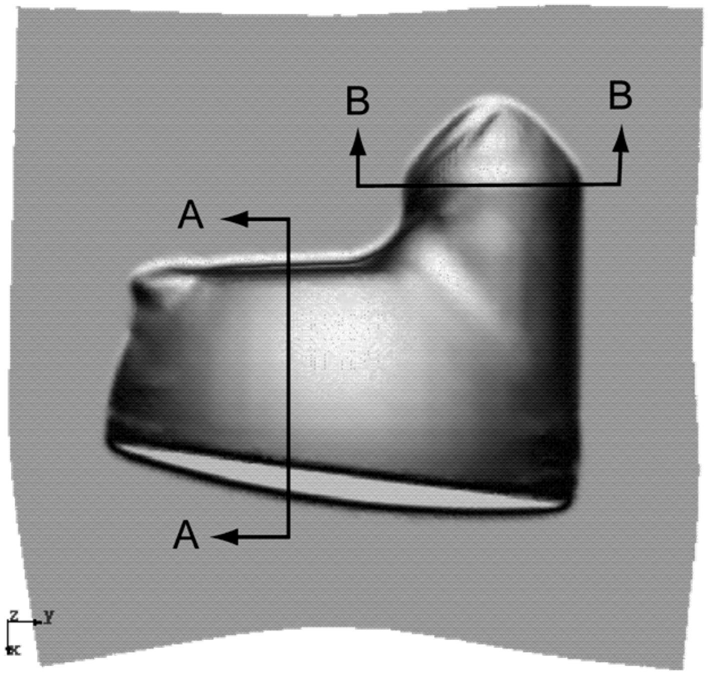
	Exp.	FEA
a	1.3970	0.1298
b	1.8796	1.5223
c	1.0795	1.3693
d	1.4732	1.4106

*unit in mm

Incremental Method

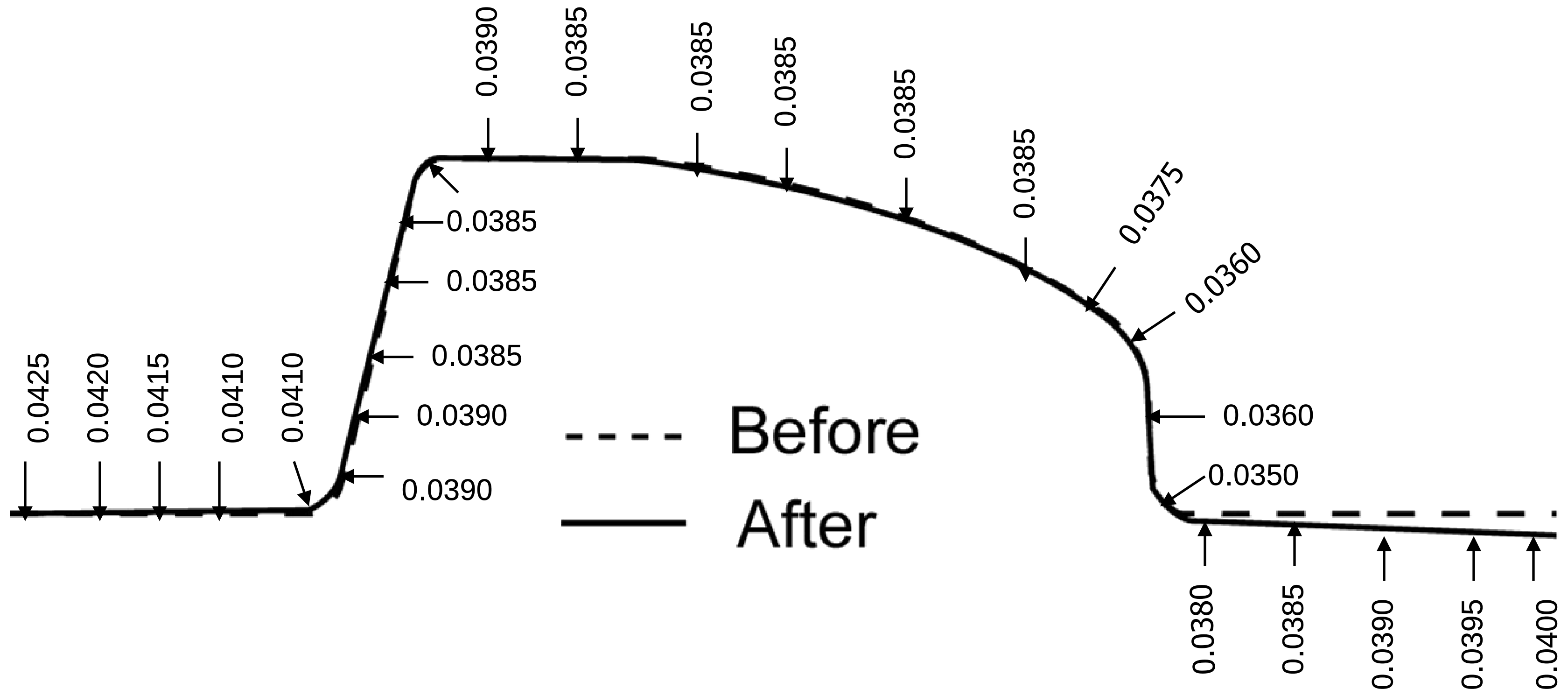
Tooling Validation and Blank Optimization





Incremental Method

Tooling Validation and Blank Optimization

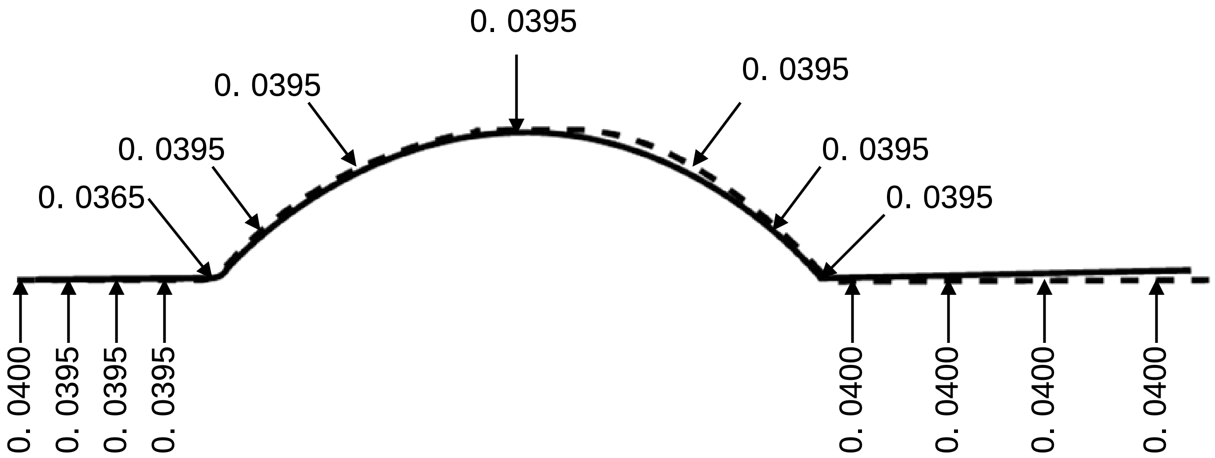


Section A - A

Initial blank thickness = 0.0405”

Incremental Method

Tooling Validation and Blank Optimization

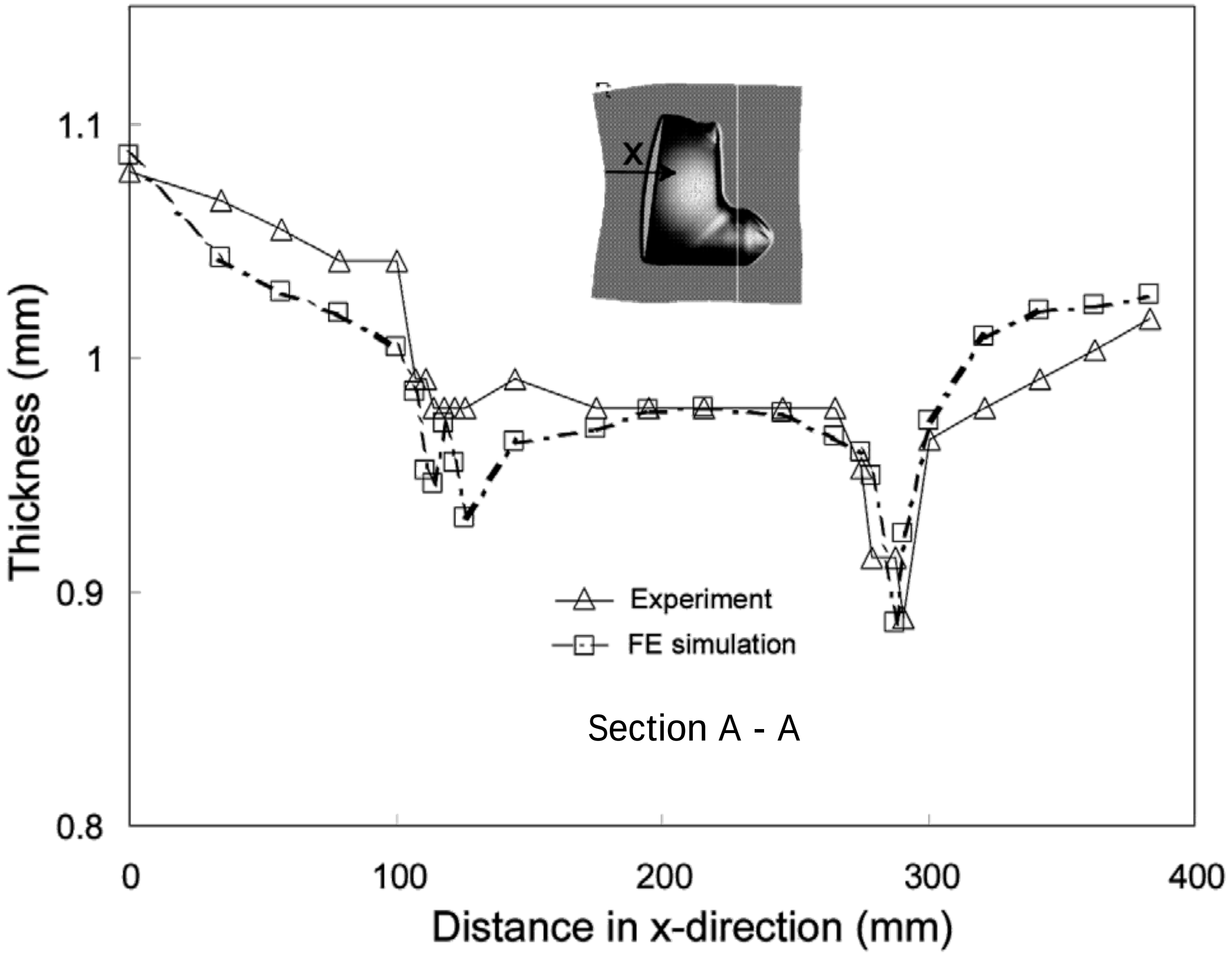


Section B - B

Initial blank thickness = 0.0405”

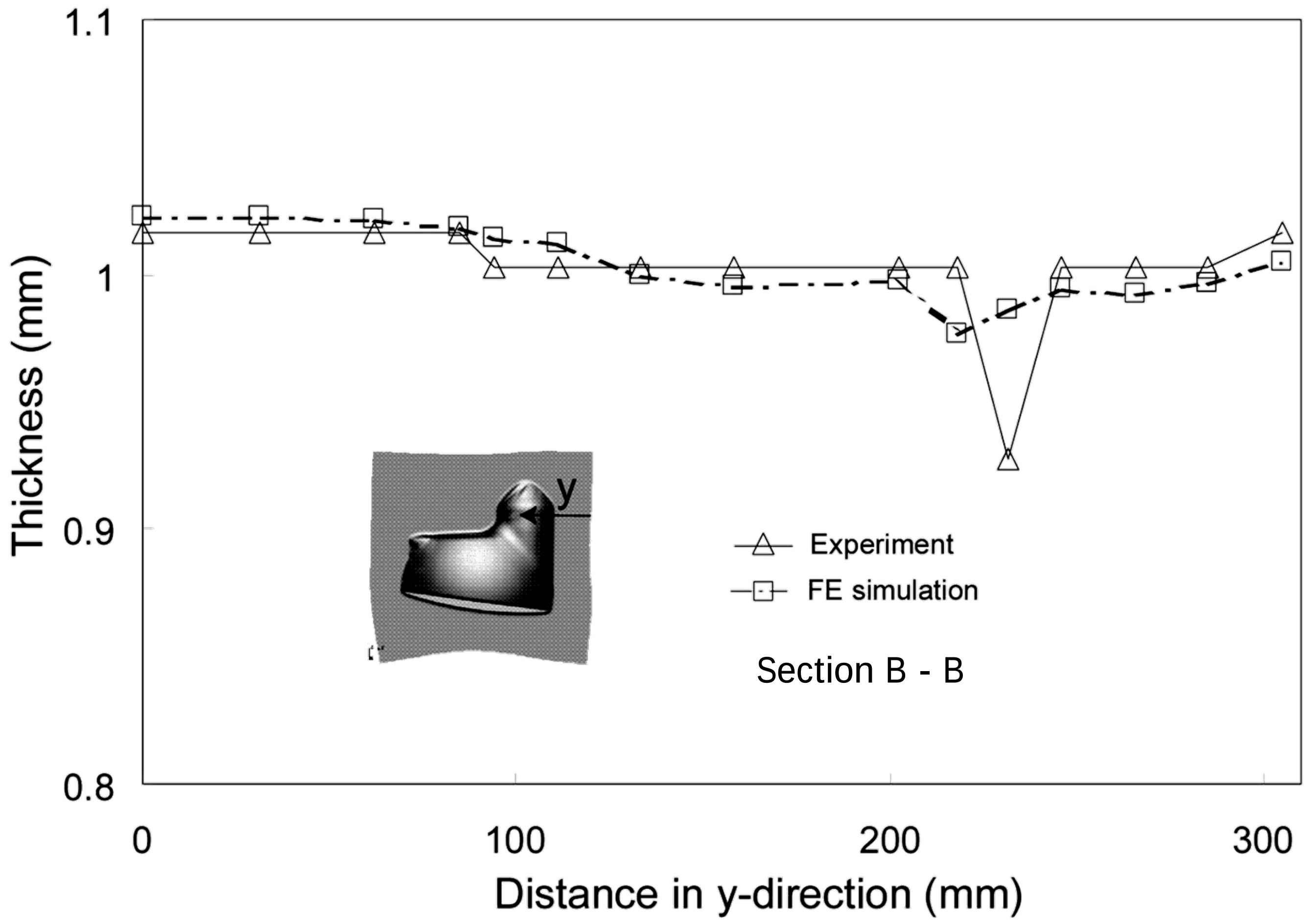
Incremental Method

Tooling Validation and Blank Optimization



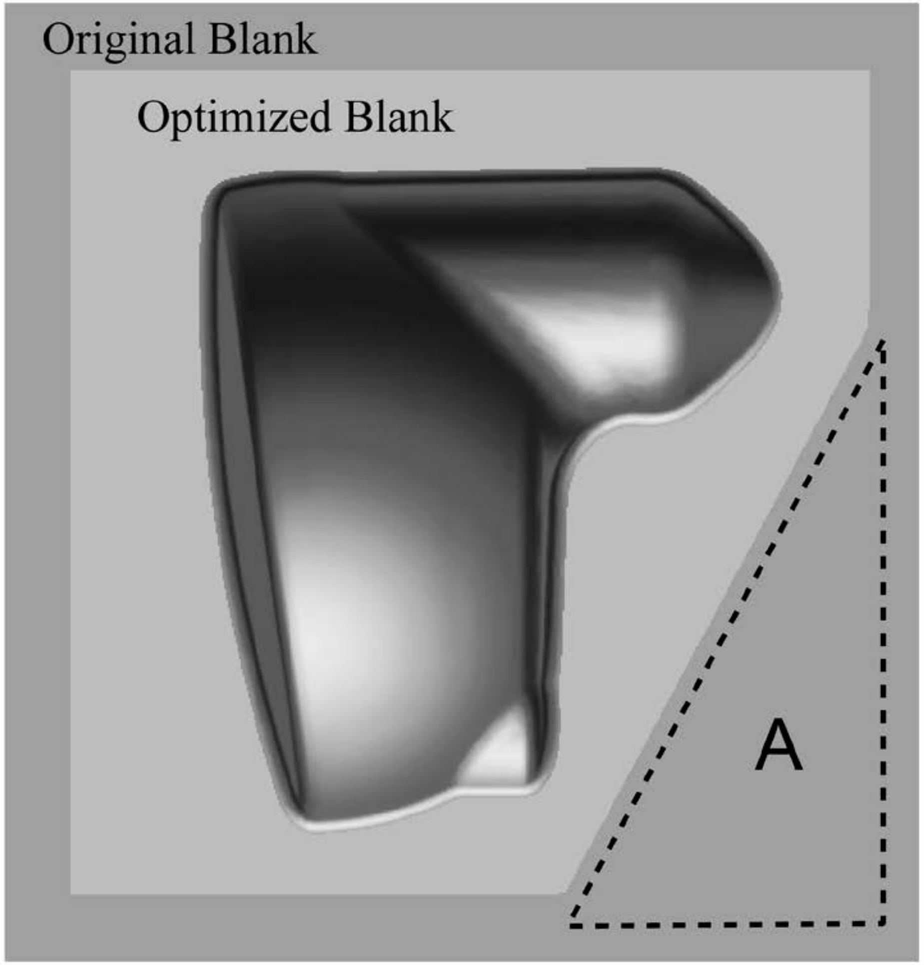
Incremental Method

Tooling Validation and Blank Optimization



Incremental Method

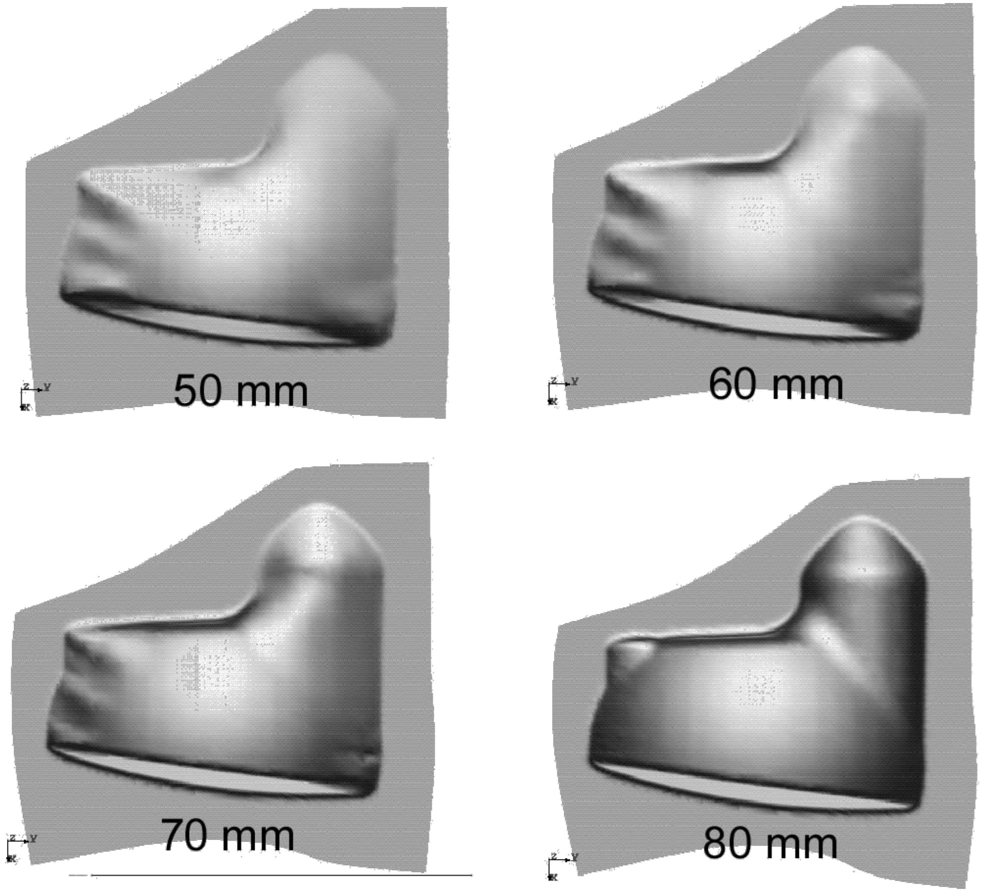
Tooling Validation and Blank Optimization



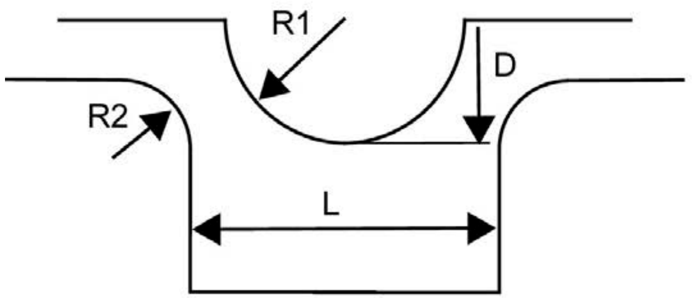
Incremental Method

Tooling Validation and Blank Optimization

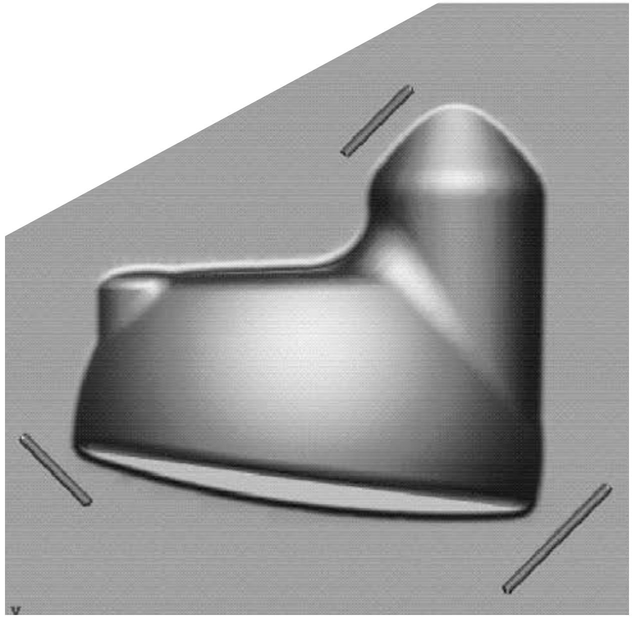
Blank Optimization Study



Draw Bead Layout



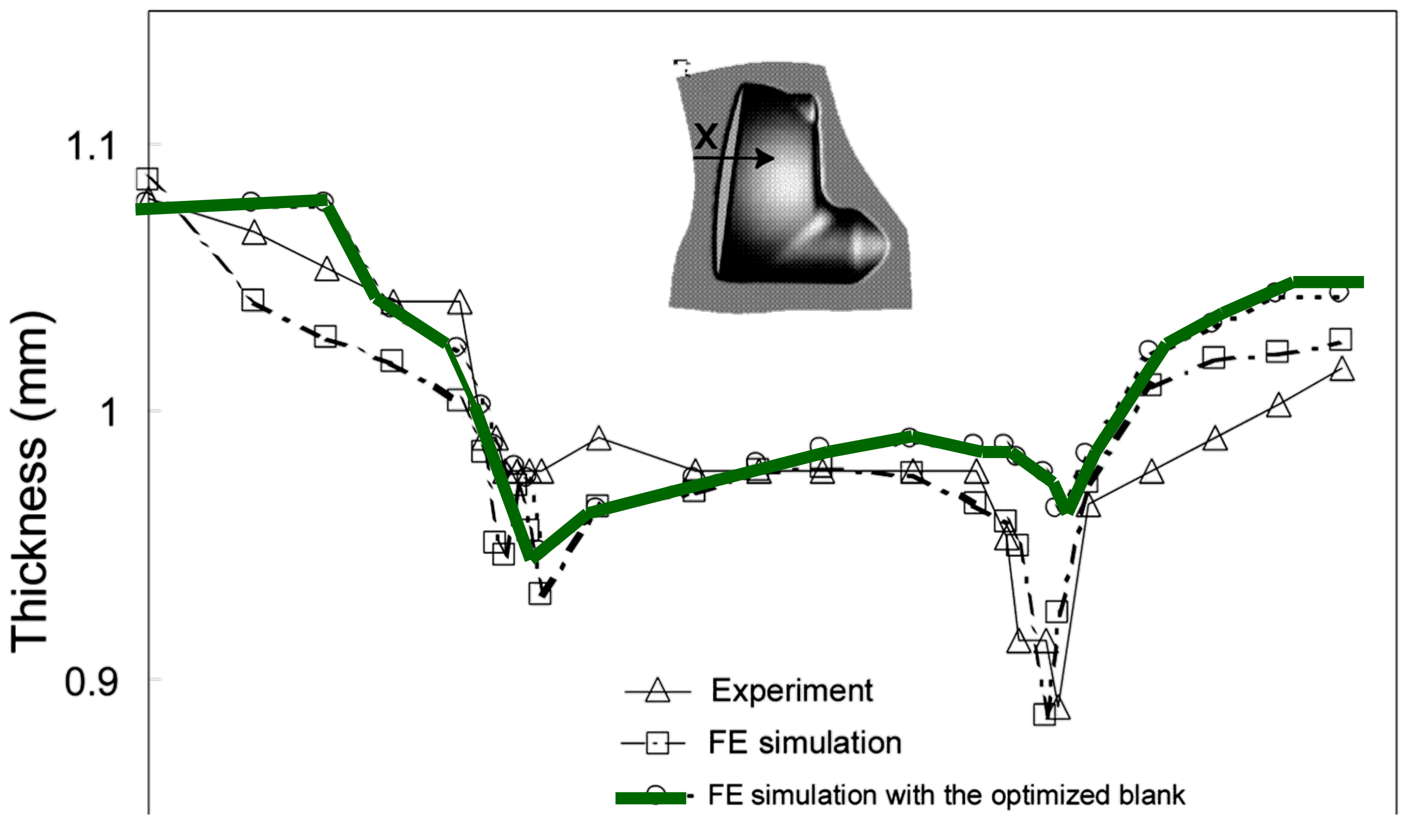
R1 = 5.0 mm
R2 = 2.5 mm
L = 10.0 mm
D = 4.0 mm



Incremental Method

Tooling Validation and Blank Optimization

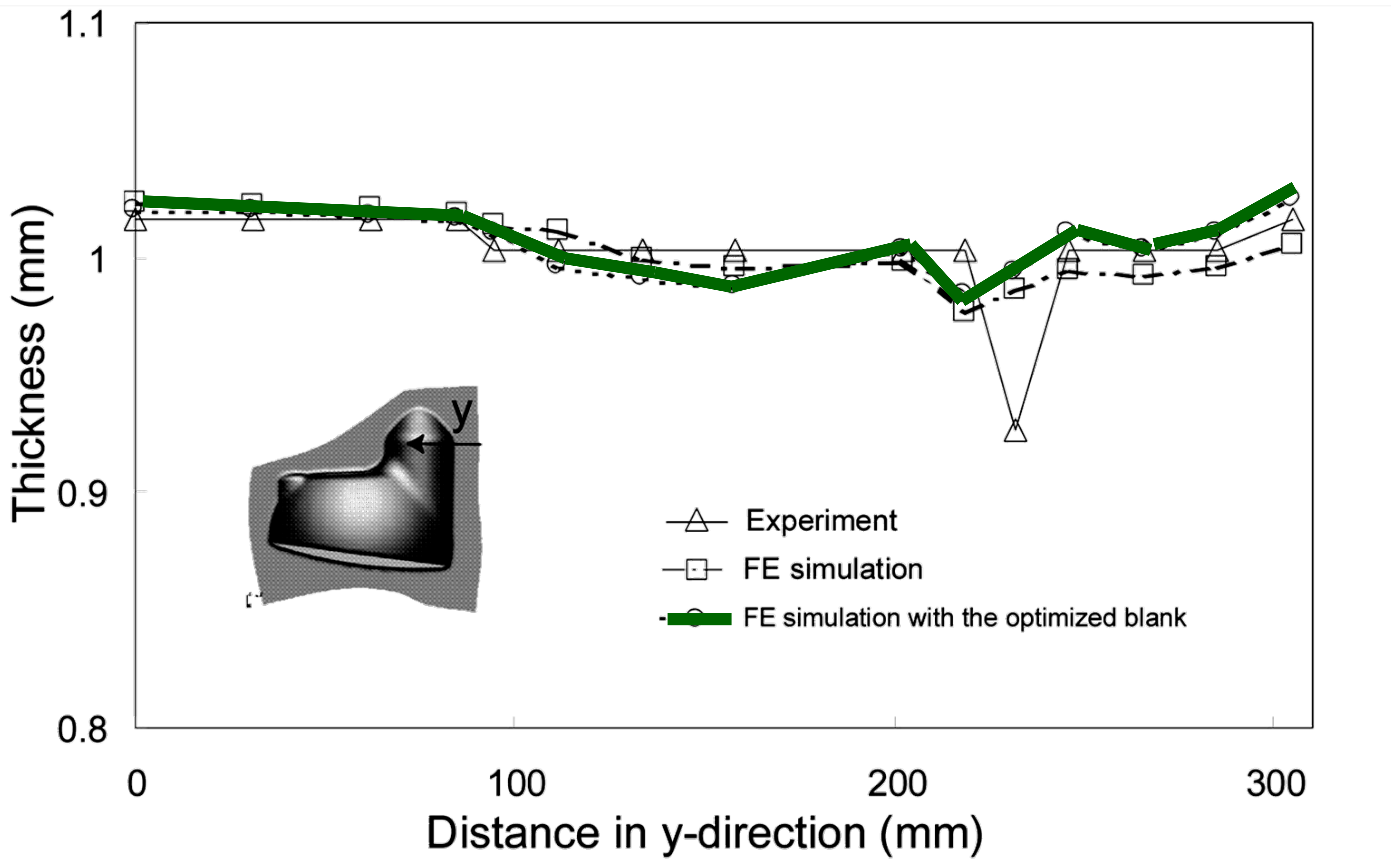
Blank Optimization Study



Incremental Method

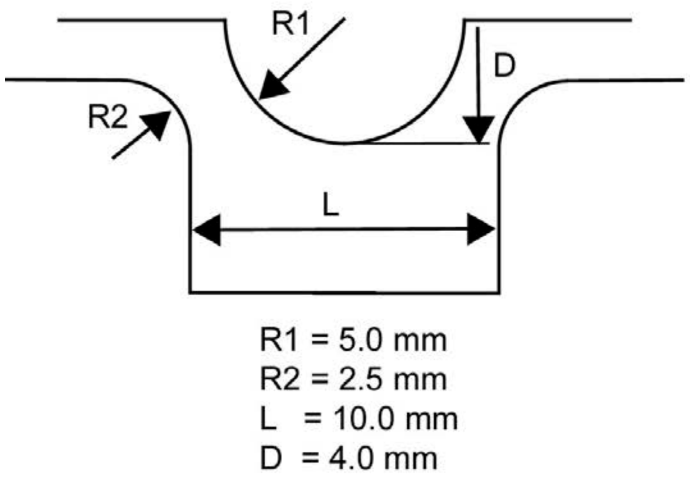
Tooling Validation and Blank Optimization

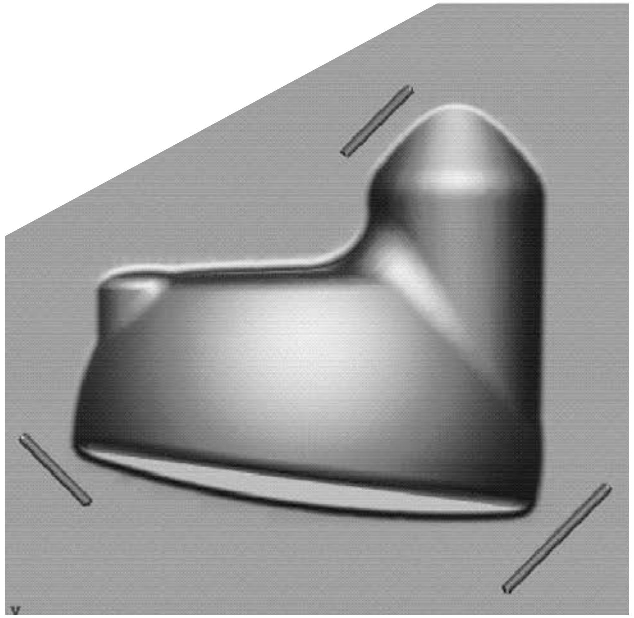
Blank Optimization Study



Incremental Method
Tooling Validation and Blank Optimization

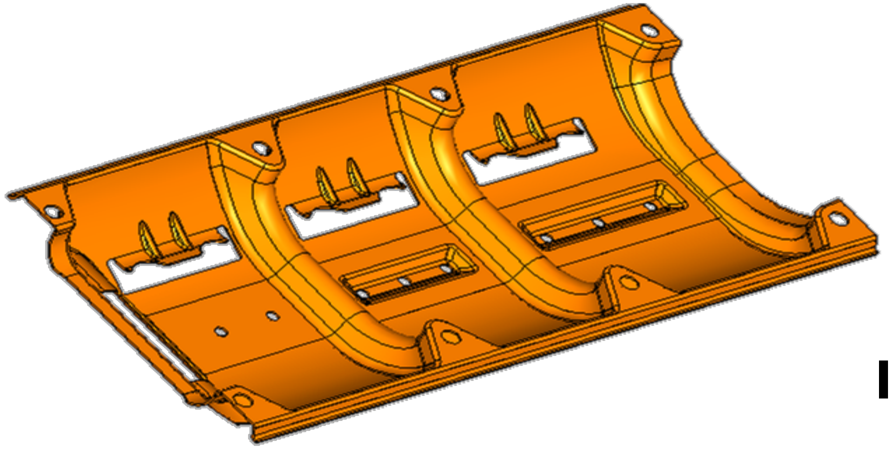
Draw Bead Profile





Case Study #2

Material Gainer Geometry and Placement



Internal Engine Component

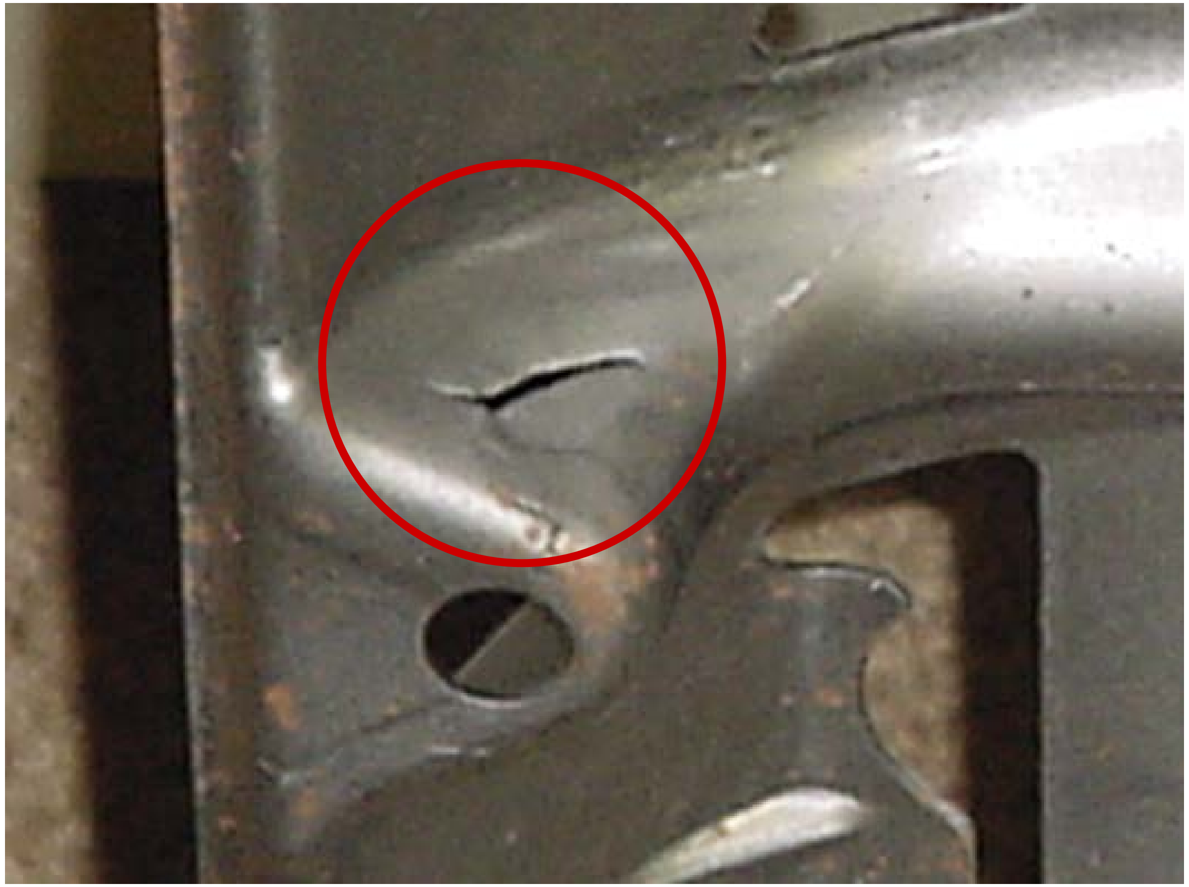
Substrate Material: AISI 1006 AKDQ
Material Thickness: 1.0 mm (0.0397”)

Surface Coating: none

Material Strength: 30 ksi yield / 47 ksi tensile

Case Study #2

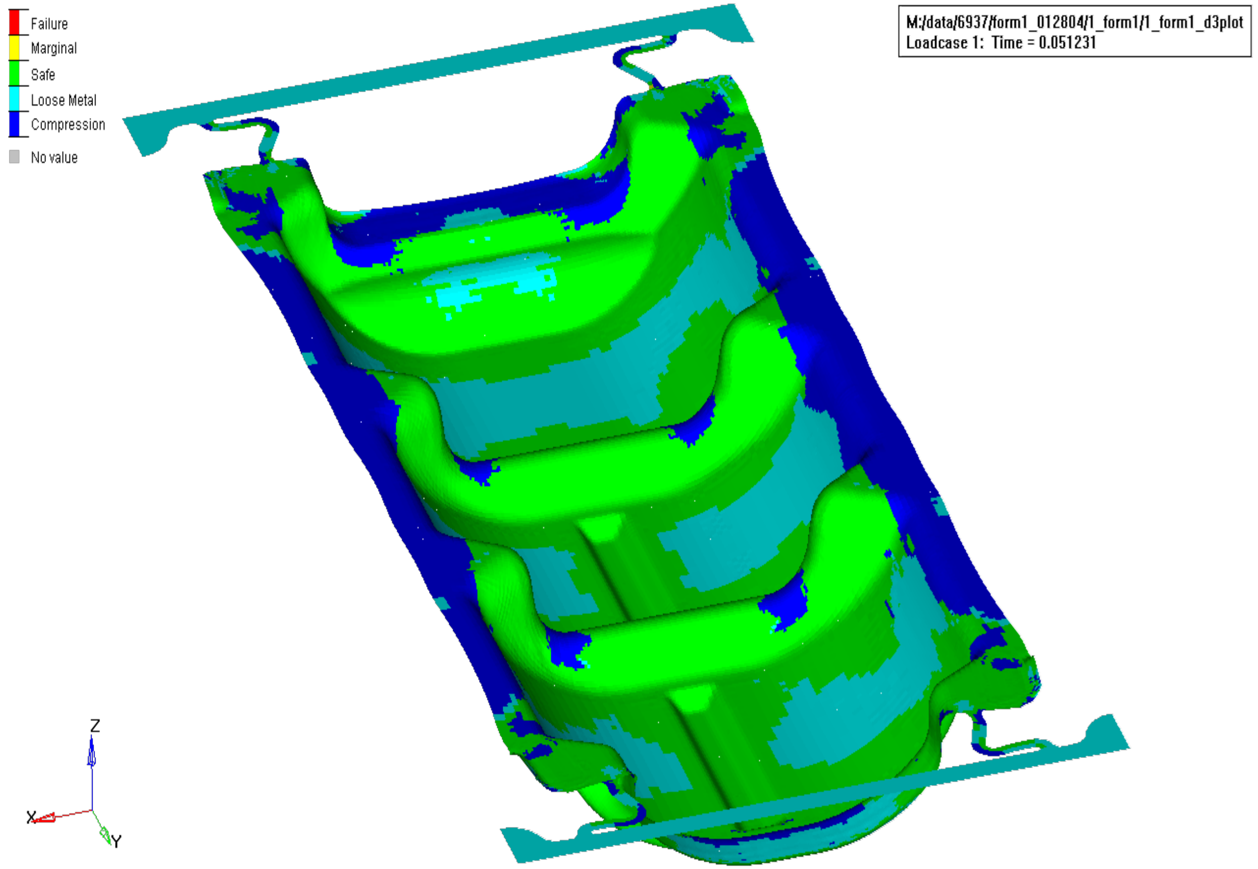
Material Gainer Geometry and Placement



Material 1006 AKDQ

Case Study #2

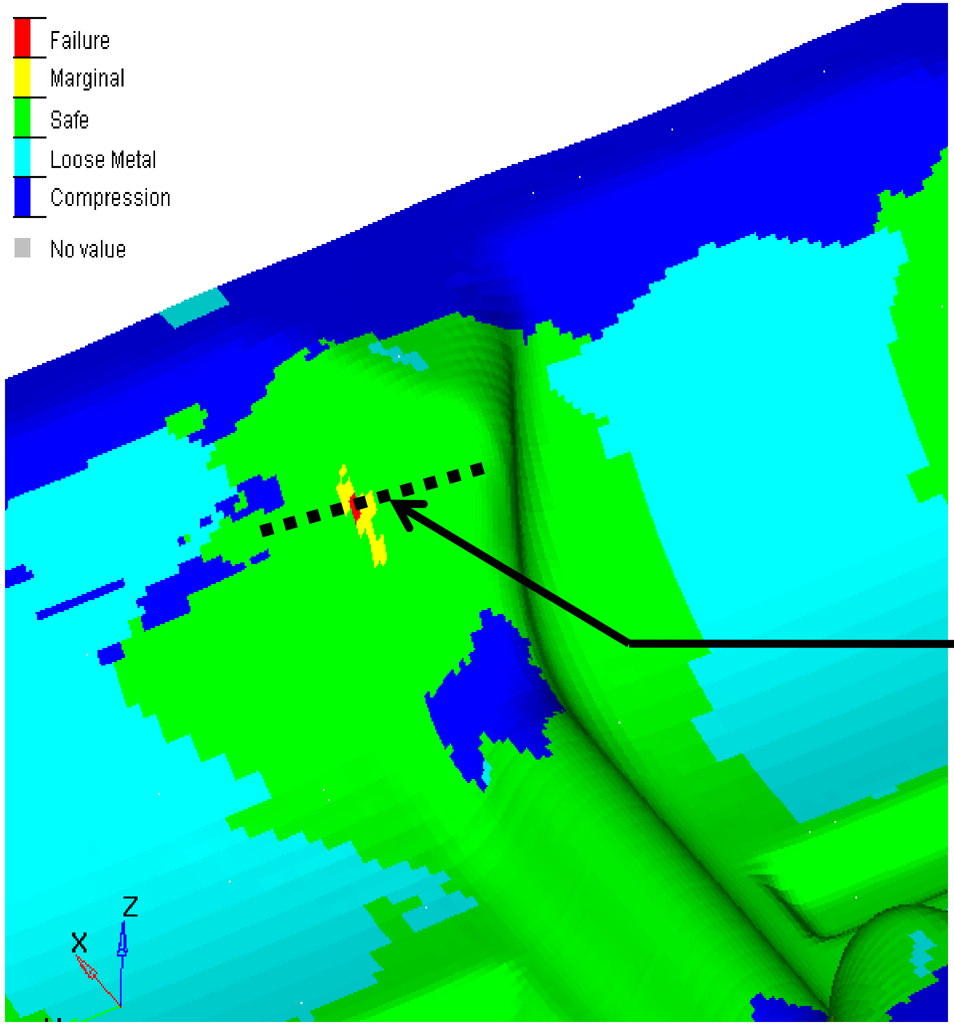
Material Gainer Geometry and Placement



Results for 1006 VD-IF material (no sim prior to tool build)

Case Study #2

Material Gainer Geometry and Placement

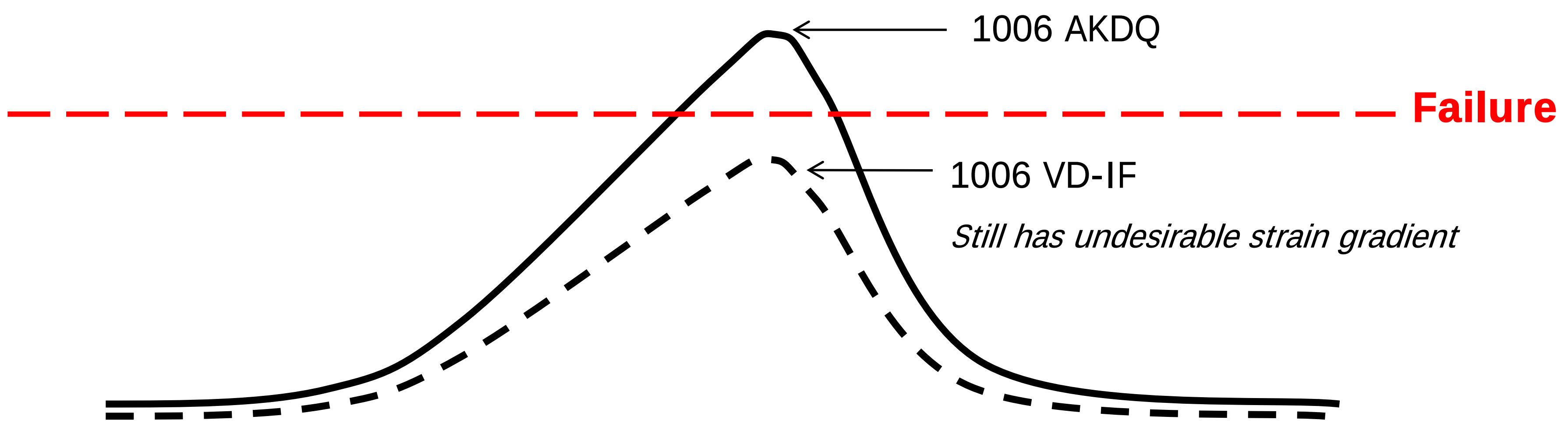


Material
1006 AKDQ

MEASUREMENT for STRAIN GRADIENTS

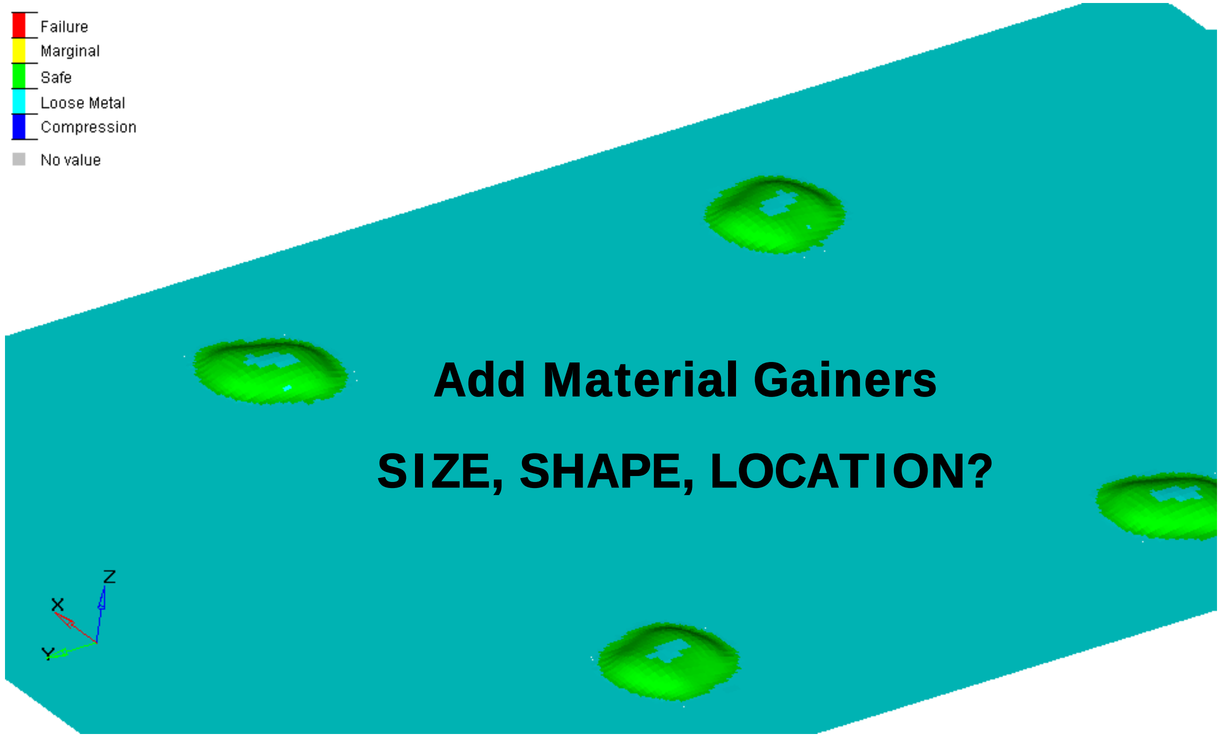
Case Study #2

Material Gainer Geometry and Placement



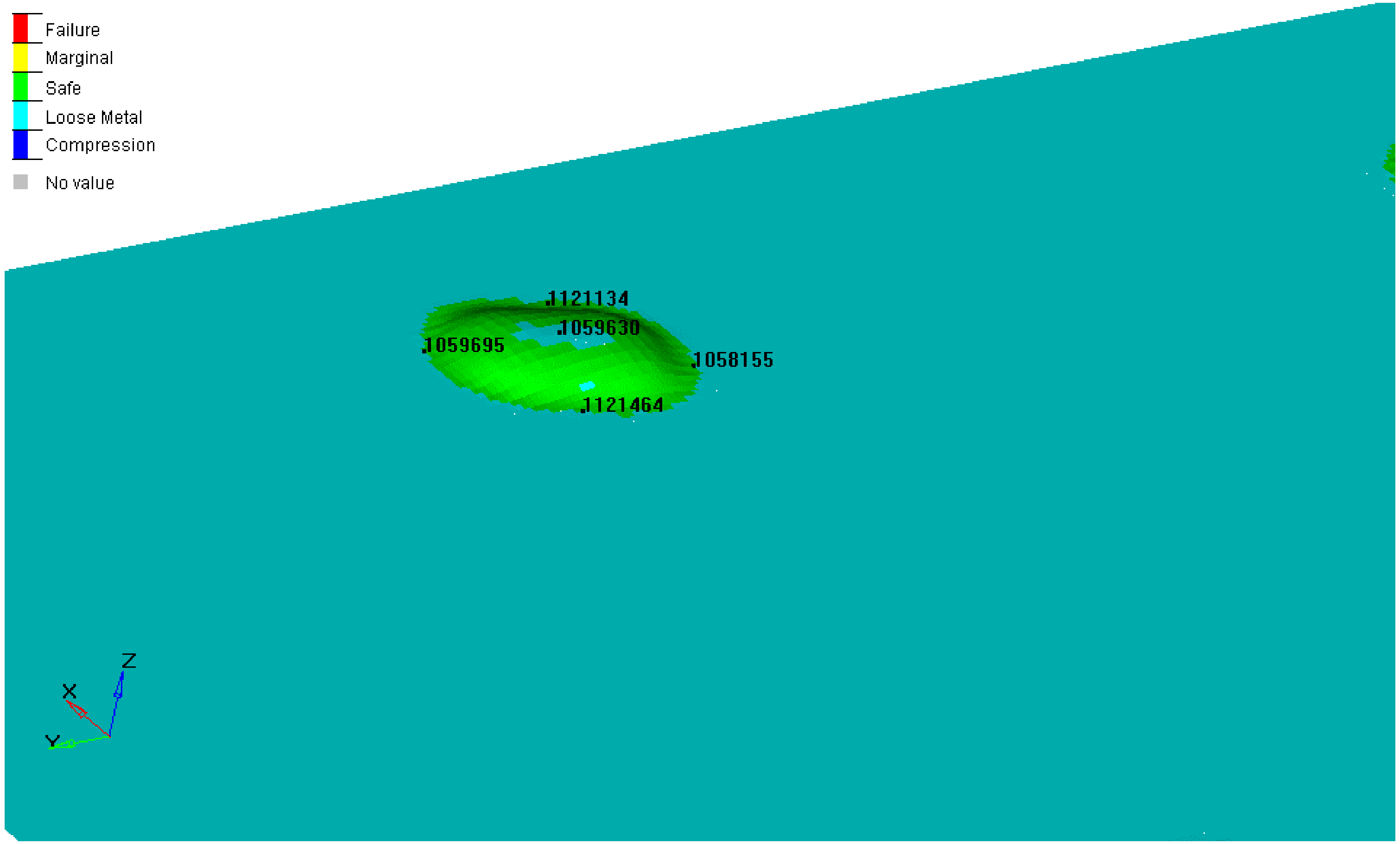
Case Study #2

Material Gainer Geometry and Placement



Case Study #2

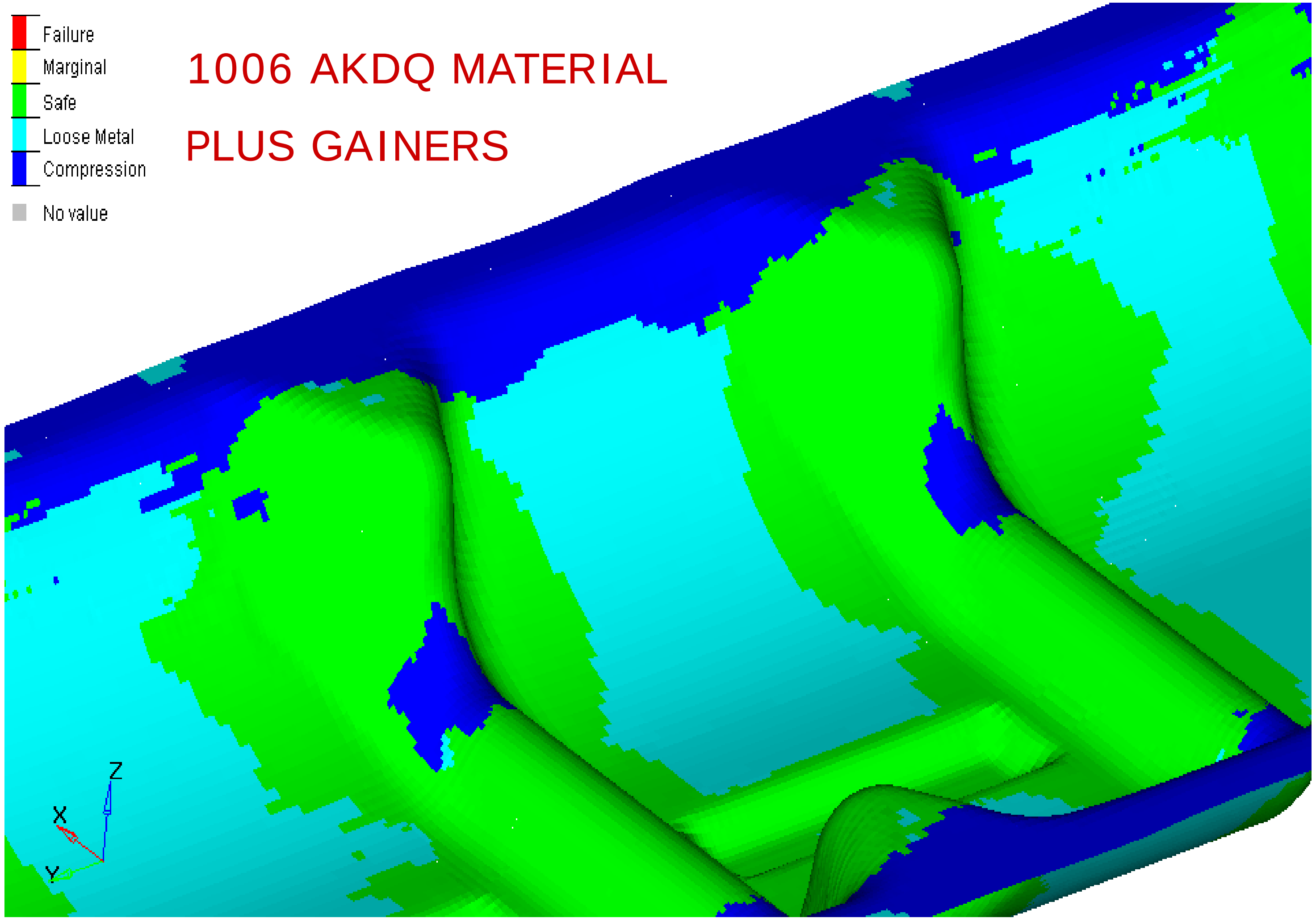
Material Gainer Geometry and Placement



video

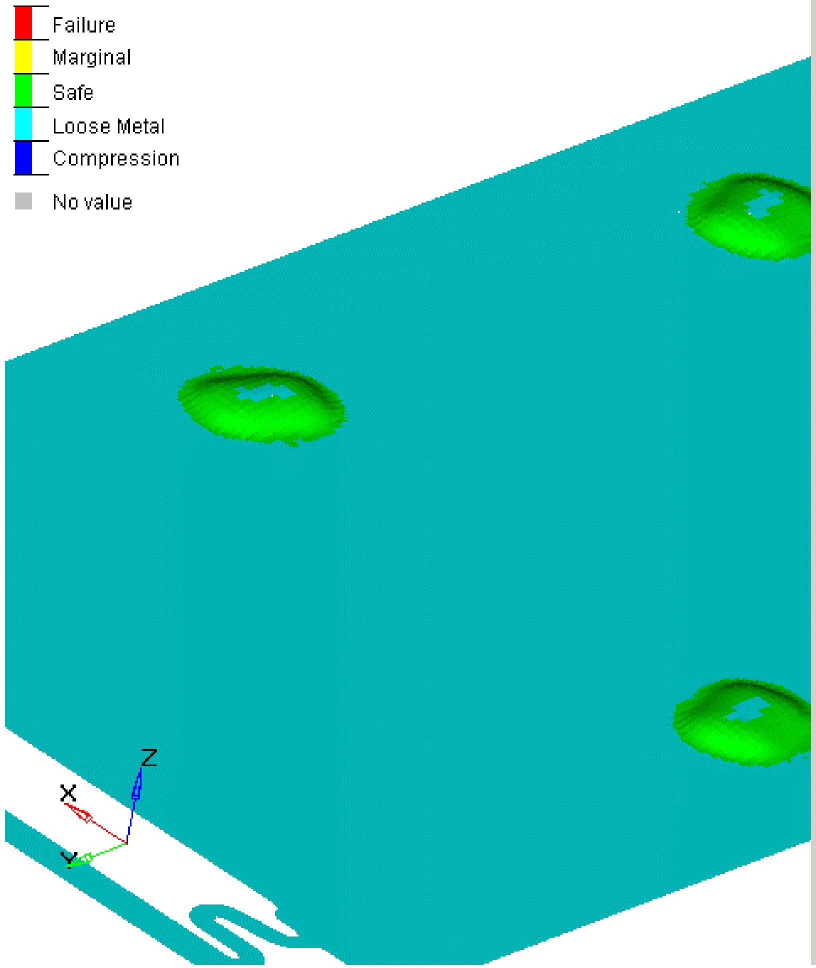
Case Study #2

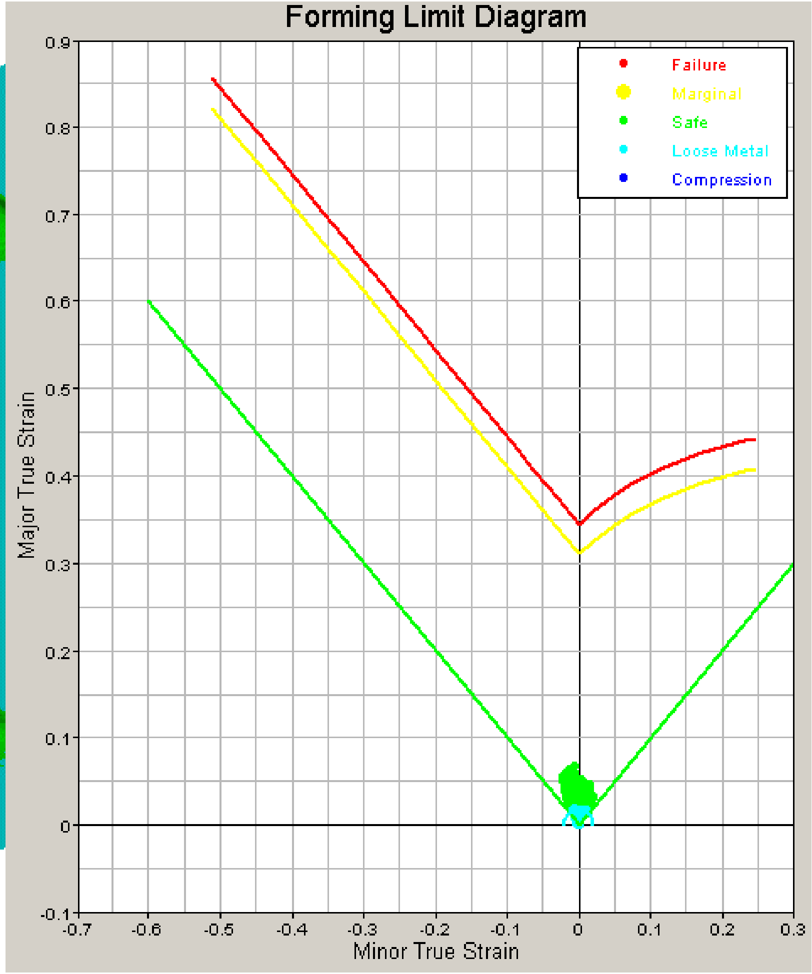
Material Gainer Geometry and Placement



Case Study #2

Material Gainer Geometry and Placement

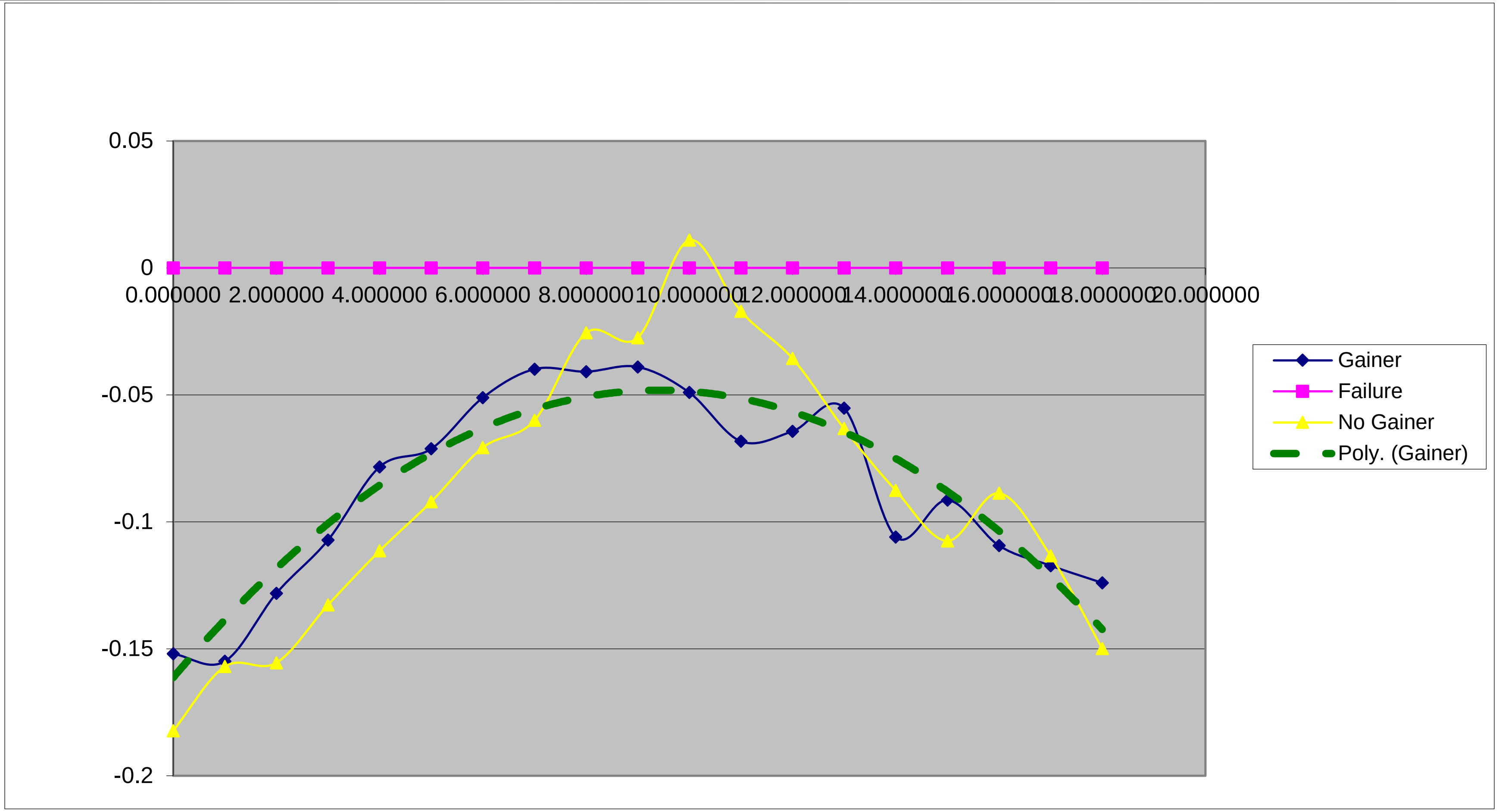




video

Case Study #2

Material Gainer Geometry and Placement



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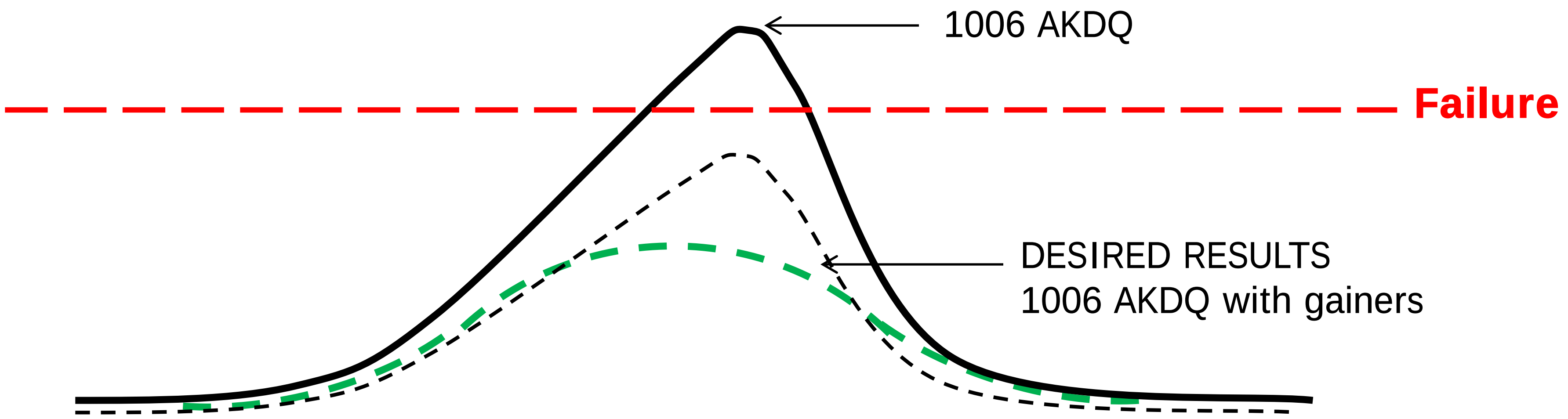
Material Gainer Geometry and Placement



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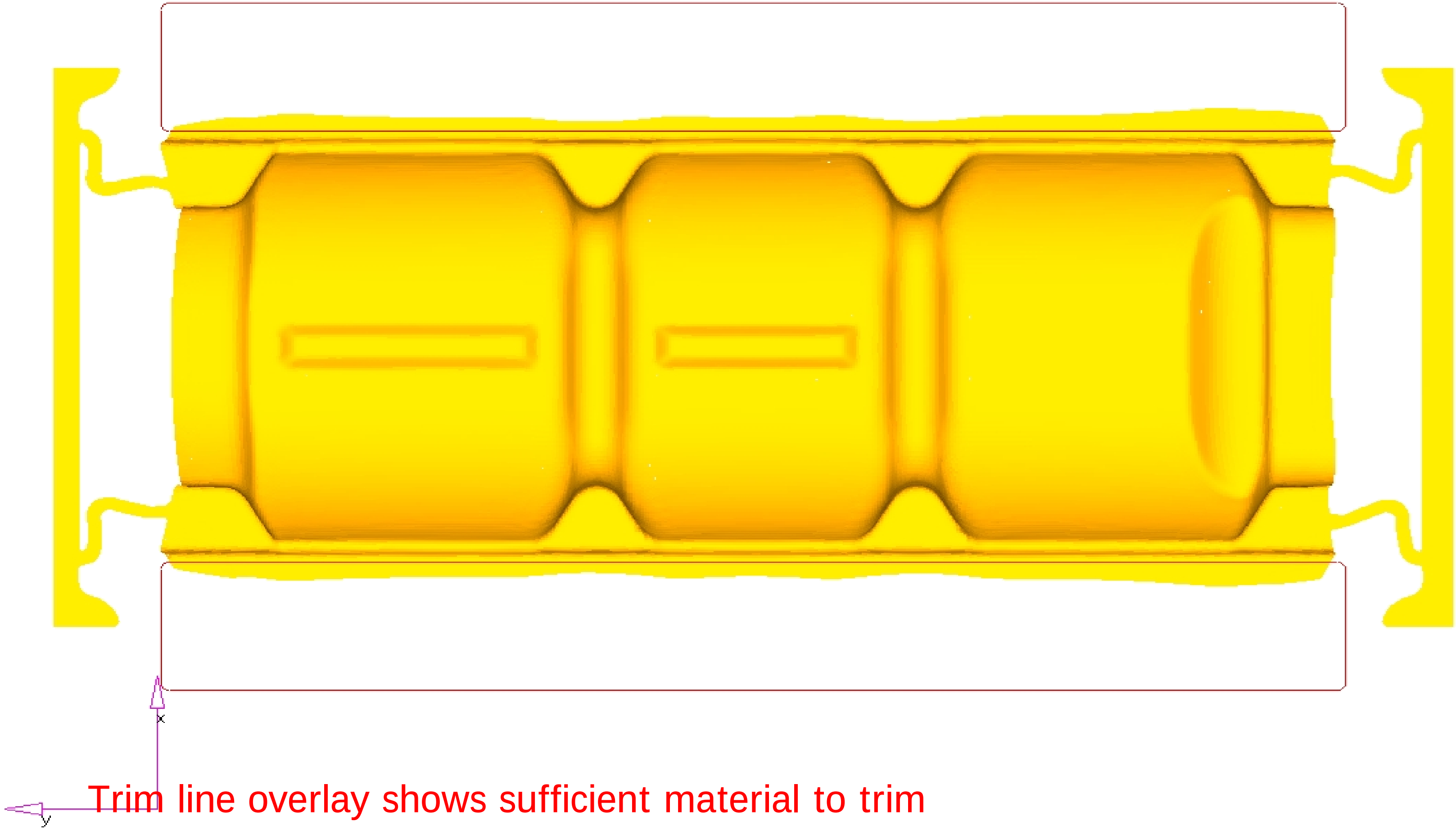
Material Gainer Geometry and Placement



Trim line overlay shows sufficient material to trim