Introduction to Simulation Technology

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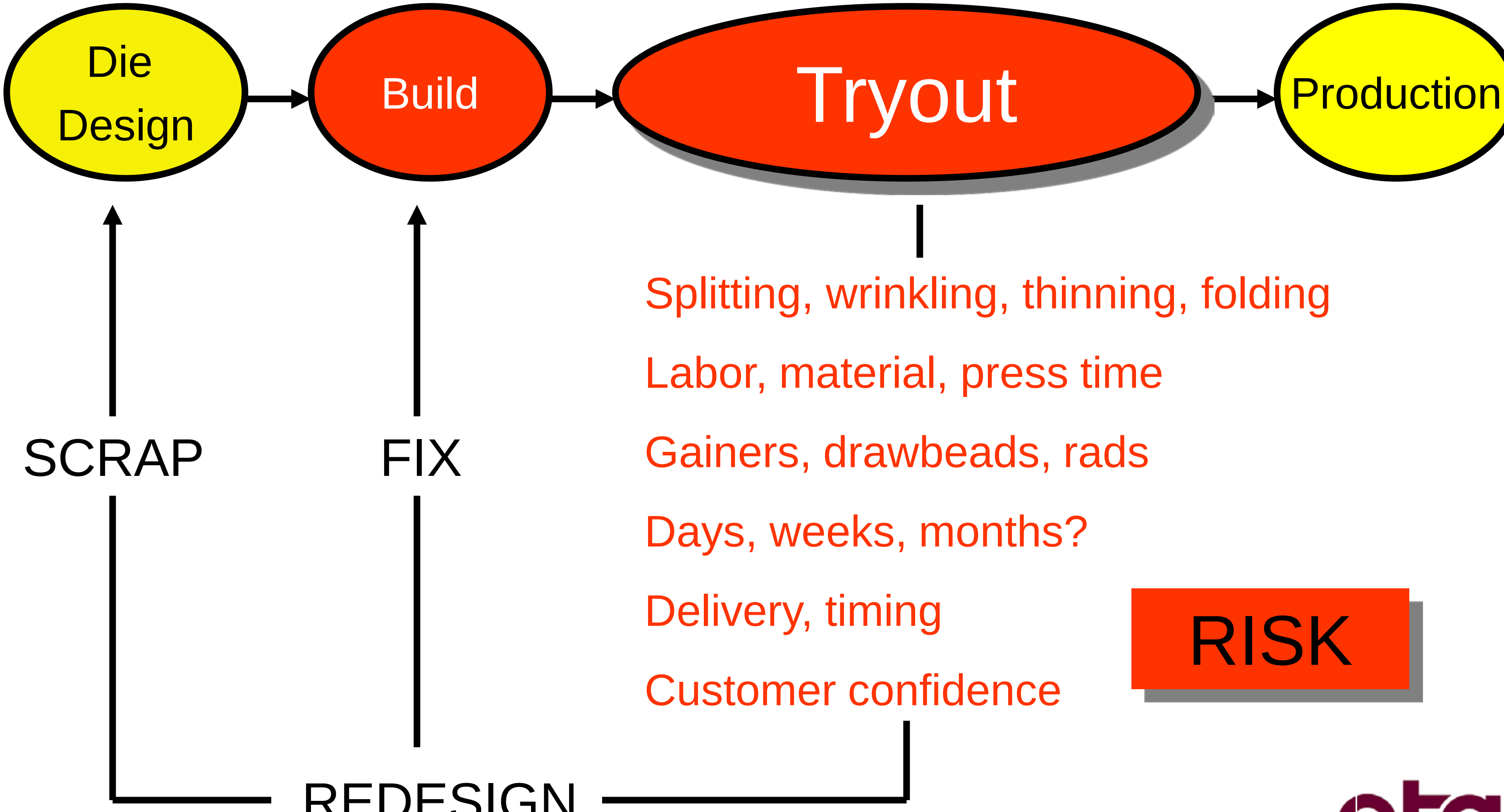
Brief History

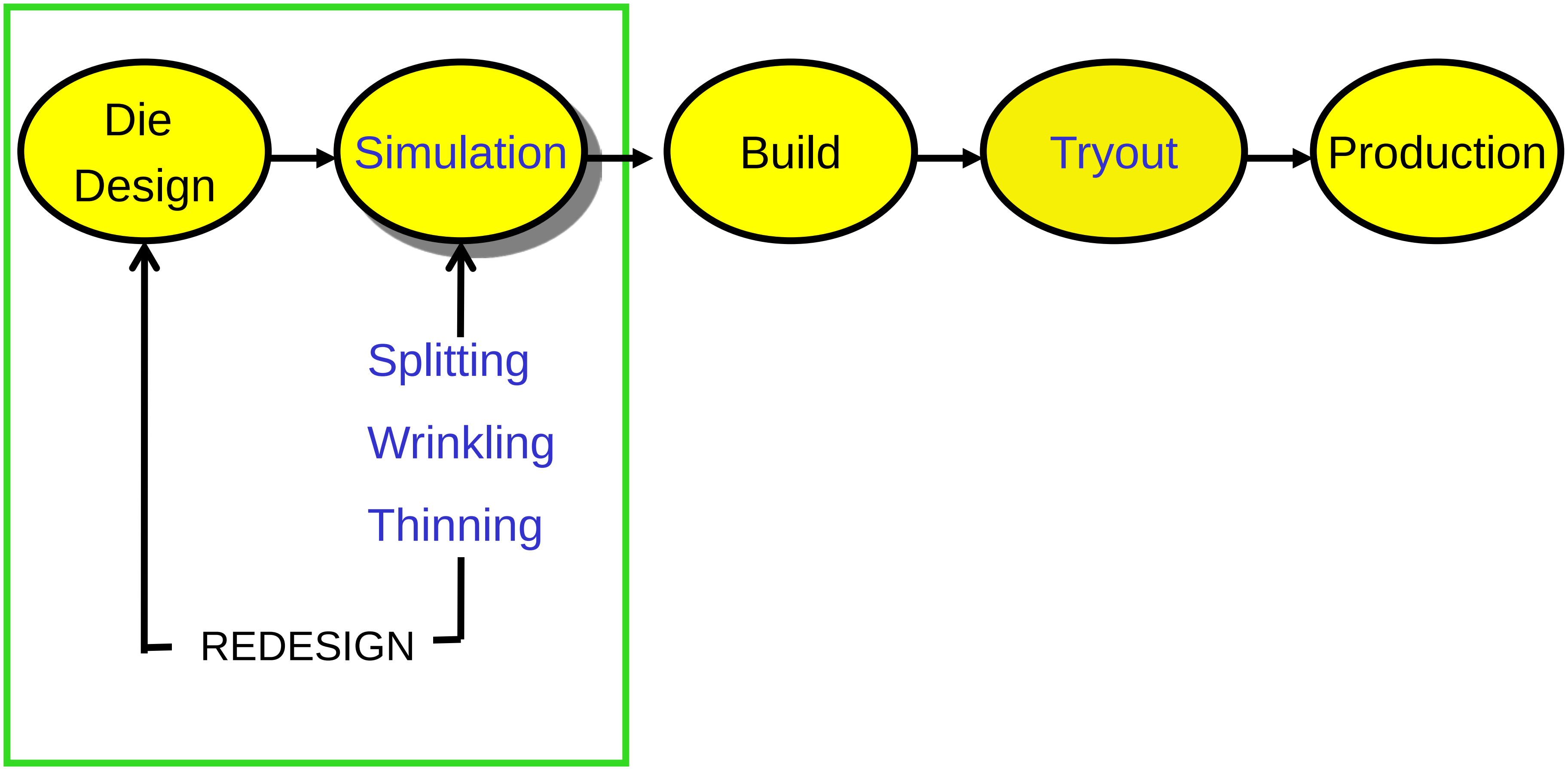
Simulation Technology is being developed with the development of the computer technology

- Mid 80's, being used by the R & D centers
- Mid 90's, being used by large OEM and steel companies
- Late 90's, being used by Tool and Die companies

Tooling Design Process



Tooling Design Process with Simulation



FEA Benefits

- Finite Element Analysis code
  - Benefits
    - Extremely accurate simulation tool
    - Predicts formability problems before tooling takes place
    - Reduced costs
      - Time
      - Labor
      - Material

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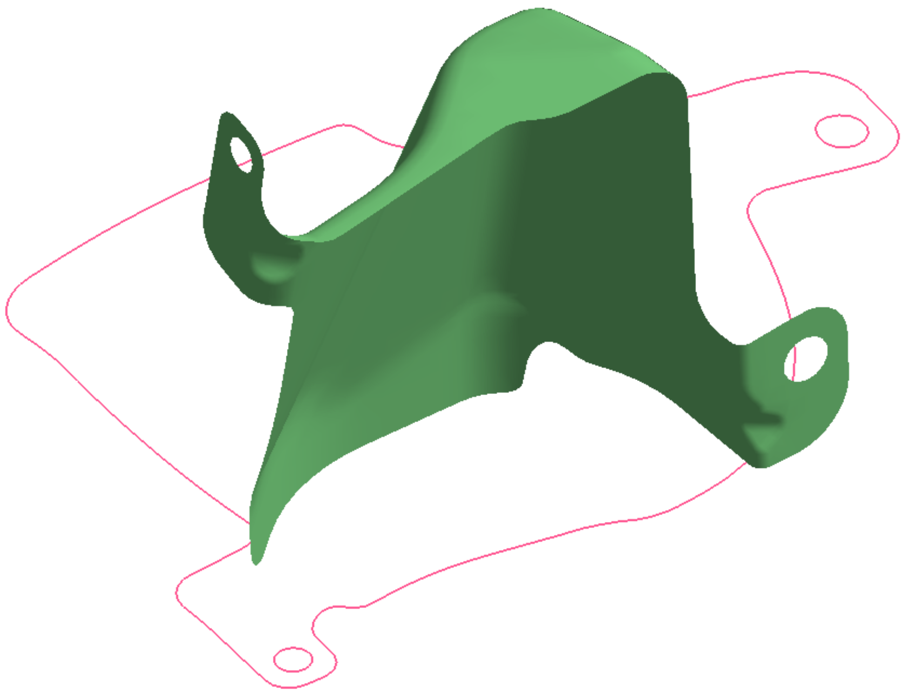
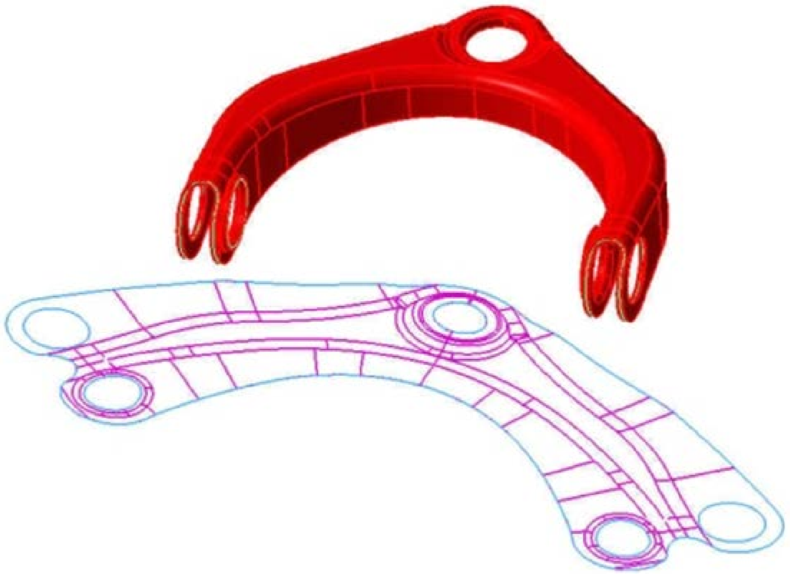
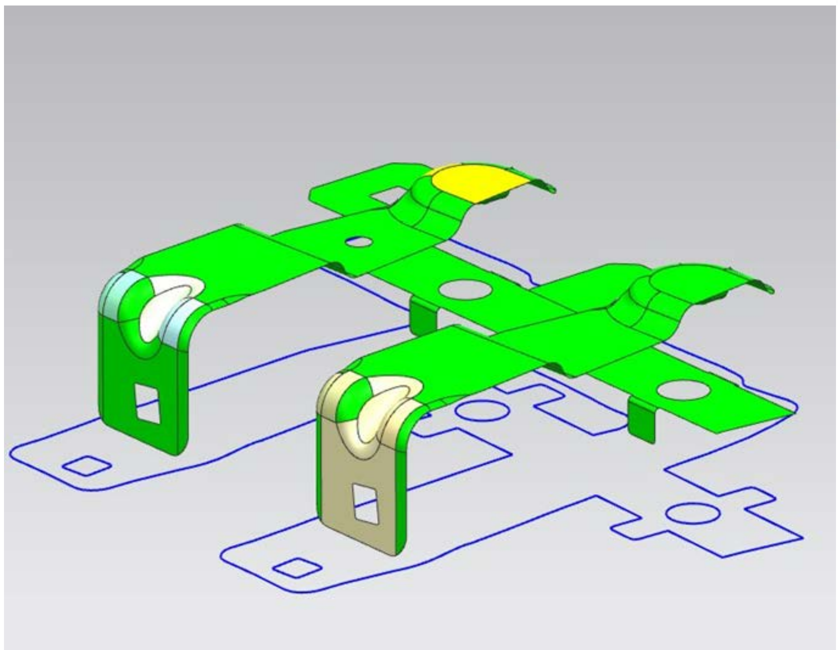
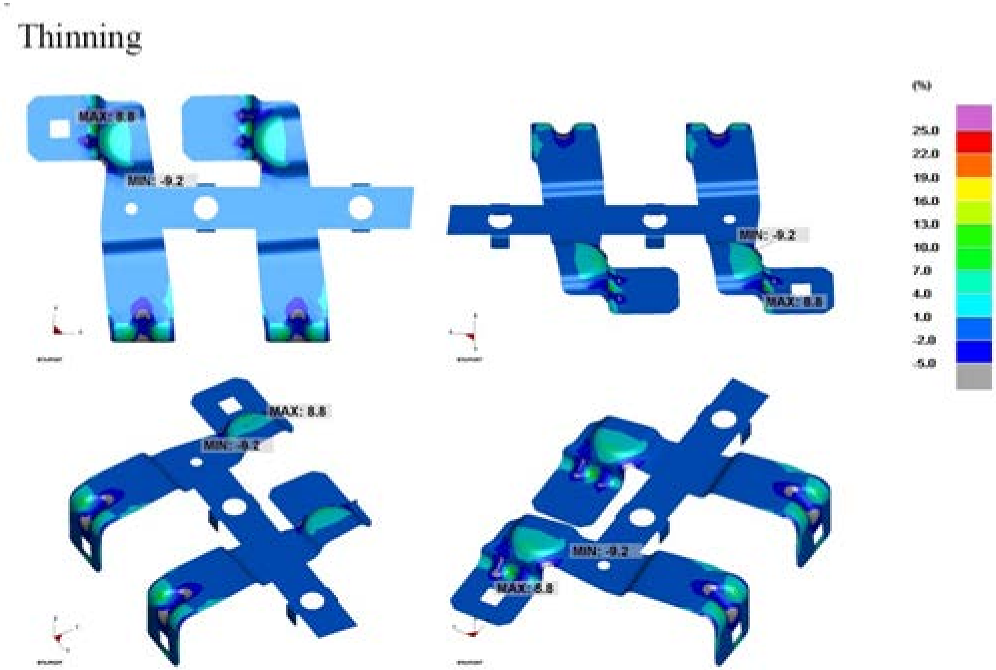
One-step Analysis





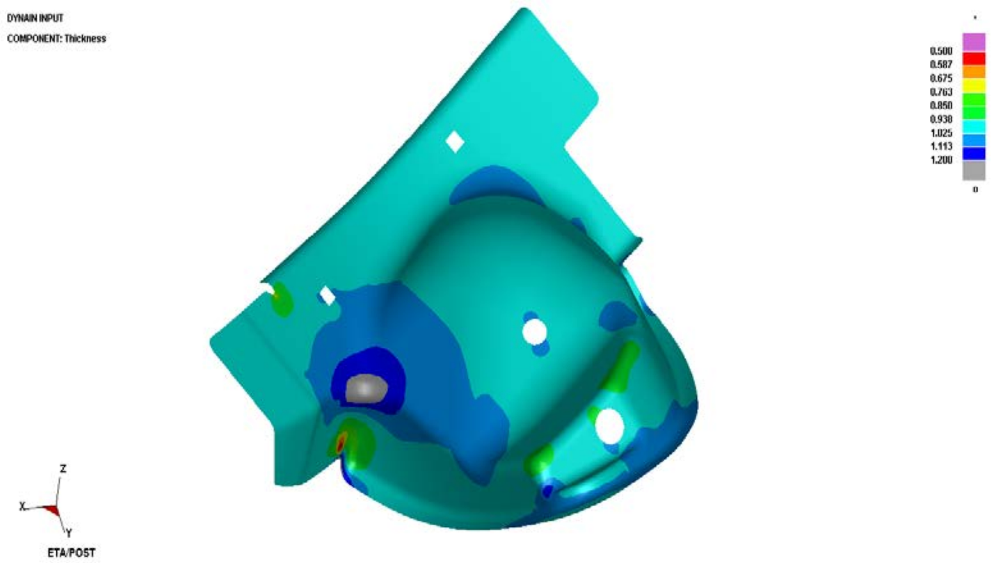
One-step Analysis





One-step Analysis

One-step analysis is based on Energy Conservation rule.



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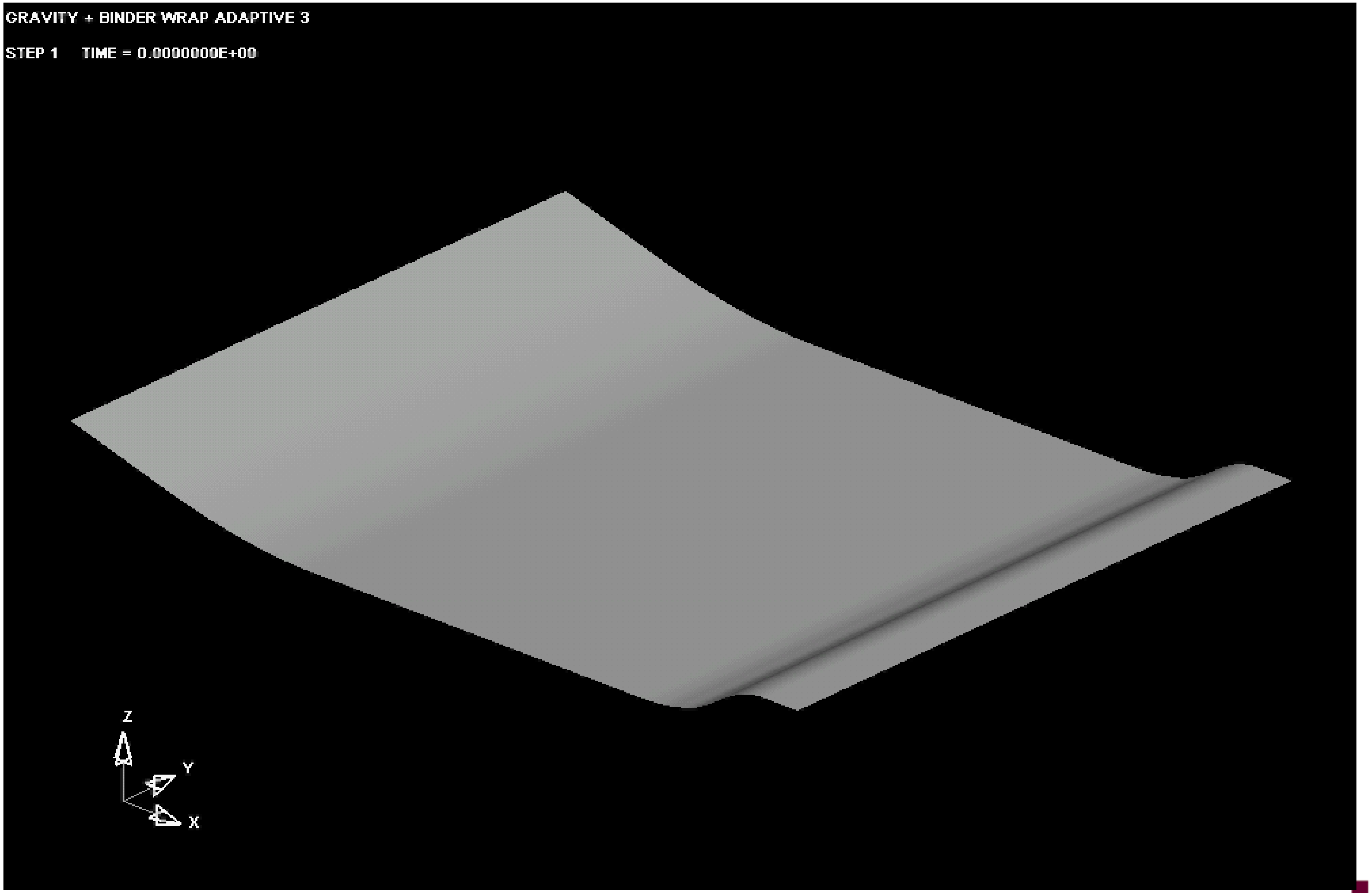
Incremental Analysis



Incremental & One-step Approaches

One-step code versus Incremental code

- One-step code is efficient for product design stage evaluation
  - Based on part design not die design.
  - Fast results, only good for feasibility study purpose.

- Incremental code is effective for the tooling stage evaluation
  -Requires die design to run the simulation.
  -Detailed, accurate and reliable results for tooling design.

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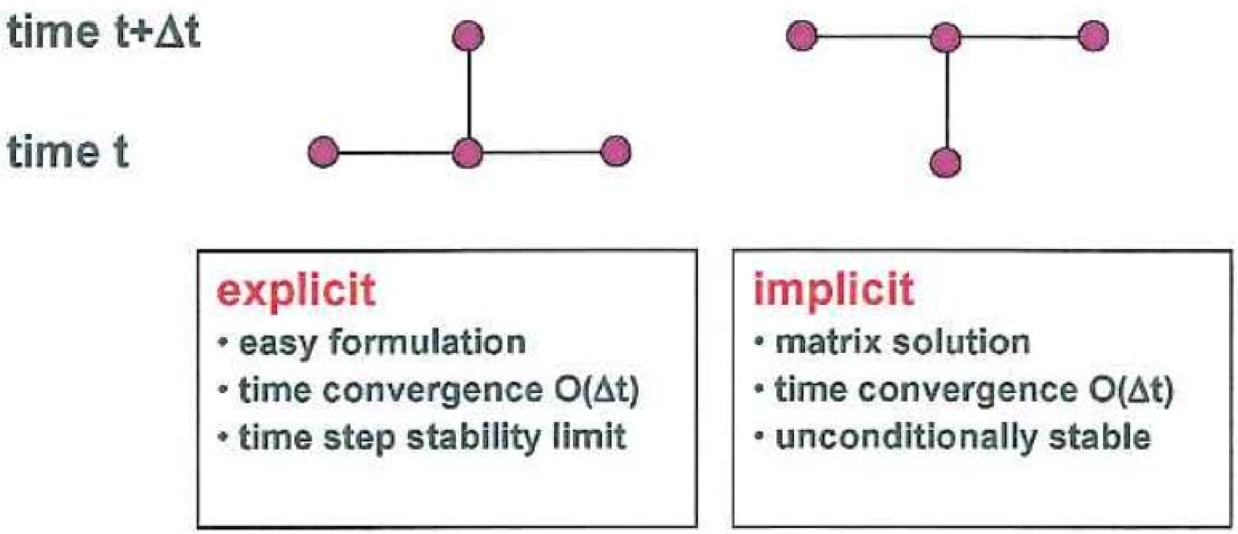
Commonly Asked Questions

- Can simulation help me determine how many toolset do I need to make this part?
- What is the dynamic affect?
- What about the rate effects?
- How accurate is the simulation results?

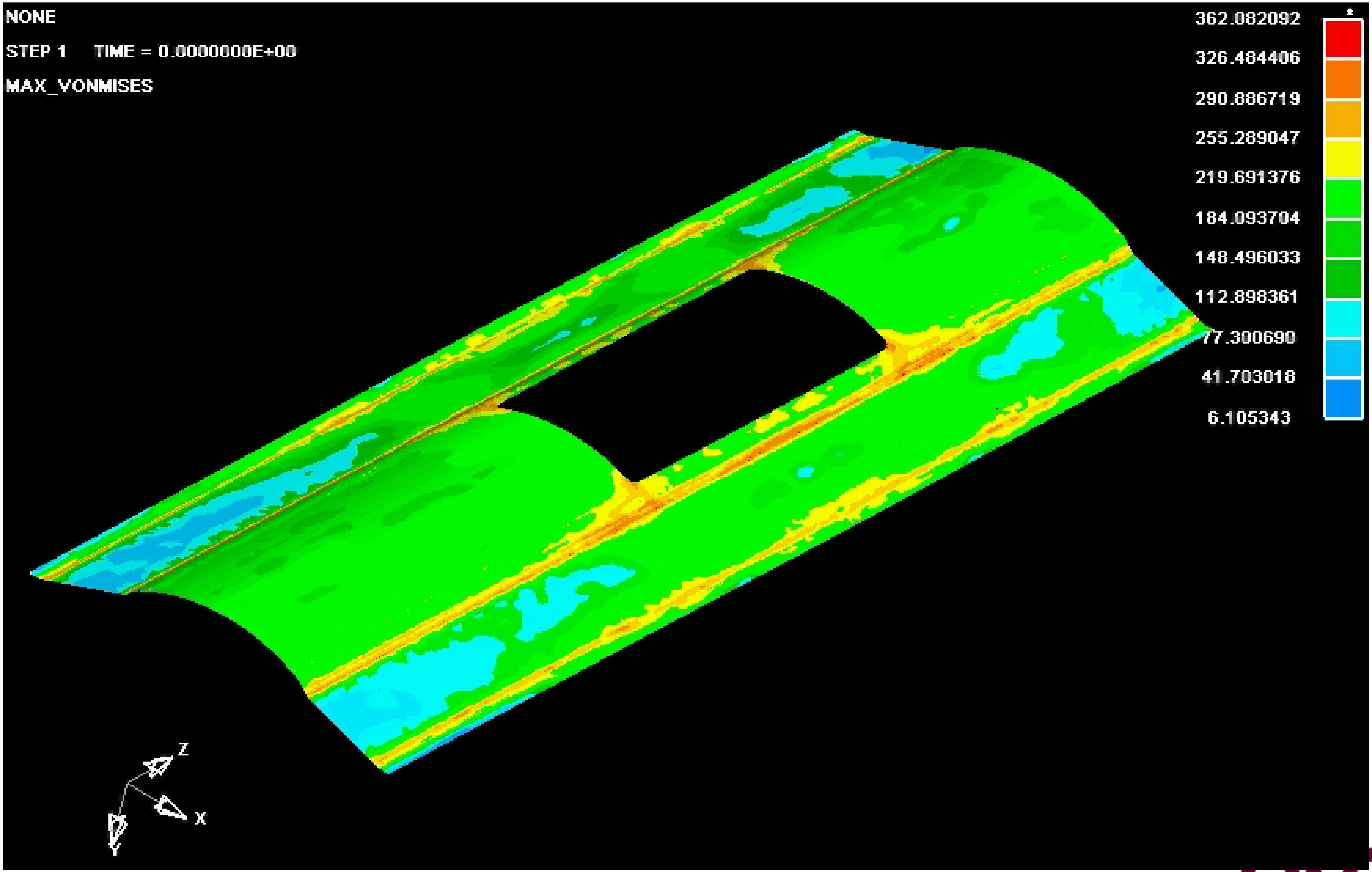
Implicit and Explicit

For incremental analysis, there are two different solving method: Implicit and Explicit

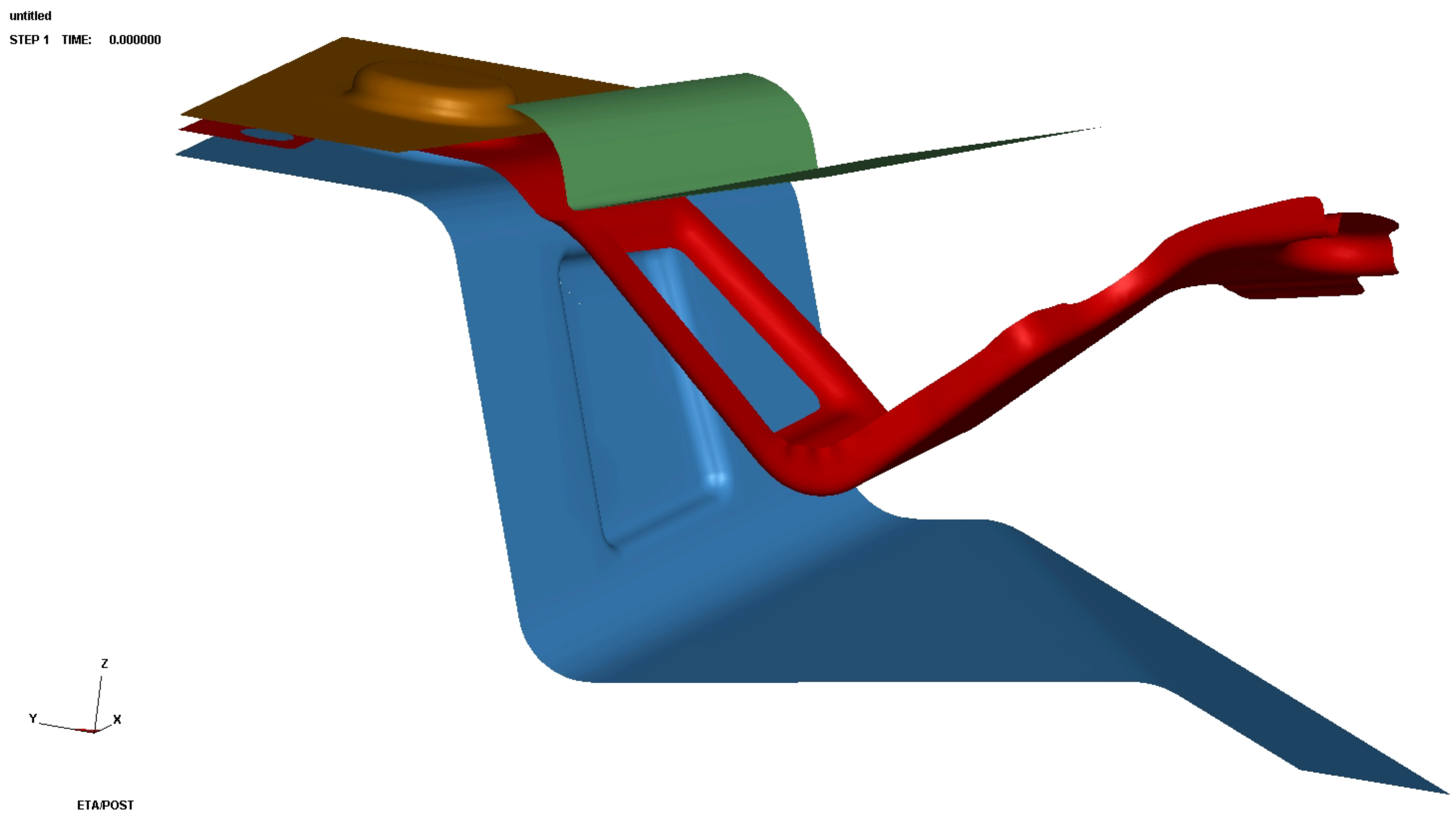


Courtesy to Dr. Shapirio from LSTC

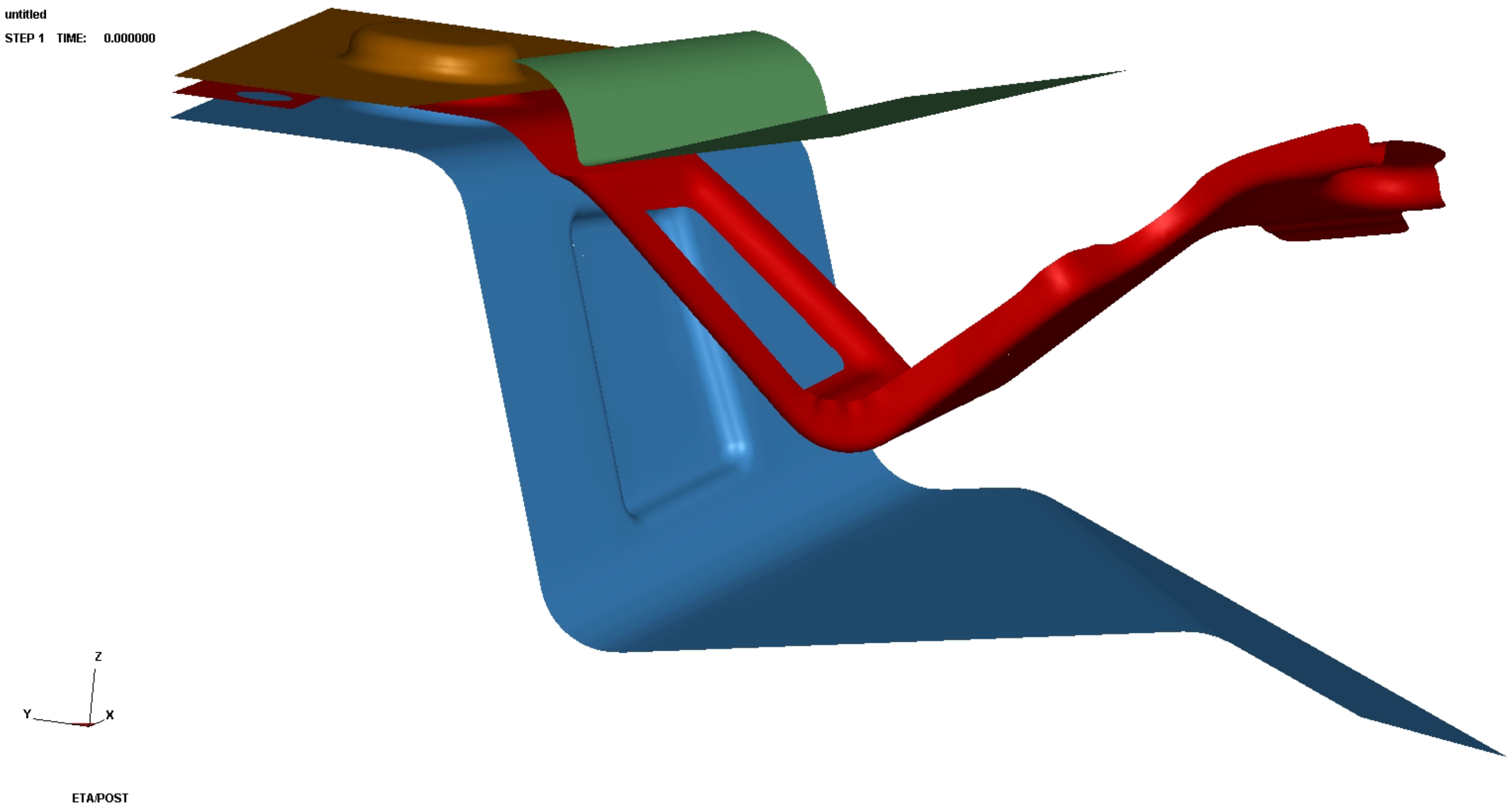
Implicit Method: Springback Prediction



Dynamic effect due to high Inertia



Implicit Analysis



Incremental: Evaluation of Binder Design

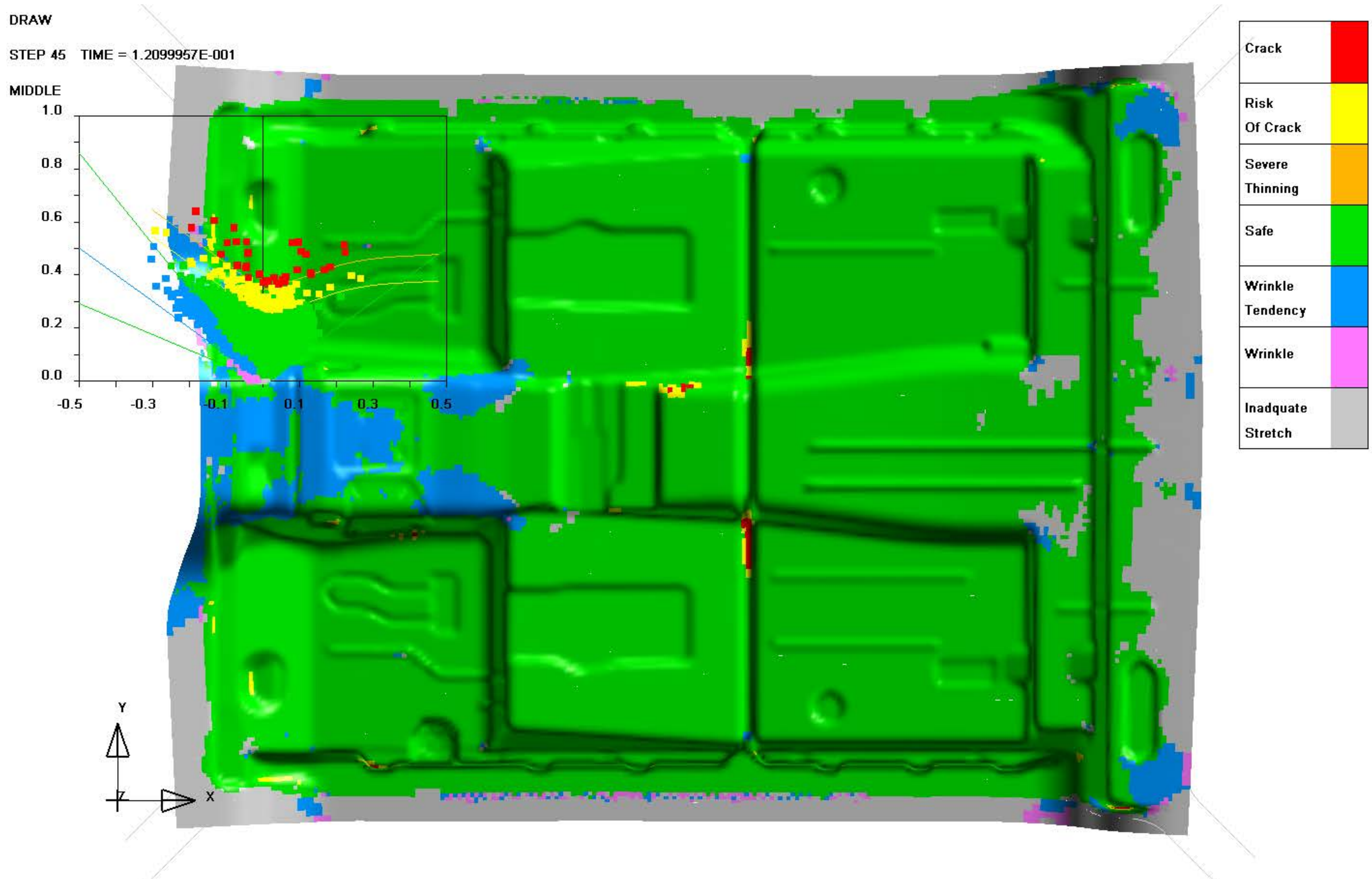
Implicit Preferred

Buckle

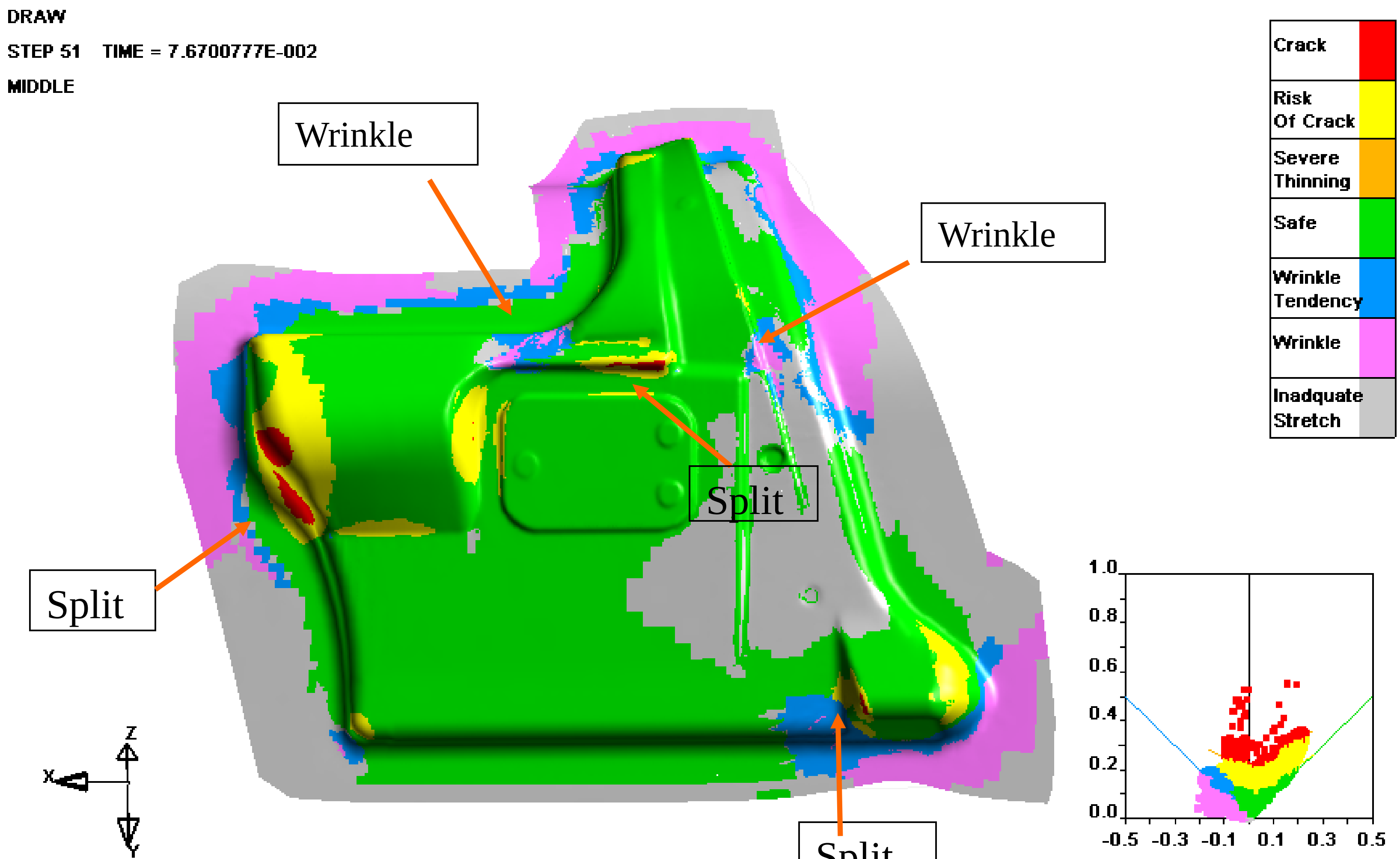
unacceptable wrapped shape

Acceptable wrapped shape

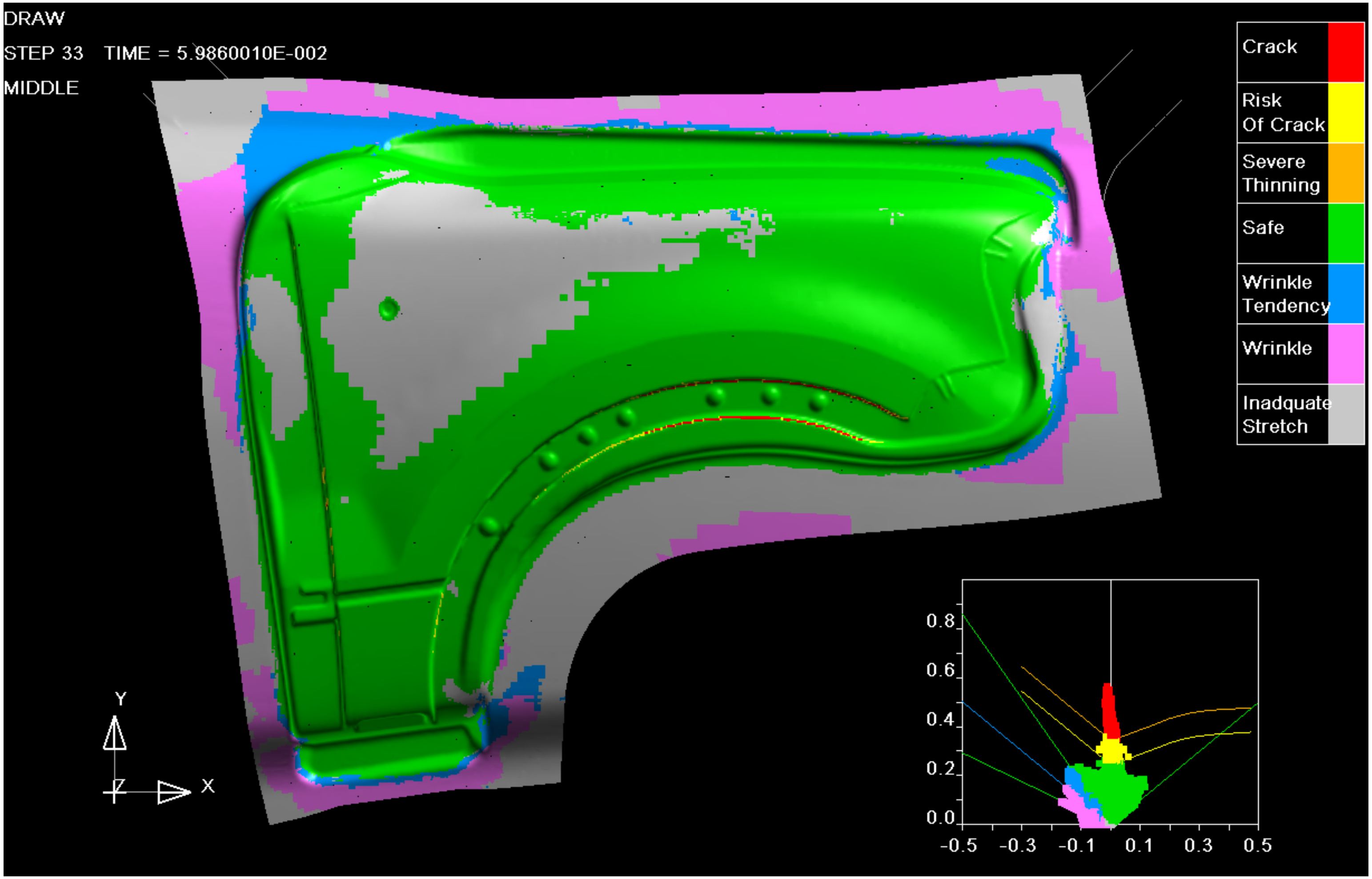
Draw Simulation



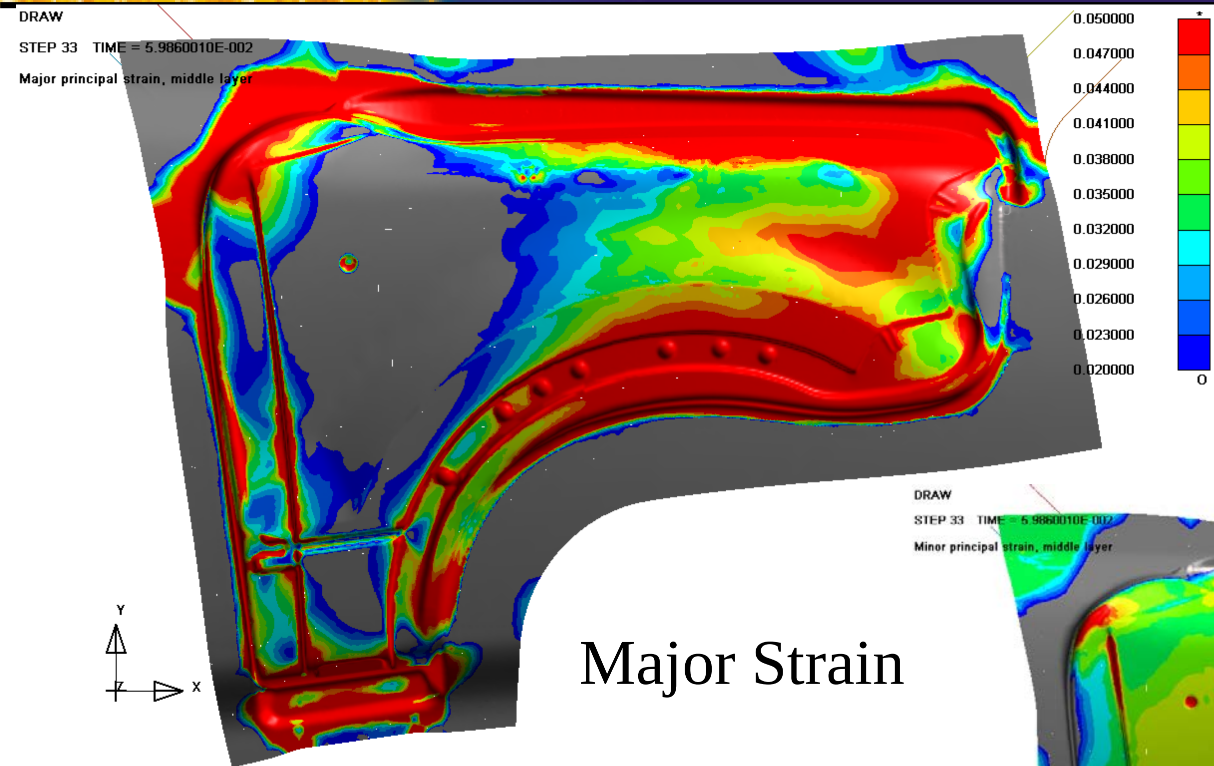
Draw Simulation



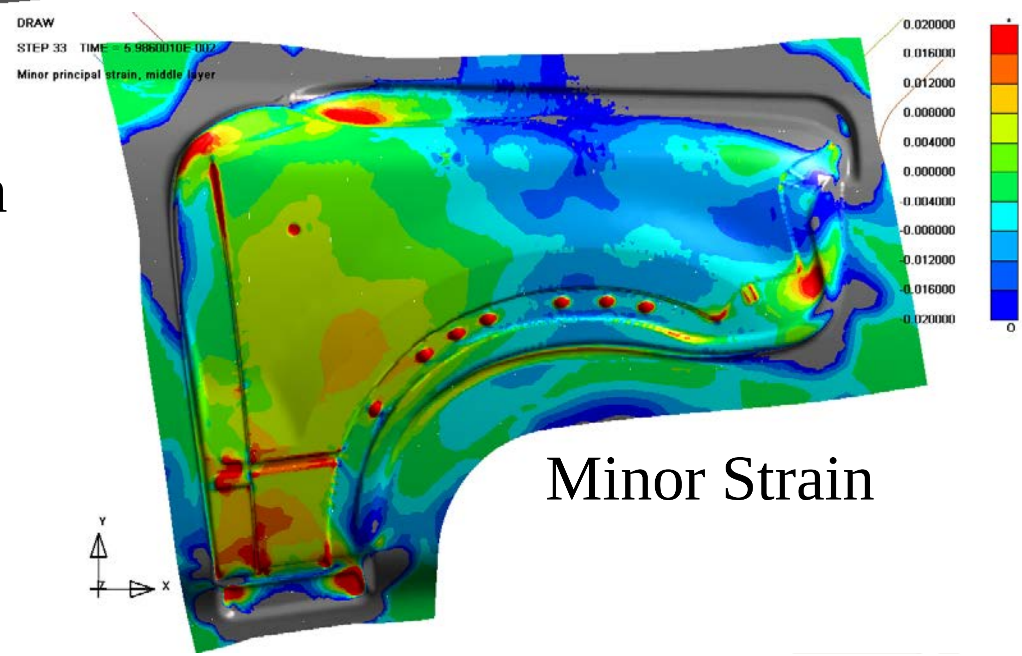
Draw Simulation



Class A Surface

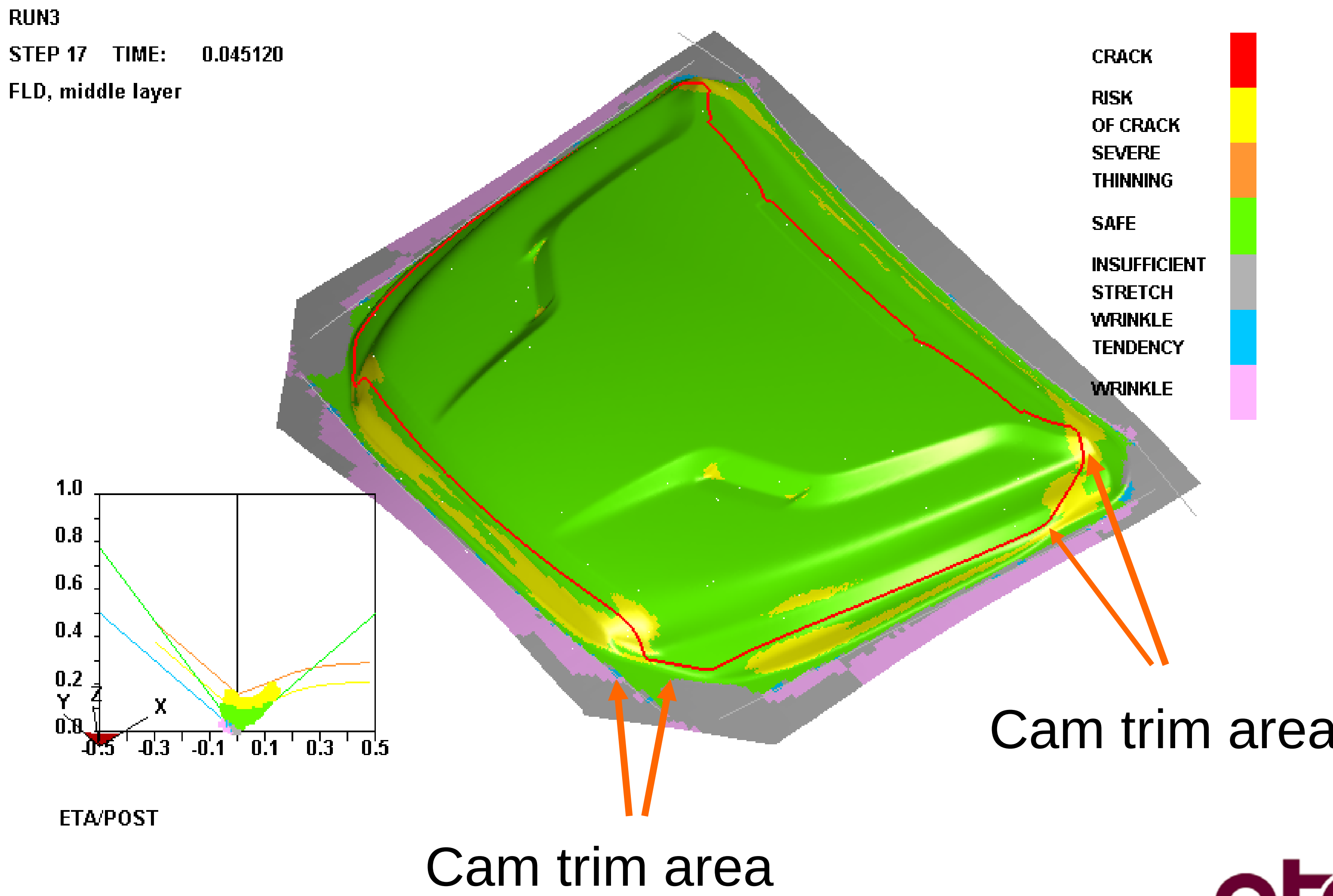


Major Strain

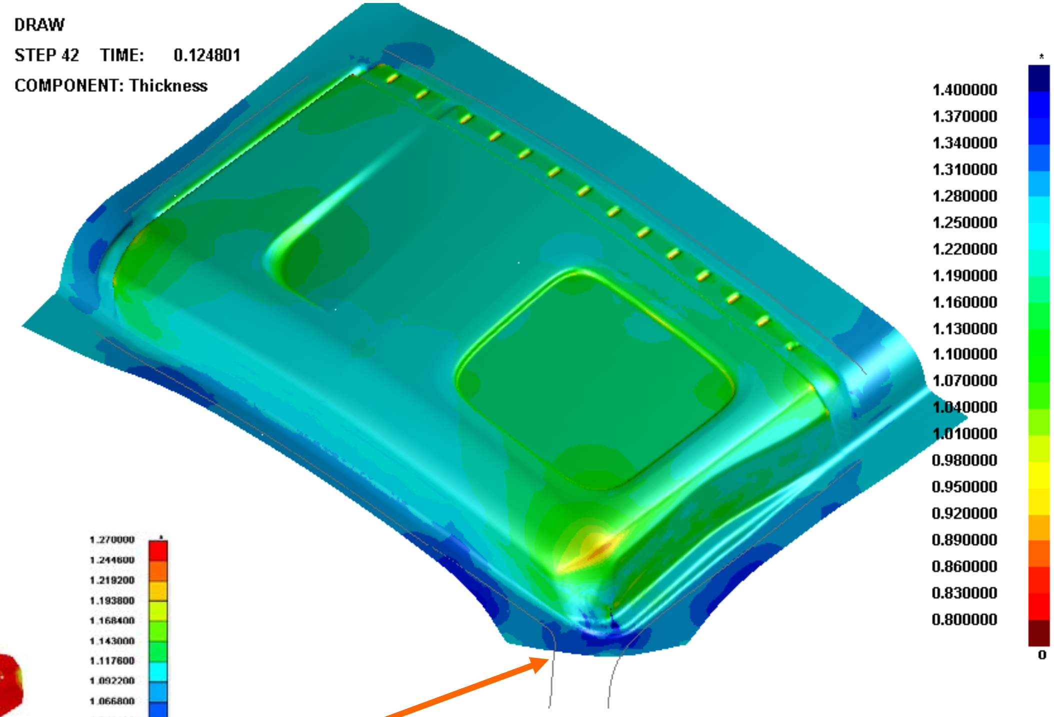


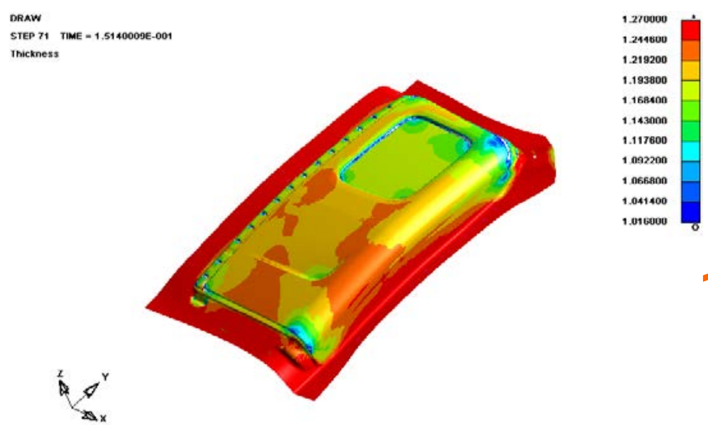
Minor Strain

Evaluation of the Trimline Layout



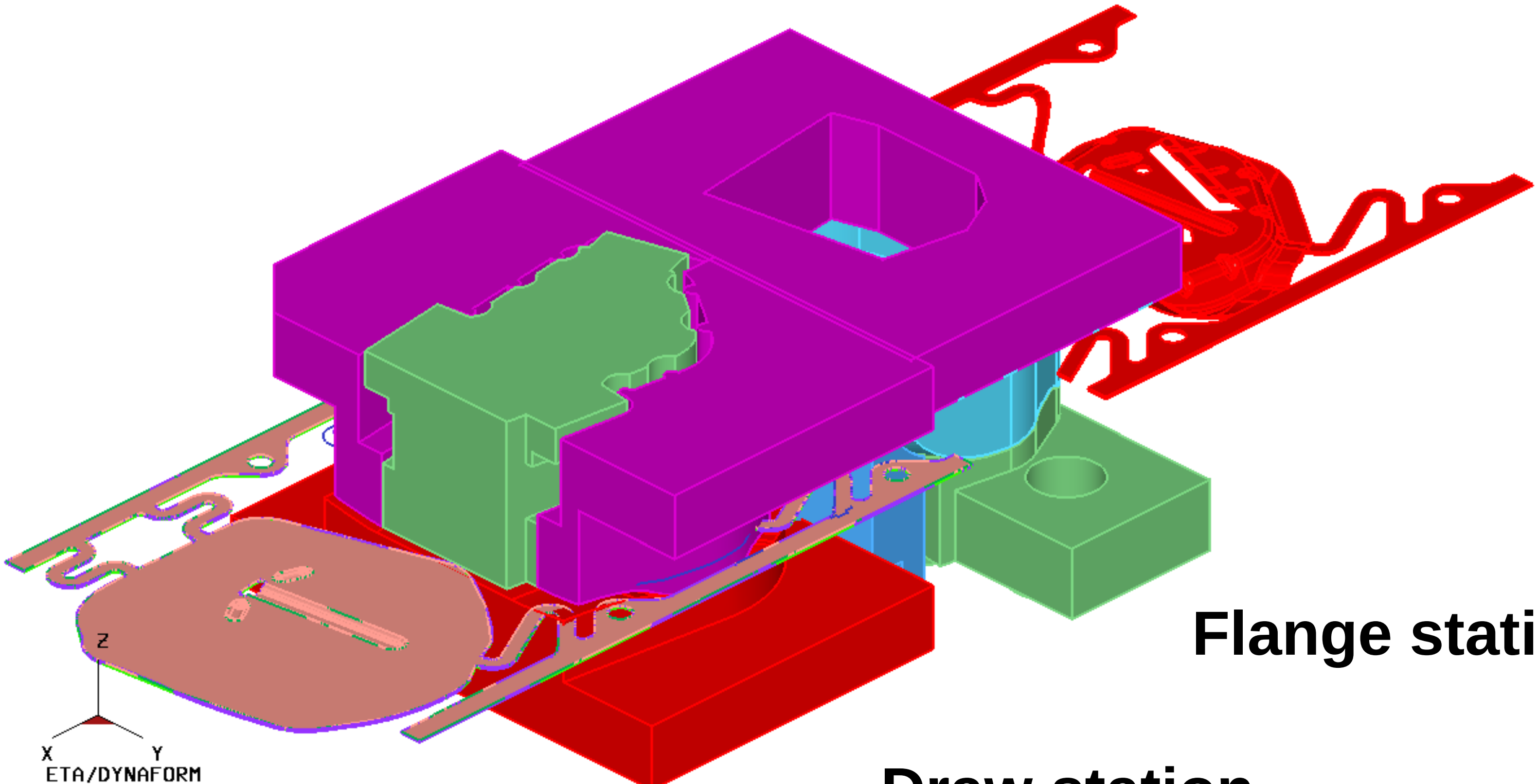
Addendum Shape Adjustment





Addendum shape adjusted area

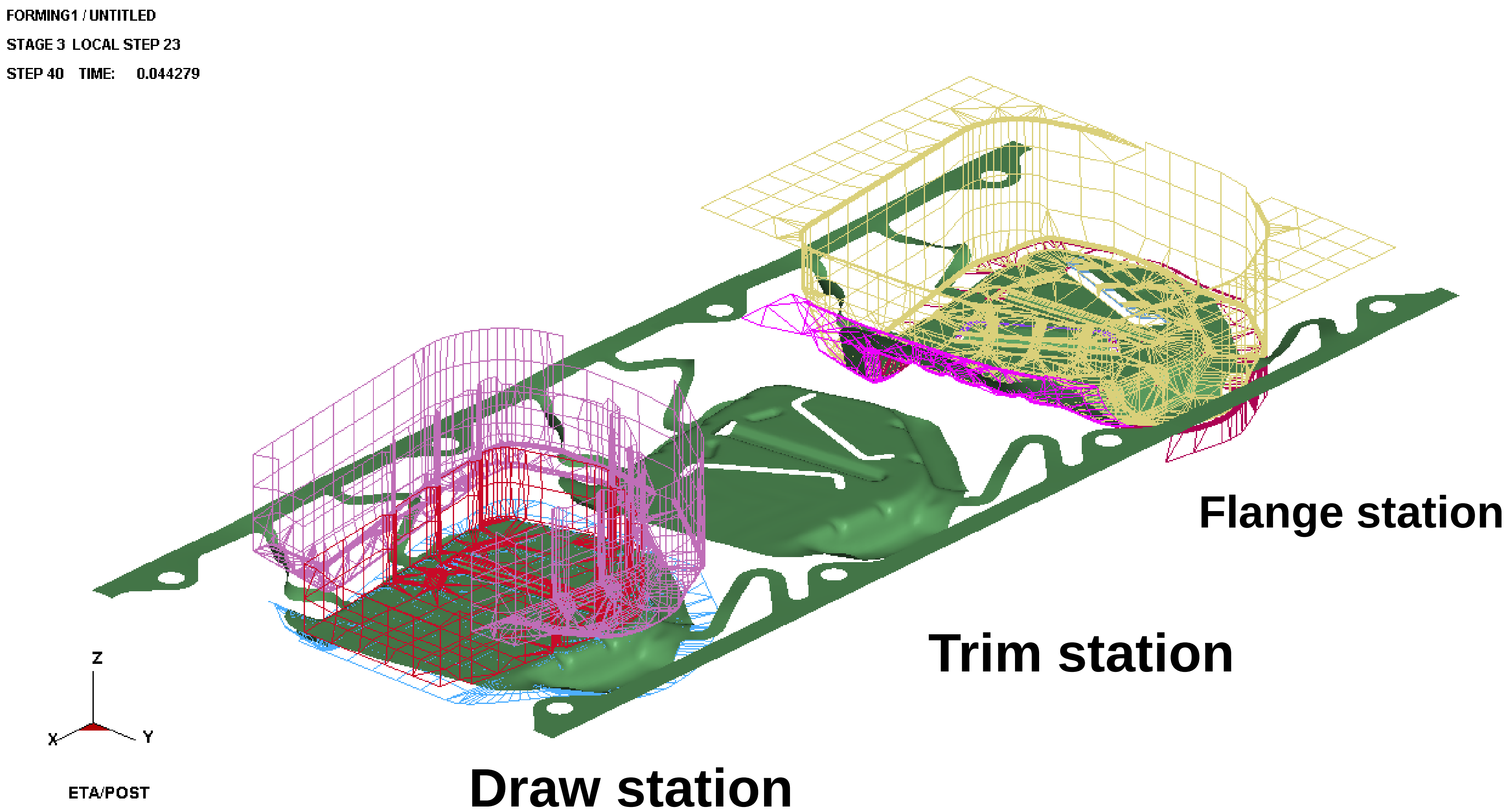
Cad Data Received



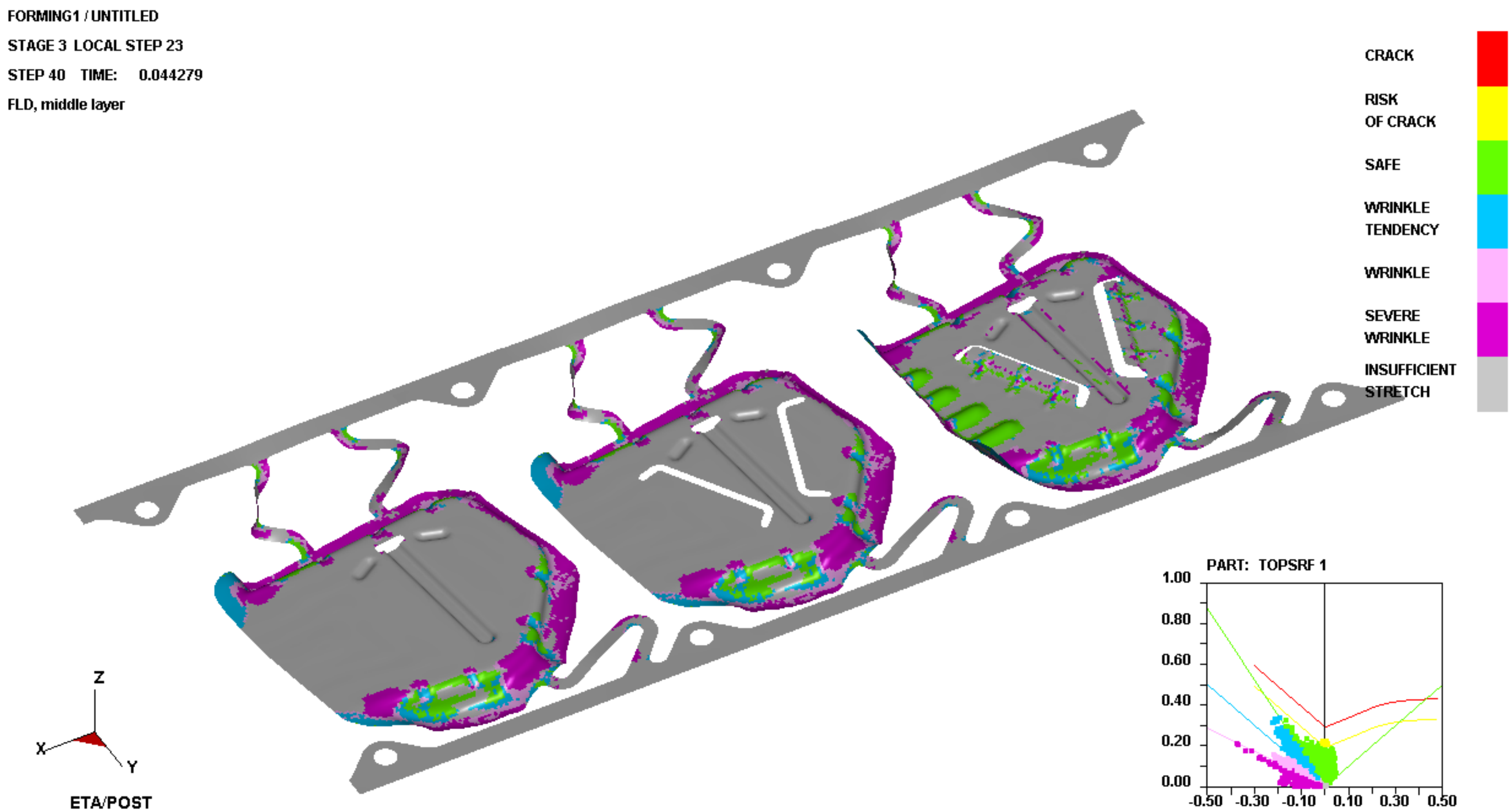
Flange station

Draw station

Simulation Setup



Overview (FLD)



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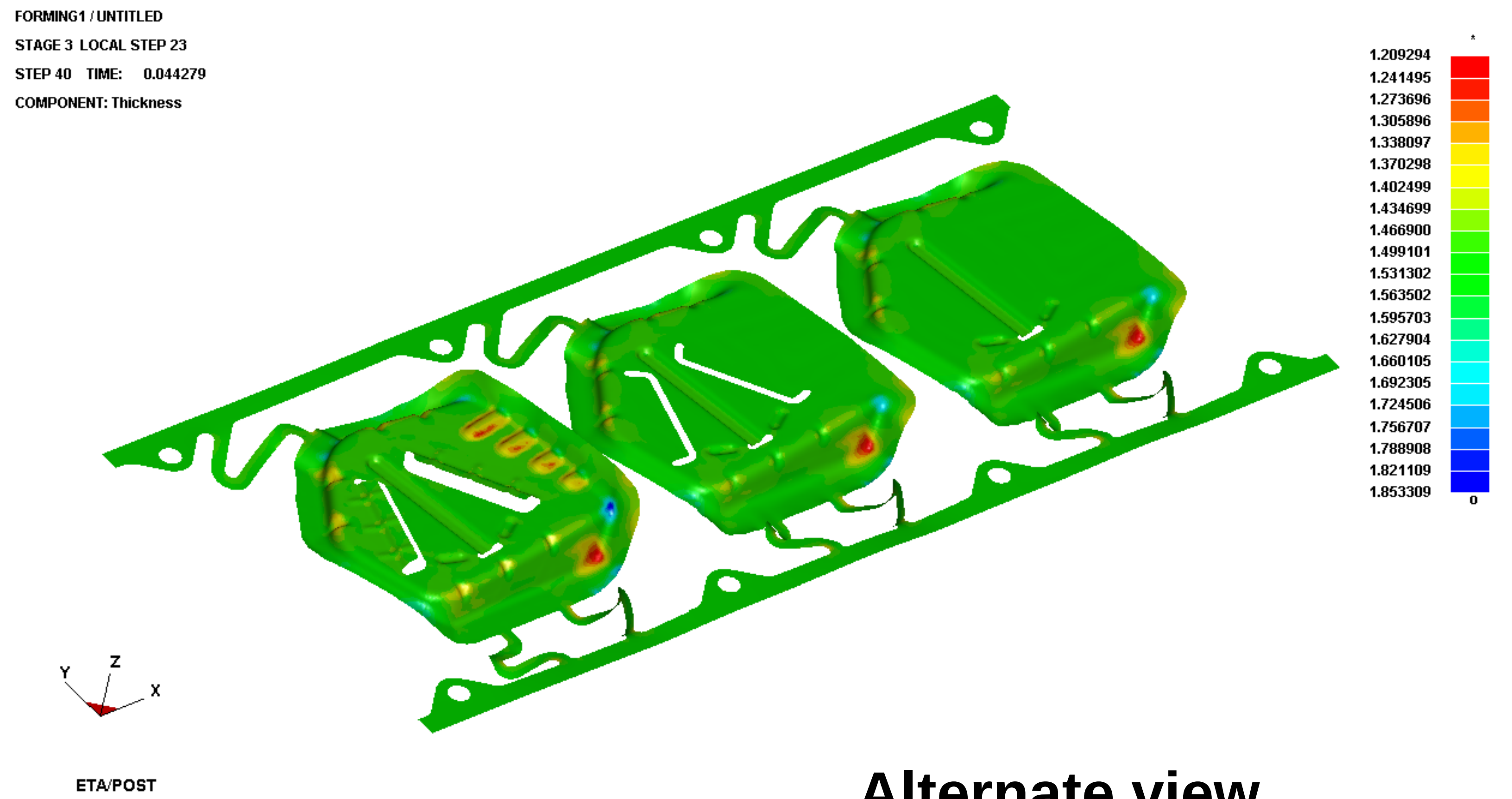
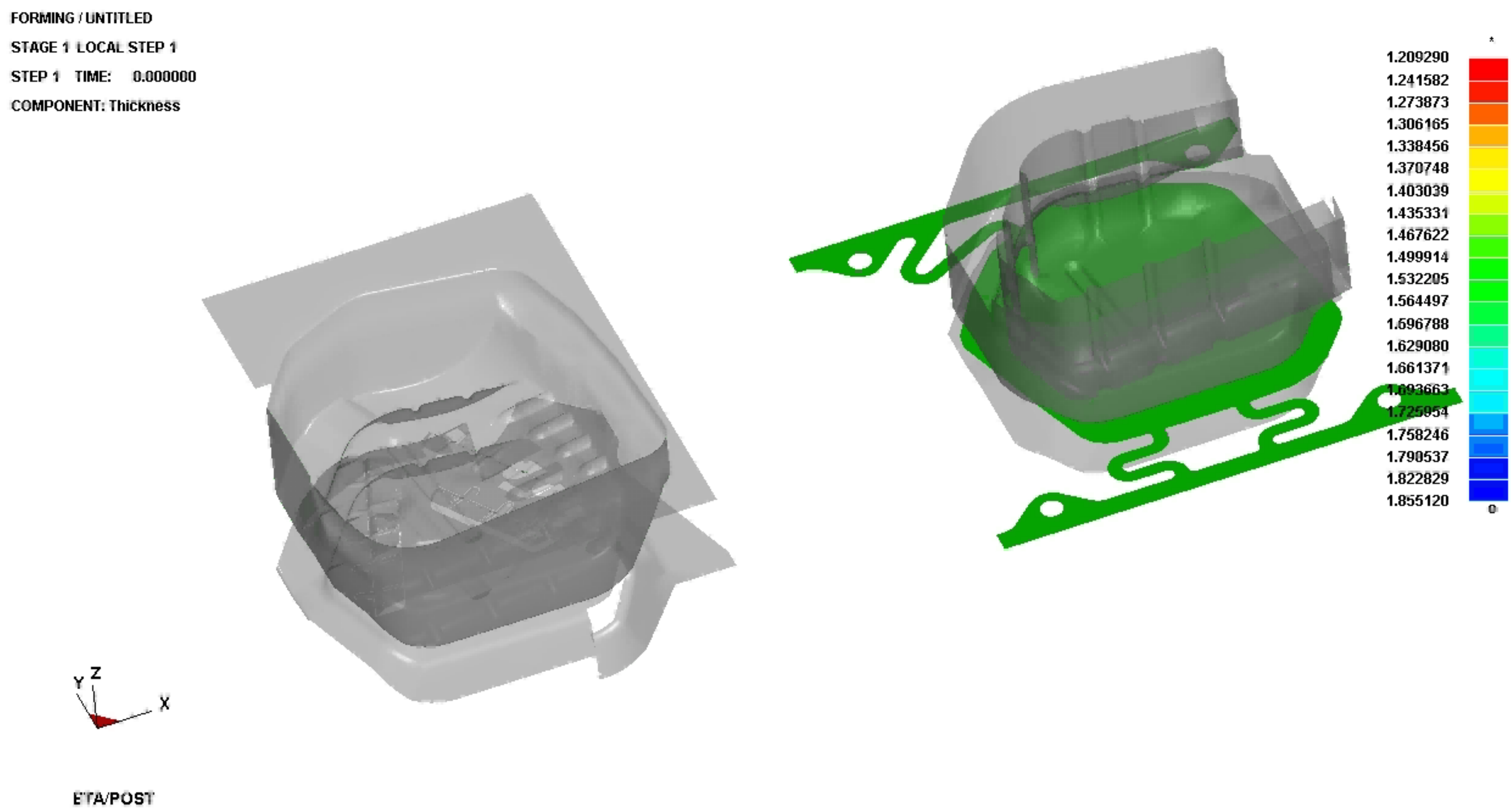
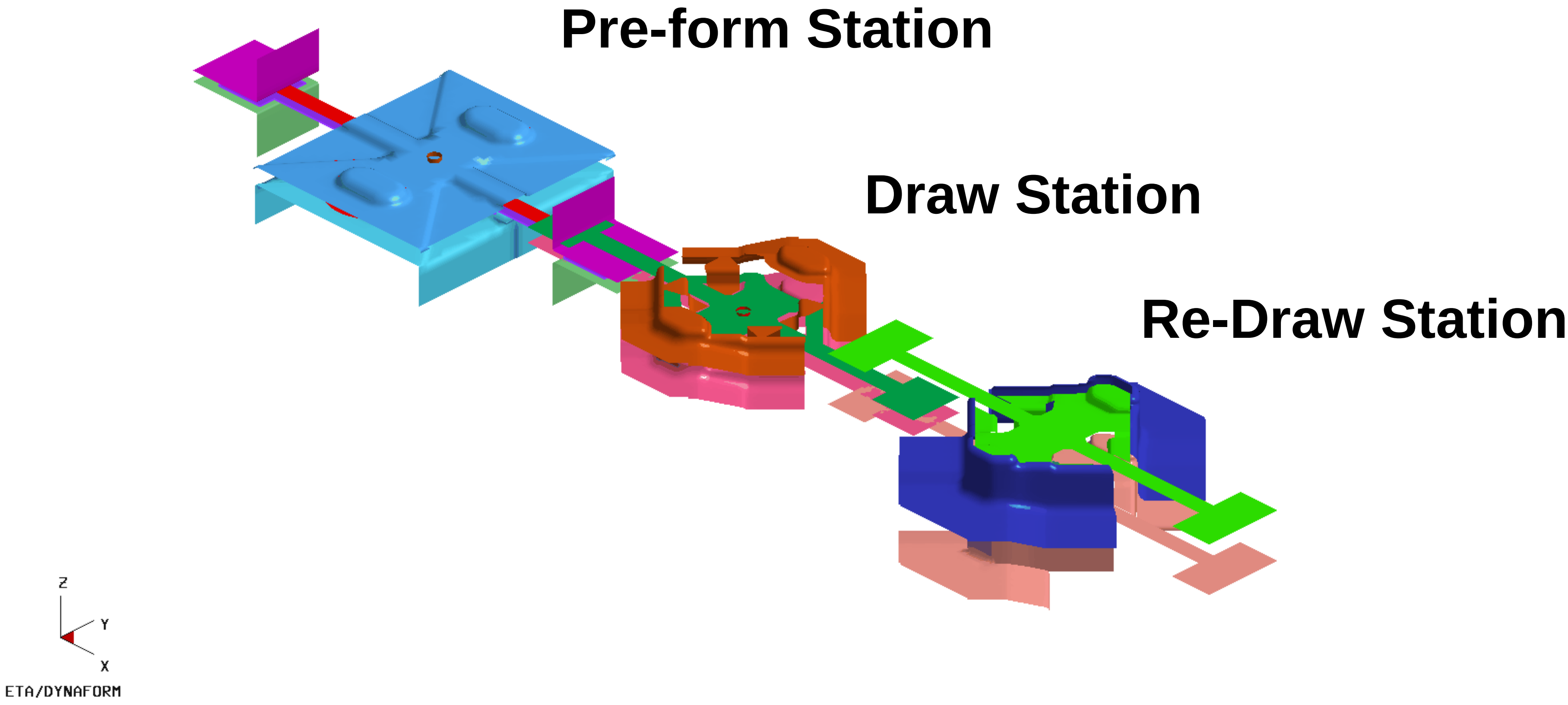
Overview (Thickness Contour)



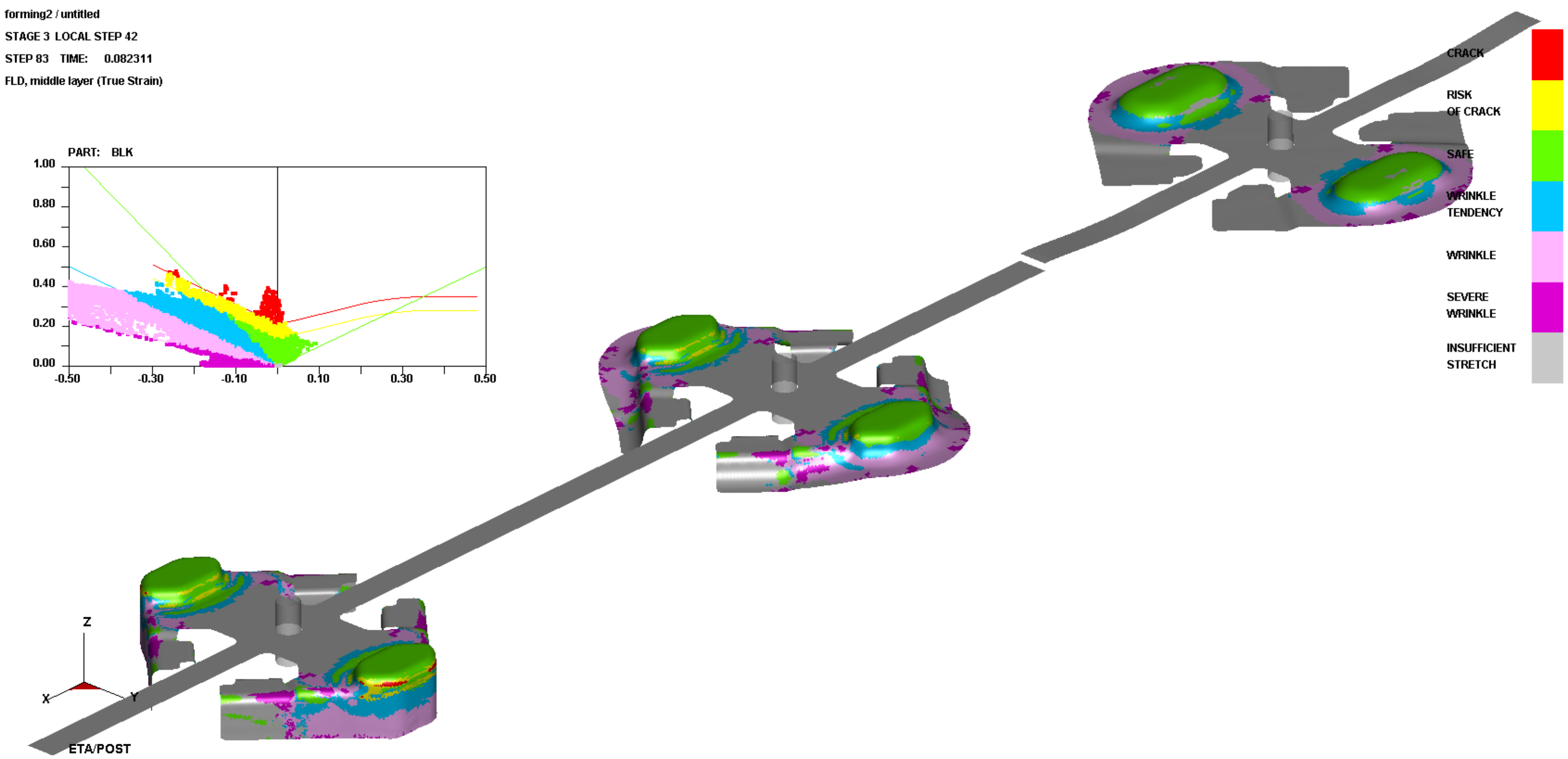
Alternate view


FORMING / UNTITLED
STAGE 1 LOCAL STEP 1
STEP 1 TIME: 0.000000
COMPONENT: Thickness
1.209290
1.241582
1.273873
1.306165
1.338456
1.370748
1.403039
1.435331
1.467622
1.499914
1.532205
1.564497
1.696788
1.629080
1.661371
1.693663
1.725954
1.758246
1.790537
1.822829
1.855120
Y
Z
X
ETA/POST

Data Received

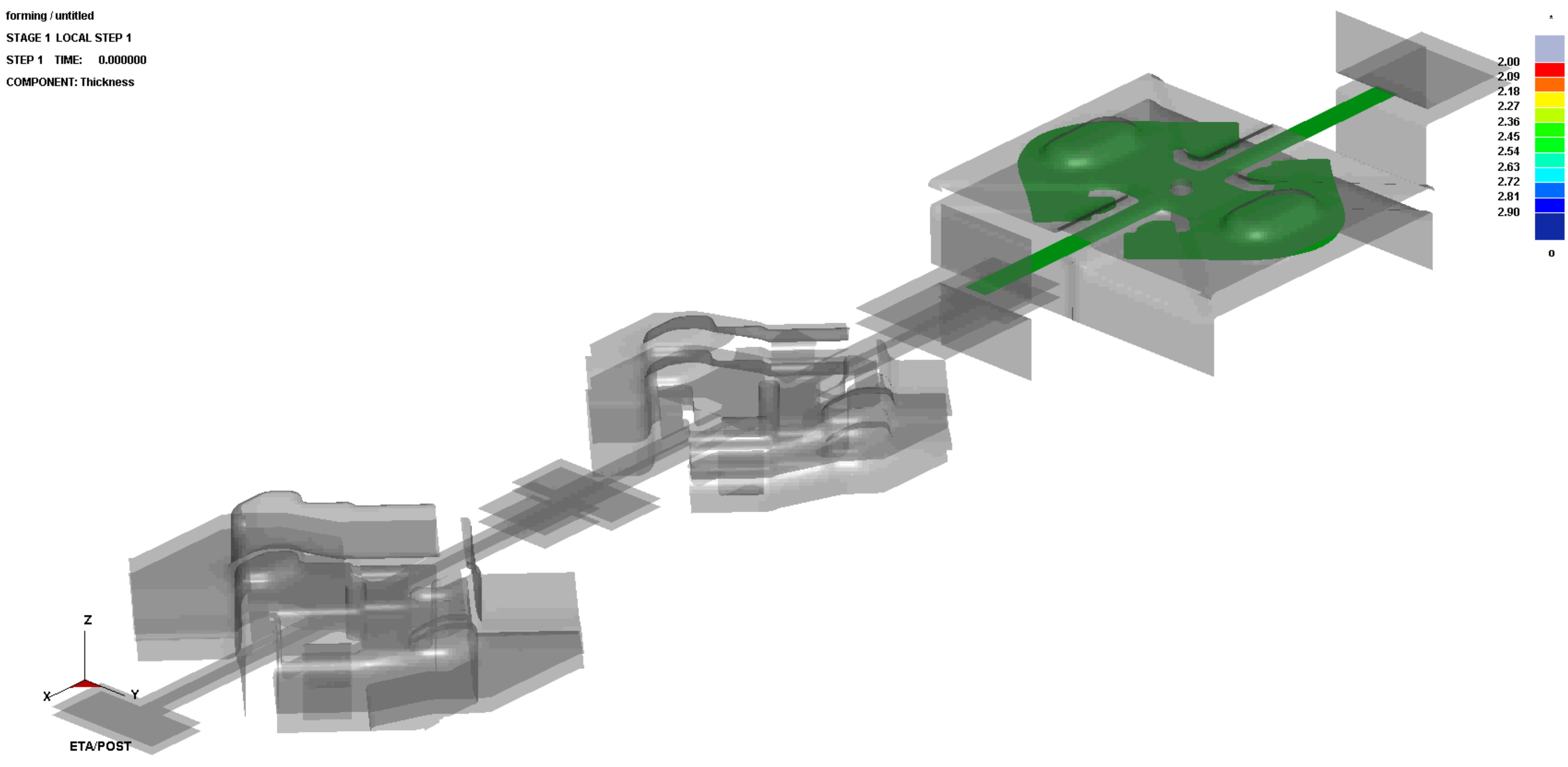


FLD Plot



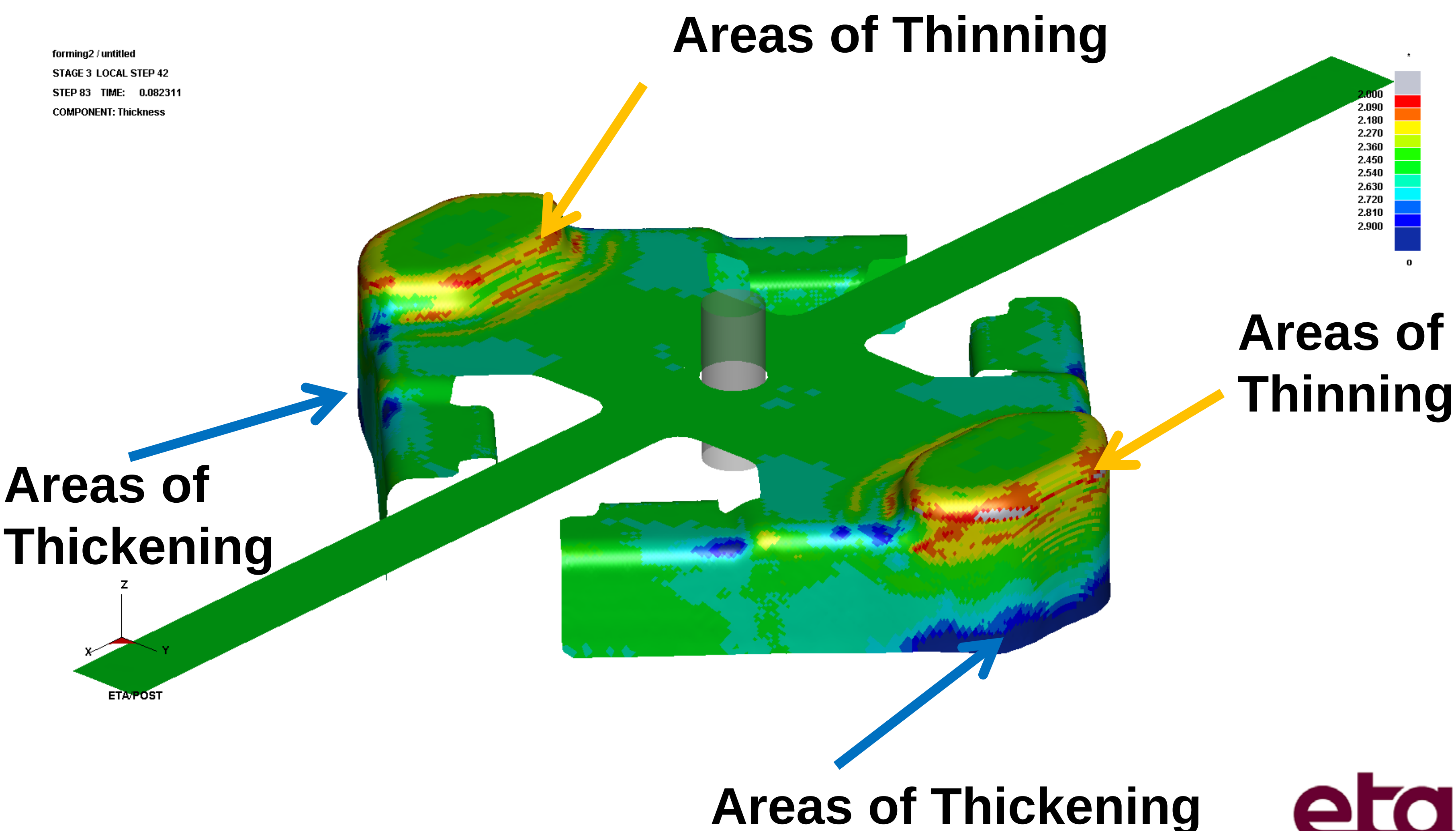
forming2 / untitled
STAGE 3 LOCAL STEP 42
STEP 83 TIME: 0.082311
FLD, middle layer (True Strain)
PART: BLK
1.00
0.80
0.60
0.40
0.20
0.00
-0.50
-0.30
-0.10
0.10
0.30
0.50
CRACK
RISK OF CRACK
SAFE
WRINKLE TENDENCY
WRINKLE
SEVERE WRINKLE
INSUFFICIENT STRETCH
Z
X
Y
ETA/POST

Simulation



forming / untitled
STAGE 1 LOCAL STEP 1
STEP 1 TIME: 0.000000
COMPONENT: Thickness
2.00
2.09
2.18
2.27
2.36
2.45
2.54
2.63
2.72
2.81
2.90
0
Z
X
Y
ETA/POST

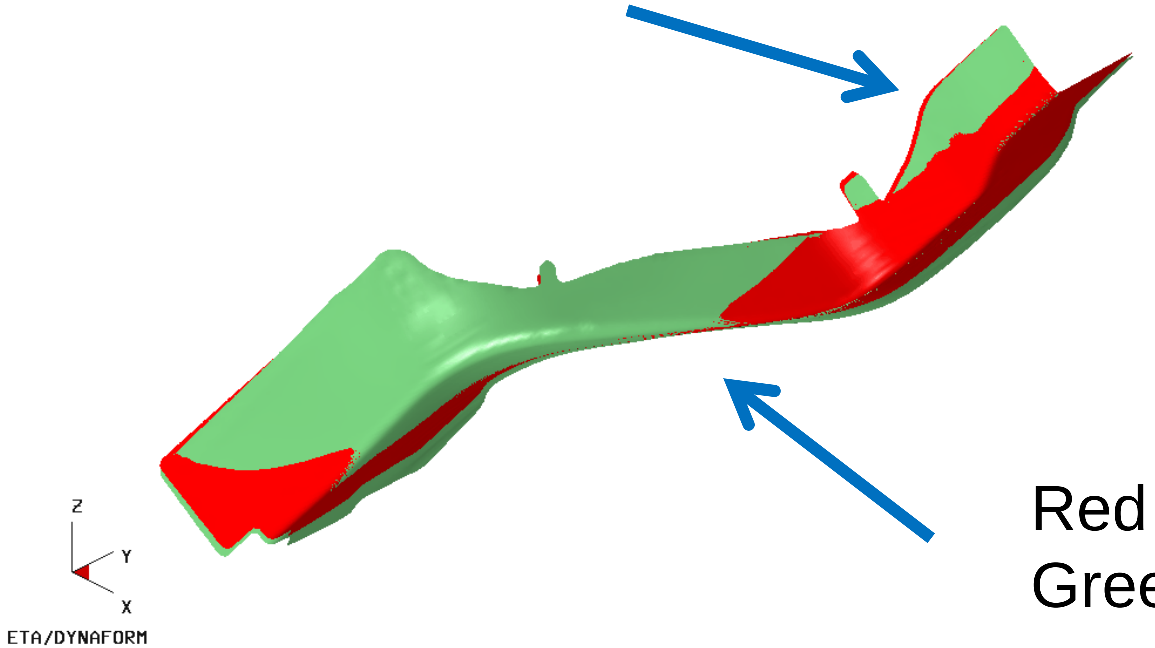
Blank Thickness After Re-draw



Simulation


Form Up / untitled
STAGE 1 LOCAL STEP 1
STEP 1 TIME: 0.000000
COMPONENT: Thickness
0.77
0.80
0.83
0.85
0.88
0.90
0.93
0.95
0.98
1.01
1.03
1.06
1.08
1.11
1.13
1.16
1.19
1.21
1.24
1.26
1.29
Z
X
Y
ETA/POST

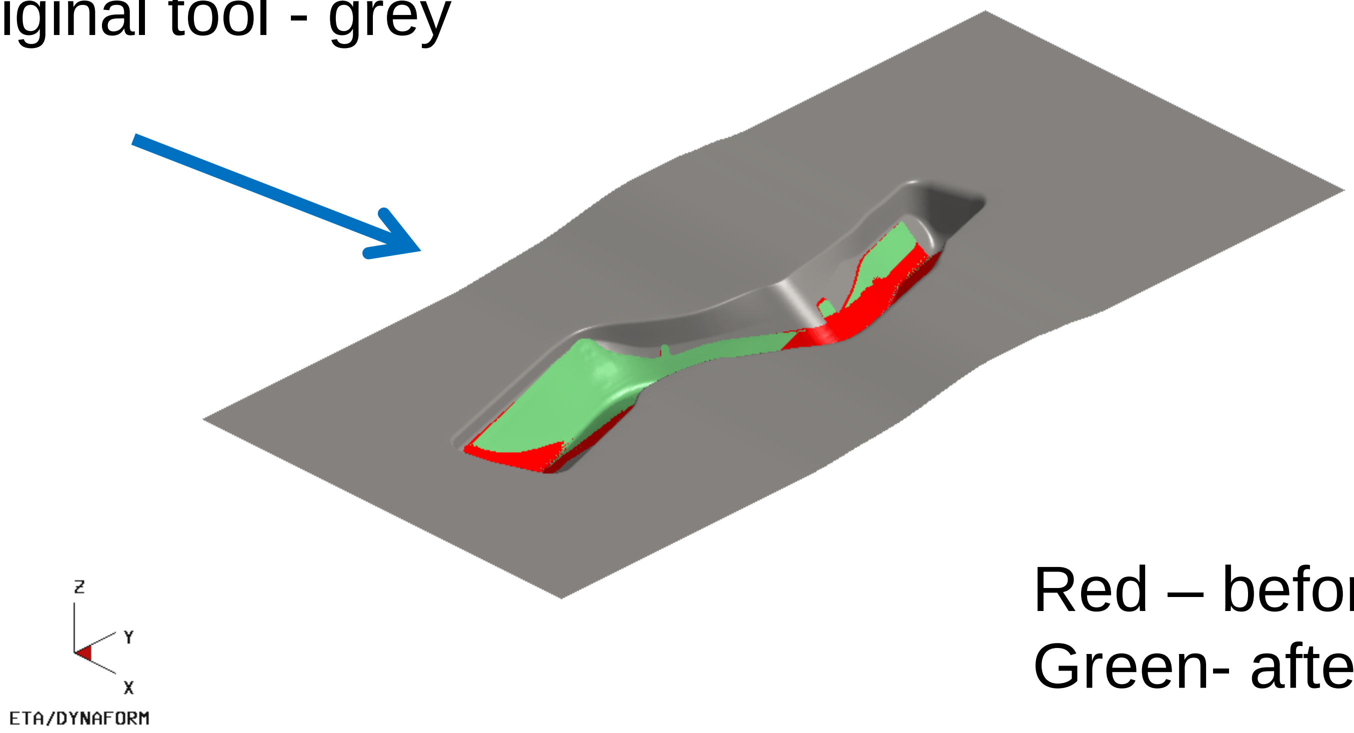
Springback Prediction



Red – before
Green- after

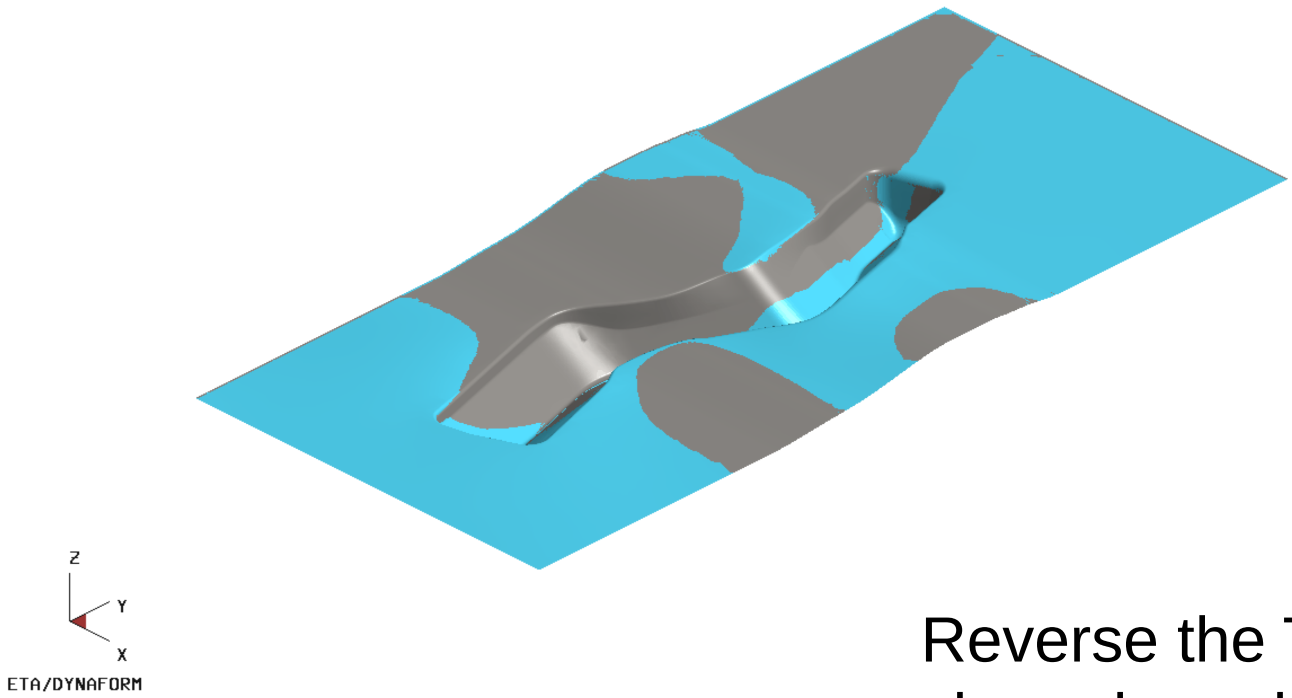
Springback Prediction

Original tool - grey



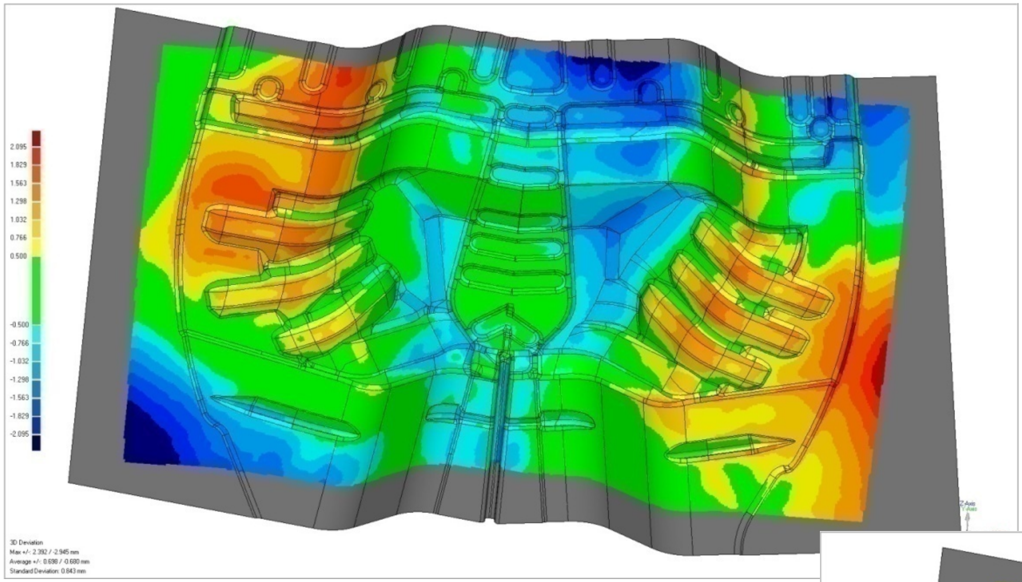
Red – before
Green- after

Compensation: Tool Shape Morph



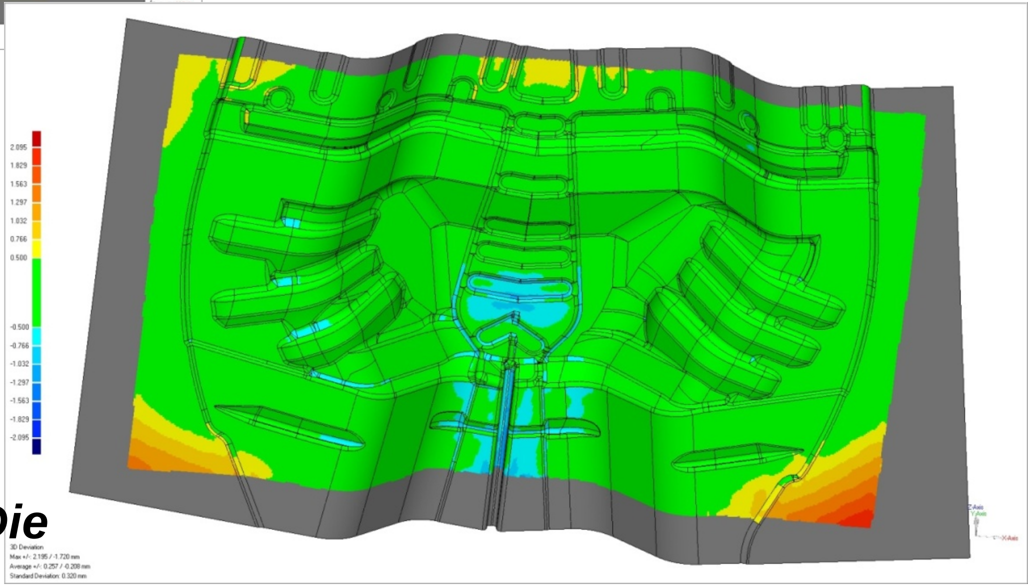
Reverse the Tool shape based on Springback results

Results Before & After Compensation



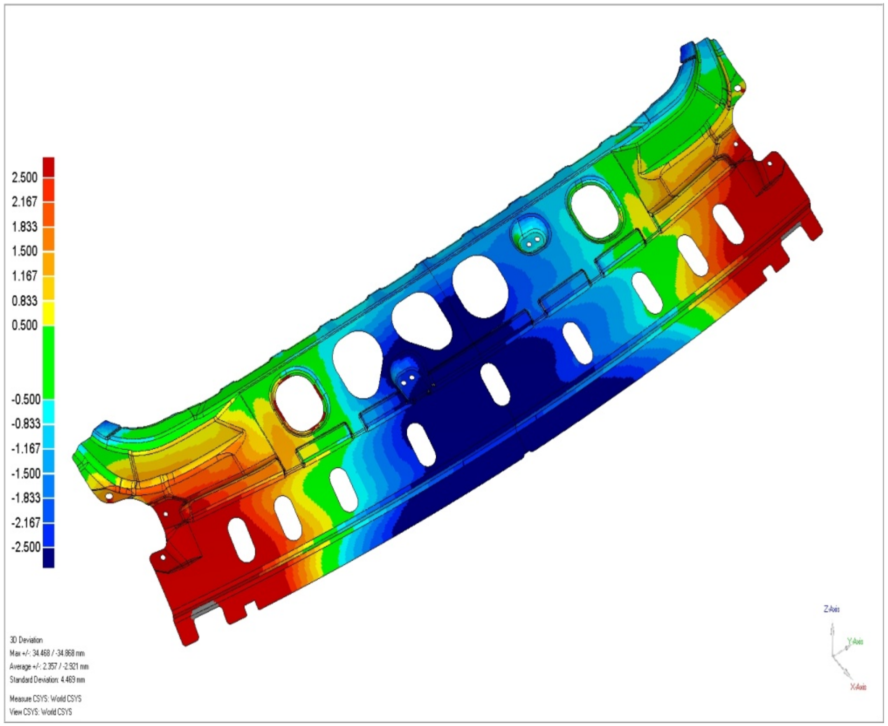
Before

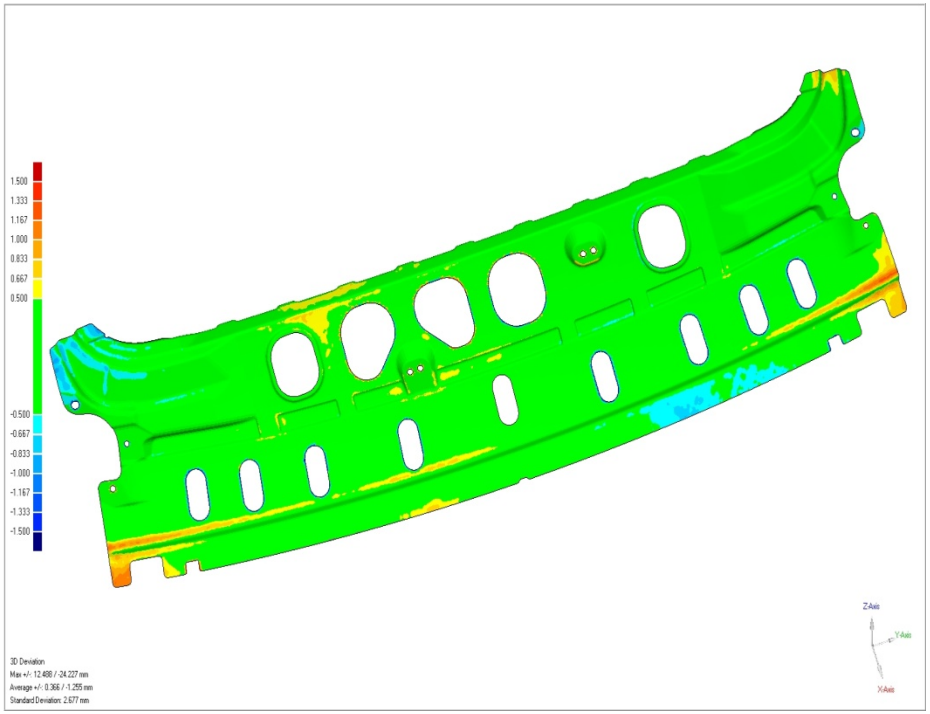
After 1 Re-cut



Courtesy of Continental Tool and Die

Contour Before and After Compensation





Courtesy of Continental Tool and Die

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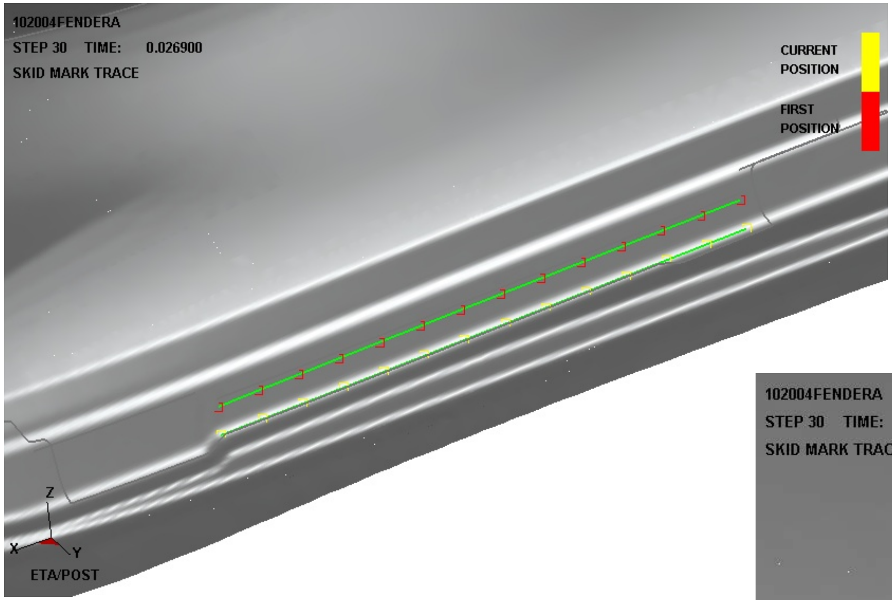
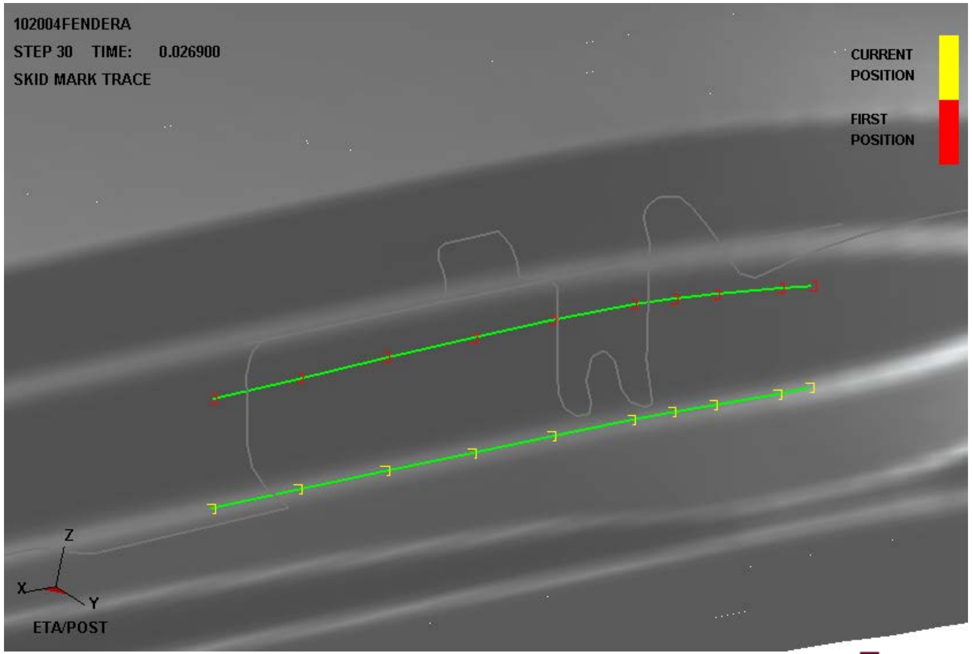
Skid Mark Check





Fender Hood Line Side
Skid Mark Check

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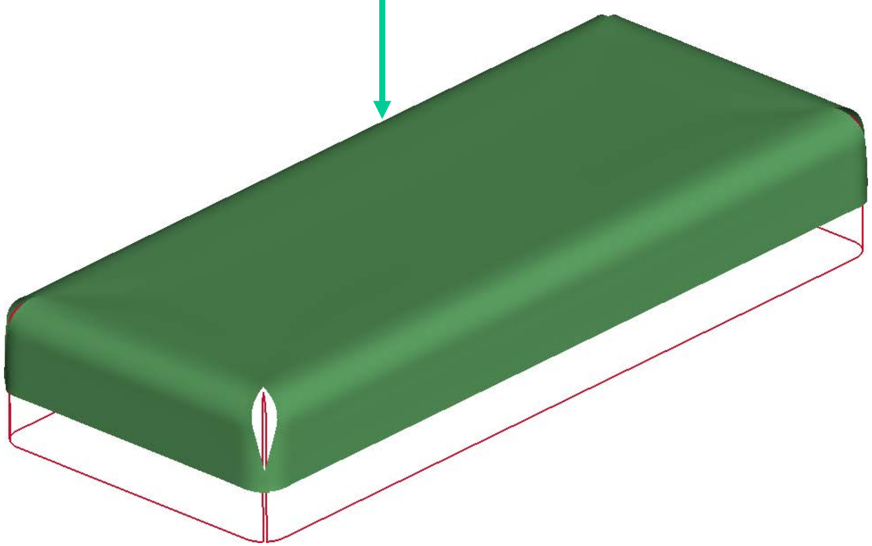
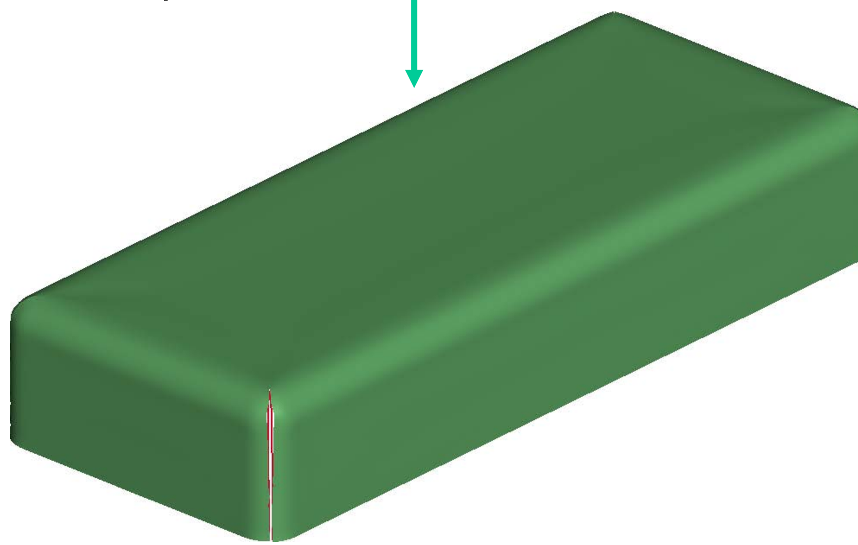
Blank Development: Corner Cut Off

Initial Outline



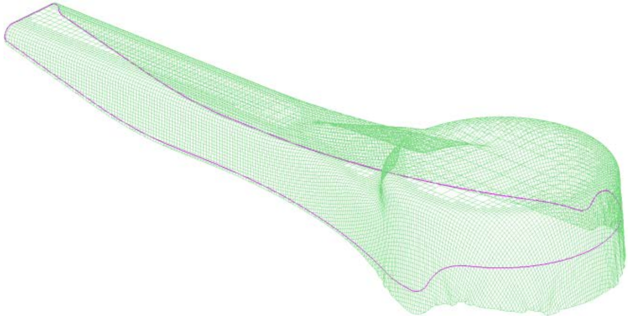
Result of Initial Blank Outline

Developed Outline

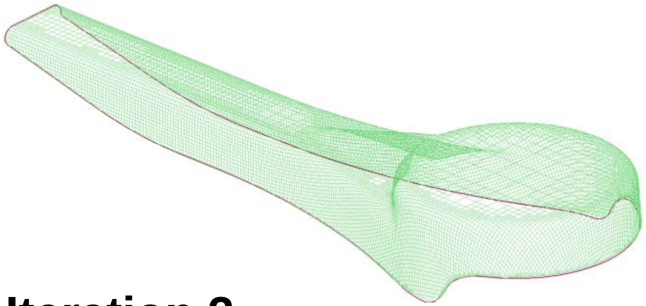


Result of Developed Blank Outline

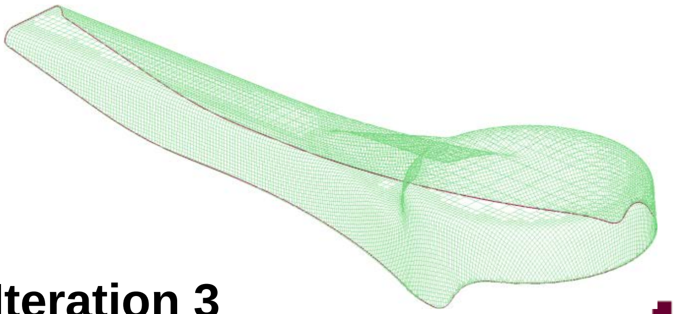
Trimline Development



Iteration 1

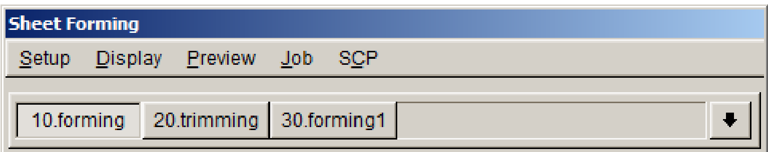


Iteration 2

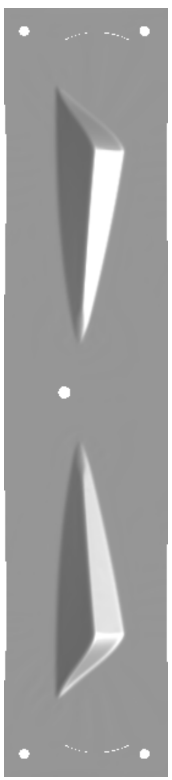


Iteration 3

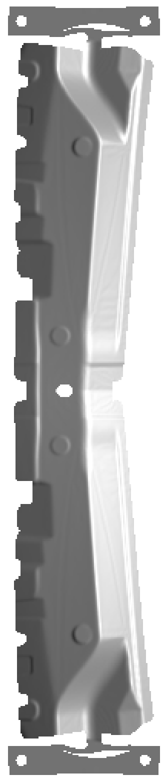
Local Trim Line Development

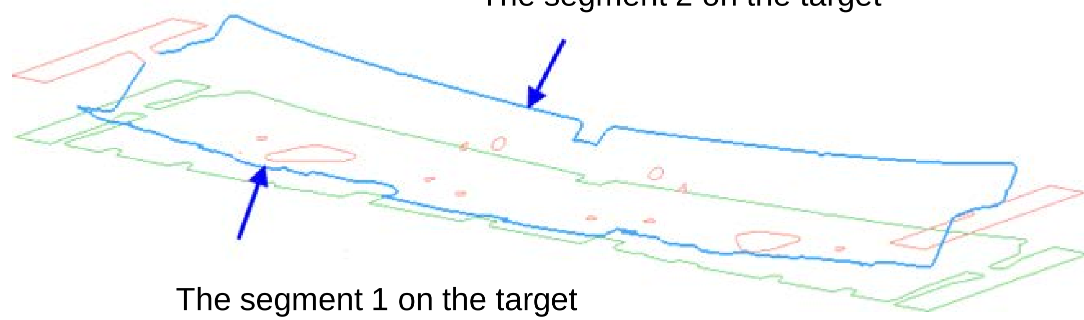


Local regions on the trim line


OP10: Forming


OP20: Trimming


OP30: Forming



Commonly Asked Questions

- Can simulation help me determine how many toolset do I need to make this part?
- What is the dynamic affect?
- What about the rate effects?
- How accurate is the simulation results?

Execution Time

- Execution time primarily depends on:
  - material properties
  - mesh size
  - number of elements
  - contacts
  - speed of computer
- CPU estimation
  - Time step Δt = minimum $\Delta x/c$
  - number of cycles = termination time / Δt
  - CPU time = (# cycles)(# elements)(time per zone cycle)
  - correction is needed for time step reduction
  - correction is needed for number and size of contacts

Dynamic effects

- Mass induced : inertia forces, usually have a small influence for slow processes but can be artificially increased due to the use of certain numerical techniques

- Material induced : viscosity or so-called strain rate effects, can be important depending upon the material, may need specific numerical treatment if the process is too slow to be simulated ‘real time’

The issue of spurious inertia

- CPU time is proportional to the number of timesteps

$$cpu \approx \frac{T}{\Delta t} \quad = \text{Cycles}$$

- In order to reduce cpu time we need to either reduce the termination time (= increase tool speed) or increase the timestep :

$$cpu \downarrow \Rightarrow \begin{cases} T \downarrow \Rightarrow v \uparrow \\ \Delta t \uparrow \Rightarrow \dfrac{l_c}{\sqrt{\dfrac{E}{\rho}}} = l_c \sqrt{\dfrac{\rho}{E}} \uparrow \end{cases}$$

Time Step

Critical (or minimum) time step size:

$$\Delta t_{\min} = \frac{l_{\min}}{C}$$

where C is the sound wave propagation speed in 3D-continuum:

$$C = \sqrt{\frac{E(1-\upsilon)}{(1+\upsilon)(1-2\upsilon)\rho}}$$

$\mathrm{E} = \mathrm{Yong's\ modulus}$

$\upsilon = \mathrm{Poisson's\ ratio}$

$\rho = \mathrm{specific\ mass\ density}$

The methods

- Consider the kinetic energy in the deformable structure (= blank) :

$$ke = \frac{mv^2}{2}$$

- Suppose we want to reduce the cpu time by a factor a>1 :

$$cpu \rightarrow \frac{cpu}{a} \Rightarrow \begin{cases} T \rightarrow \frac{T}{a} \Rightarrow v \rightarrow av \Rightarrow \frac{mv^2}{2} \rightarrow a^2 \frac{mv^2}{2} \\ \Delta t \rightarrow a\Delta t \Rightarrow \rho \rightarrow \rho a^2 \Rightarrow m \rightarrow ma^2 \Rightarrow \frac{mv^2}{2} \rightarrow a^2 \frac{mv^2}{2} \end{cases}$$

- Reducing the cpu by a factor a will increase the kinetic energy by a-squared !

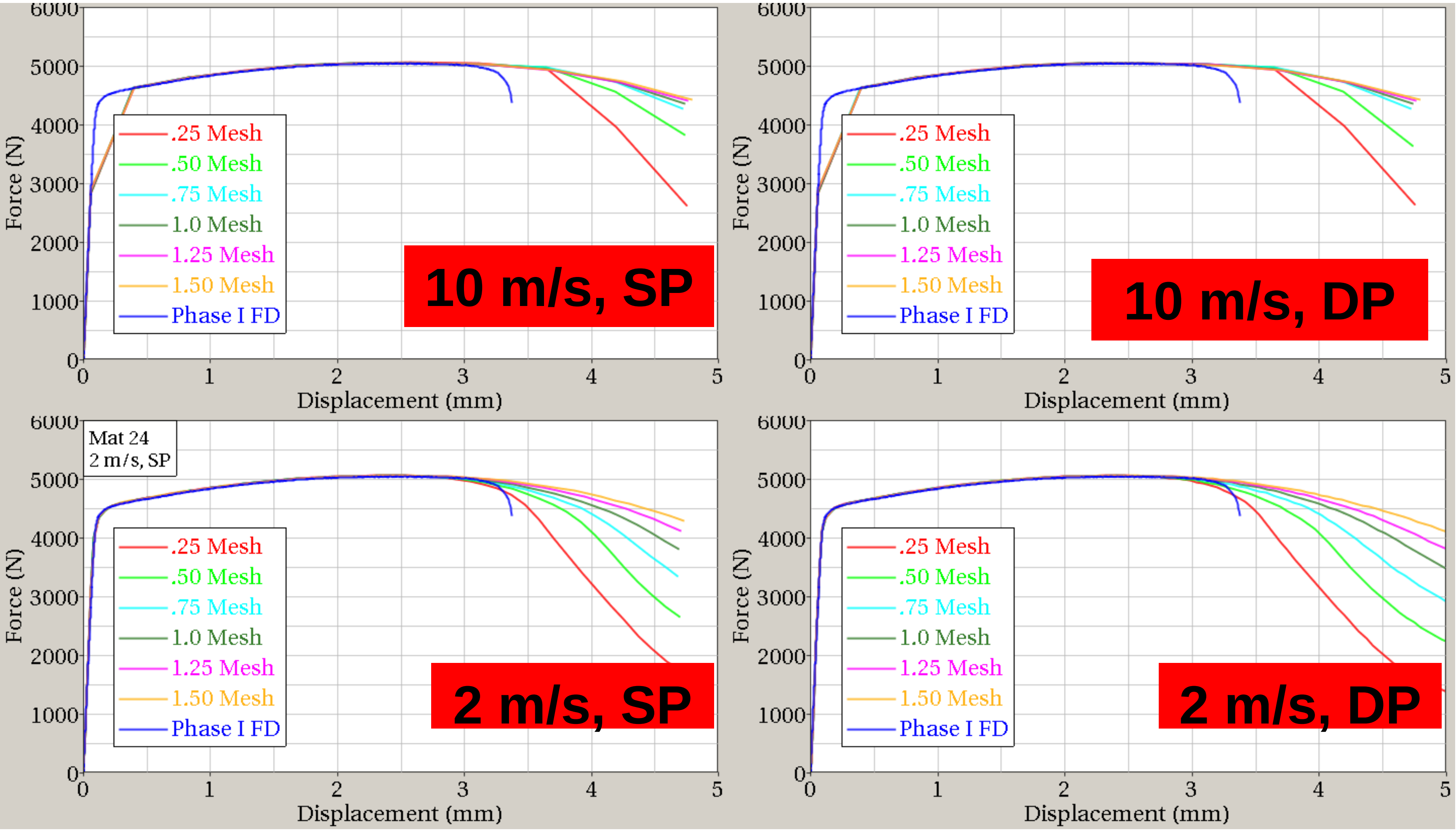
Consequence for the application

- For a quasistatic and /or slow dynamic process (such as stamping) we need to make sure that the ‘numerical’ ke des not influence the solution

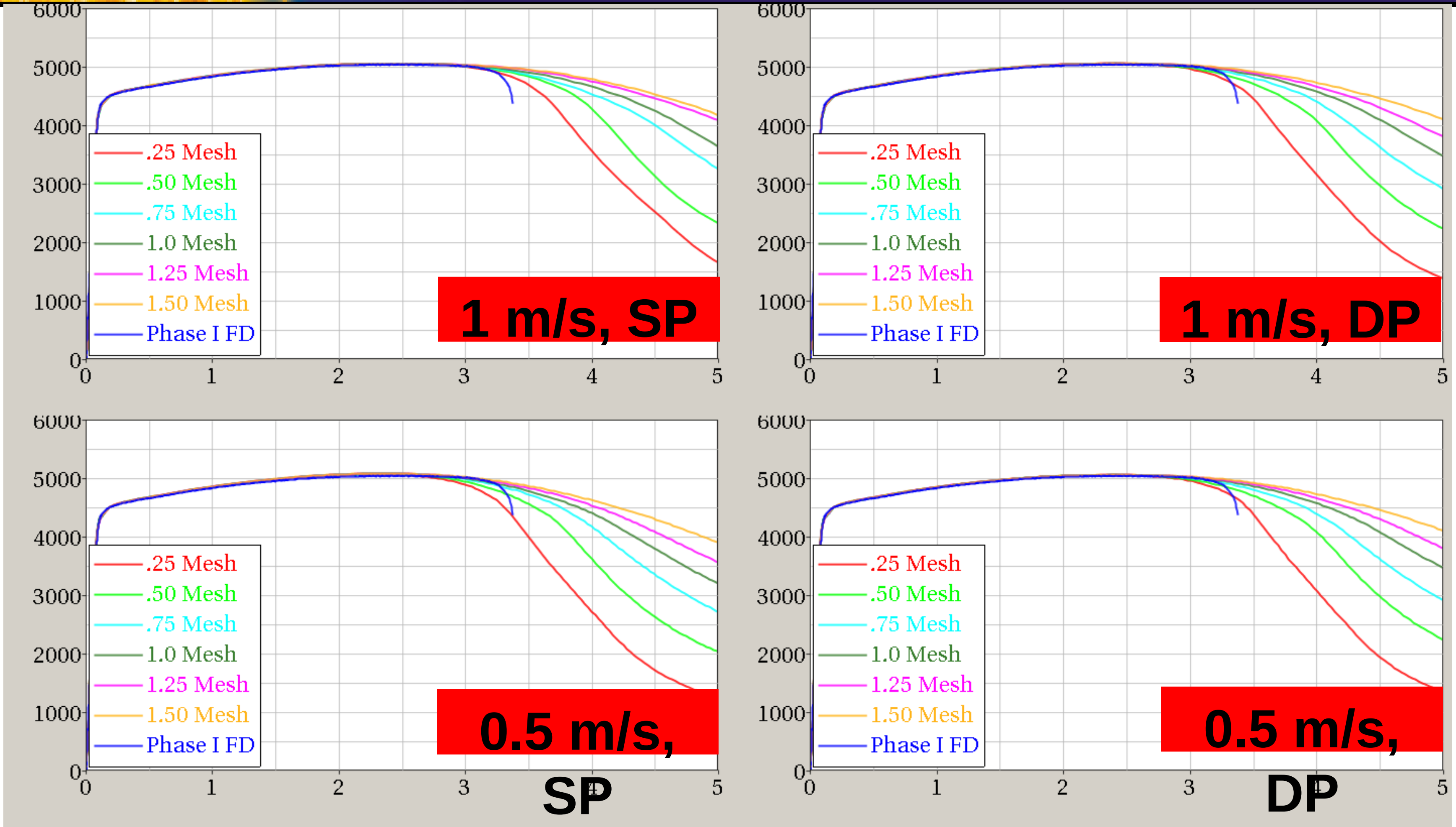
- Need to get the same answer for 2 different (low enough) speeds

- This is illustrated in : LS-Dyna Mat 36 Regularization Investigation: AL 6060
  Update (Anthony Smith, Honda R&D, LS-DYNA conference Detroit 2014)

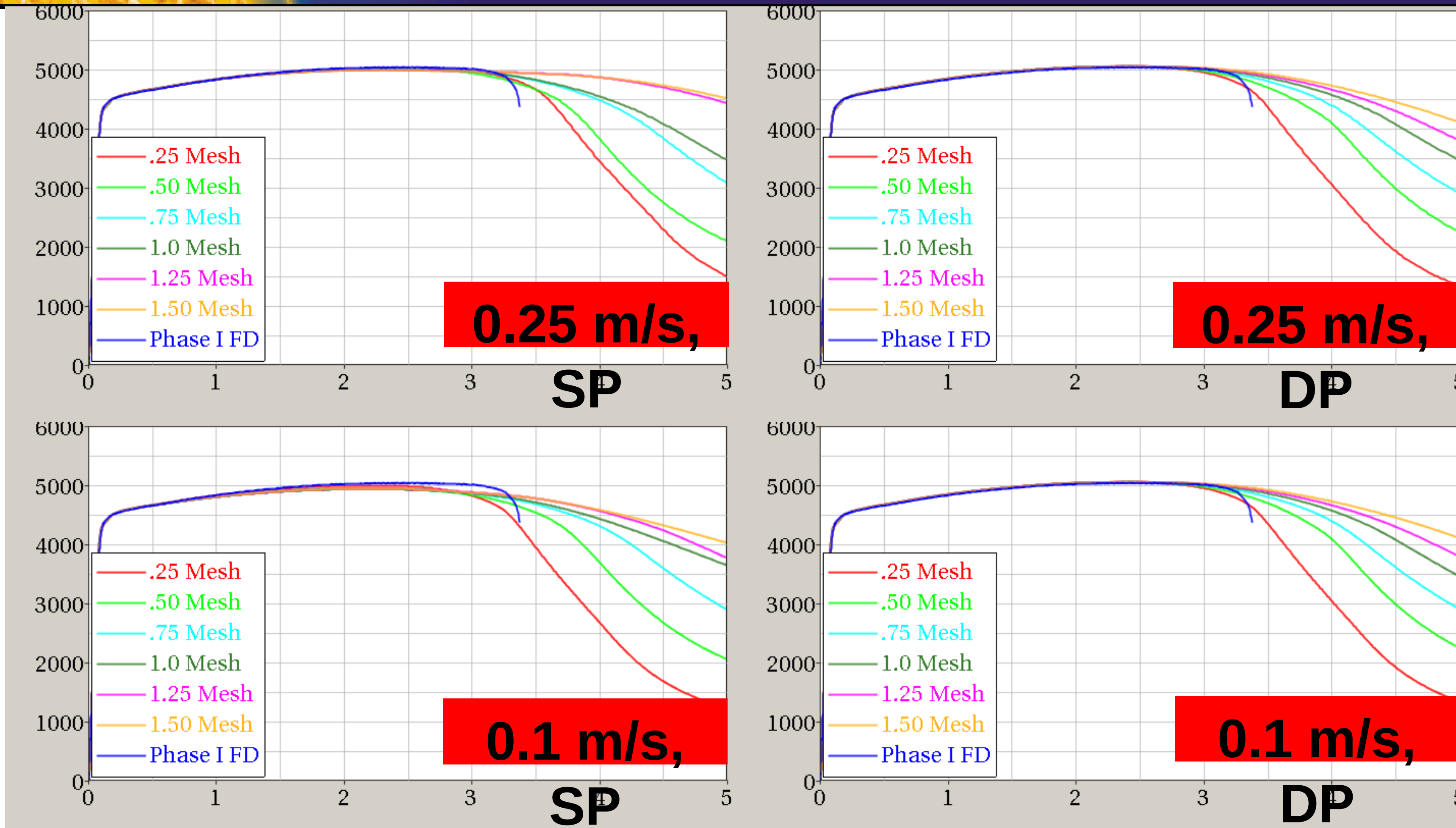
Mat 24 – ELFORM 16



Mat 24 – ELFORM 16



Mat 24 – ELFORM 16



Mat 24 , ELFORM 16

Nominal Velocity:	Exact Velocity:	Strain Rate:	# Cycles	SP Region?	QS Region?
m/s	m/s	s^{-1}			
10	10.664	426.56	25512	YES	NO
2	2.1328	85.312	127563	YES	NO
1	1.0664	42.656	255125	NO	NO
0.5	0.5332	21.328	510263	NO	YES
0.25	0.2666	10.664	1020513	NO	YES
0.1	0.10664	4.2656	2551394	NO	YES

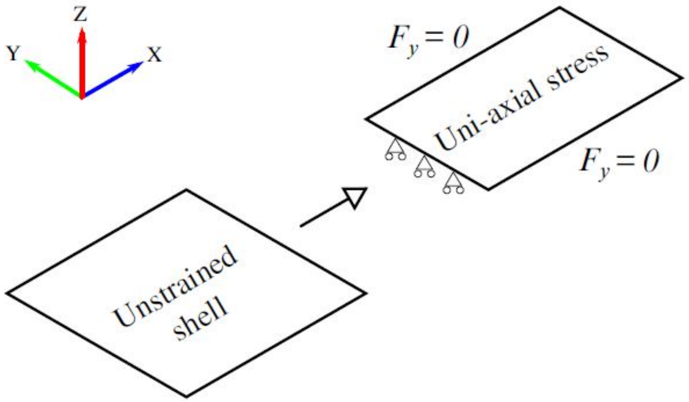
Rate effects

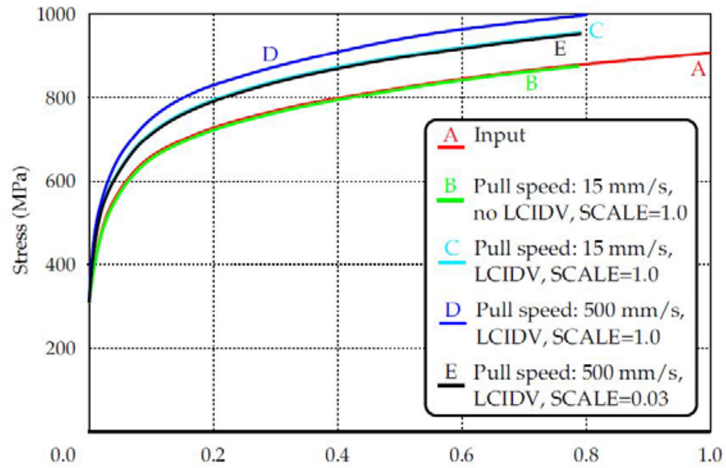
- What if viscosity influences the material response for strain rates < 1/s ?
- Use of ‘SCALE’ in MAT_260A and MAT_260B in LS-DYNA :

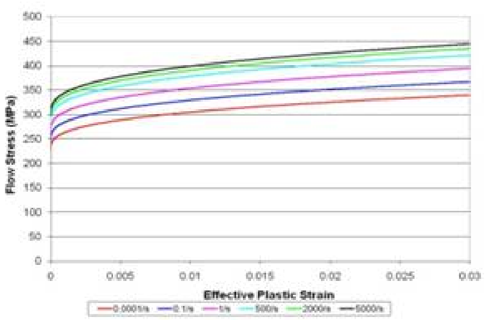
> The variable SCALE is very useful in speeding up the simulation while equalizing the strain rate effect. For example, if the real, physical pulling speed is at 15 mm/s but running at this speed will take a long time, one could increase the pulling speed to 500 mm/s while setting the SCALE to 0.03, resulting in the same results as those from 15 mm/s with the
>
> benefit of greatly reduced computational time. See examples in Verification.

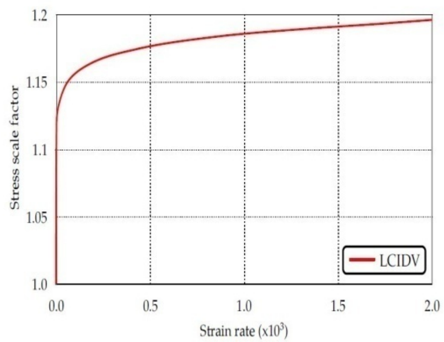
- This is the way to assess rate dependency for low rate values while performing a simulation at higher velocity then physical
- Very reliable for displacement driven problems

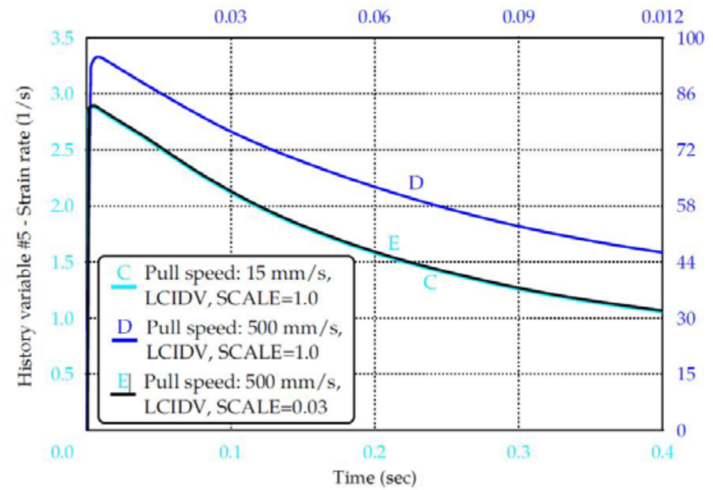
Example from LS-DYNA manual











Conclusion

- Simulation has strength and limitations
- Effectiveness of the simulation relay on the understanding of the technology properly

Future

- Highly interactive preprocessor will allow user design tooling surface virtually
- Obtain simulation result instantly
- Optimized process and design will be possible through large database system