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3D Simulation of Pinch and Welding using Form3D

SigBlow Team: Z. Benrabah and A. Bardetti

November 19, 2015



National Research
Council Canada

Conseil national
de recherches Canada

Canada

Outline

- Recall of Form 3D Capabilities
 - Comparison 2.5D / 3D / Solid-Shell (from April 2011)
 - When to use 3D simulation
- Examples: Forming of 3D Details
 - Welding Simulation (Compression Moulding)
 - Pinch Shape Prediction (2 Case Studies)
- Sensitivity Analysis and Best Practices
- Conclusion and Future Work

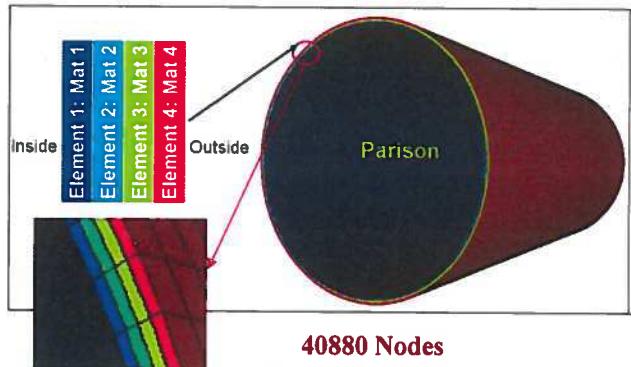
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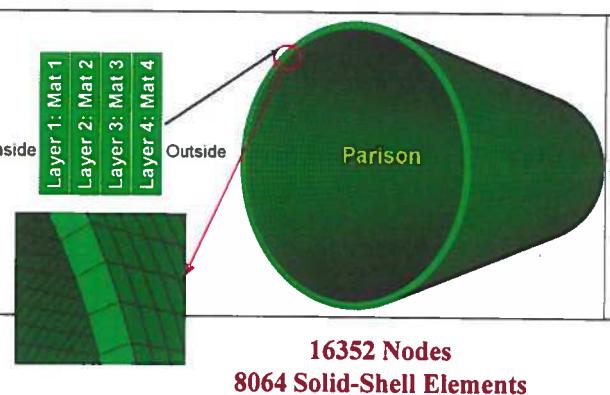
Recall of Form3D Capabilities (April 2011)

EBM in 3D case: 4 layers and 4 materials

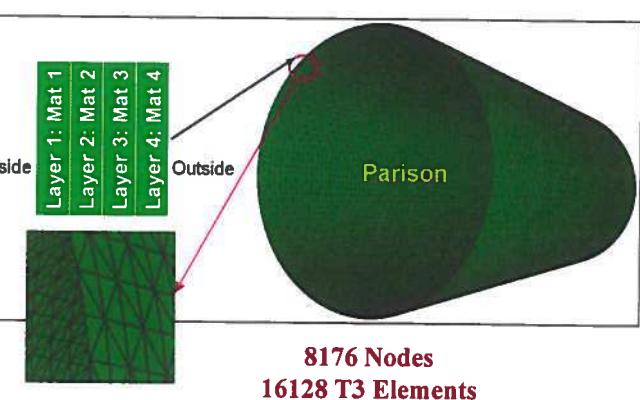
Standard 3D H8 Brick



3D Multilayer Solid-Shell



2.5D Multilayer Membrane



Mat1: HDPE BA46-055 Virgin

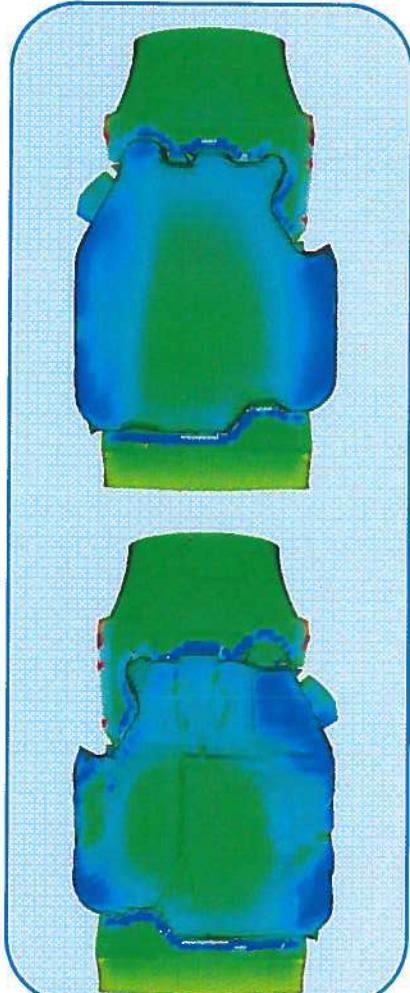
Mat2: HDPE Lupolen 4261A + EVOH Recycled

Mat3: HDPE Lupolen 4261A

Mat4: HDPE BA46-055 Virgin

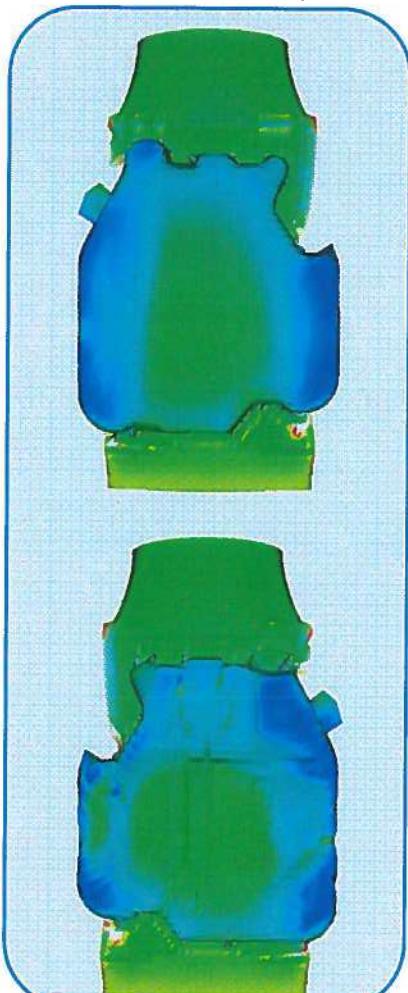
Numerical Results and Comparison (Standard 3D/Solid-Shell/2.5D)

Standard 3D



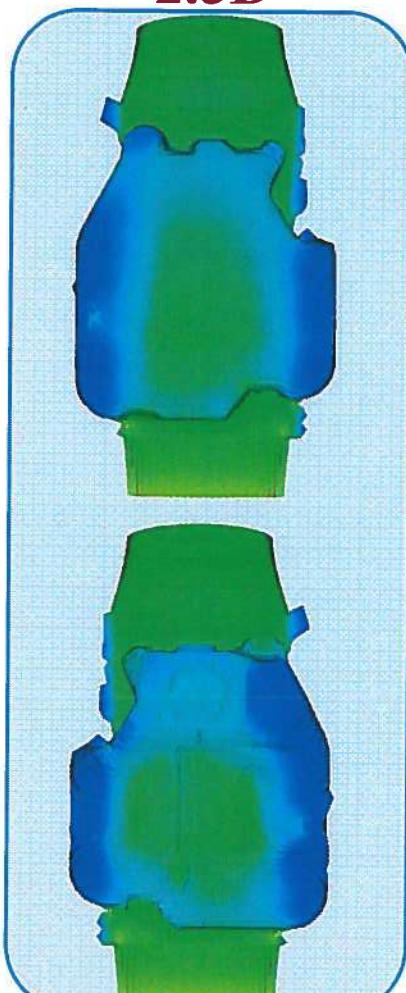
4 H8 Elements: CPU: 242 mins

Solid-Shell

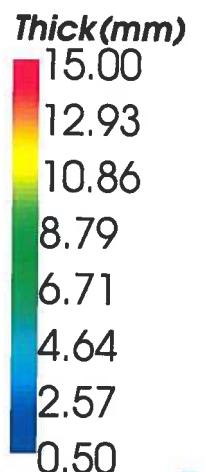
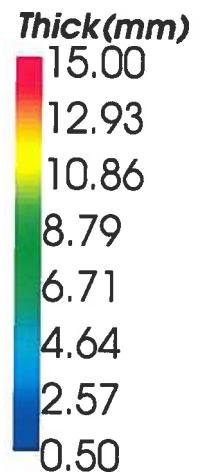


4 Layers: CPU: 150 mins

2.5D



4 Layers: CPU: 15 mins



Recall of Form3D Capabilities...

- Multilayer solid-shell element has become one of the most favourable element in forming analysis due to its numerical efficiency :
 - High accuracy (stress-strain, thickness)
 - Low order element
 - Low computational cost
 - Multilayer and multi-material
 - Material and thickness repartition across the thickness regardless of the mesh
- Comparison of 2.5D / 3D / Solid-Shell shows almost no added value for thickness prediction when deformable body contact is not taken into account (in the pinch area).

When to use 3D?

Added value of using 3D compared to 2D...

- Material incompressibility is better managed
- Thickness calculation is more realistic in the compression areas, however, in most cases, there's no significant added value for wall thickness prediction in the cavity.
- The following, non-exhaustive topics, are not possible with the 2D approach:
 - Pinch shape prediction
 - Compression moulding for welding prediction
 - Vacuum vs. pressure effects on the final wall thickness
 - etc.

Outline

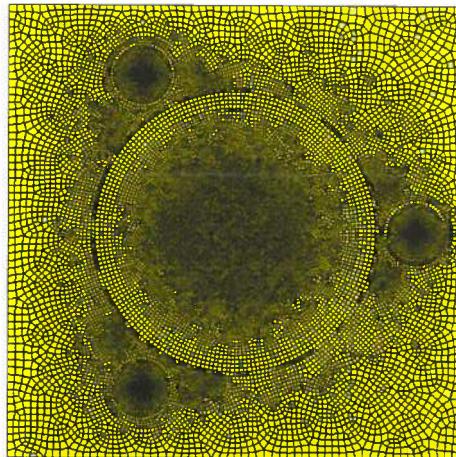
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Welding Example

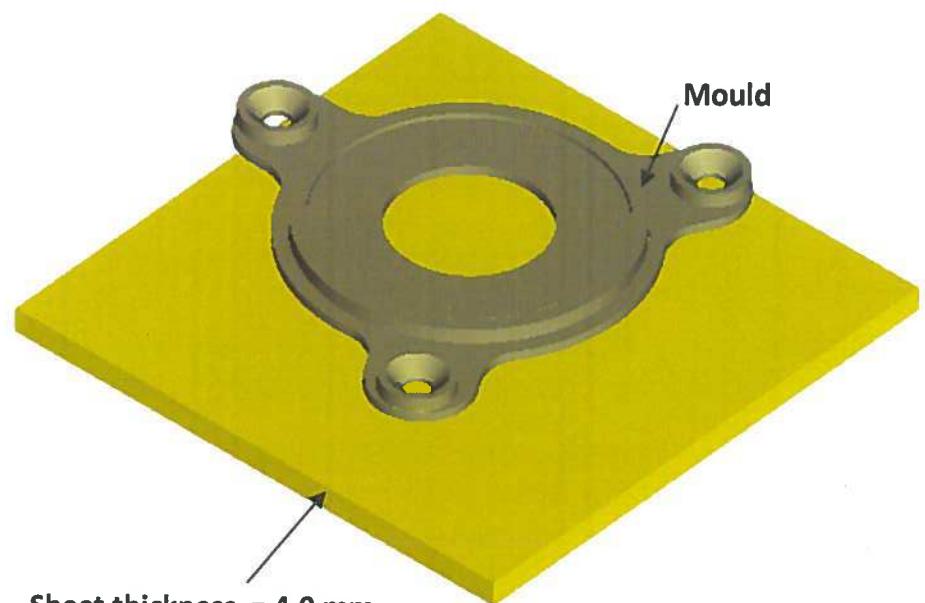
Sheet info

- 4 mm
- Solid shell element
- 1 layer through the thickness
- KBKZ model for HDPE
- Mesh created with CAD software
(non-uniform, refined mesh)
- 46174 Nodes, 22966 Elements

Sheet Mesh



Mould Set-up

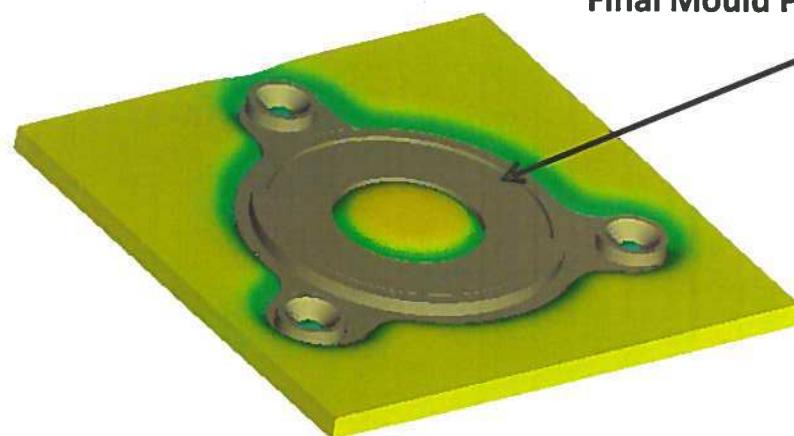


Welding Example



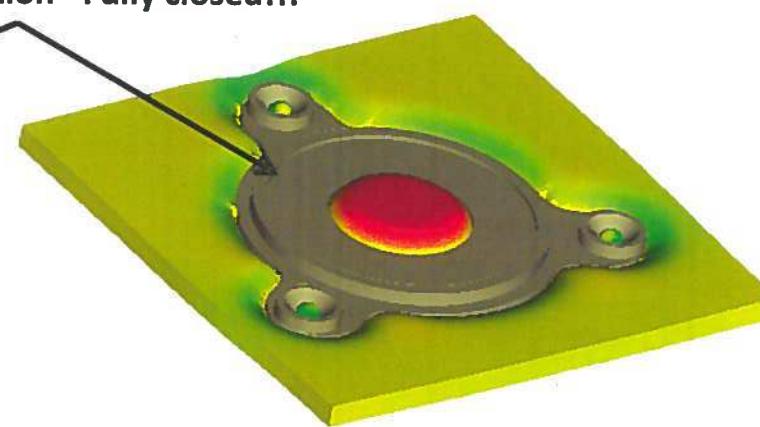
Welding Example

Default Incompressibility Constraint

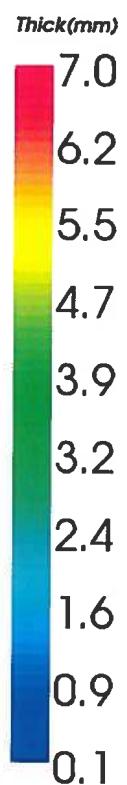
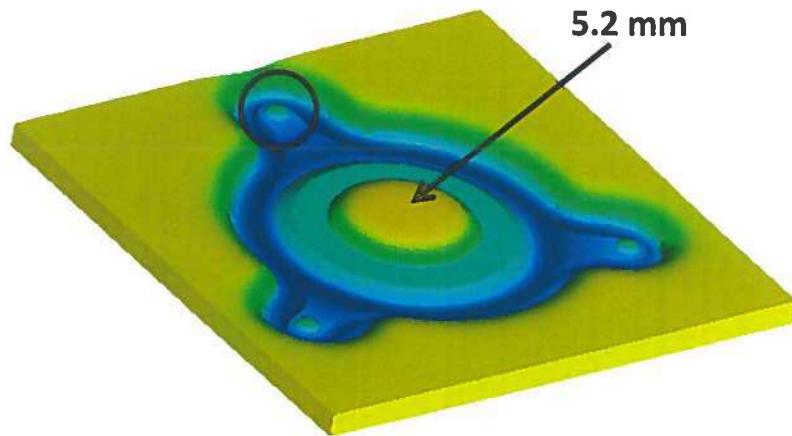


Thickness:
5.2 mm

Increased Incompressibility Constraint



Thickness:
6.9 mm



Pinch Example 1

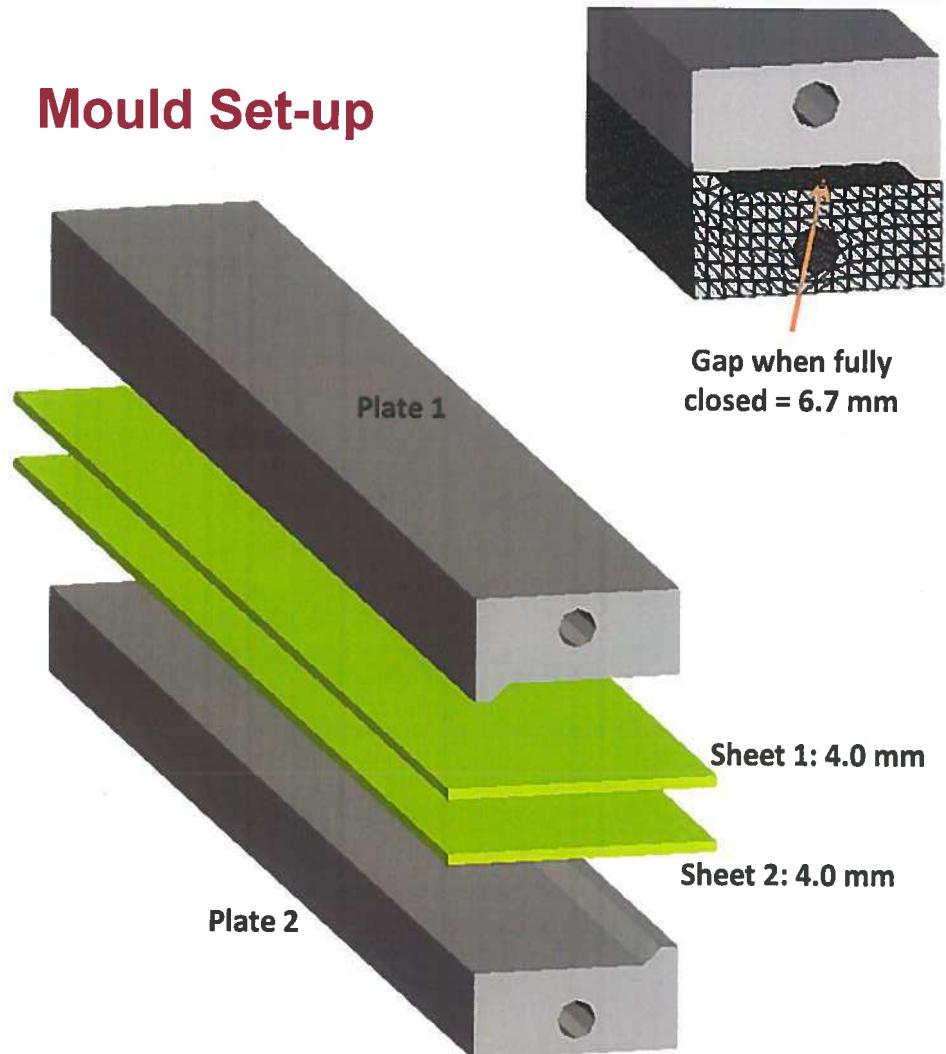
Sheet info

- Created with Sheetmesh3D
- 4 mm each
- Solid shell element
- 1 layer through the thickness
- KBKZ model for HDPE
- Pinch Plates courtesy of:

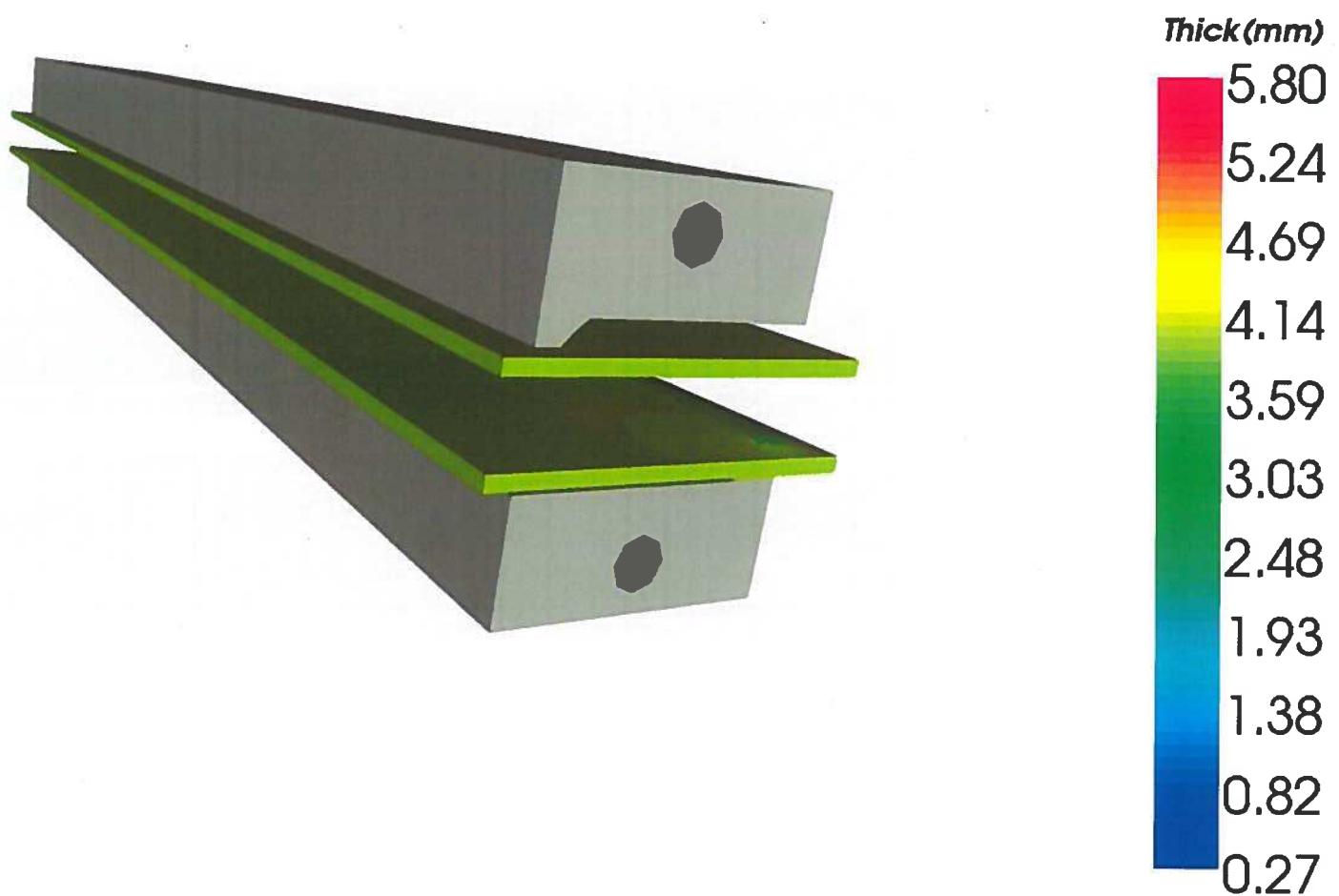


- Multibody contact

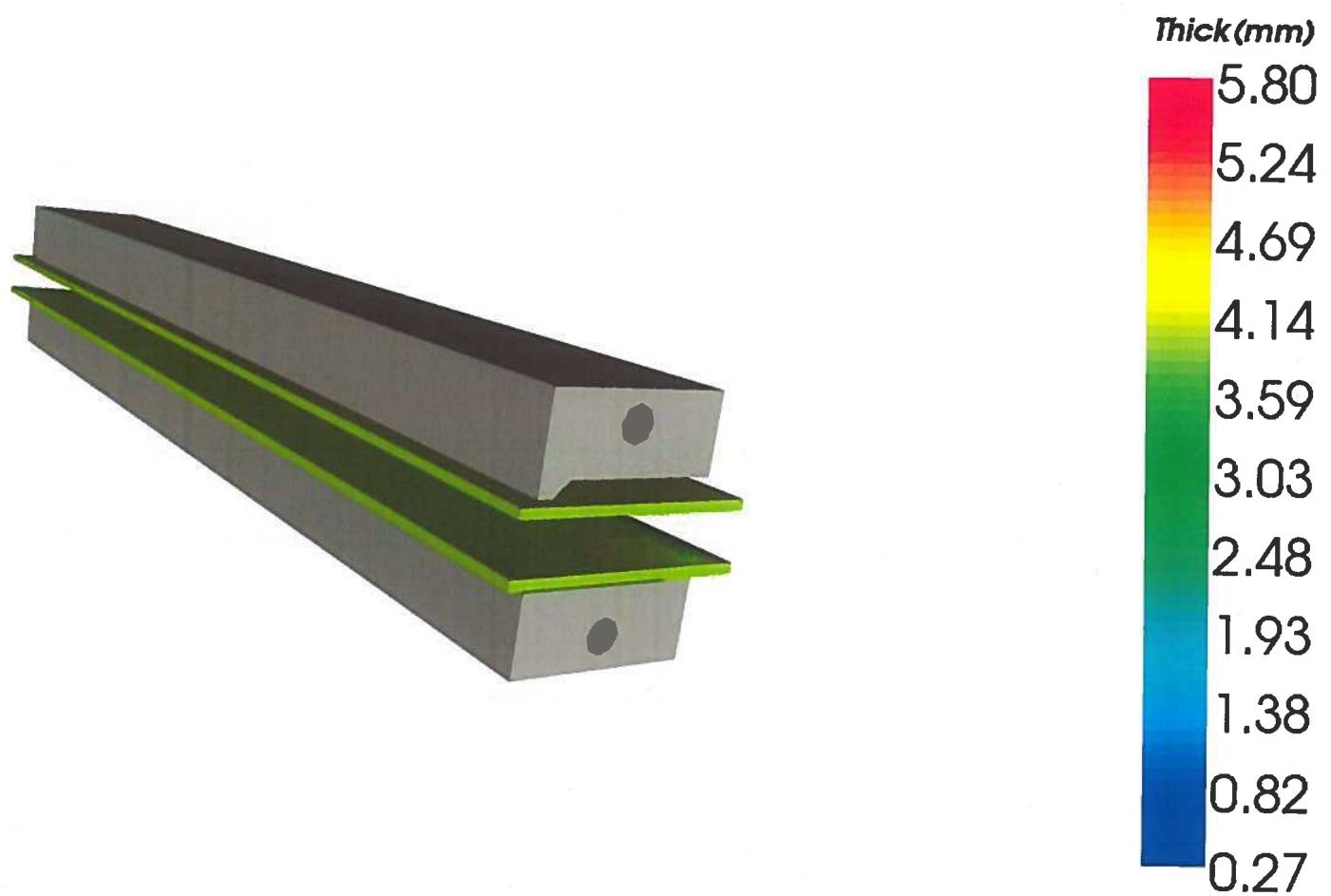
Mould Set-up



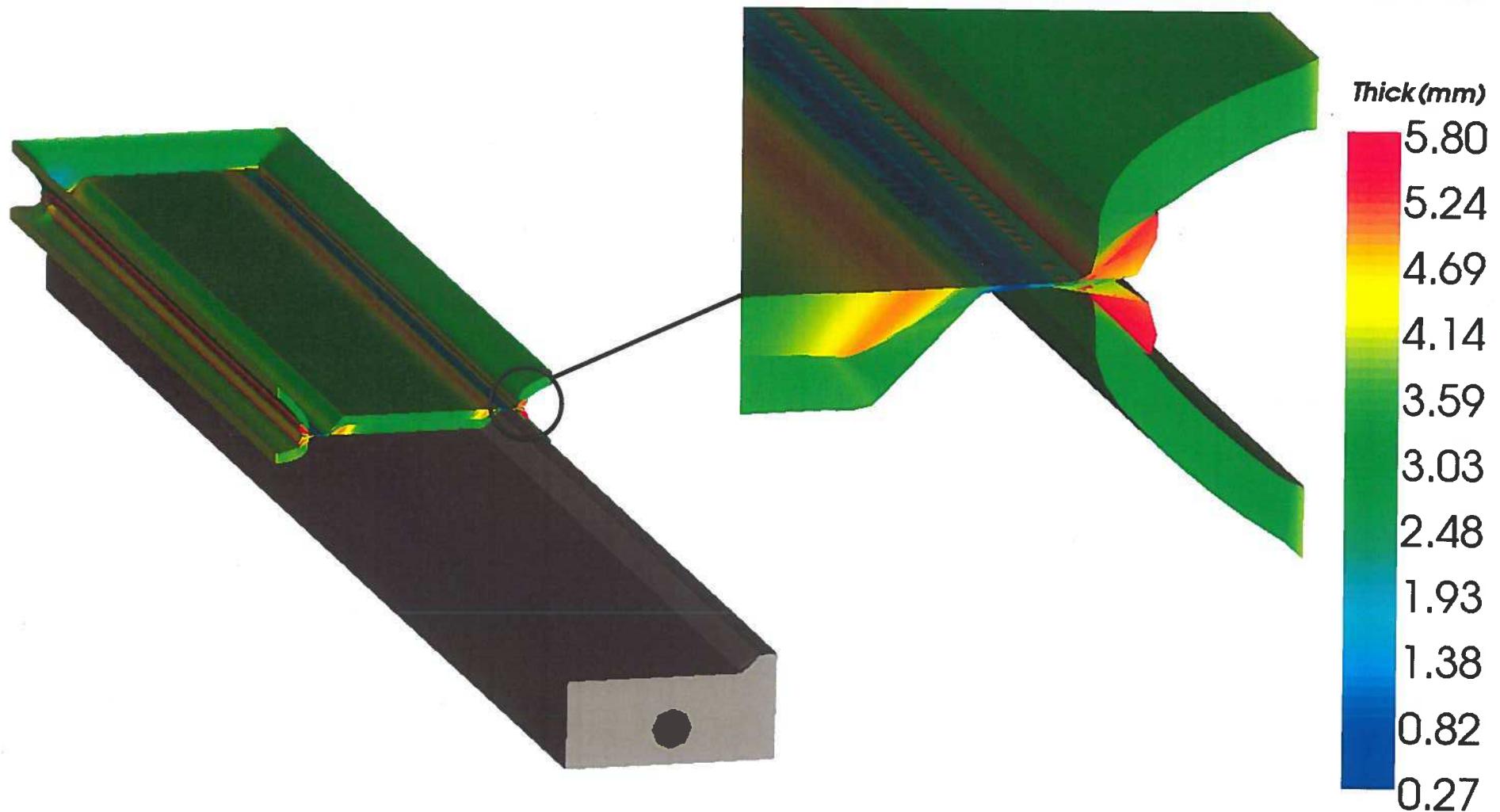
Pinch Example 1



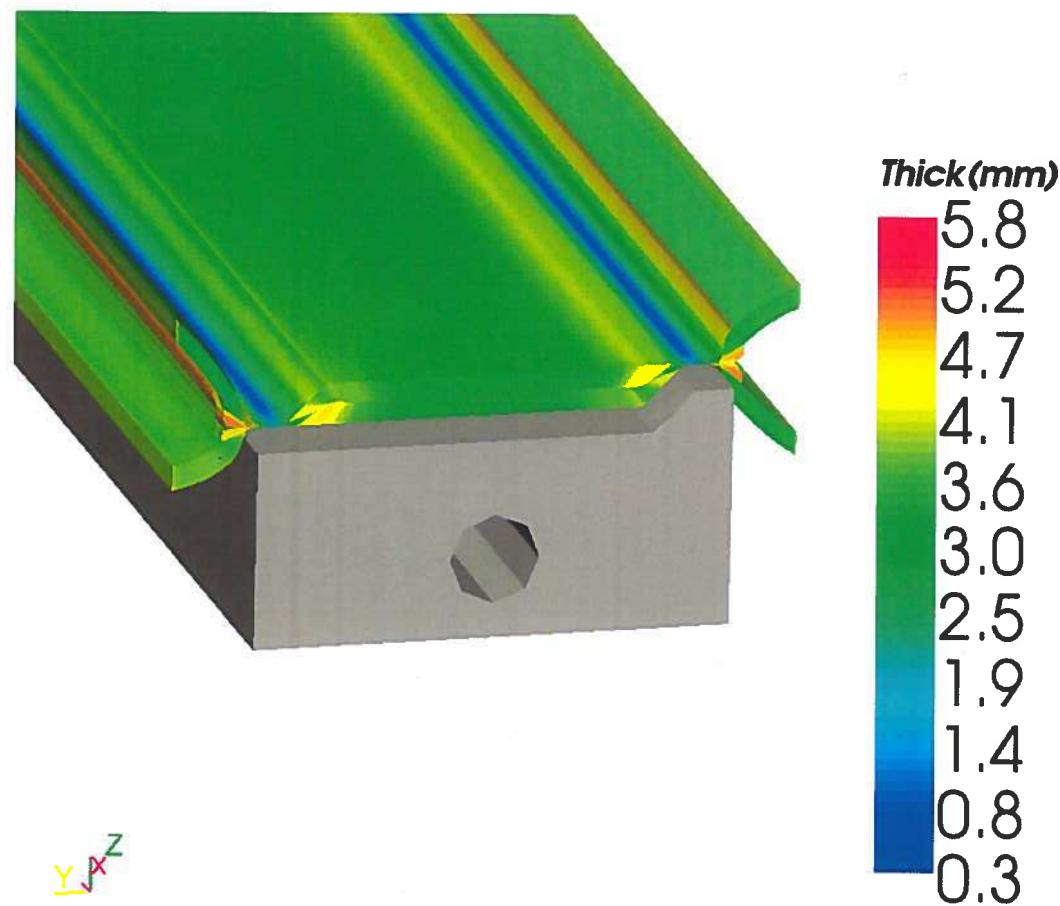
Pinch Example 1



Pinch Example 1



Pinch Example 1



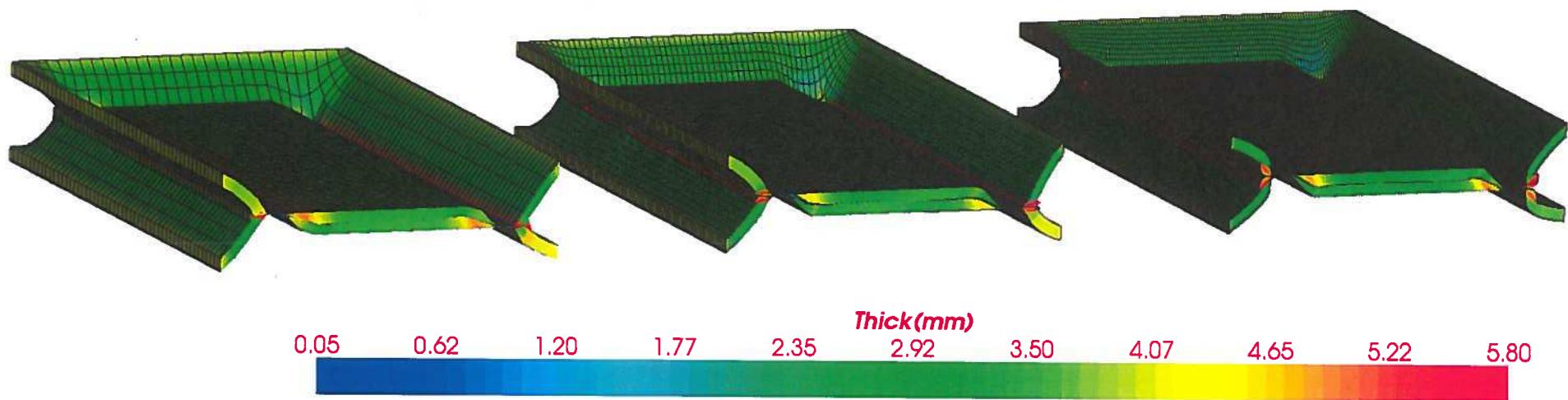
Pinch Example 1

Effect of Mesh Size on the Pinch Shape Prediction

Mesh Size = 15
24428 Nodes
11760 Solid-Shell Elements

Mesh Size = 30
95404 Nodes
46800 Solid-Shell Elements

Mesh Size = 60
378004 Nodes
187200 Solid-Shell Elements

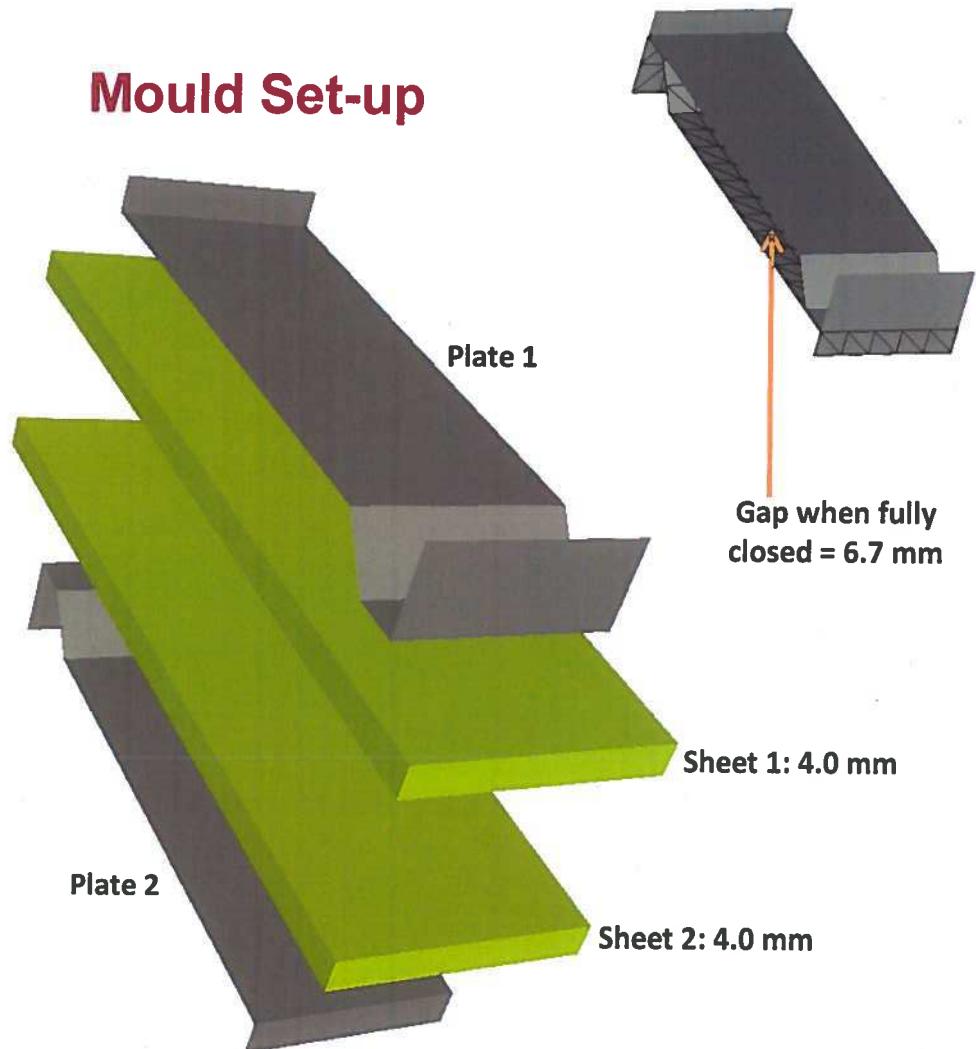


Pinch Example 2

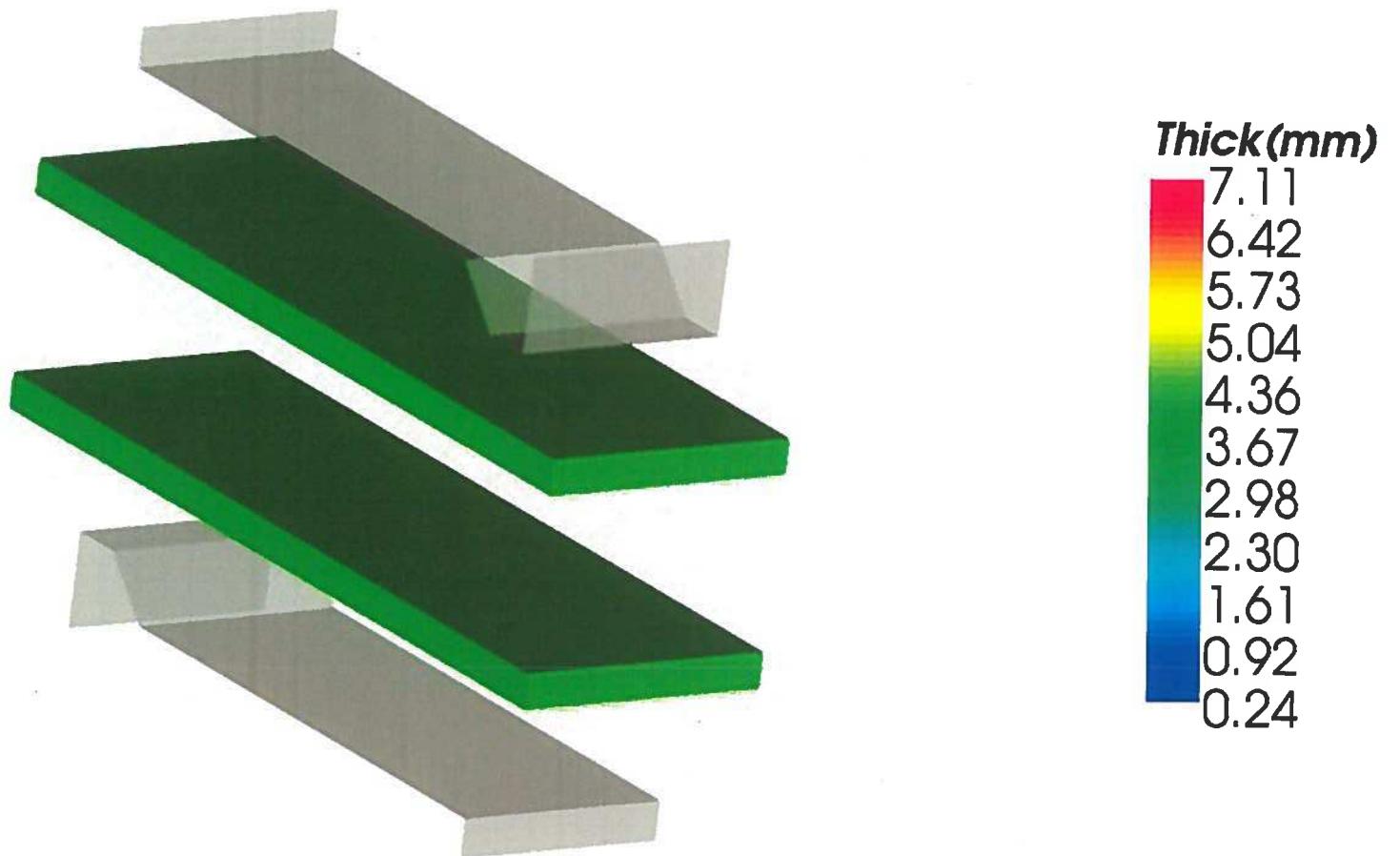
Sheet info

- Created with Sheetmesh3D
- 4 mm
- Solid shell element
- 1 layer through the thickness
- KBKZ model for HDPE
- Multibody contact
- Incompressible material

Mould Set-up

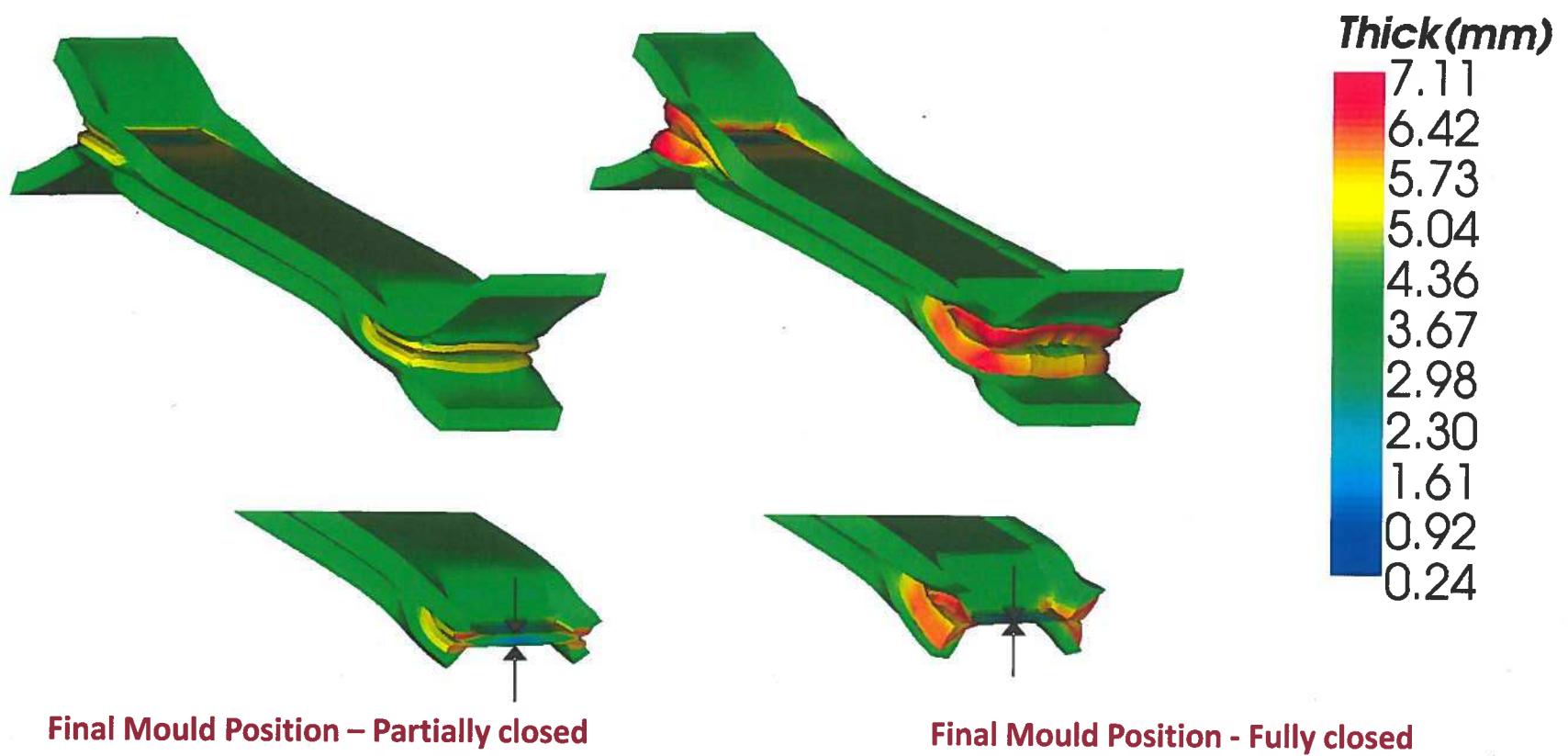


Pinch Example 2



Pinch Example 2

Effect of the Final Mould Gap on the Pinch Shape Prediction



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Numerical Input Parameters

Must specify the following parameters in the Form3D definition file:

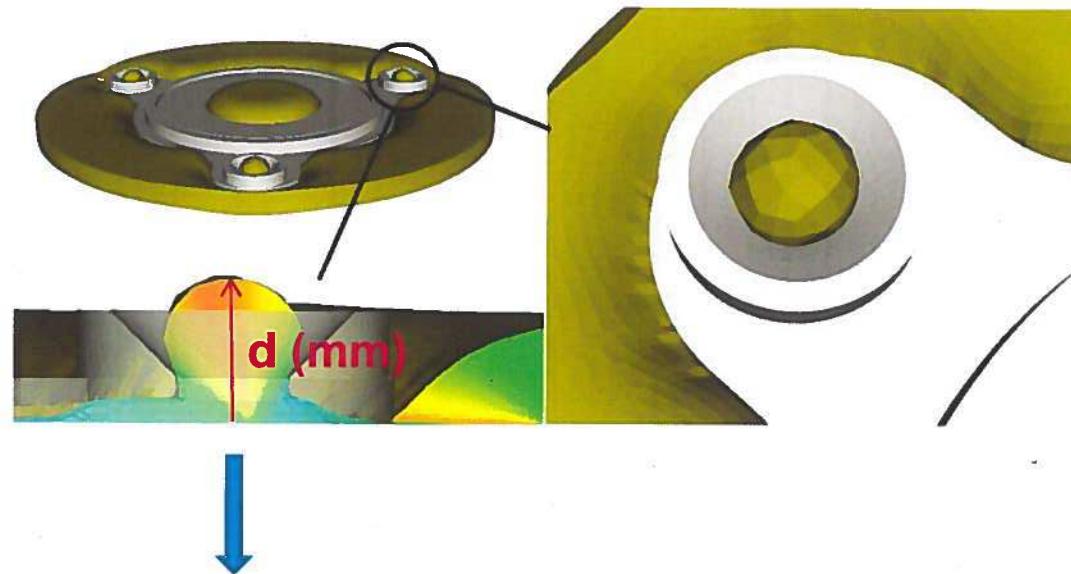
1. Incompressibility parameters in the command line:

“MatProp, a, b, c”

2. Artificial/numerical stiffness, S1 and S2 in the command line:

“StfStrs, 1, Fix, S1, S2”

Sensitivity Analysis with respect to incompressibility constraint parameters



Incompressibility parameters in the definition file: “**MatProp, a, b, c**”

		a				
		0.1	2	4	5	6
c	3	2.308	3.995	5.801	6.018	6.539
	30	2.305	4.478	4.621	4.745	4.814
	100	2.305	3.165	4.538	4.626	4.719

Note: parameter *b* is set to 0.3

Numerical Input Parameters: Best Practices...

Definition file of form3d:

1. Set the incompressibility parameters in the command line:
“MatProp, a, b, c” to:
 - a: between 4 and 6
 - b: always 0.3
 - c: 3

2. Increase the initial numerical parameters S1 and S2 in the command line:
“StfStrs, MatId, Fix, S1, S2” by one or two orders of magnitude when the material is too squeezed (mould fully closed).

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Conclusion and Future Work...

- Form3D is a very suitable tool for predicting pinch-forming and modelling material incompressibility
- Material incompressibility is the most challenging constraint to meet when the material is excessively squeezed (pinch and compression area)
- Numerical parameters monitoring the incompressibility constraint and its related (high) pressure should be automatically updated where needed, when needed...
- Contact algorithm needs to be improved for multibody and self-contact including an efficient control of friction