

Thermoforming simulation in LS-Dyna

Dynamore Nordic User's Conference 2018

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About Thule Group

Thule Group is world leader in products that make it easy to bring along the things you care for – easily, securely and in style – when living an active life.

Under the motto *Active Life, Simplified.* we offer products within **Sport&Cargo Carriers** (roof racks, roof boxes and carriers for transporting cycling, water and winter equipment by car), **Packs, Bags & Luggage** (e.g. computer and camera bags, luggage and hiking backpacks), **RV Products** (awnings, bike carriers and tents for motorhomes and caravans) and **Active with Kids** (bike trailers, strollers and child bike seats).

Thule Group has approximately 2,200 employees at 9 production facilities and 35 sales offices worldwide. Its products are sold in more than 140 markets and sales in 2017 amounted to SEK 5.9 billion.

The Thule Group Vision – Active Life, Simplified.



Thule Group»



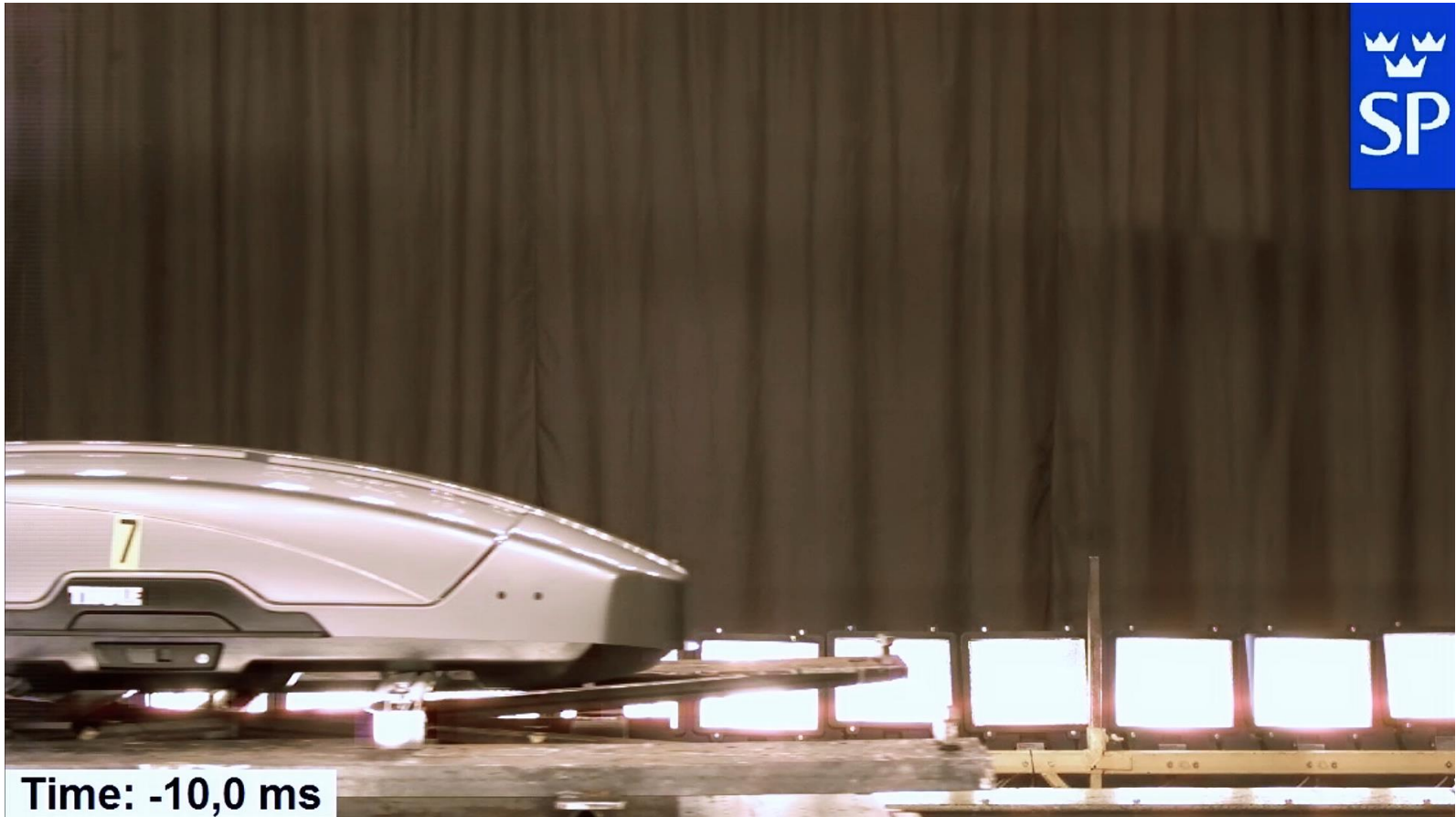
Simulation at Thule Sweden

- 6 people + 1 consultant
- ANSA/MetaPost (LS PP)
- LS-Dyna

- Implicit – Static
- Implicit – Dynamic

- Explicit

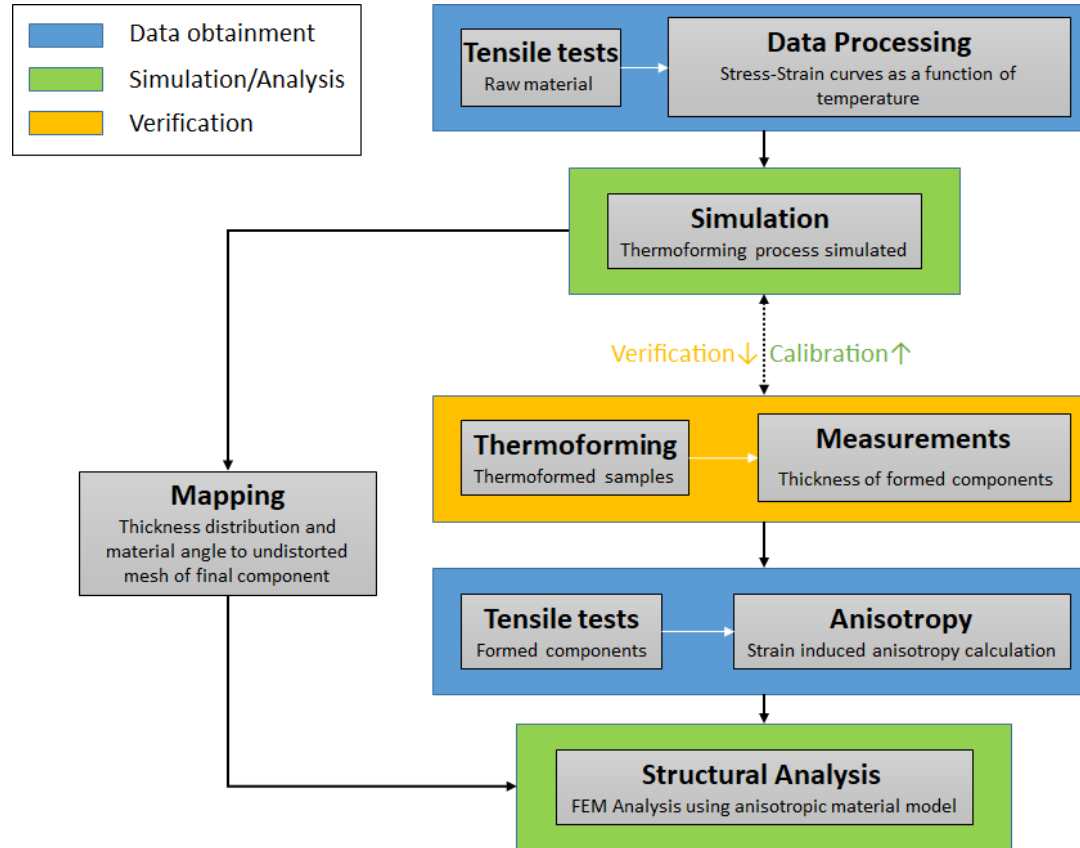
Roof box crash



Thermoforming of roof box base (and lid in background)



Method and implementation



Experiments

- Tensile tests to identify raw material properties at elevated temperatures
- Vacuum thermoforming to identify thickness distribution
- Tensile tests to identify obtained material properties in room temperature (RT)

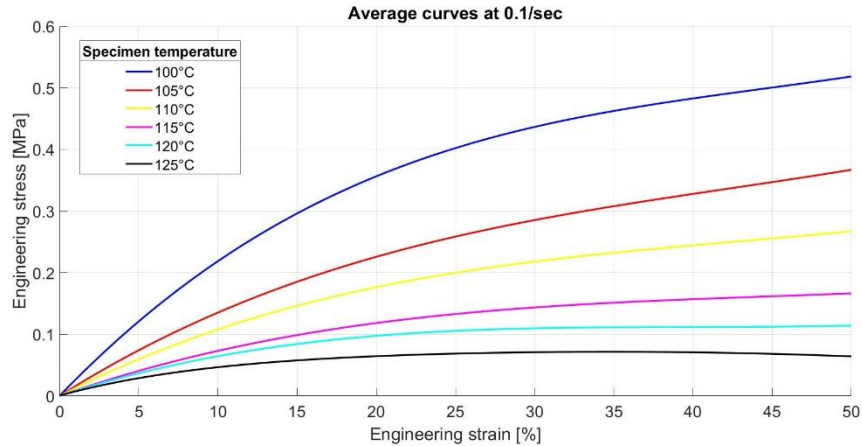
Tensile tests (raw material)

- Purpose: Identify the hyperelastic behaviour of ABS material at elevated temperatures up to 170°C
- Results not considered reliable above 130°C
- Tested specimens:

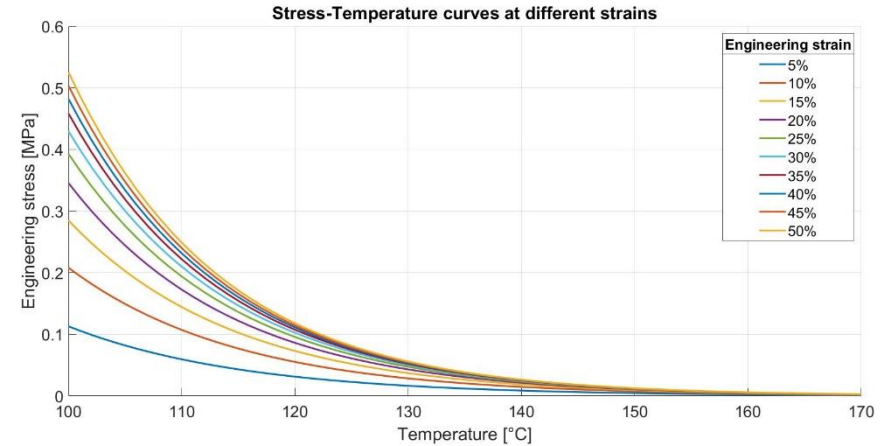
Temperature [°C] @ 48 [mm/min]	80	100	105	110	115	120	125
No. Of samples	5						

Tensile tests

Mean stress-strain curves at different temperatures

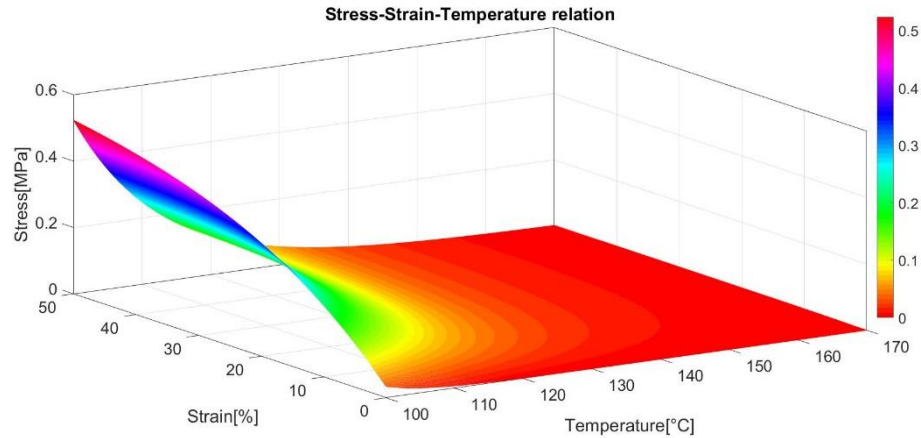


Mean stress-temperature curves at different strains

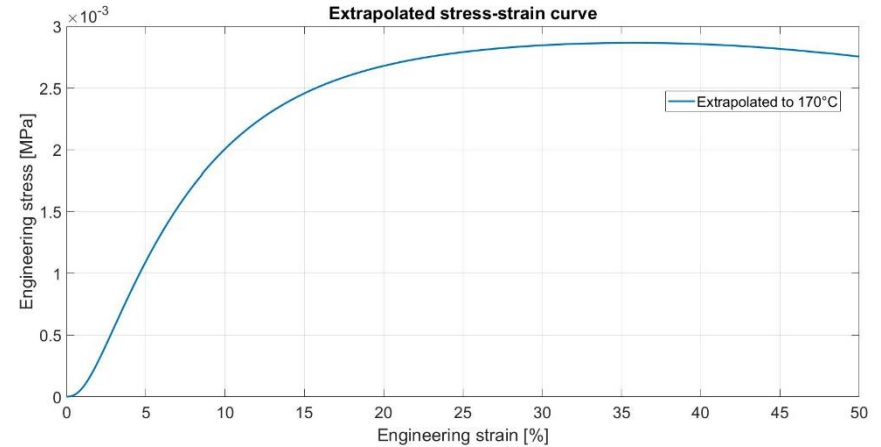


Tensile tests

Stress-strain-temperature relation

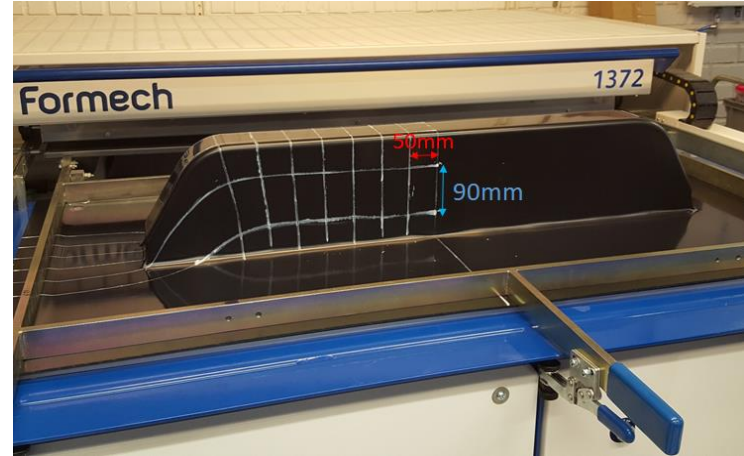
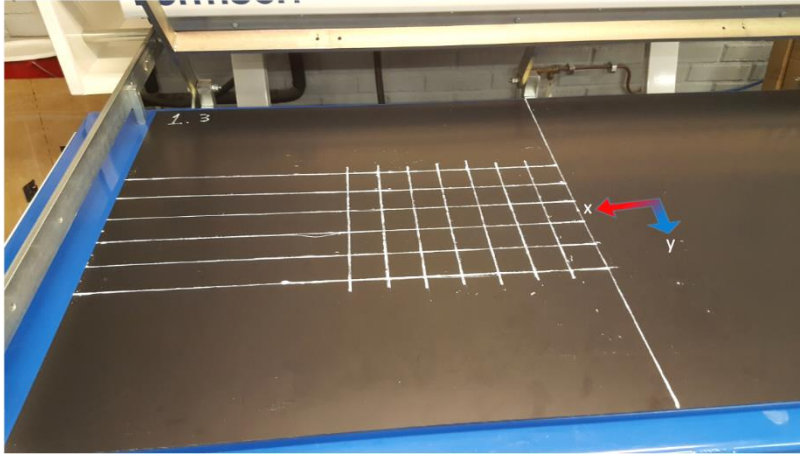
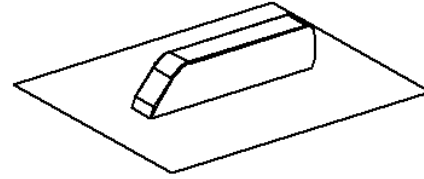


Cross section at 170°C



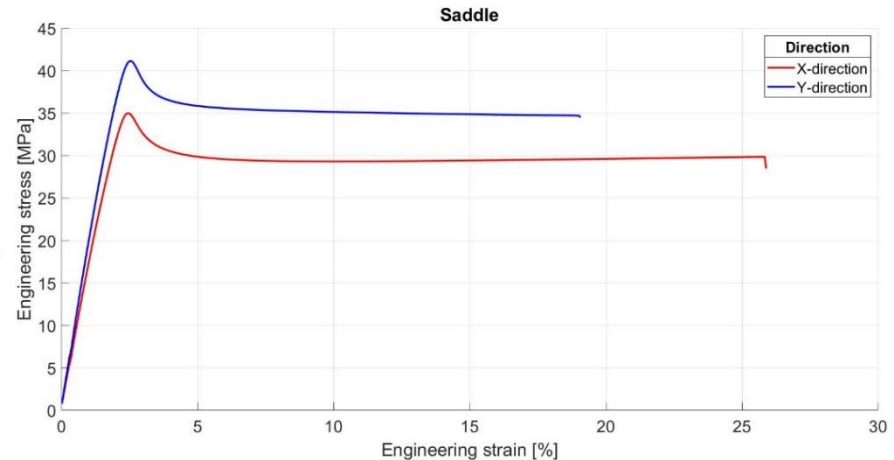
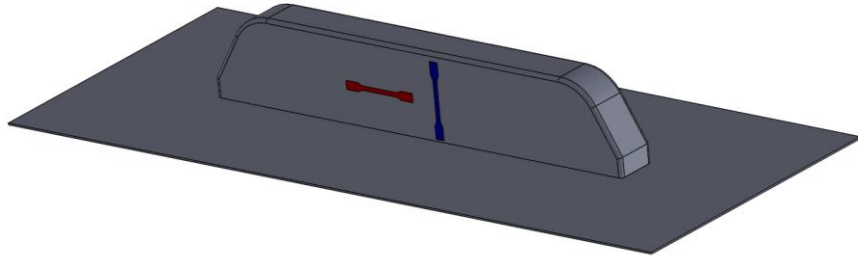
Vacuum thermoforming

- A "saddle" shaped geometry was used
- 50x50mm square pattern



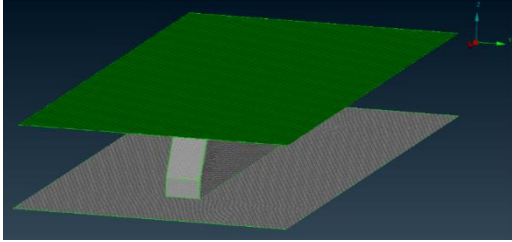
Tensile tests (from formed components)

- Samples in **X** and **Y** direction to identify strain induced anisotropy
- A total of 10 samples from each direction were tested
- Mean curves plotted



FE-model

- 1st order quadrilateral shell mesh for both the tool and the sheet

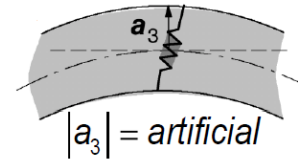
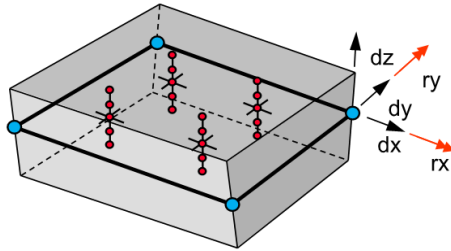


	Thickness [mm]	Element size [mm×mm]	NIP*	ELFORM**
Tool	1	3×3	2	2
Sheet	4	2.5×2.5	5	26

*NIP = Number of through thickness Integration Points

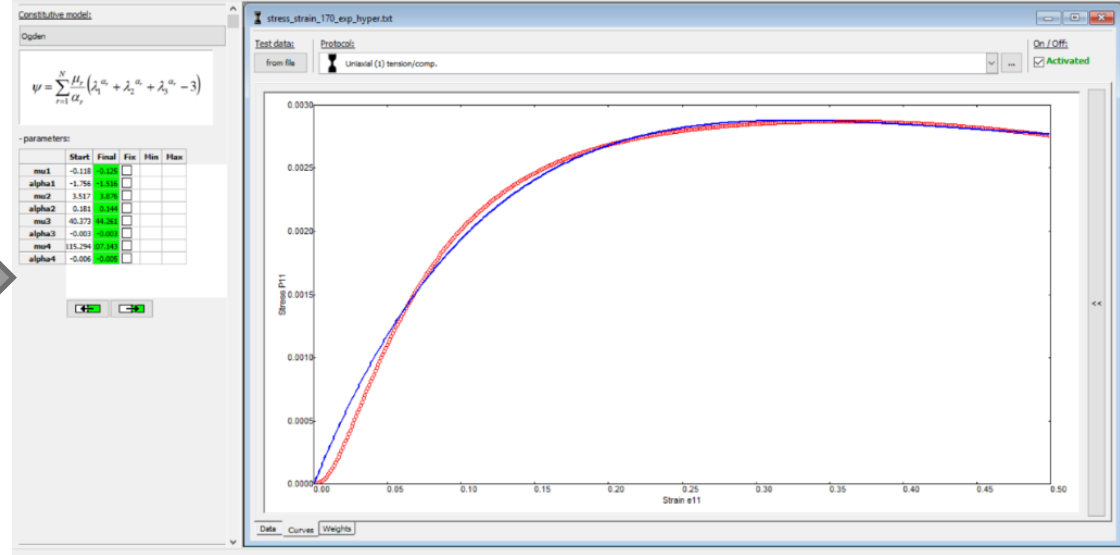
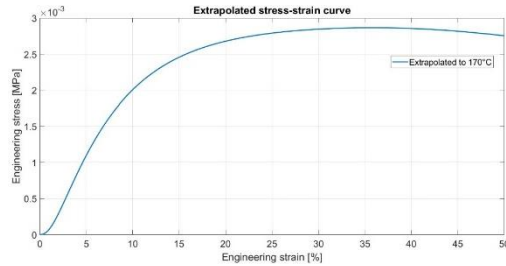
**ELFORM = Element formulation

ELFORM 26



Material data

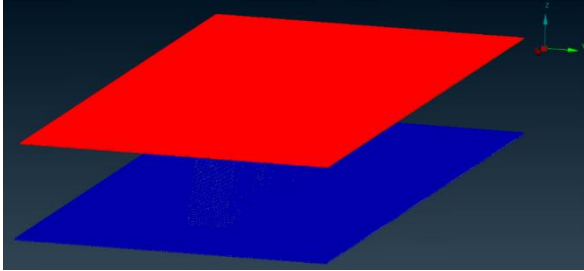
- Hyperfit software was used to identify Ogden parameters



Load case

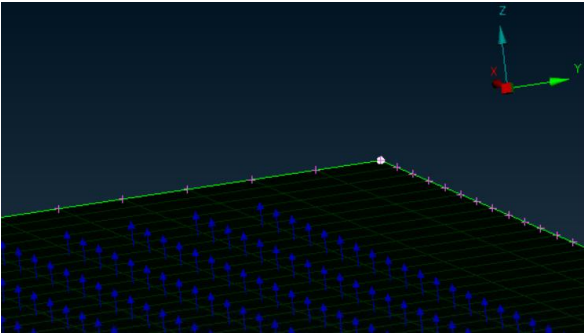
CONTACT

*AUTOMATIC_SURFACE_TO_SURFACE

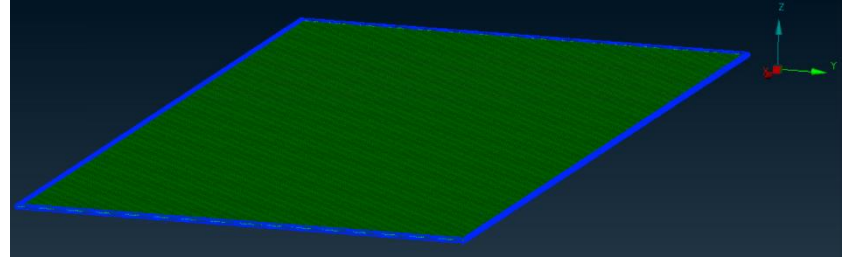


Element load

*LOAD_SHELL

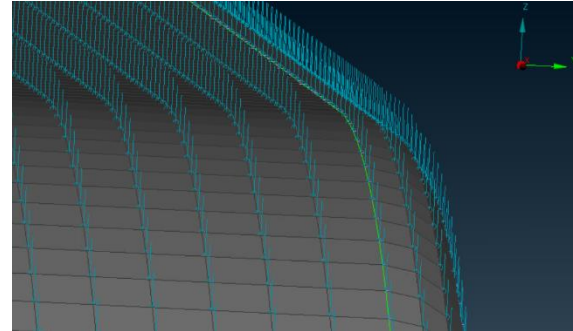


BOUNDARY CONDITIONS



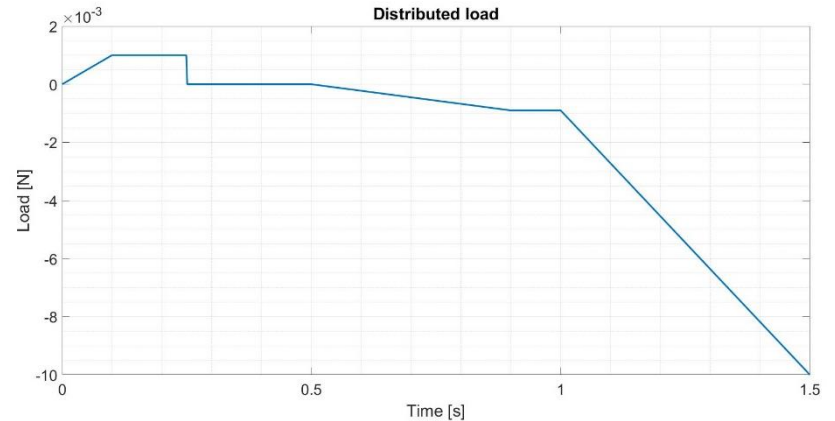
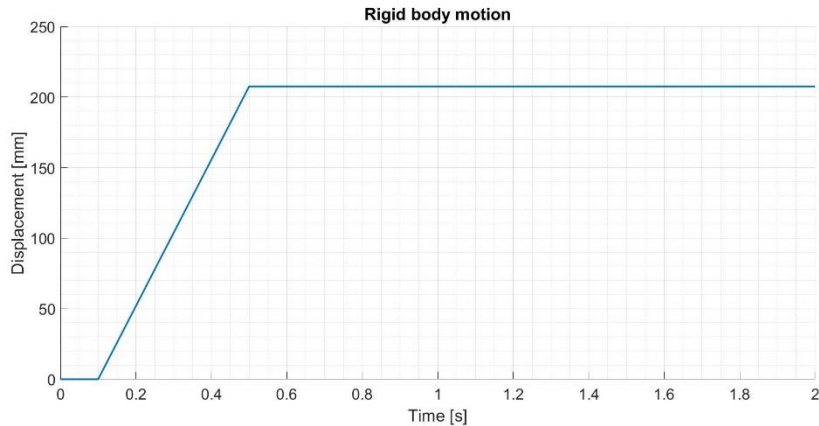
Tool displacement

*BOUNDARY_PRESCRIBED_MOTION

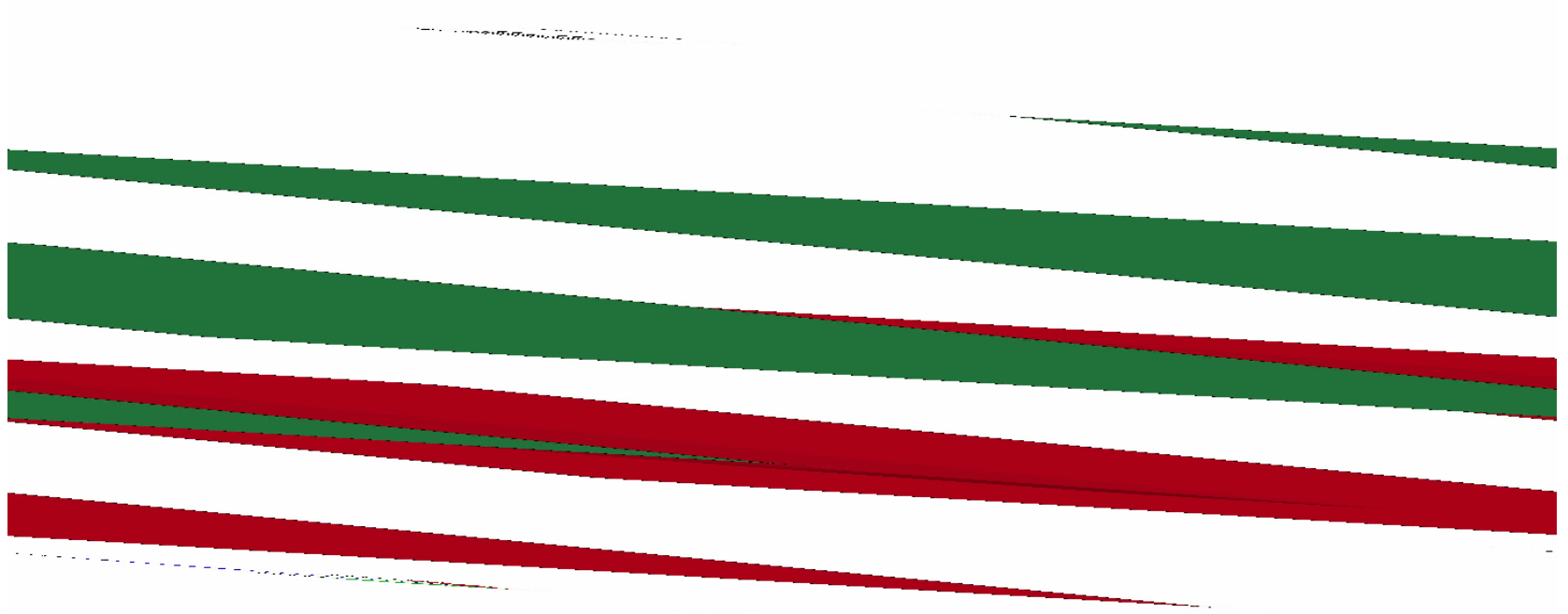


Load case

- Two curves to govern the raising of the tool and the load magnitude/direction

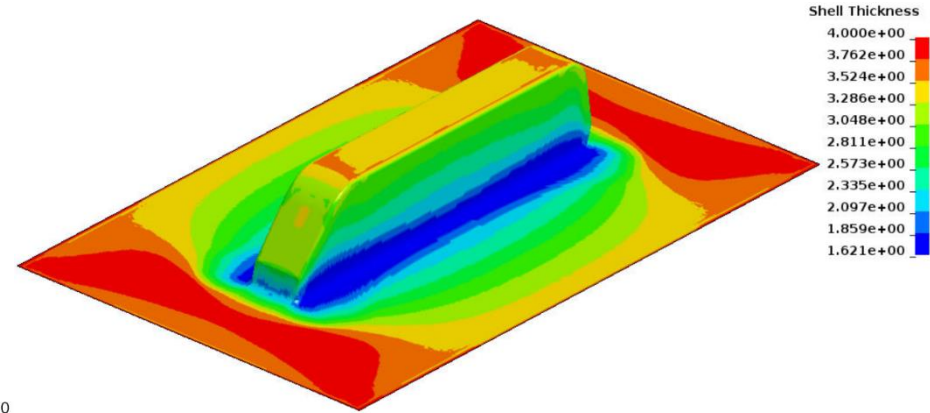
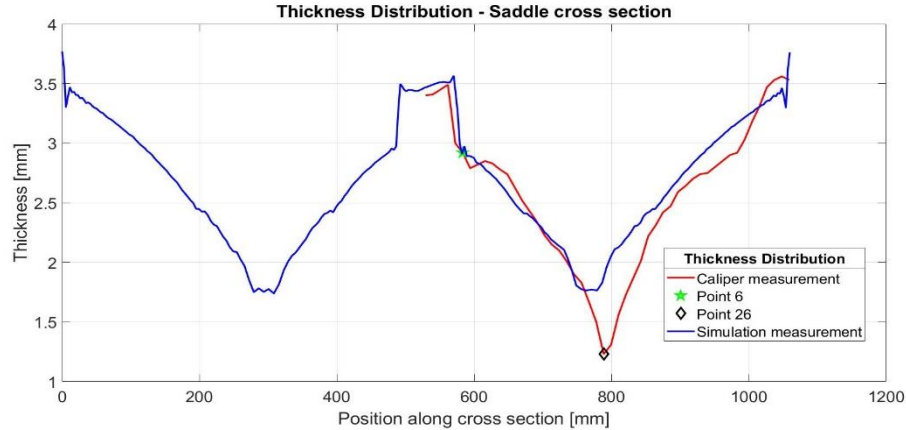


Simulation video



Verification and calibration

- The friction coefficient, between the tool and the sheet, in the simulation was adjusted so that the simulation results would agree with the measured data.



Structural analysis

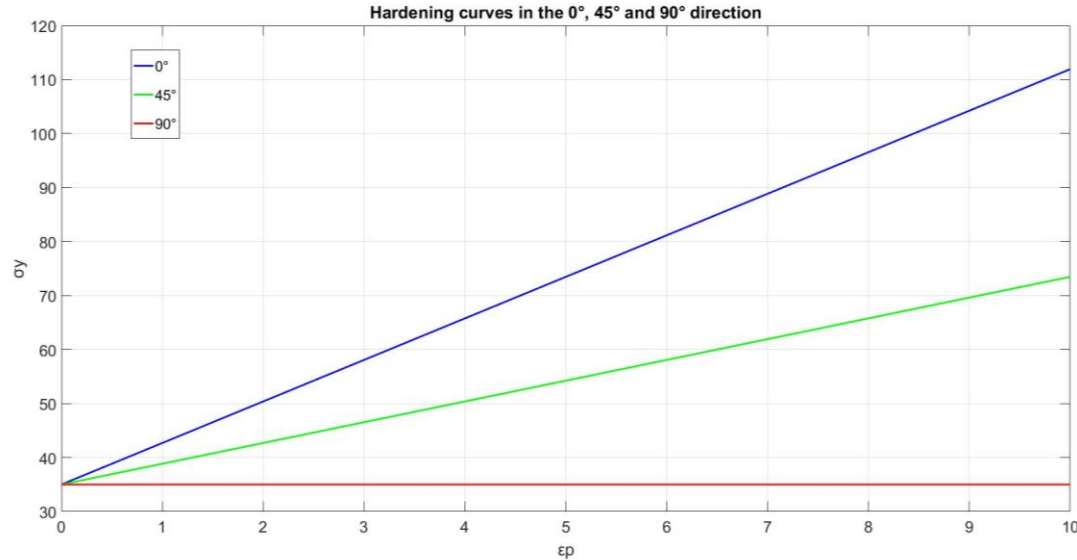
- Barlat's three-parameter plasticity model (*MAT_036) was used
- Allows strain hardening and dynamic Young's modulus (not directional though!)
- Young's modulus as a function of effective plastic strain based on tensile tests

$$E = 369.375e_p + 34.996$$

- Linear hardening was assumed in directions 0° and 45°
- Weighting functions to approximate hardening in 45° direction
- Perfect plasticity in the 90° direction

Structural analysis

- Plastic hardening curves input to the material model



$$\sigma_y^{0^\circ} = 7.6929e_p + 34.996$$

$$\sigma_y^{45^\circ} = 3.84645e_p + 34.996$$

$$\sigma_y^{90^\circ} = 34.996$$

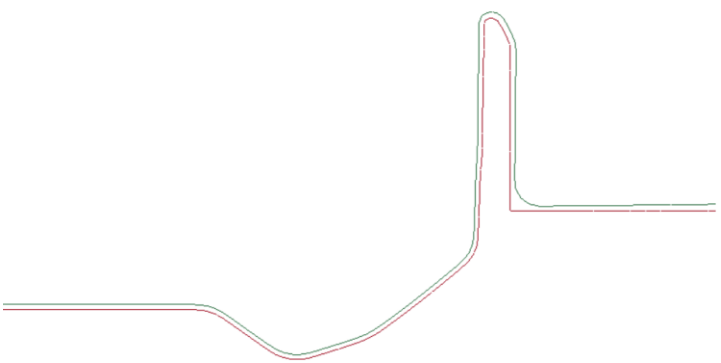
Geometrical results

- Formed sheet after thermoforming simulation
- Overall good agreement with the tool geometry

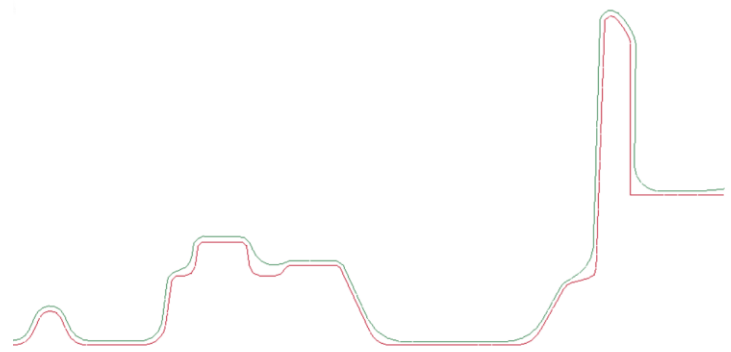


Geometrical results

Section view along the length

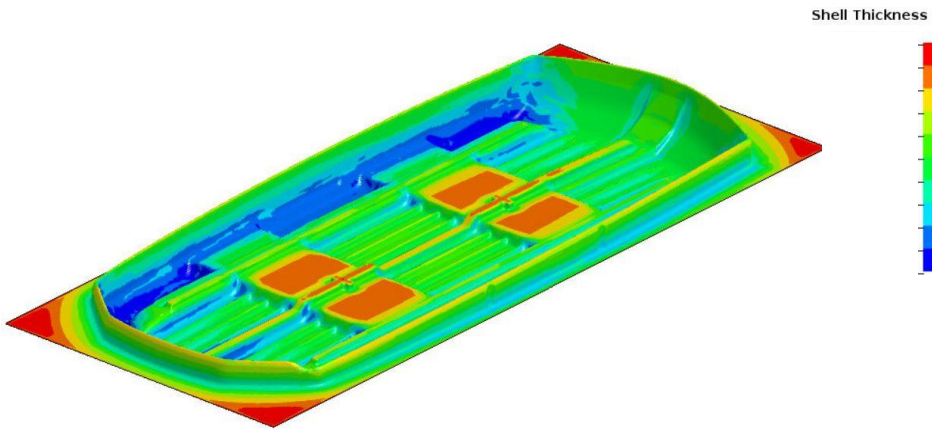


Section view along the width

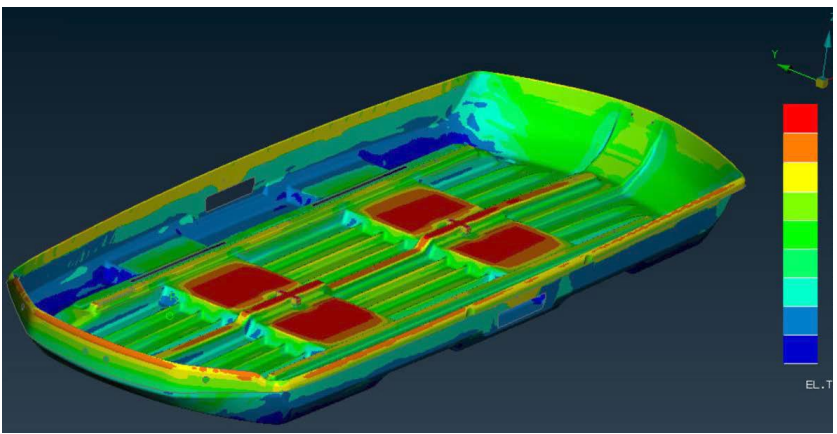


Thickness results - Mapping

Thickness distribution – LS-PrePost

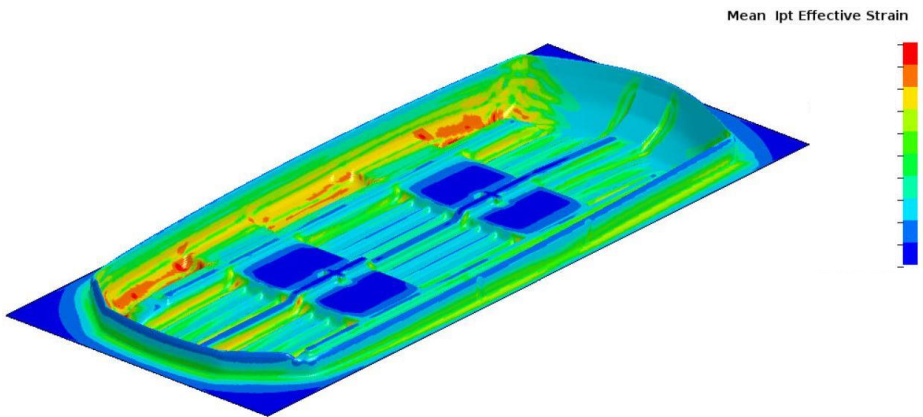


Mapped results – BETA ANSA

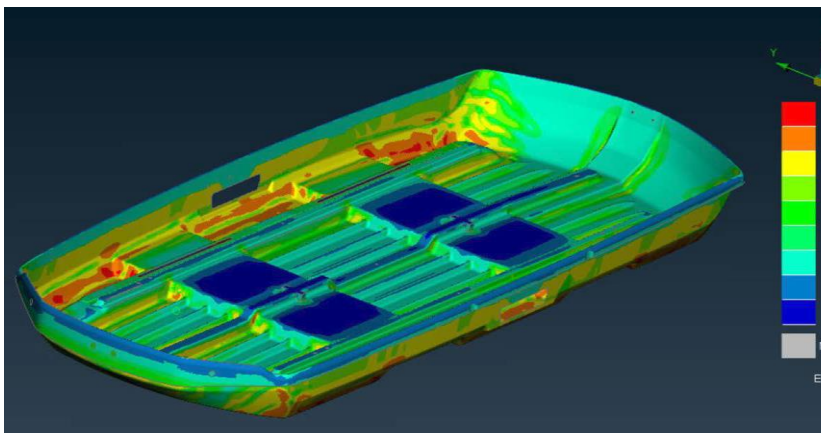


Strain results - Mapping

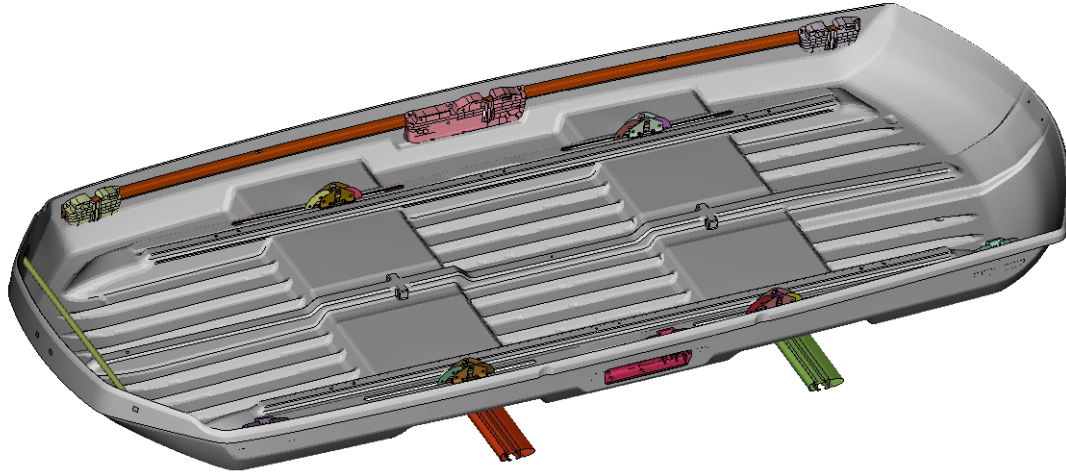
Strain distribution – LS-PrePost



Mapped results – BETA ANSA



0:d3plot : P18040 Thule assembly 180927:024-1,Explicit crash sequence,more BC:s,hig : STATE 1 ,TIME 0.00000000E+00



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