Hotforming as a multi-discipline simulation challenge

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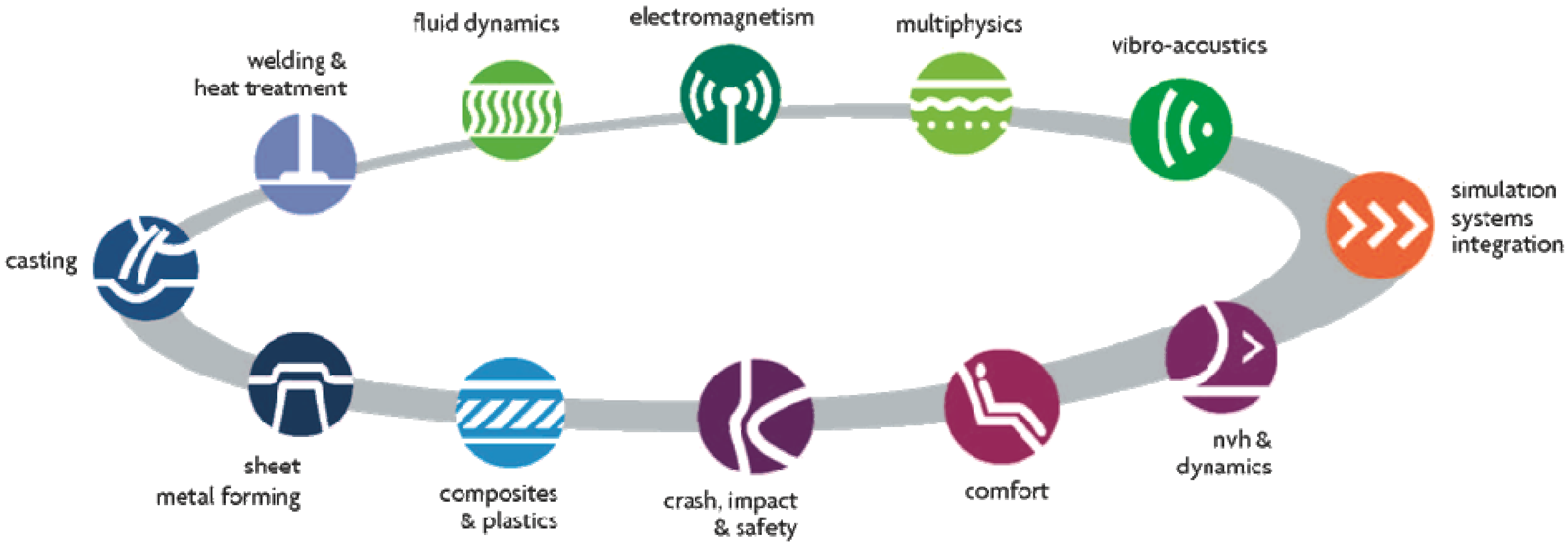
Dr. Roger Andersson
Svensk Verktygsteknik

Provider of Virtual Prototyping for the Industrial World



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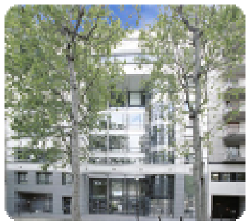

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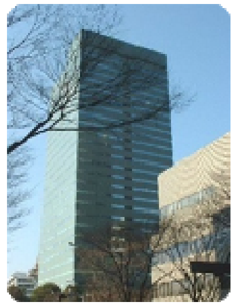

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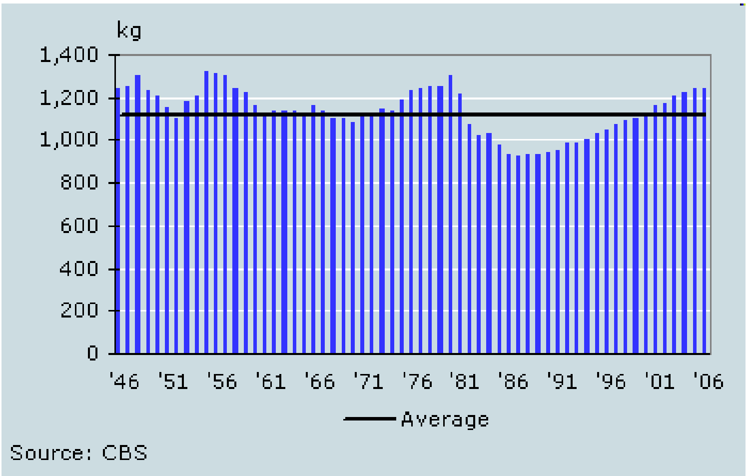
Car crash trends

- The objective of the crash test in recent years has always been:

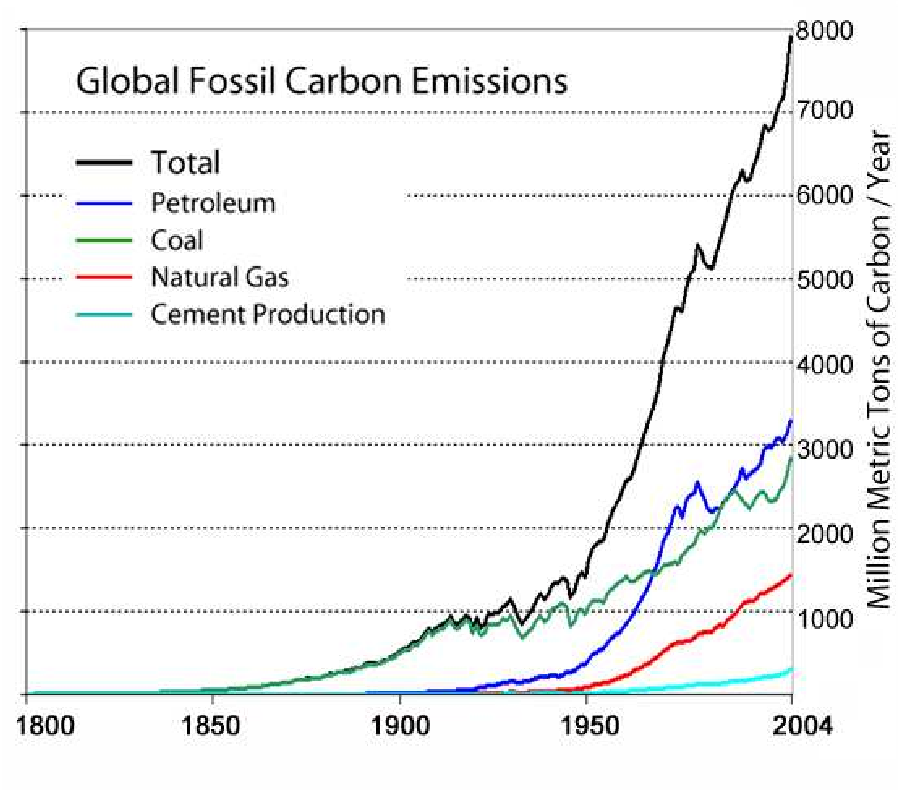
★ ★ ★ ★ ★

- Traditionally, this has been achieved by building stronger & stiffer cars → which has inevitably lead to the production of heavier cars over the past 20 years



Requirements to lower CO² emissions and fuel consumption

- EU Commission requirement: Average carbon dioxide emissions of the vehicles produced in 2012 to be no more than 120 g/km

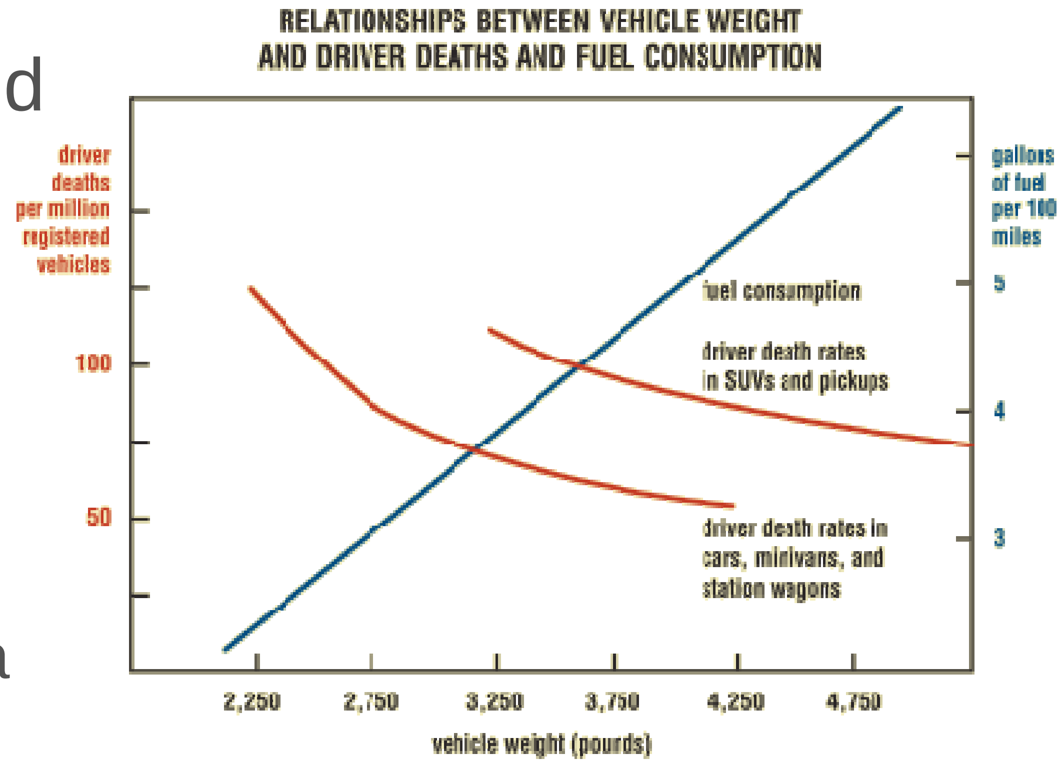


Source: Wikimedia commons

Contradictory requirements!

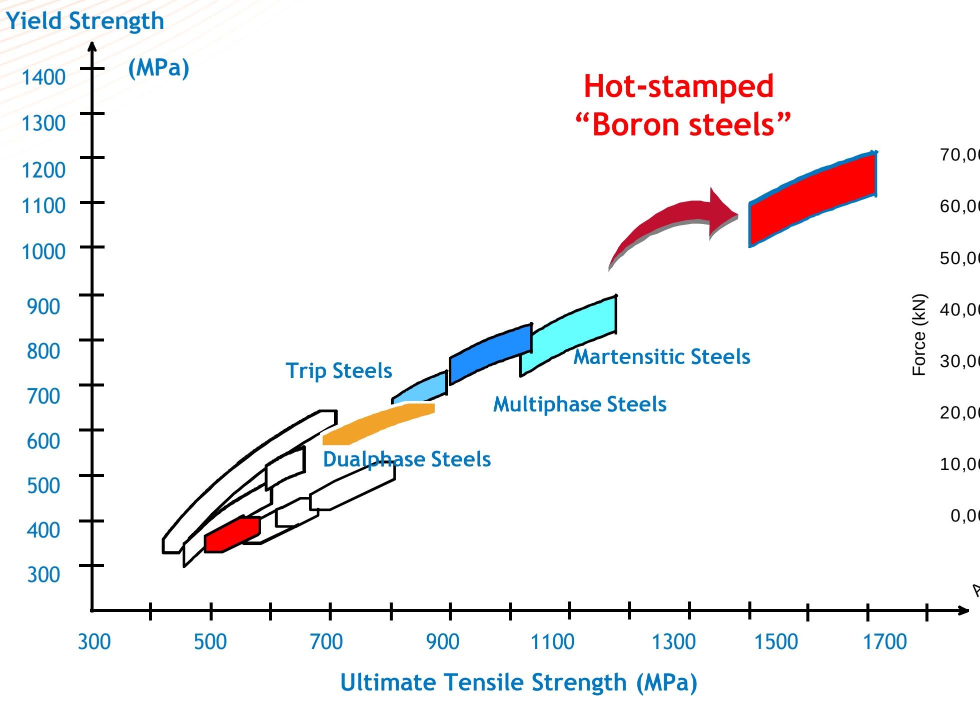
- Increase safety and reduce weight
  - → Conflicting requirements!

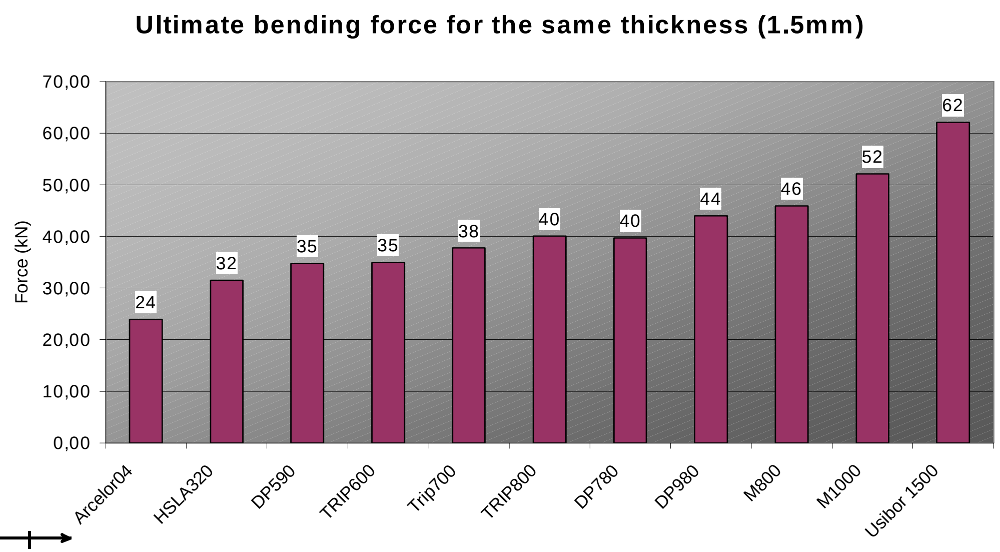
- The challenge:
  - → How to increase a vehicle's safety & reduce its weight?



Source: Insurance institute for highway safety

One solution is Hotforming



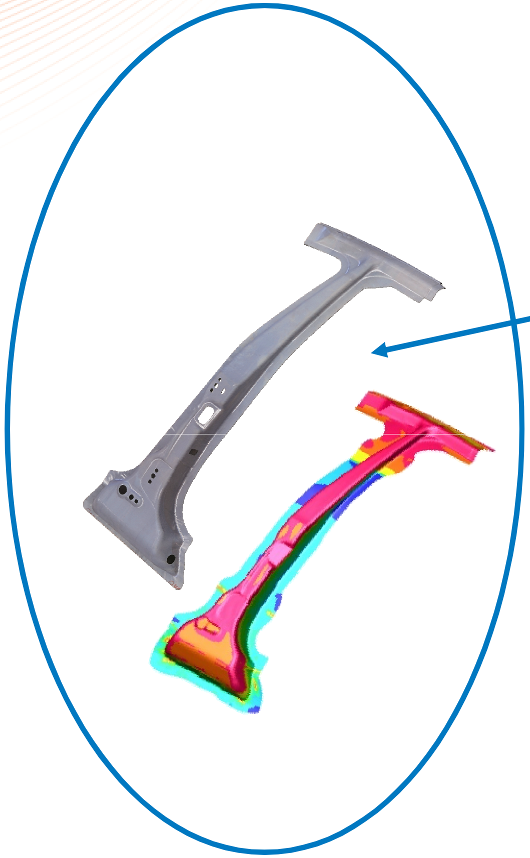


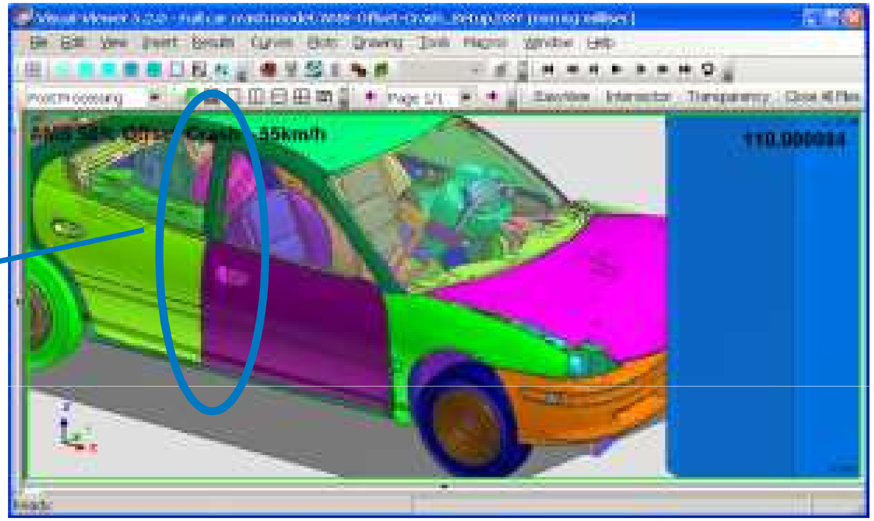
3 Point Bending Test at 29Km/Hr (10KJ)

Gives increased strength and crash performance, whilst saving weight!

Source: ArcelorMittal

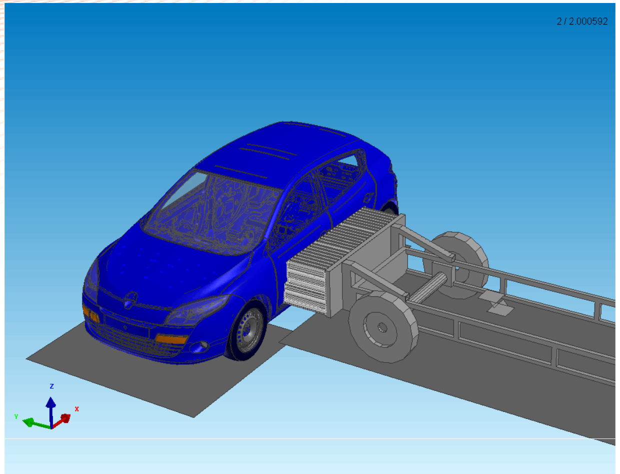
Virtual Prototyping



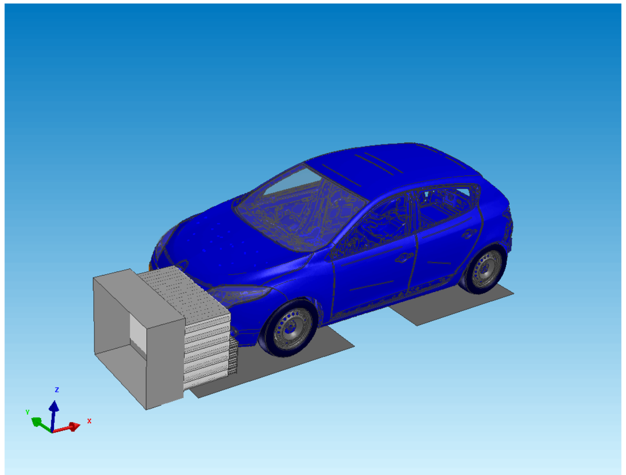


E.g. changing from conventional to hotformed B-pillar, will change the manufacturing and the crash performance. The virtual manufacturing will influence the virtual performance of the car!

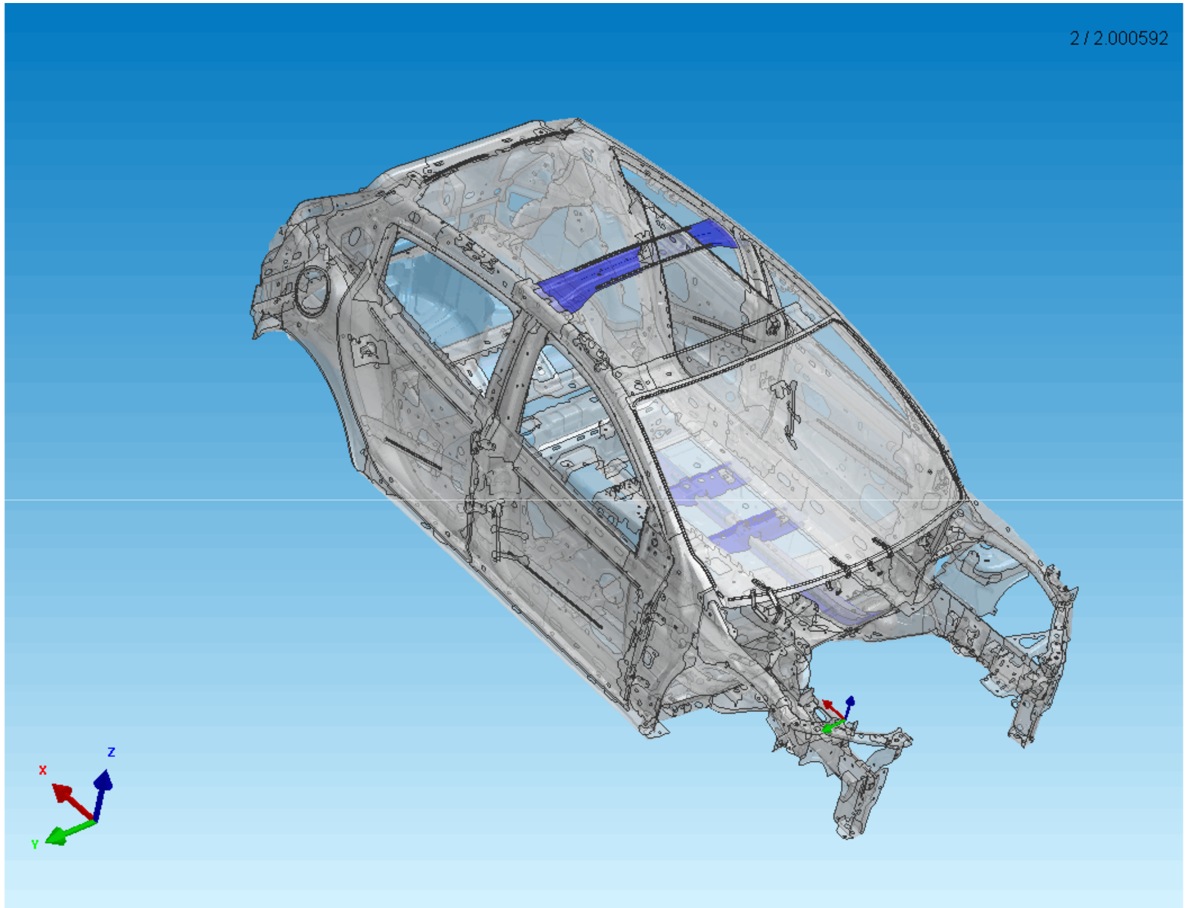
Performance evaluation under different criteria:



Lateral Crash



Frontal Crash



" Simulation is key to our project development process. PAM-CRASH allows us to identify not only the behavior of standard vehicle definition but also the probability to improve our crash performance and to build virtually every element that has an impact on our decision-making."
Eric Duguet, CAE Body-in-White Manager, Renault Group.

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Forming & quenching simulation

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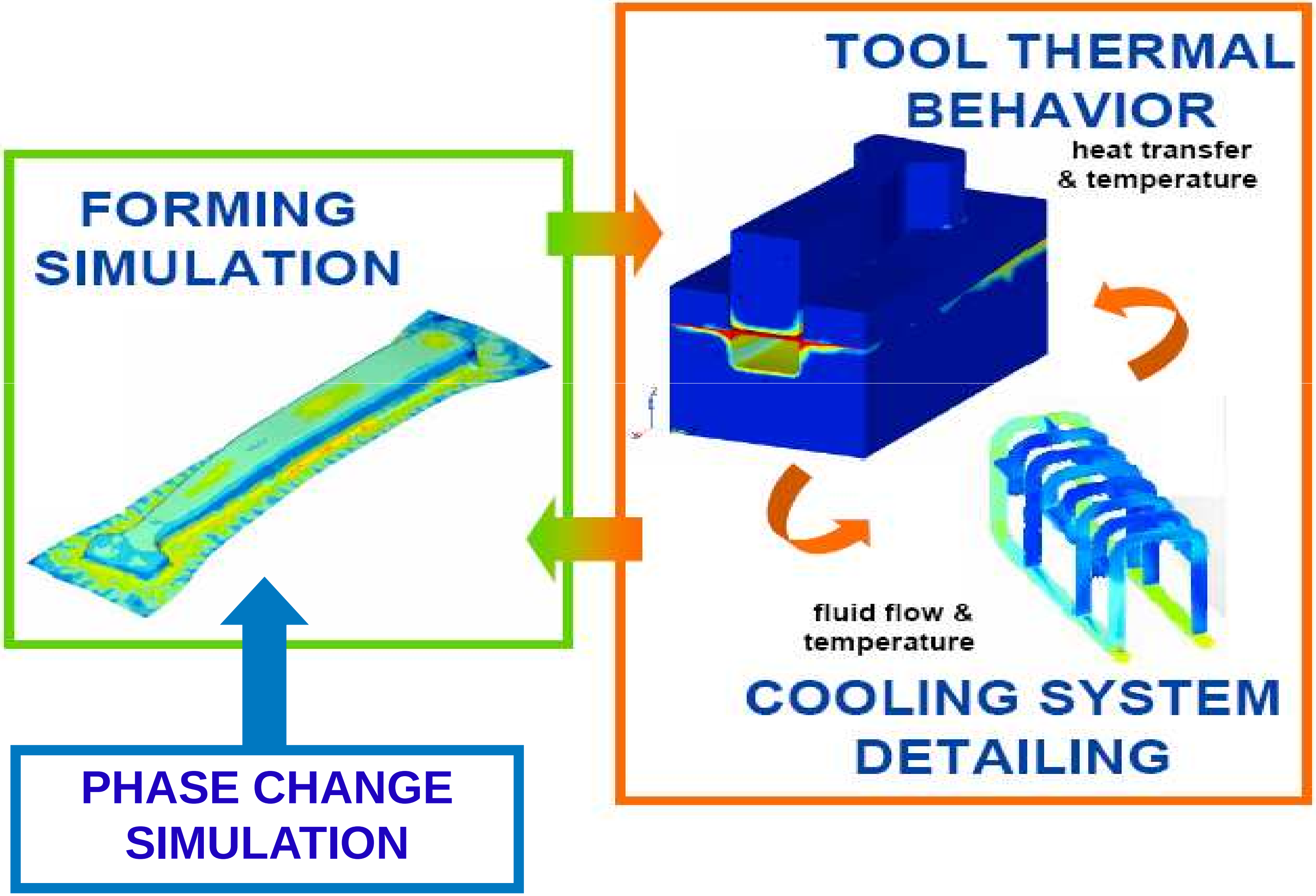
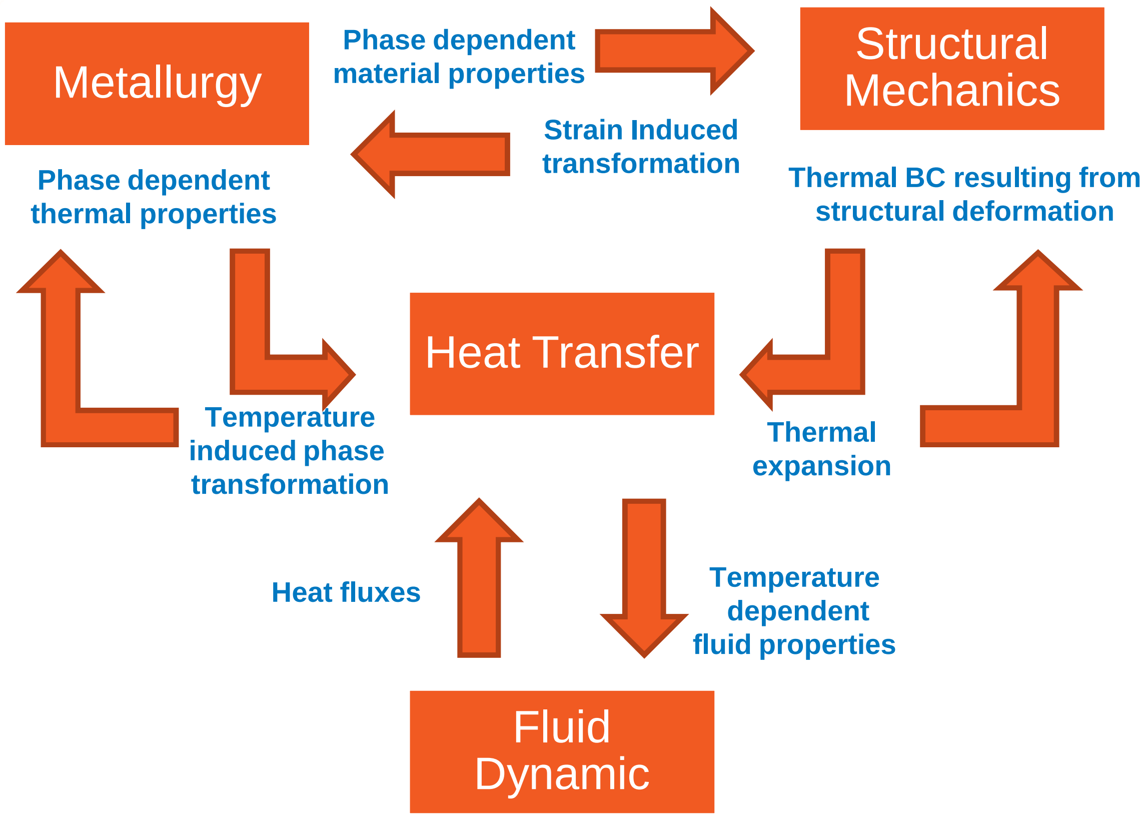
Simulation overview



Courtesy of TU Graz

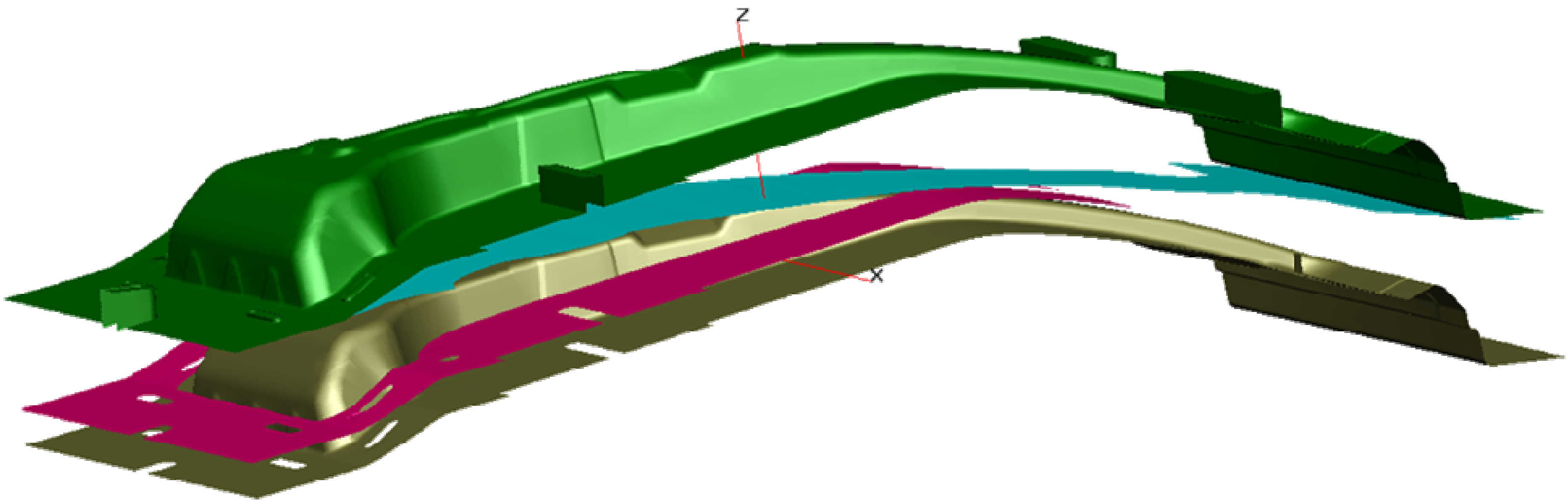
Complexity overview of the hotforming process



➔ The stamping engineer is confronted with several new areas where he has to have a high level of knowledge to get the process right.

Hotforming sample “B-pillar”

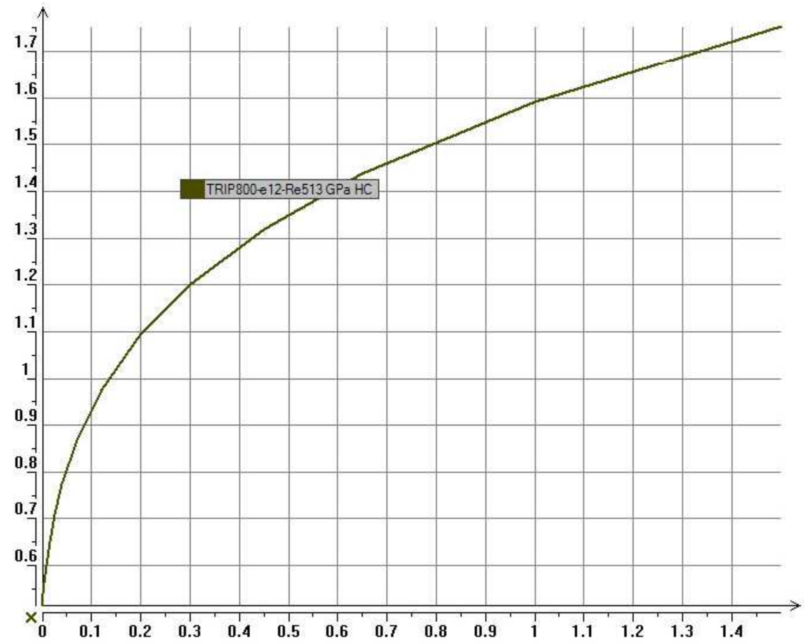
- Comparison hotforming vs. normal stamping



Courtesy of: AP&T

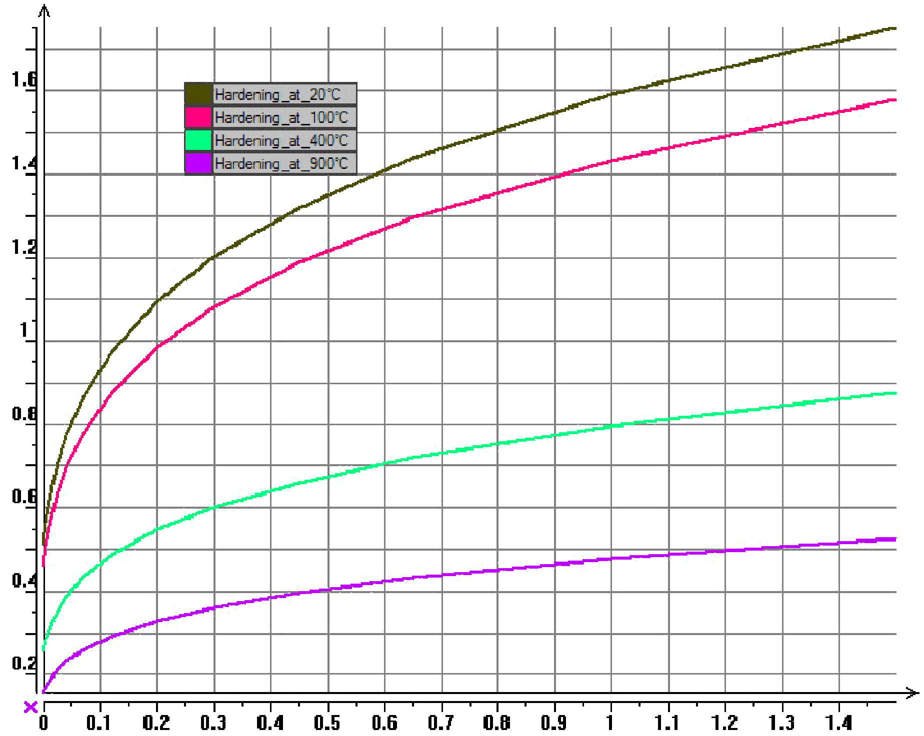
Hotforming sample "B-pillar"

- Normal stamping
- Material trip steel
- Thickness 1.6 mm
- Blank at room temperature
- Tools at room temperature



Hotforming sample “B-pillar”

- Hotforming
- Material boron steel
- Thickness 1.6 mm
- Blank initial temp = 800º
- Tools imposed temp = 200º
- Temperature dependent material data:

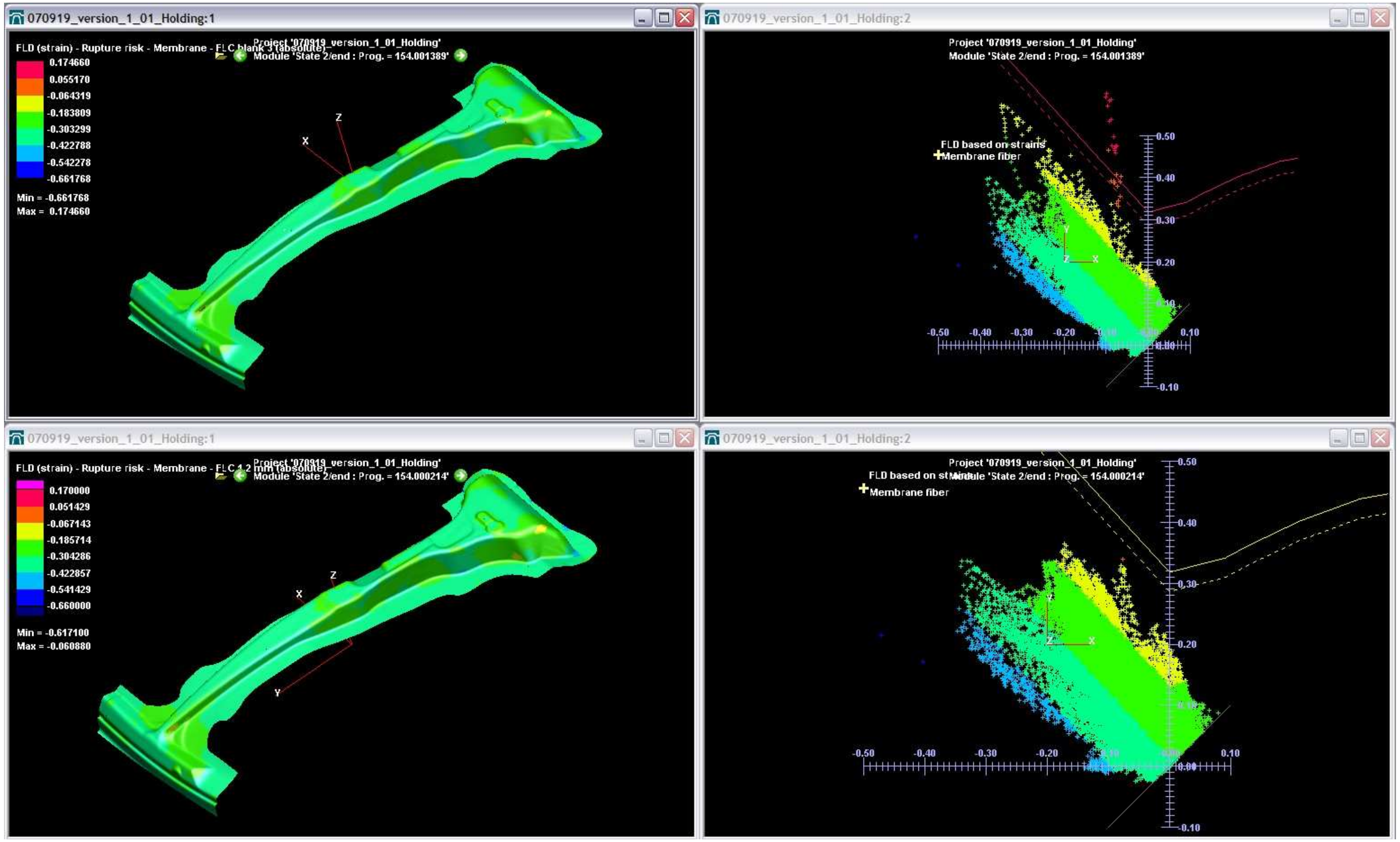


Hotforming sample “B-pillar”

- FLD – rupture

Cold

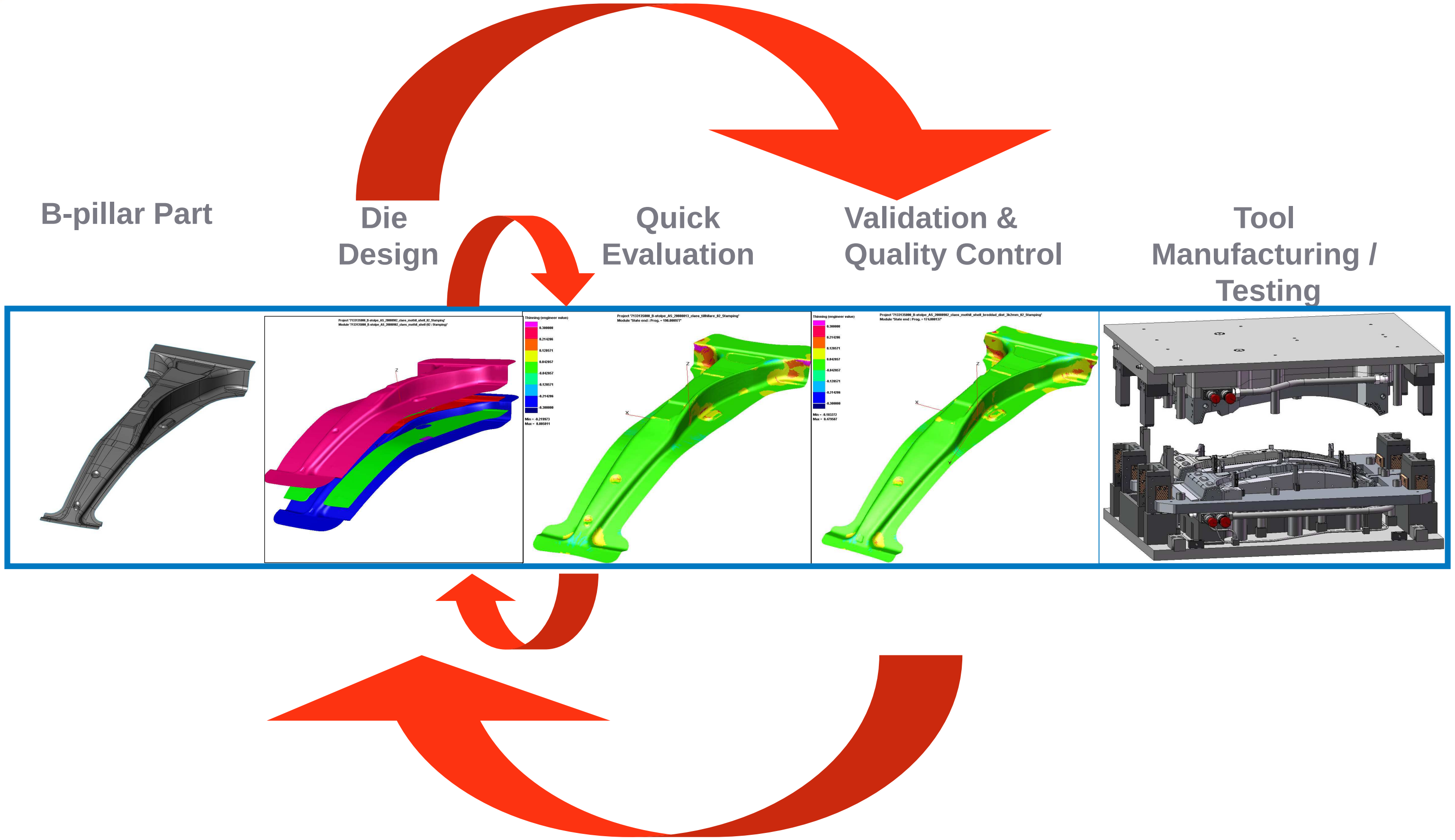
Hot



Courtesy of: AP&T

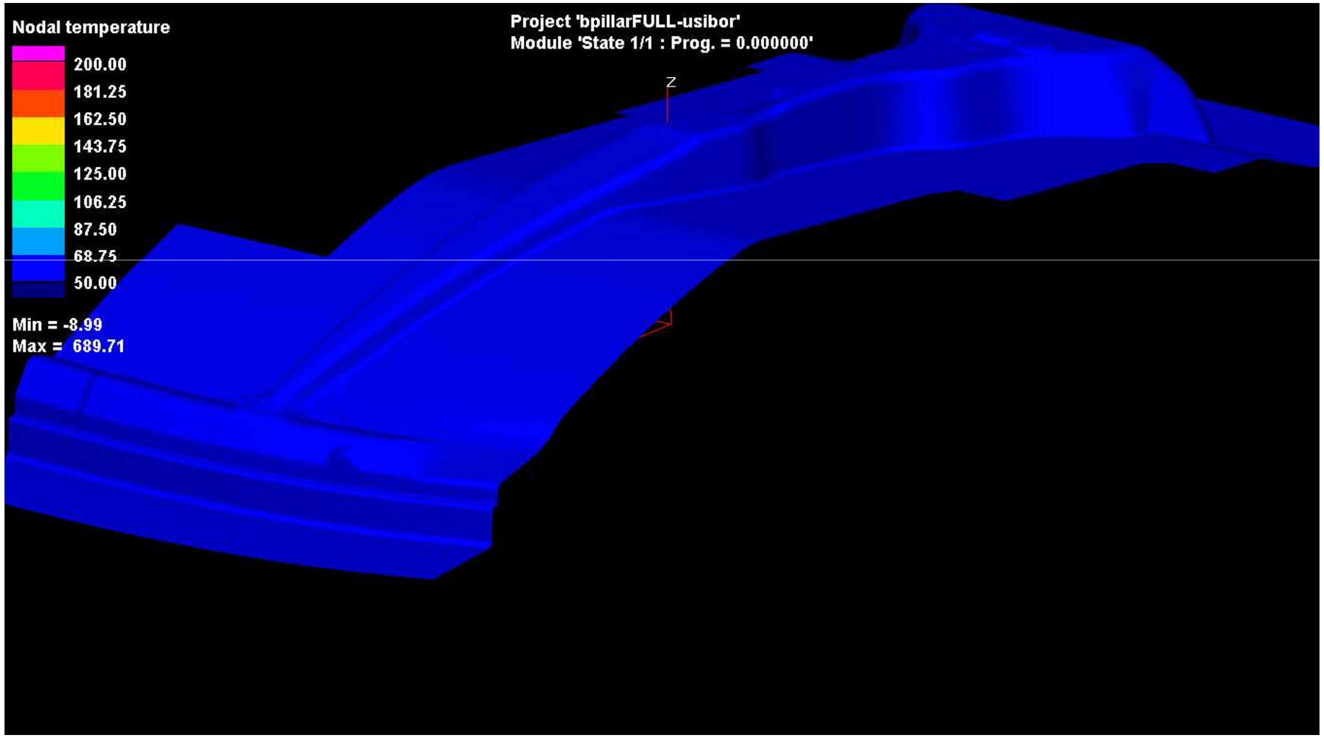
Quick evaluation

AP&T Tooling Solutions
Process & Die concept for Hot Forming



Hotforming sample "B-pillar"

- Stages: holding, stamping, quenching

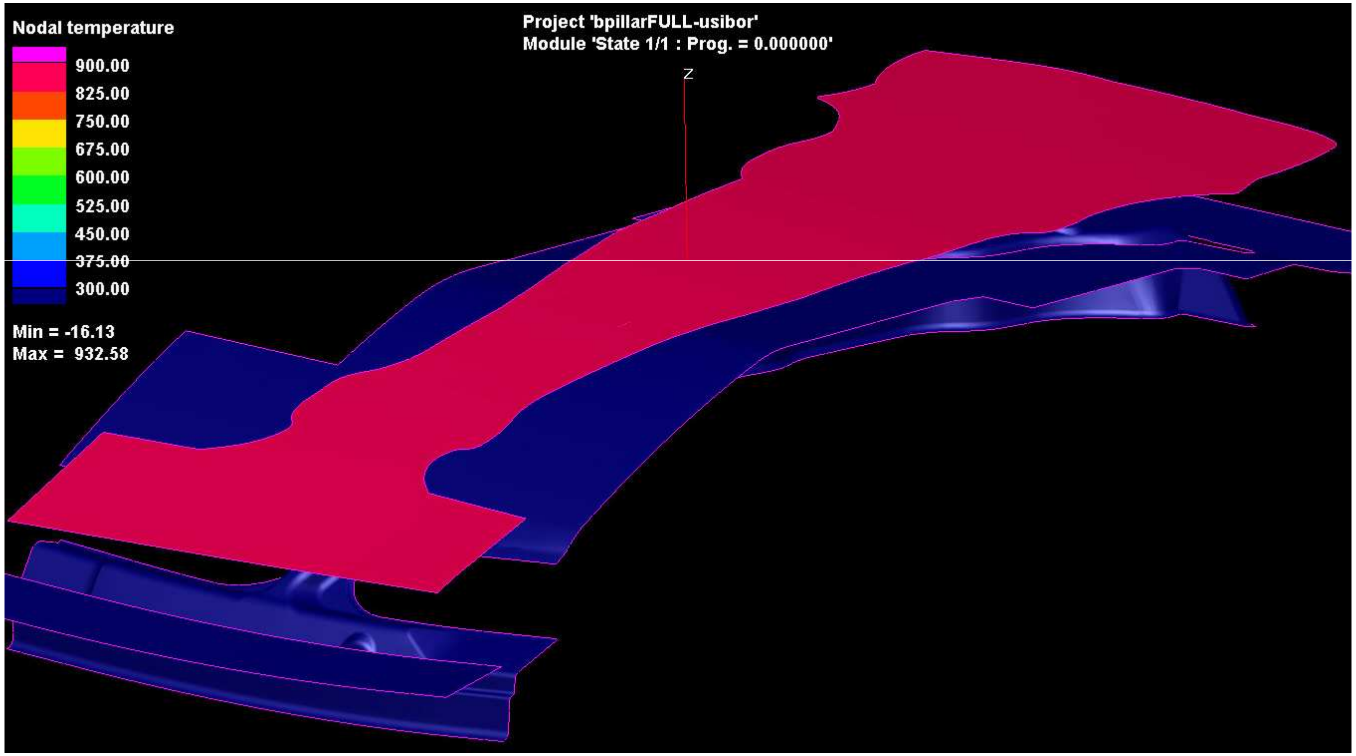


Temperature distribution on tool surface

Courtesy of: AP&T

Hotforming sample “B-pillar”

- Stages: holding, stamping, quenching



Temperature distribution on blank surface

Courtesy of: AP&T

Phase transformation simulation

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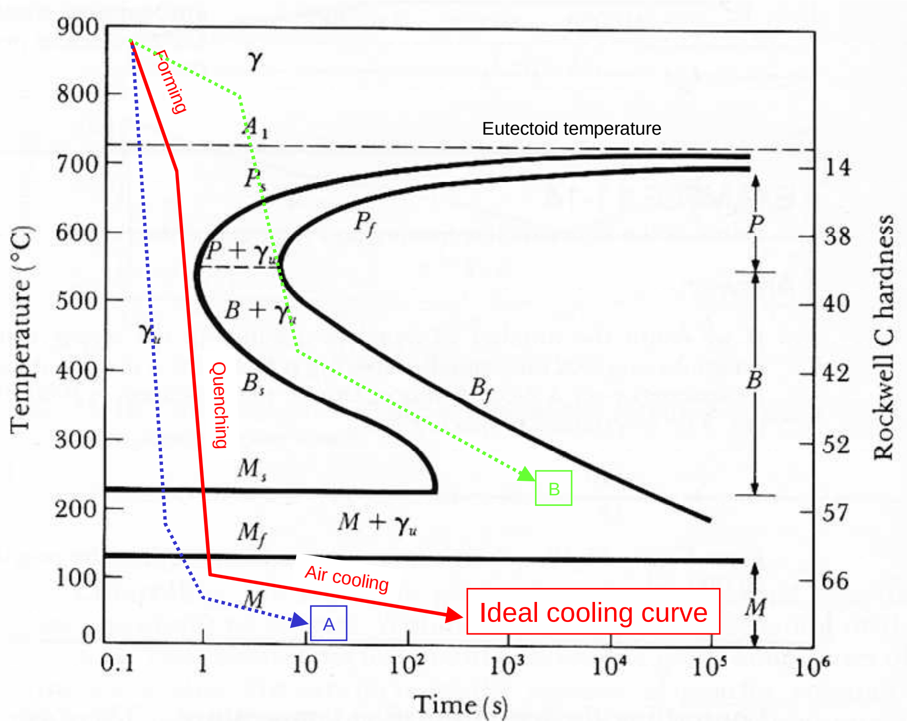
Critical issue

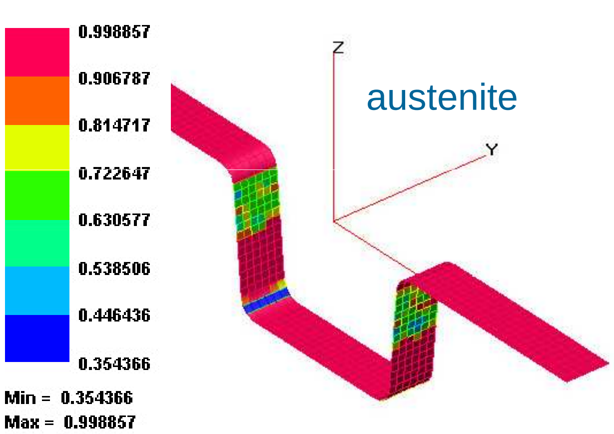
- Critical Issue: Heat Transfer Control
- Effectiveness of process controlled by cooling curve:

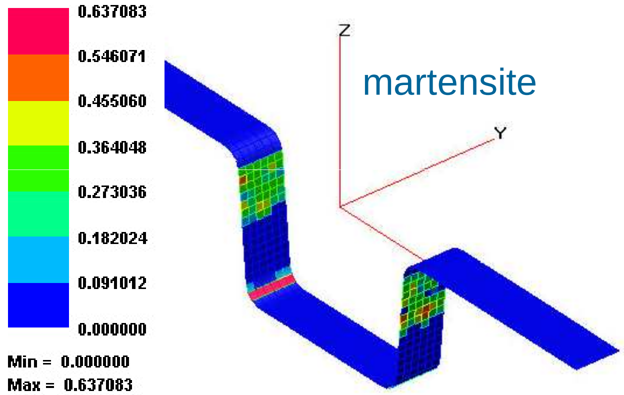


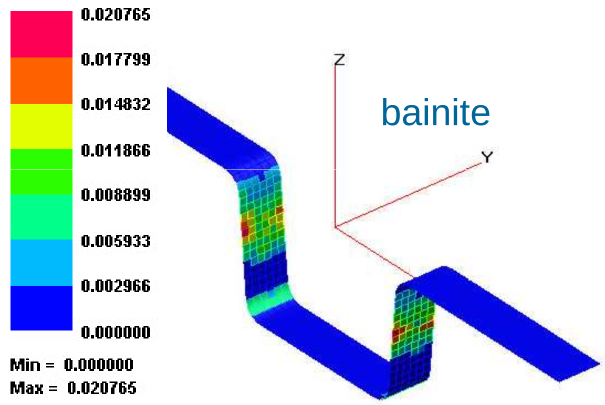
Phase transformations

- Control of heat transfer:
  - Cooling system embedded in die
  - Effectiveness of heat transfer (design of cooling system and flow rate)
  - Duration of hardening phase inside tools
  - Heat capacity of tools
  - Heat path (thermal contact between blank and tools)

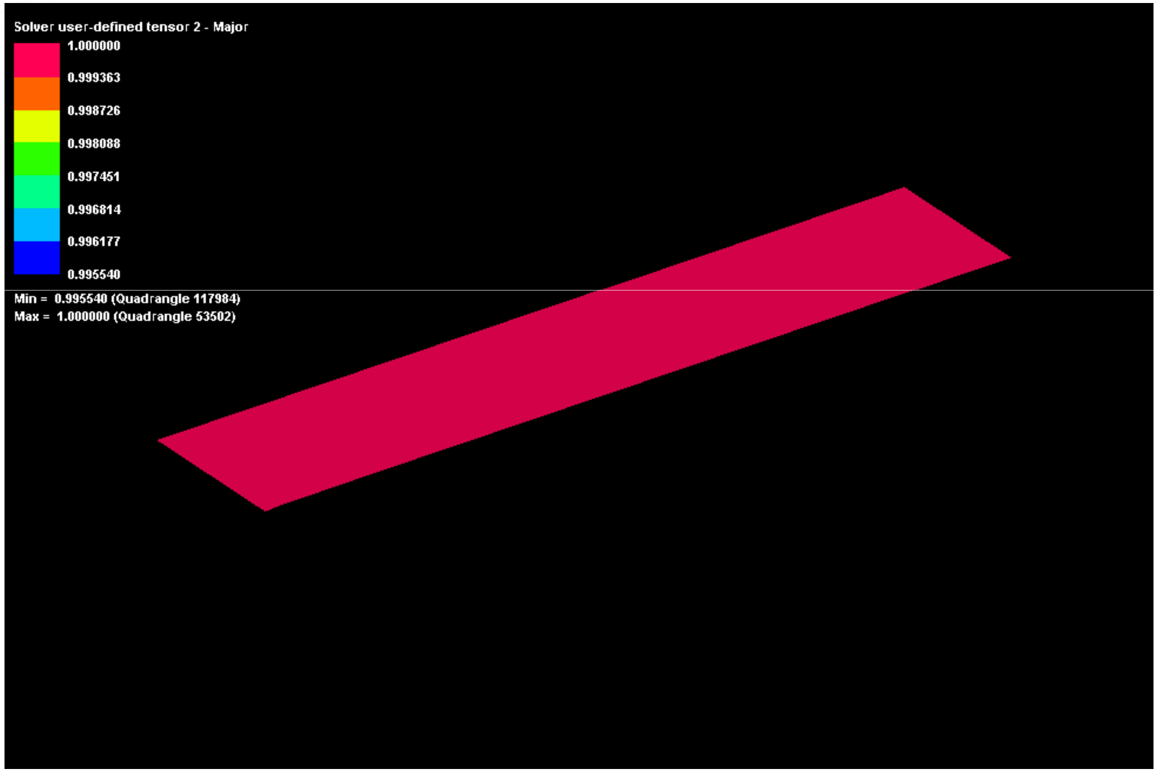
Phase transformations







Phase transformations



Proportion of austenitic phase

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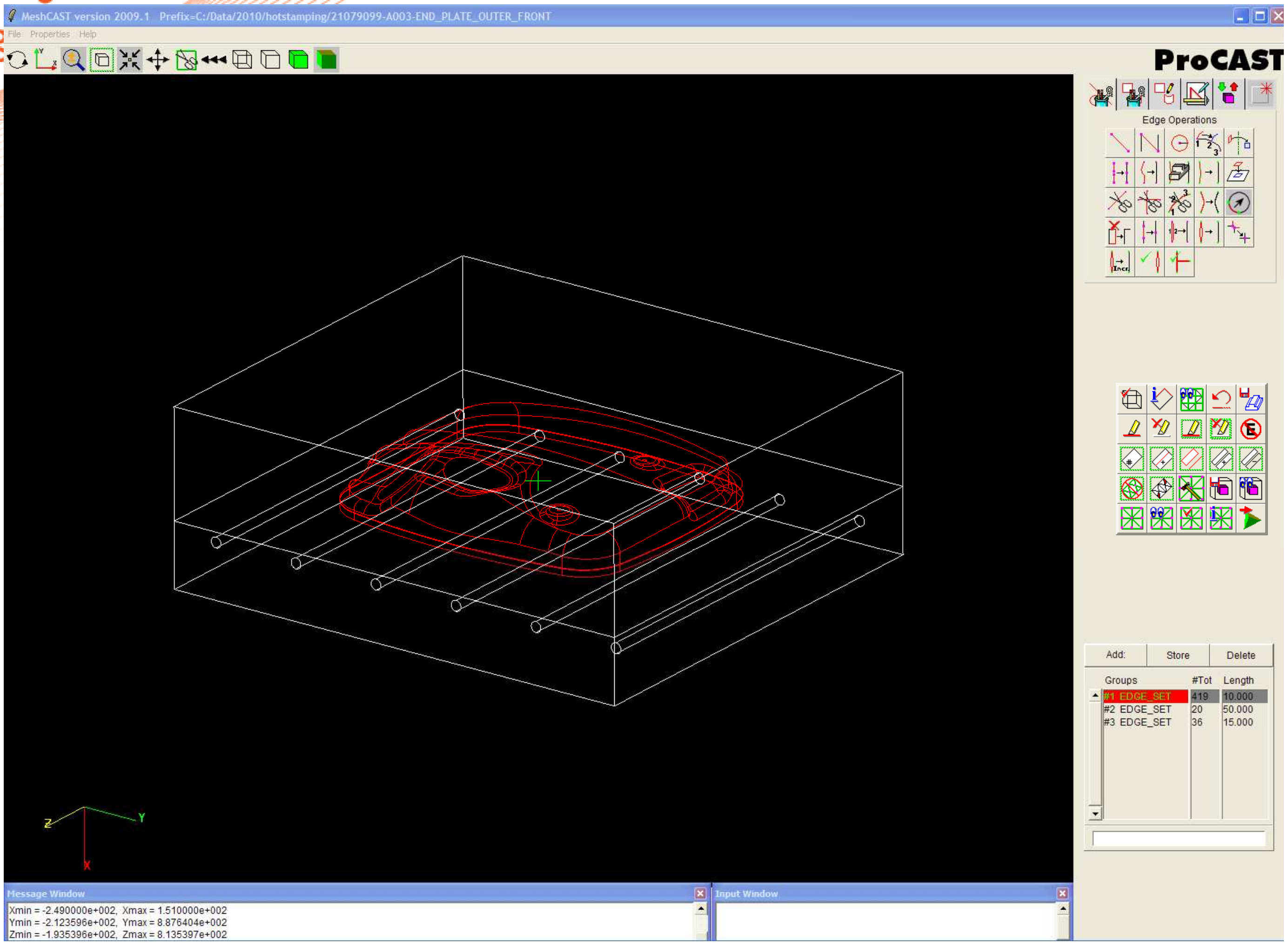
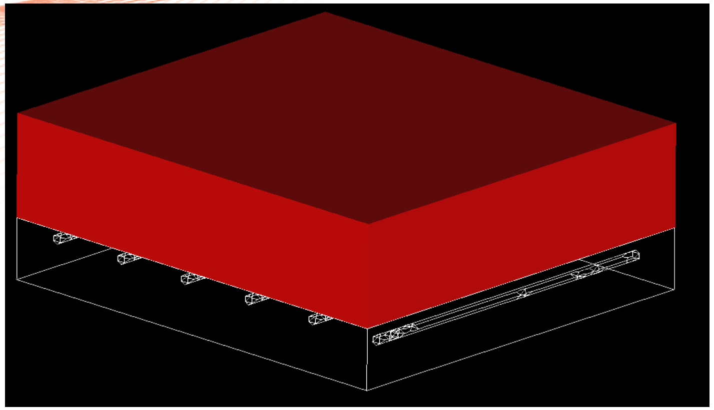
Simulation of cooling with casting software

mesh

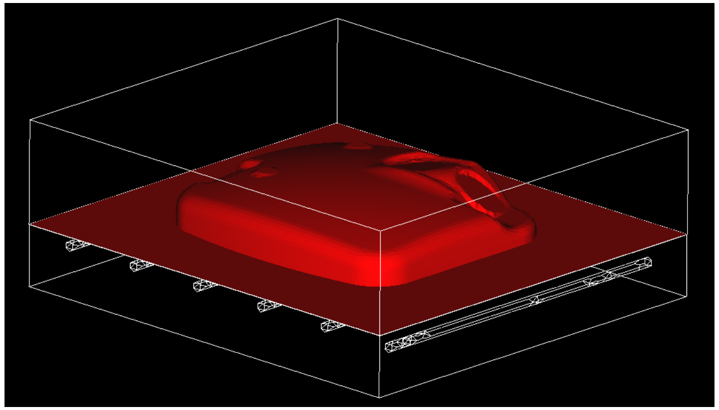


- Geometrical description in MeshCAST
- Red lines – geometry of the part
- White lines – geometry added in Meshcast

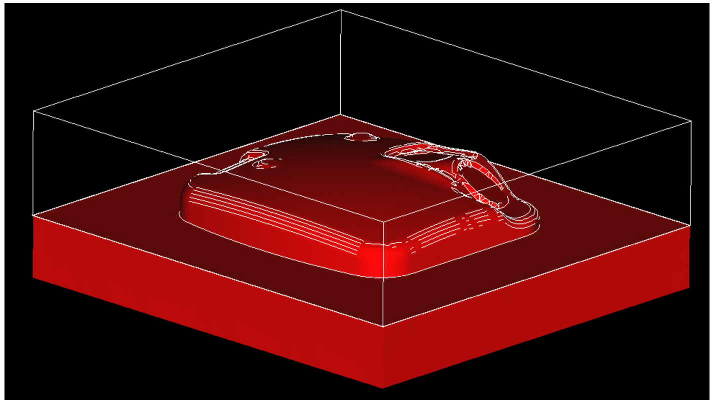
Contained in the geometry:



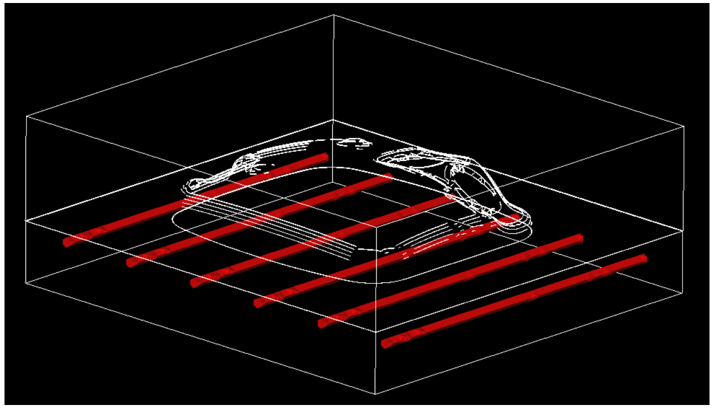
- Upper tool



- blanket

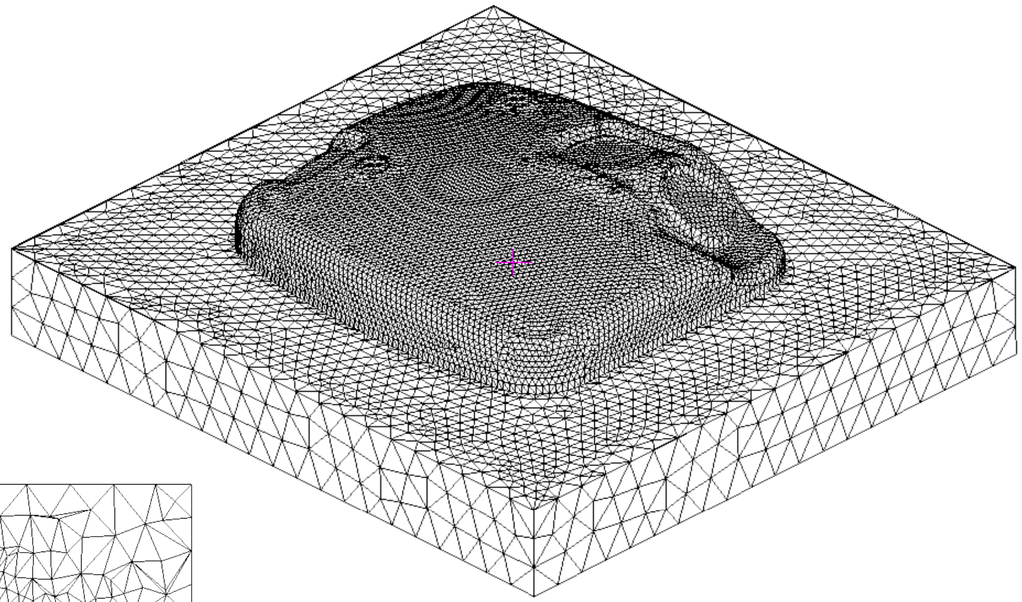


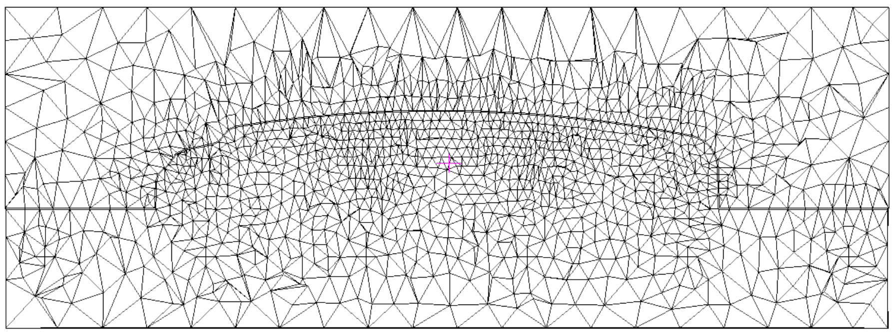
- Lower tool



- Cooling lines

FEM mesh





Cut of the mesh

- 390’000 tetraeder elements
- 15’000 wedge elements (blanket)

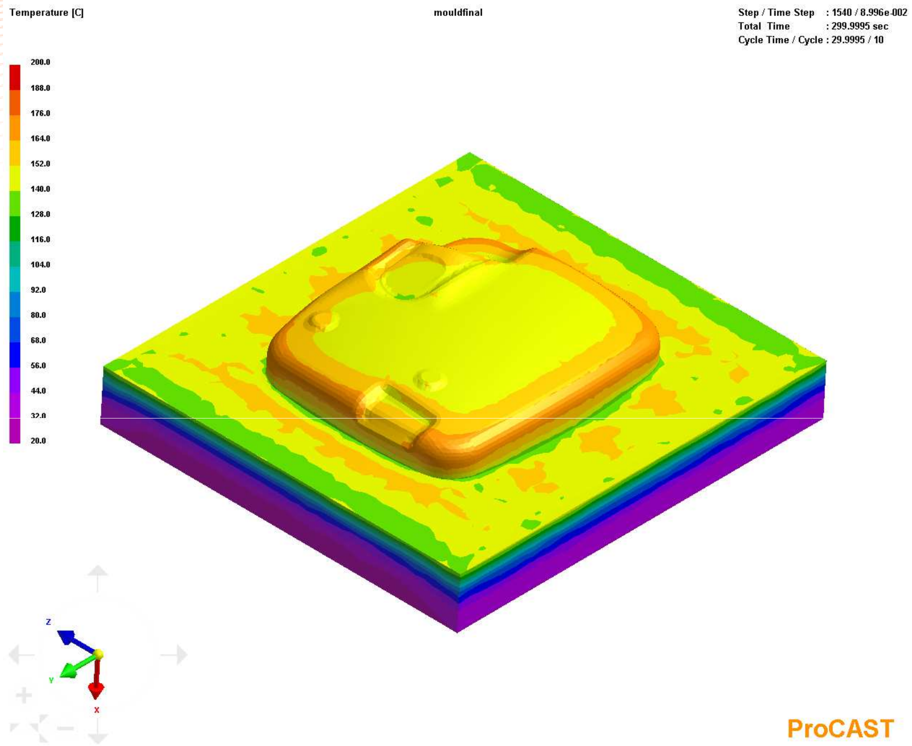
Tool steel: 1.2379
Blank: 22MnB5

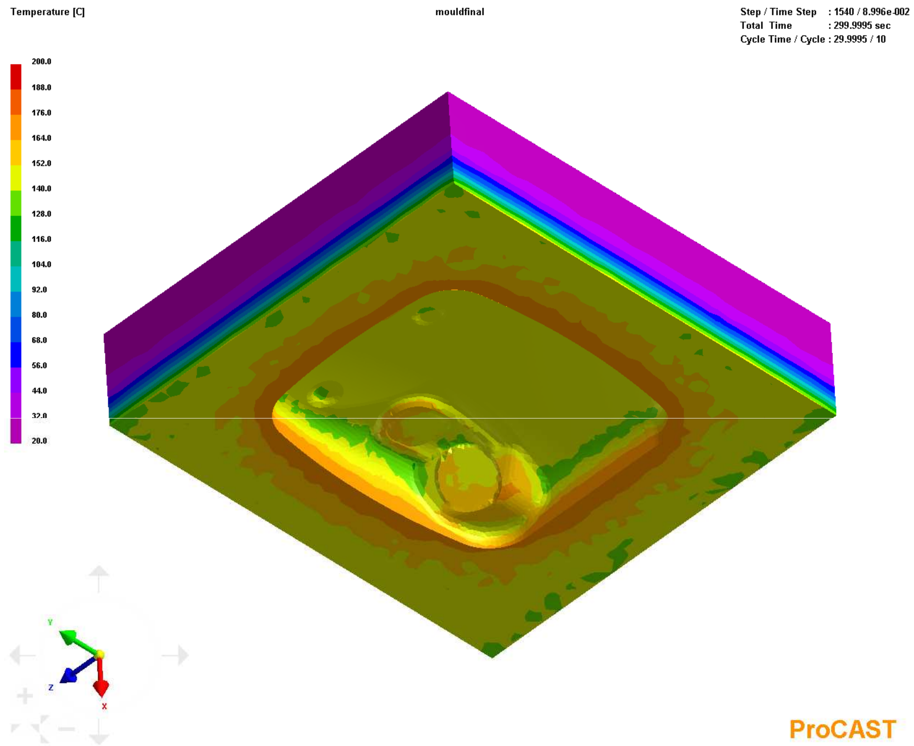
Boundary conditions

- Process parameter:
  - Initial blank temperatur 850 ^{o}C
  - Initial tool temperatur 25 ^{o}C
  - Cycle time: 30 sec
  - The tool is 20 sec closed and then open for 10 sec
- Contact blank – tool: 5000 W/m^{2}K
- Tool contact to air: 3.6 W/m^{2}K, air temperature 20 ^{o}C
- Cooling lines: 4700 W/m^{2}K, water temperature 20 ^{o}C

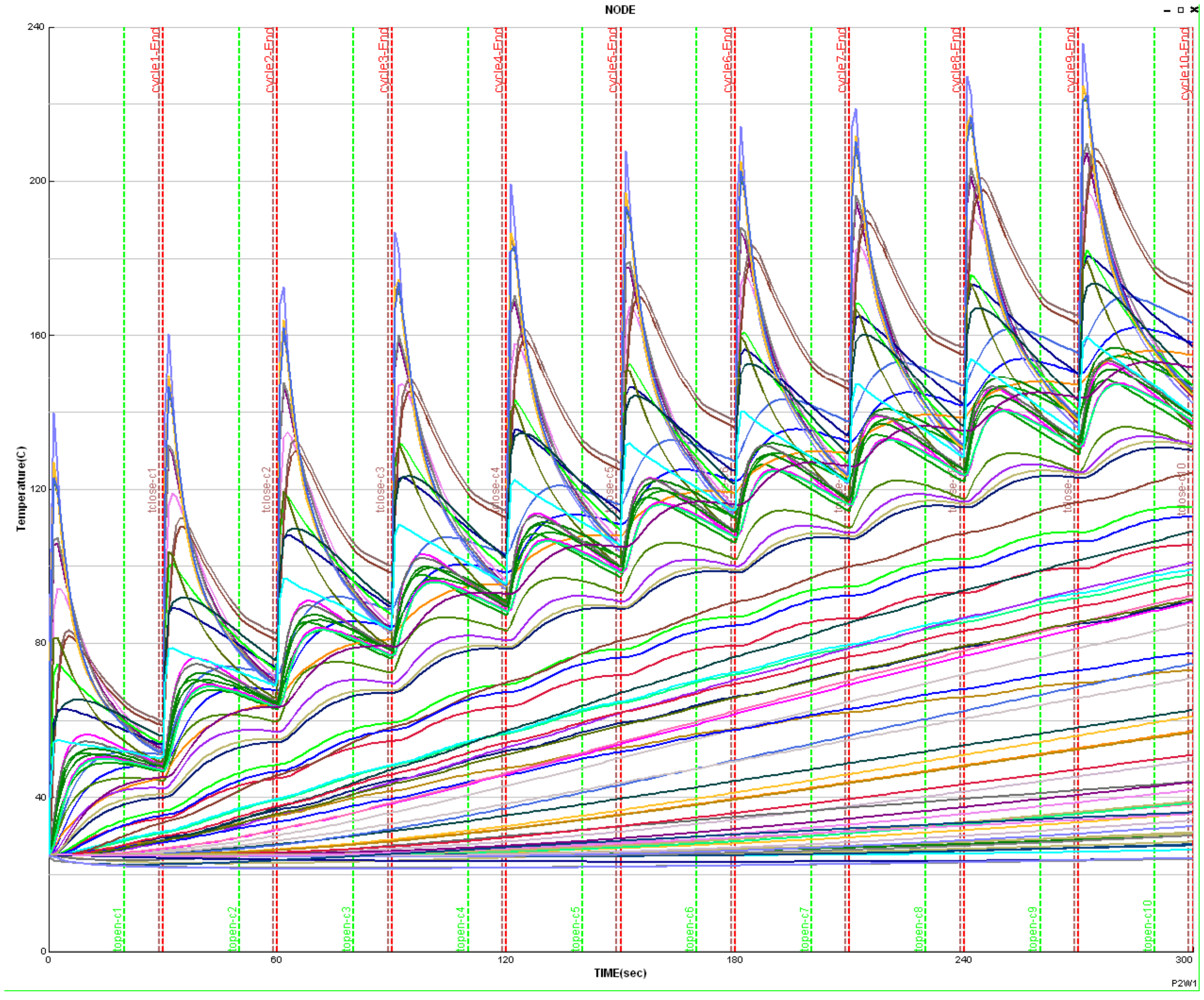
BC from: Method for optimizing the cooling design of hot stamping tools; Steinbeiss, So, Michelitsch, Hoffmann; Prod. Eng. Res. Devel. (2007) 1:149-155

Tooling temperature after 10 cycles

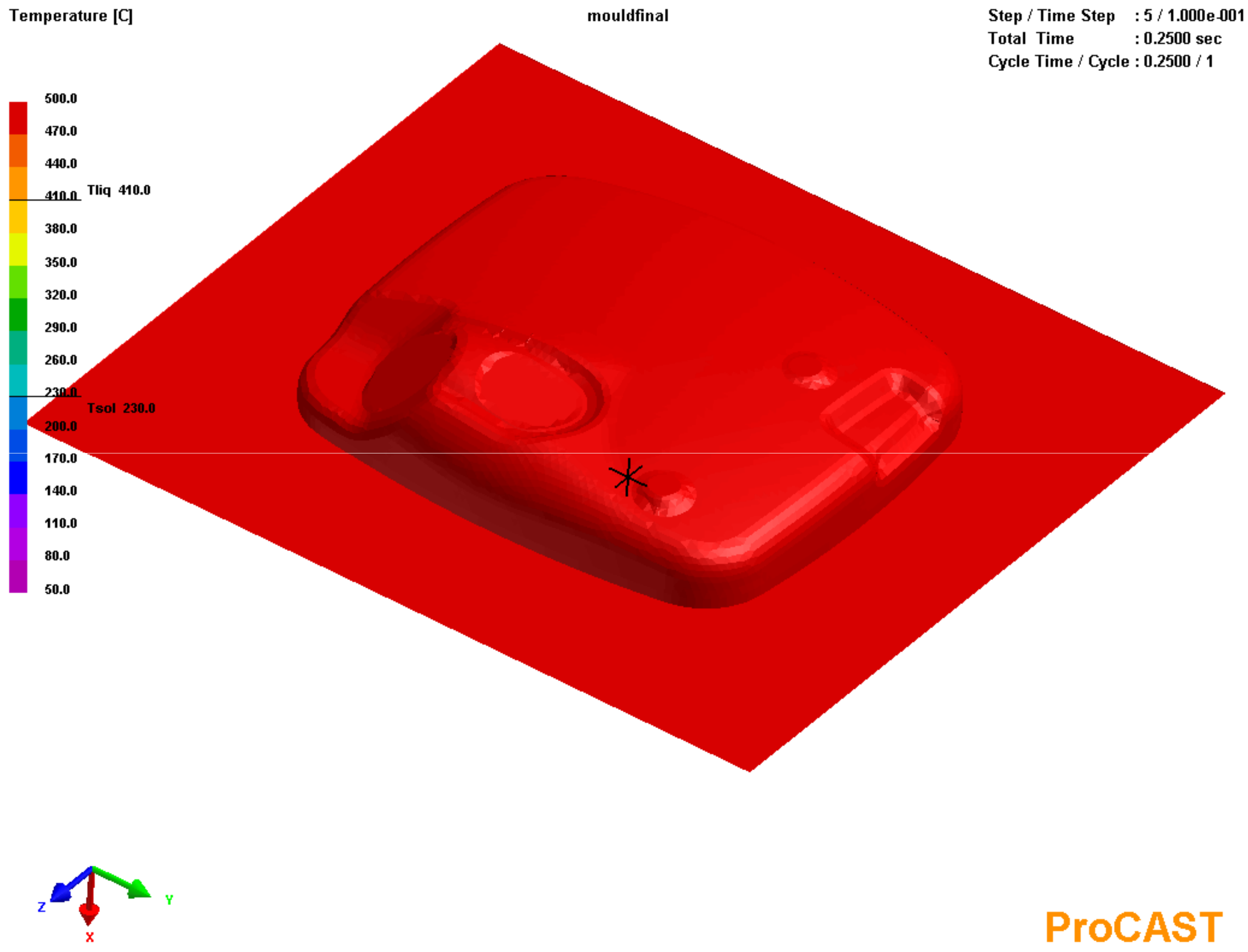




Heating of the tool at different nodes

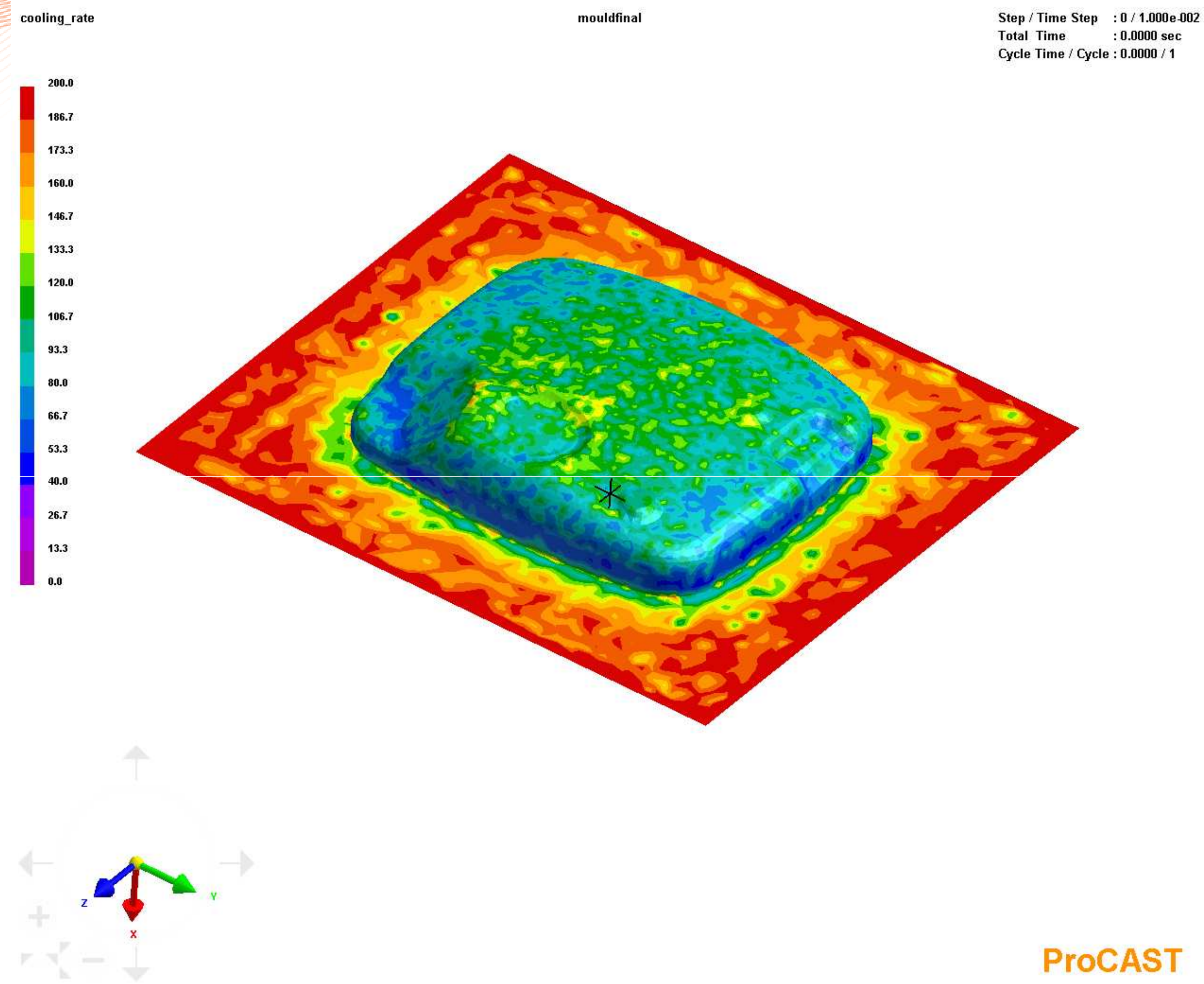


Cooling in the 11 cycle



Tliq = Martensite start temperature, Tsol = Martensite end temperature

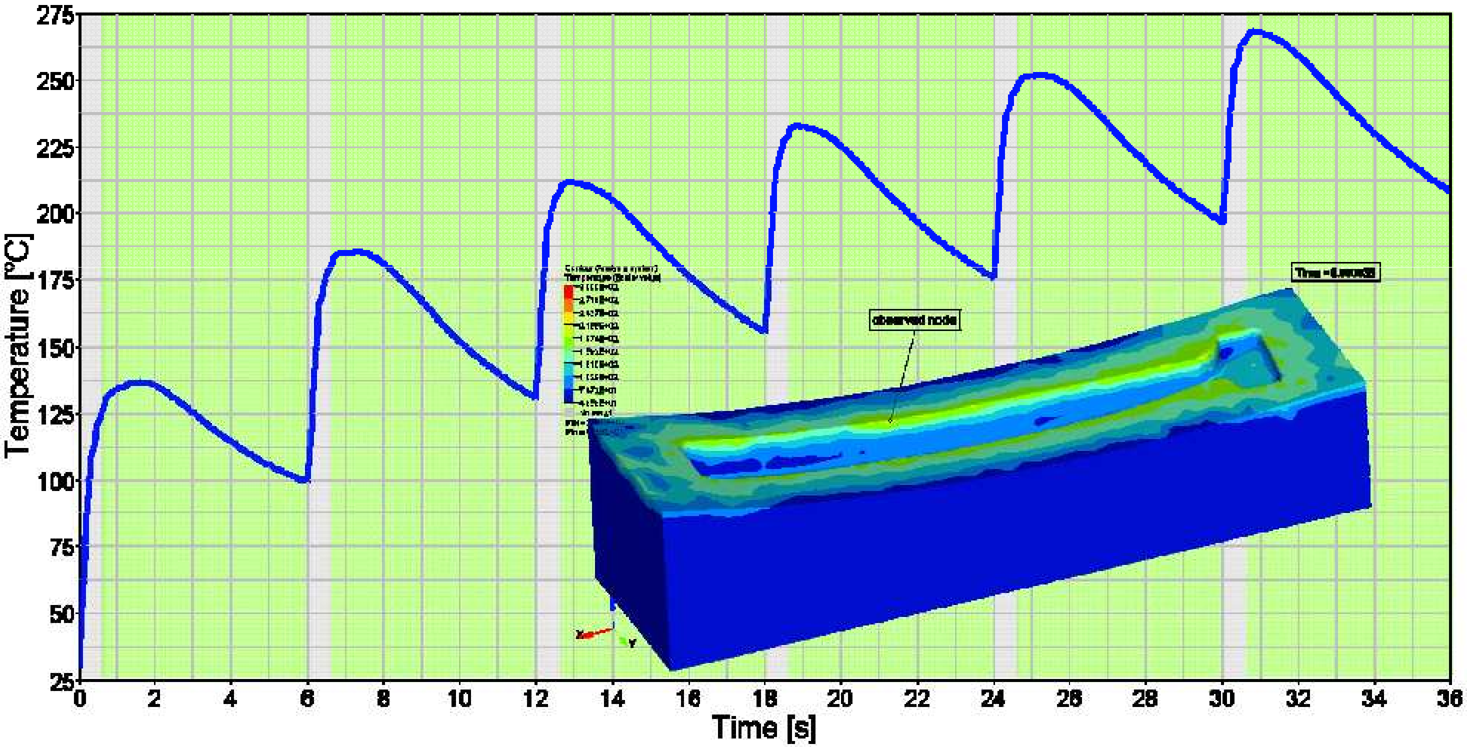
Cooling rate [^{o}C/sec]



Cooling rate during Martensite formation

Simulation of cooling liquid flow with CFD software

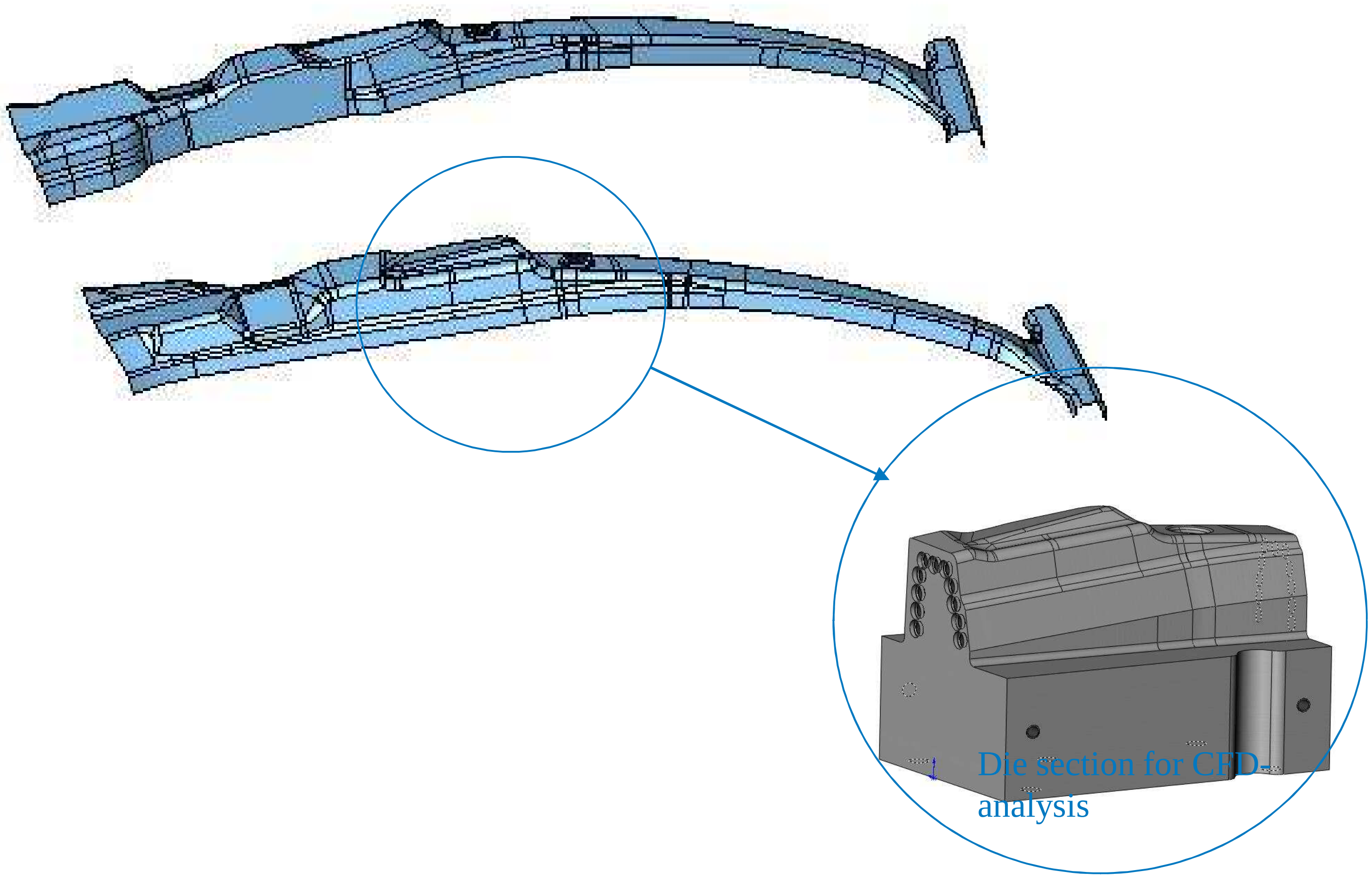
Hot Stamping Process overview



stamping cooling ➔ steady state after 6 to 7 sheets

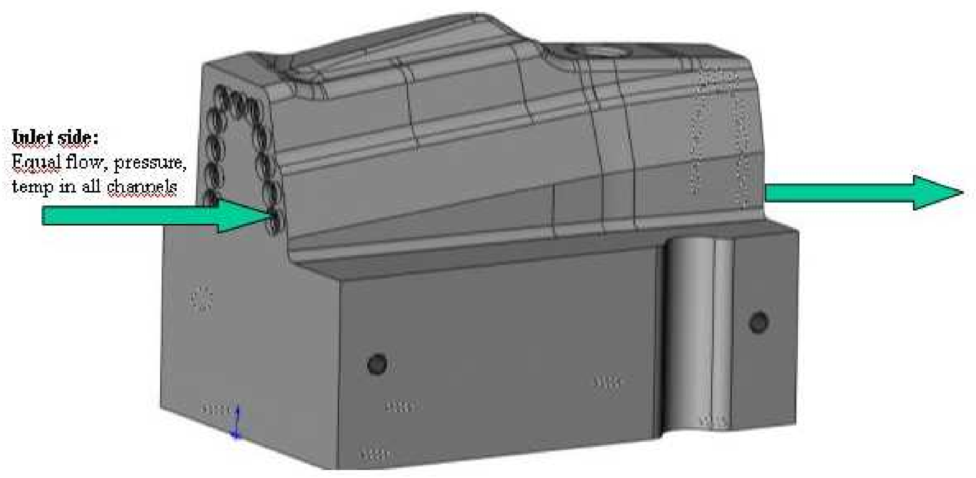
Courtesy of TU Graz

Cooling sample



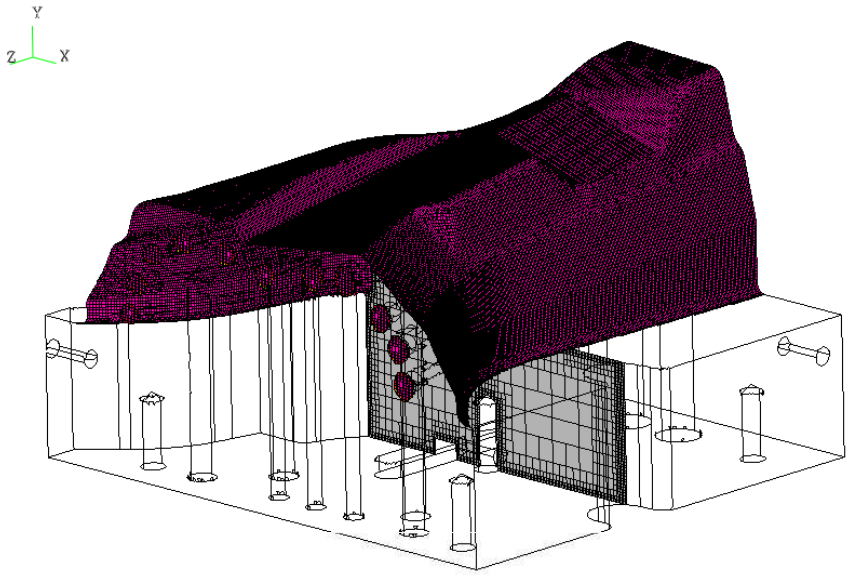
Geometry & Boundary Conditions

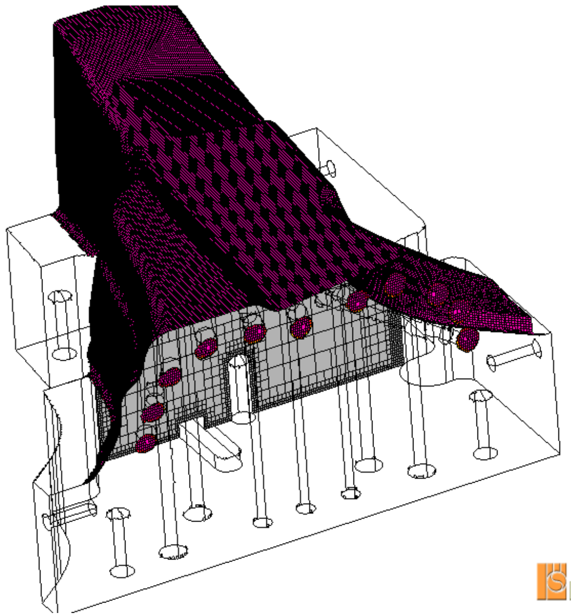
- Cooling Liquid
  - Water
  - 50 l/min
  - Inlet temp.: 27°C
- Work piece
  - Initial Temperature: 800°C
- Die
  - Steel
  - Outer walls: Adiabatic

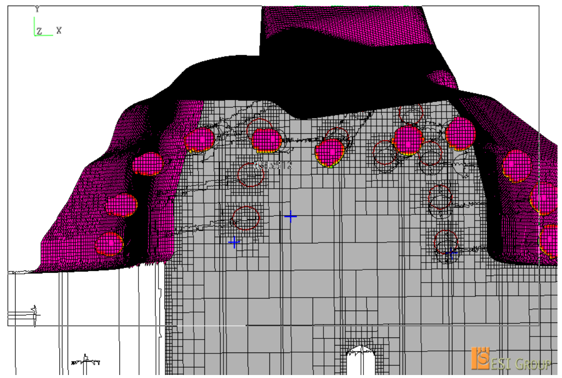


Grid

- 1 118 746 Polyhedral cells
- Multidomain grid
  - Solid
  - Fluid

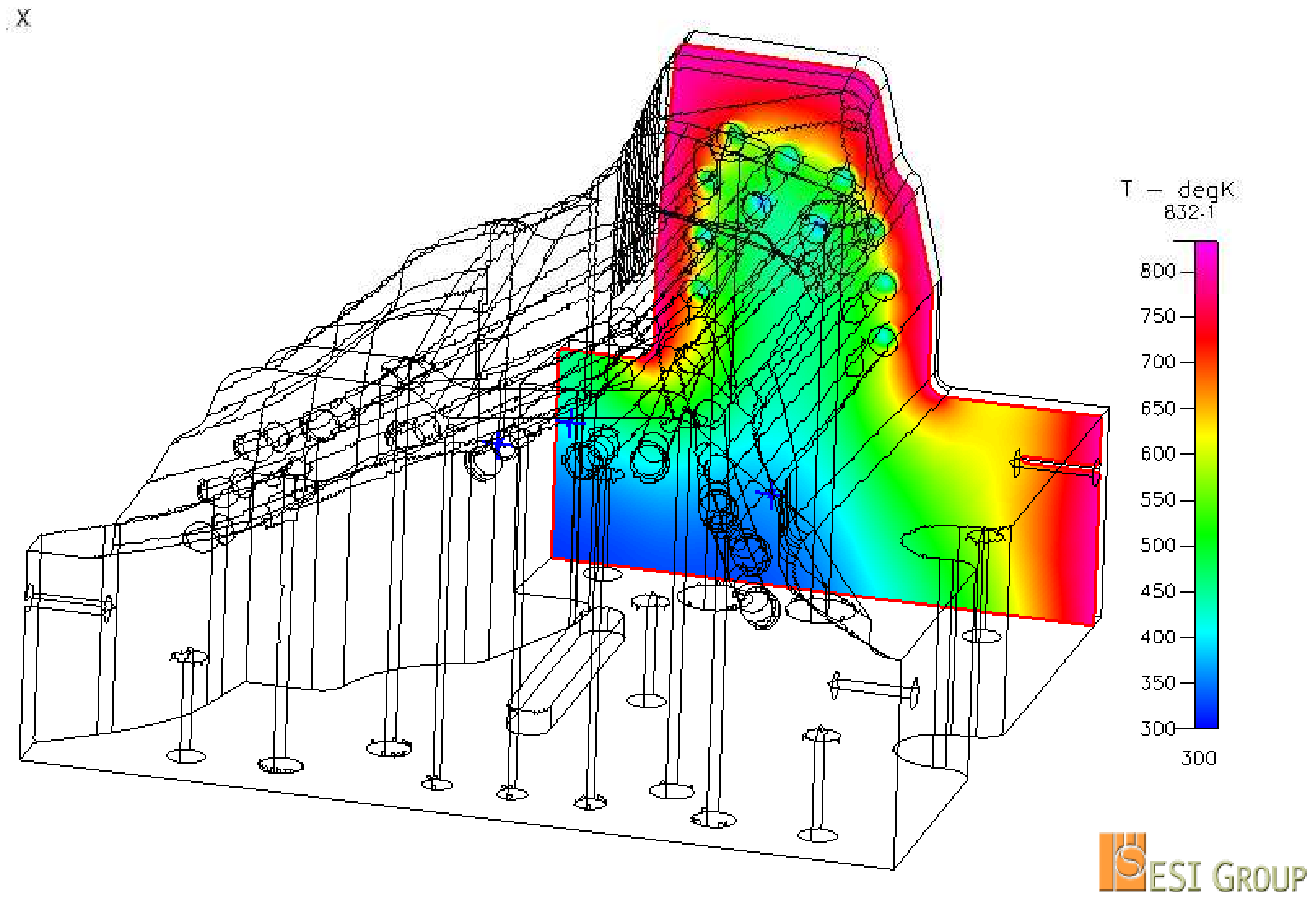






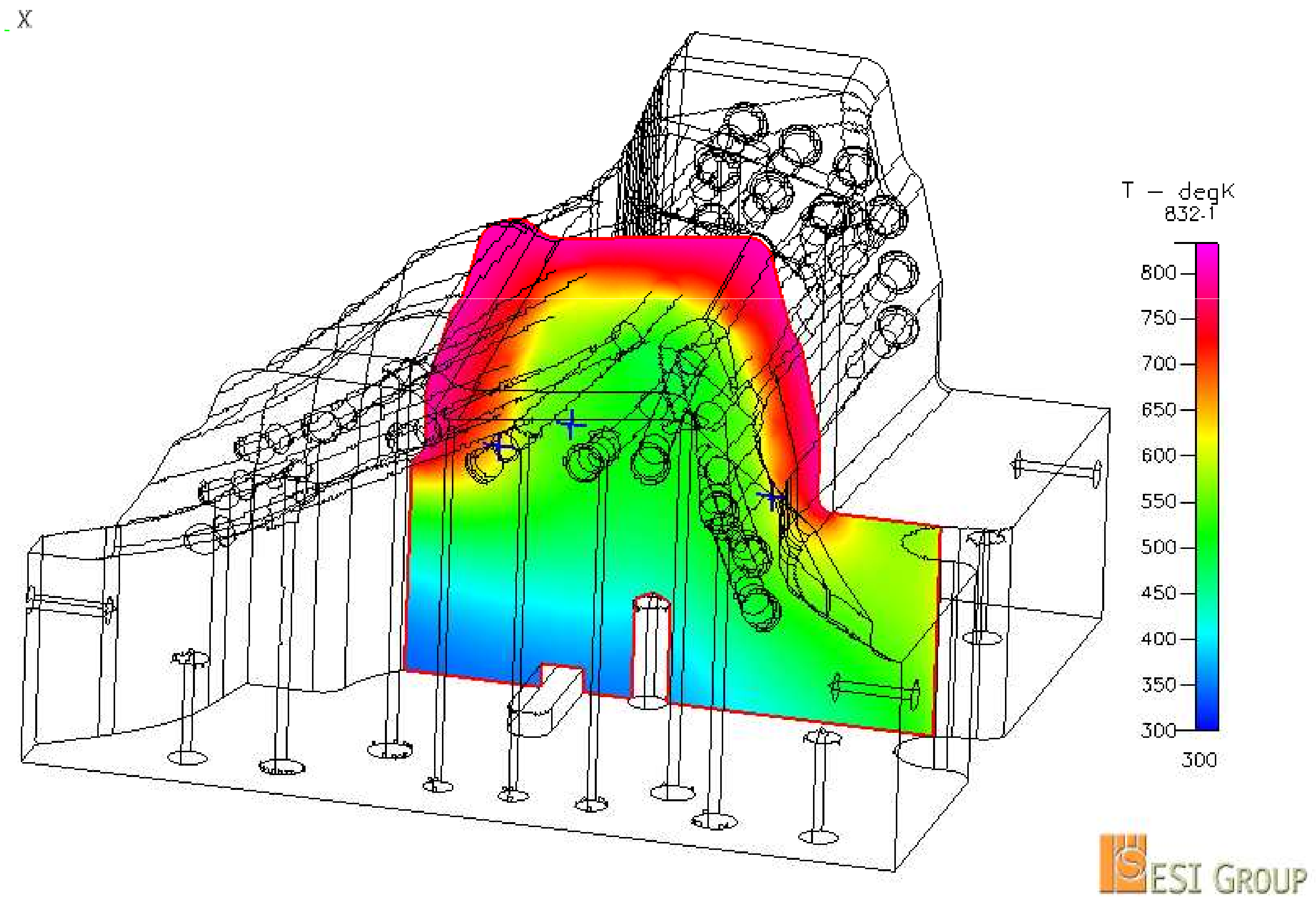
Temperature Distribution

- Near cooling channel inlets



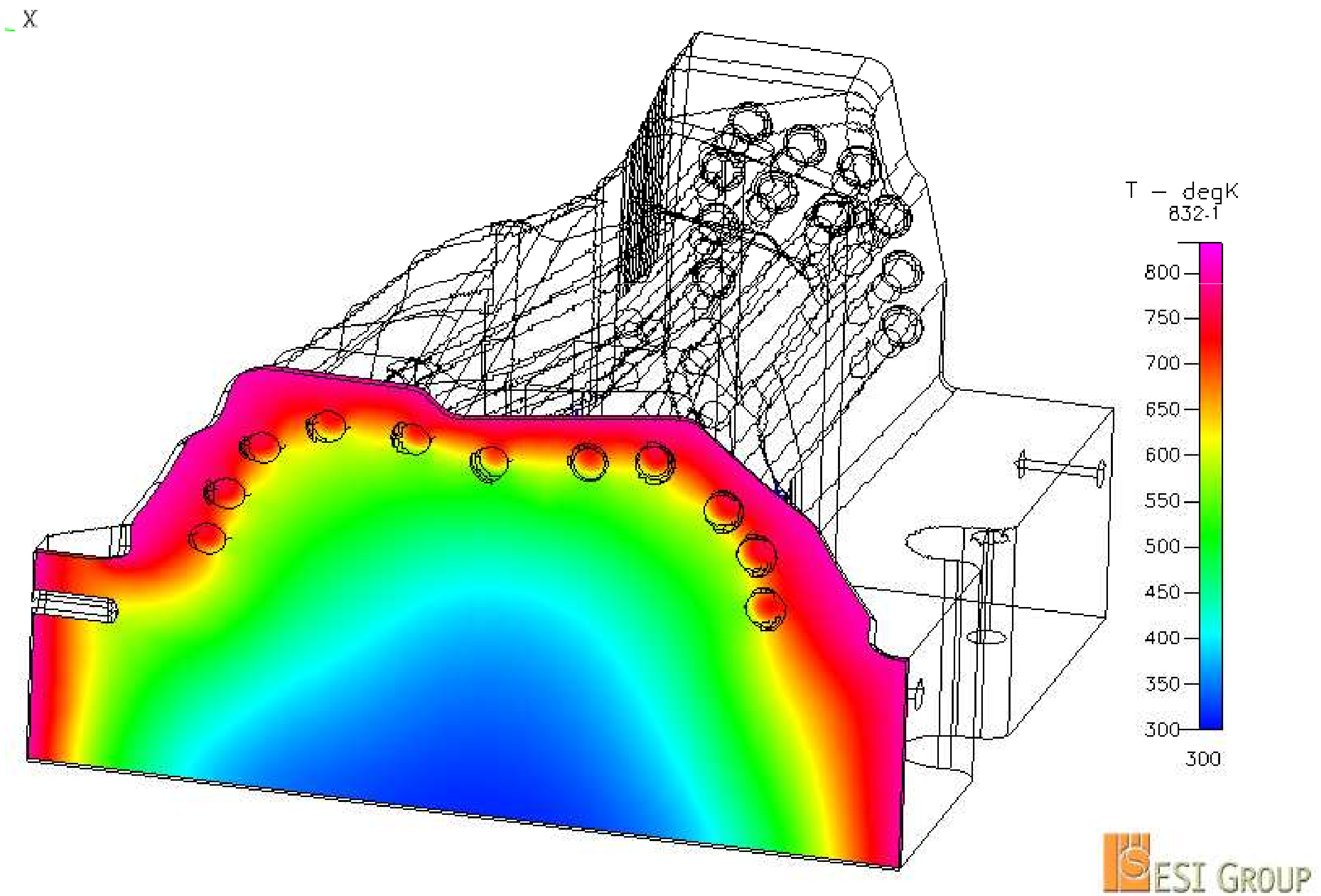
Temperature Distribution

- Centre plane

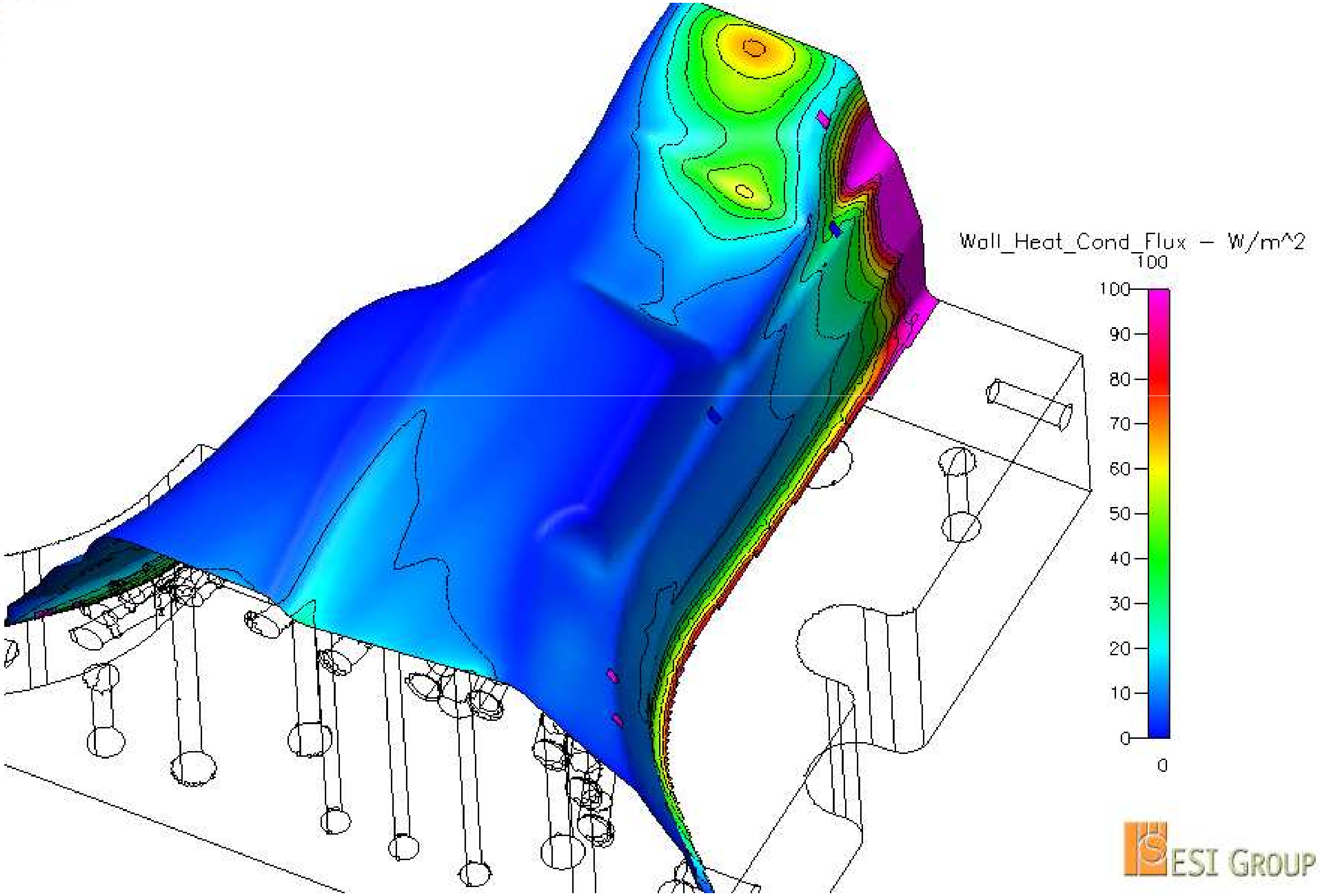


Temperature Distribution

- Near cooling channel outlets



Heat Flux on Work Piece



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To summarize

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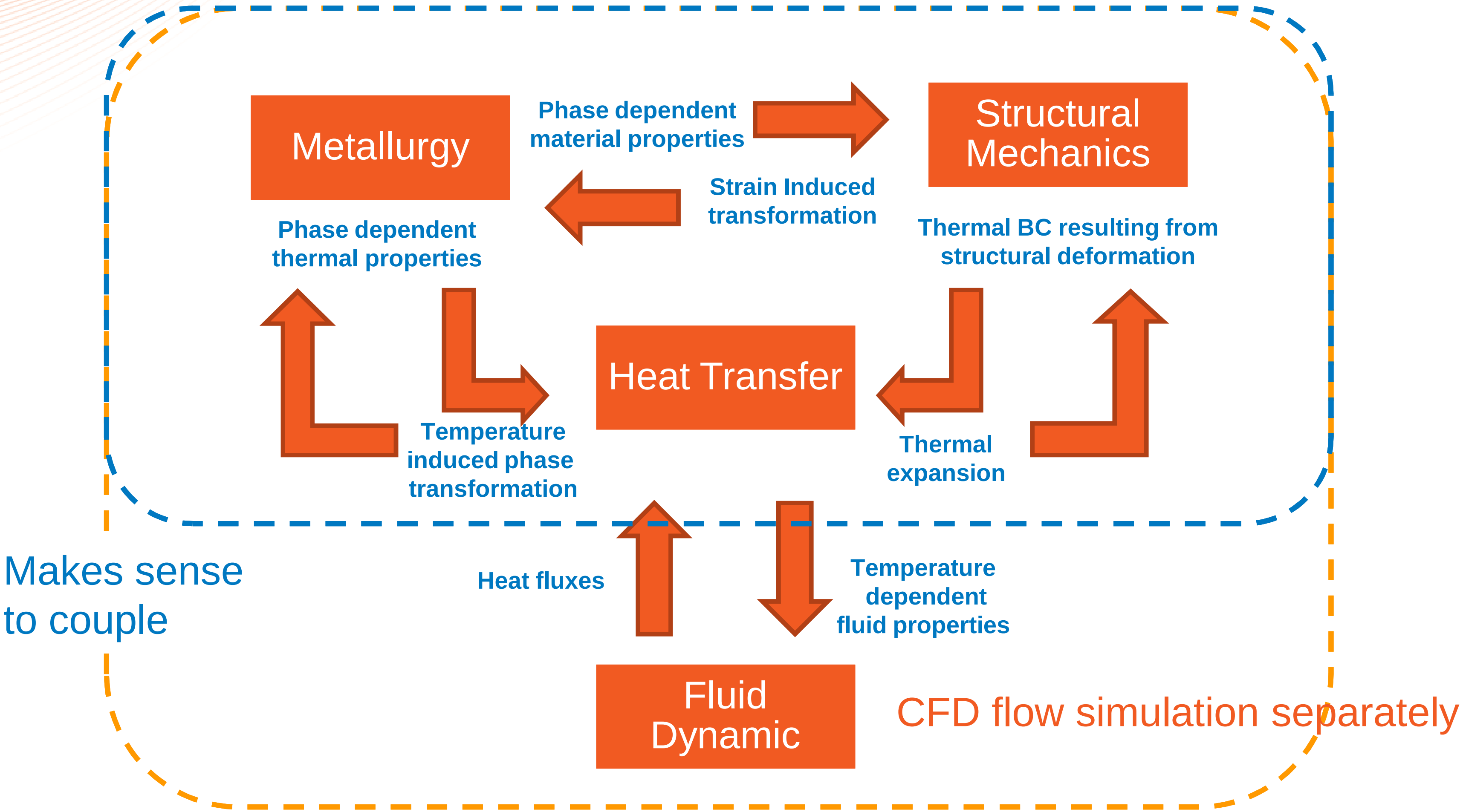
Hotforming, Virtual Manufacturing & Virtual Prototyping

- Designing and manufacturing hotformed parts is significantly more complex than the job of designing and manufacturing normal stamped parts.
- Cooling simulation can be coupled or done separately depending on required level of accuracy
- The part manufacturing can be tested virtually, resulting in:
  - thickness variations
  - stresses
  - strains
  - phase changes
- These phase changes are important for the part performance in the final crash simulation.

Complexity overview of the hotforming process



Crash simulation separately

Thank you for your attention!

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