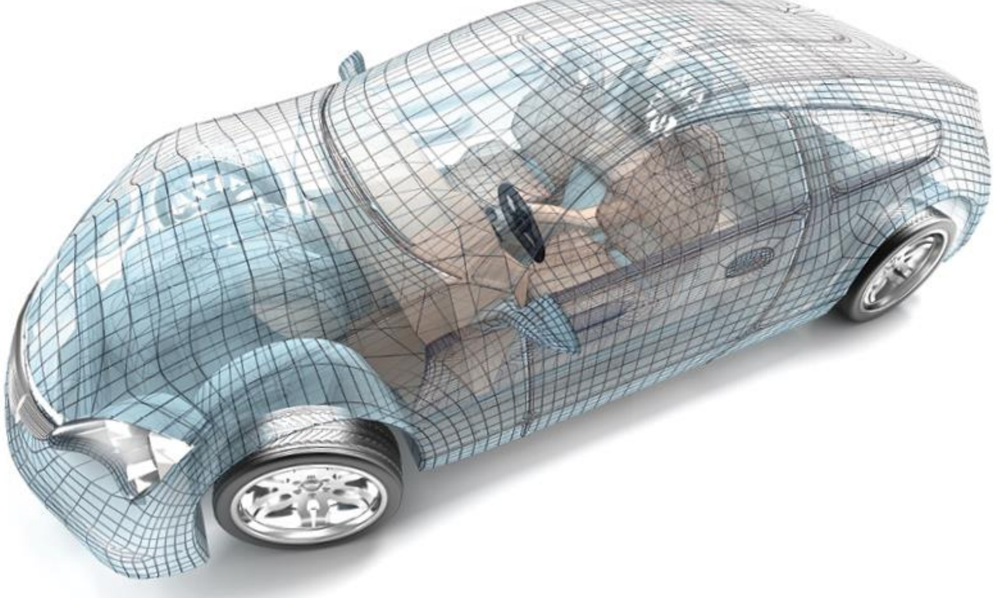
Press Forming Simulation of a Continuous Fiber-Reinforced Thermoplastic Composite

Numerical simulation is a powerful tool in manufacturing since it provides a lower cost and faster analysis than actual trial-and-error testing. Press forming manufacturing and injection molding simulation can be realized with many system configurations including different boundary conditions and material set up. Solvay presents a numerical analysis methodology that include the development of an advanced material card for manufactured thermoplastic continuous fiber.

TCC 2020
THERMOPLASTIC COMPOSITES CONFERENCE

A VIRTUAL EVENT
APRIL 29 – MAY 1, 2020



Press Forming Simulation of a Continuous Fiber-Reinforced Thermoplastic Composite

Presented By: Fabio Bressan and Frederic Lani
Virtual Engineering Team
Solvay Composite Material

A History of Pioneering

1863

Ernest Solvay invents a new process for **producing soda ash**

1878

Solvay **innovates in social welfare** (paid vacations, social security, 8-hour day)

1880

Solvay is **the first industrial multinational operating** simultaneously in the US and Europe

1911 & 1927

The congresses **bring together the greatest scientists of their time**

1965

Solvay develops PSU, a **revolutionary healthcare polymer** used for **hemodialysis membranes**

1978

Solvay launches PEEK, a **very strong thermoplastic** to replace metal for lighter, more fuel-efficient planes

1990

Solvay **invents precipitated silica for green tires**

2011

SOLVAY

Solvay **acquires Rhodia**

2013

1st Chemistry for the Future Solvay Prize

CHEMISTRY FOR THE FUTURE Solvay Prize

2015

Solvay **flies around the world with Solar Impulse**

Solvay **acquires Cytec**

2019 Key Figures

24,100
Employees

64
Countries

115
Industrial sites

21
Major R&I centers

€10.2 billion
Underlying net sales

€2.3 billion
Underlying EBITDA

53%
Net sales generated by sustainable solutions

-5%
Greenhouse gas emission

TOP 3
Market position in ~ 90% of portfolio

We are an advanced materials and specialty chemicals company, committed to address key societal challenges

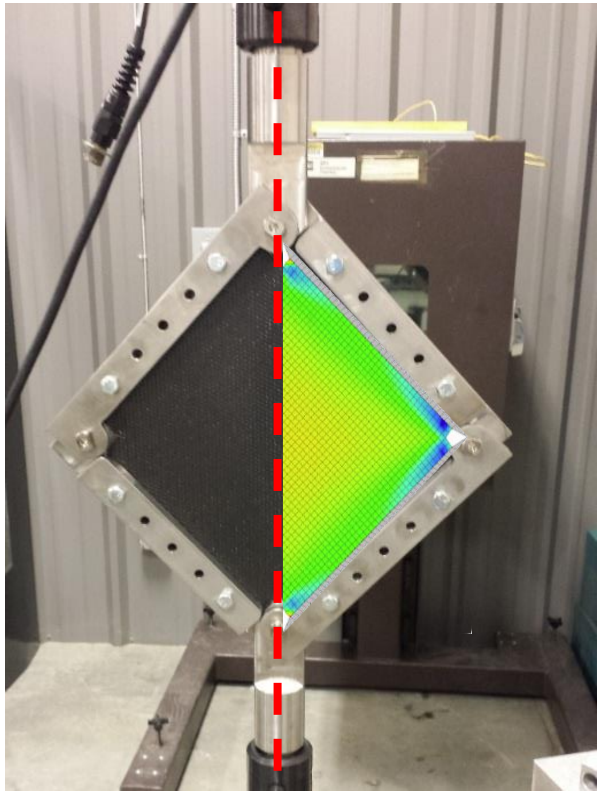
Figures take in account the divestment of the polyamide business completed on 2020 january 31

1 Value Proposition of Manufacturing Simulation

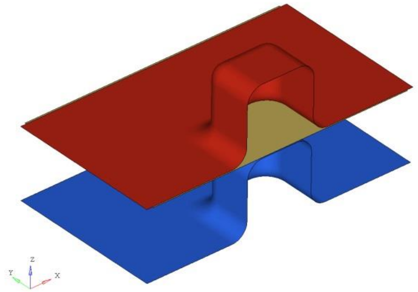
Virtual Engineering Team

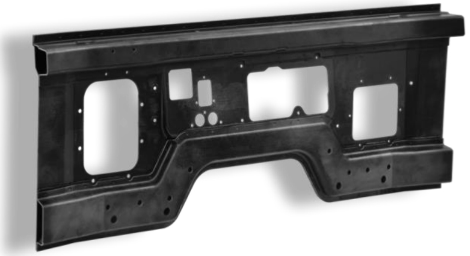
SOLVAY

2 Material Card Methodology Developed



3 Simulation and Correlation





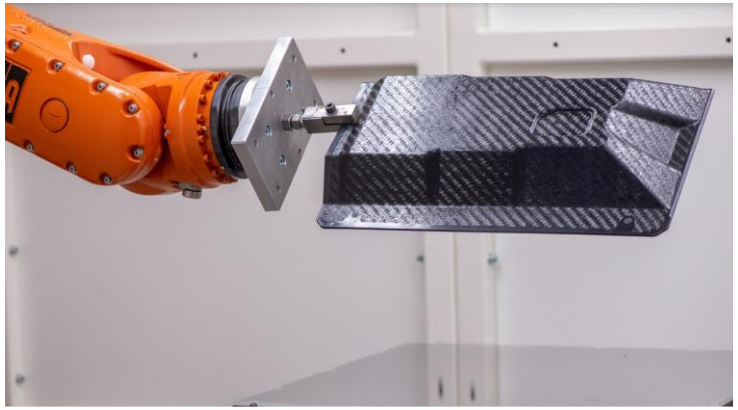
We allow the client to virtually explore new manufacturing solutions
We minimize the RISKS and shorten the development time

SOLVAY

Digital Material (Material Card) is:
Free, Prefect and Instant

Virtual Manufacturing Simulation provides a technology solution (not just a material solution)

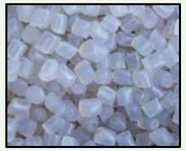
1. Value Proposition: MSAC - Customer Engagement Center



From Innovative Ideas

Innovative Materials

PAEK
PPA
PPS
PVDF
.....



CF
sizing
....

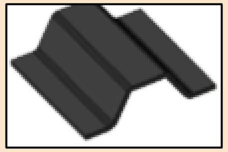
Innovative CFRTP

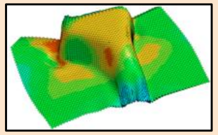
APC PEKK
APC PEEK
APC PAEK
.....

Evolite PPA
Evolite PPS
Evolite PVDF
....

MSAC Application Development

Consolidation
Stamp Forming
Overmolding
.....
Part Testing
VIrtual Engineering
Data package





To Solutions to our Customer needs

The *Customer Engagement Center* in Brussels is the physical place where we collaborate with our customers to develop solutions and accelerate the market adoption of thermoplastic

1. Value Proposition: MSAC in a nutshell

In MSAC we can demonstrate the manufacturing of parts from tapes or fabrics by blank consolidation, stamping-forming and overmolding

In MSAC we work together with our customers to speed up the development of Thermoplastic Composites solutions

Part prototyping

Blank formation, stamp forming, injection & overmolding, machining, recycling, 3D printing

All data stored in a Data Lake

Testing

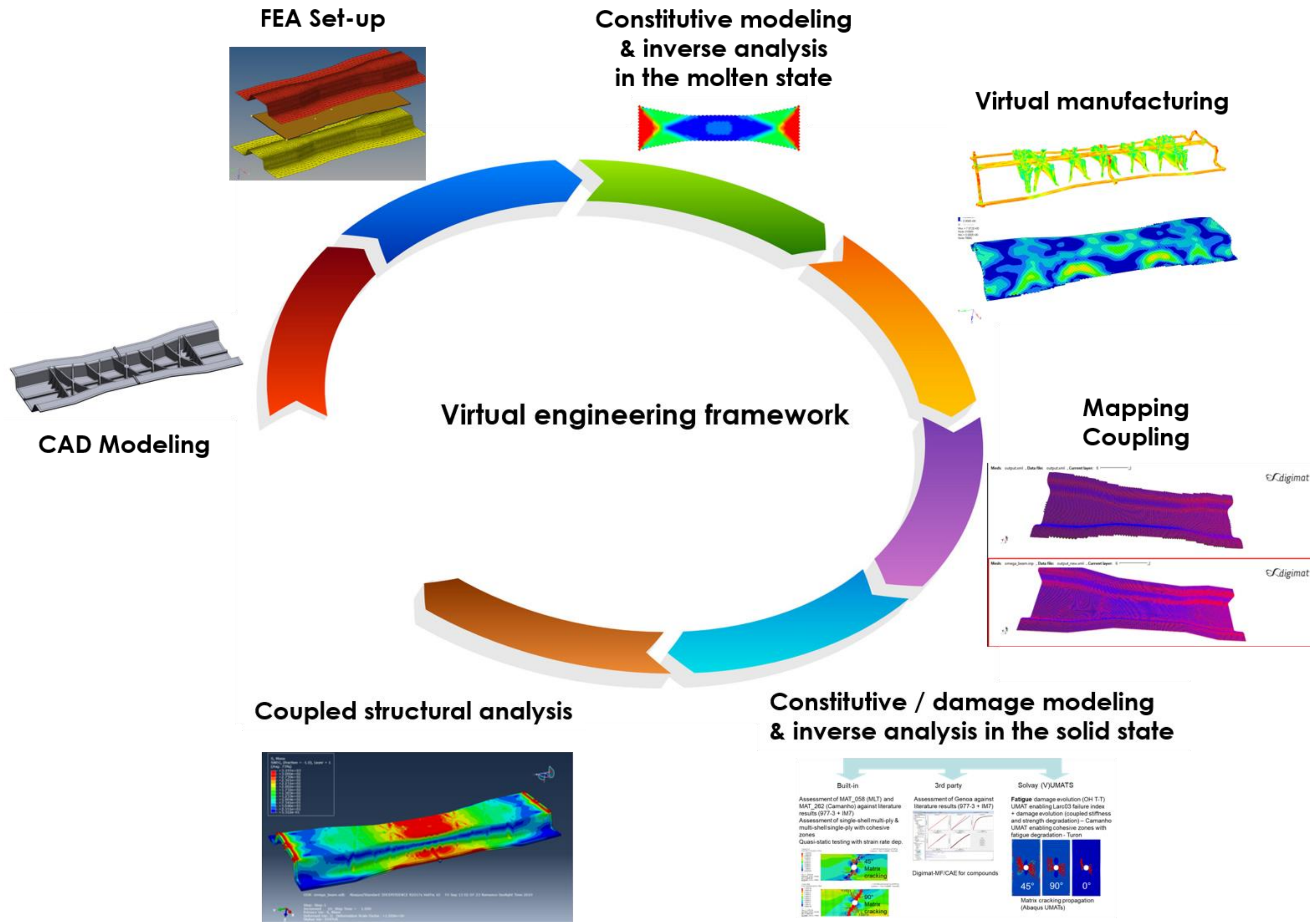
Advanced mechanical testing (fatigue, creep, aging, high-speed multiaxial, NDT,….)

Virtual Engineering

Advanced material - process - part modeling and simulation

In MSAC we can simulate the whole process - prototyping, testing, in service performance – using state of the art computational tools

In MSAC we can evaluate the performance of parts using advanced characterization techniques



Large CAD/CAE expertise and extended software portfolio for maximum compatibility with customers CAD/CAE environment

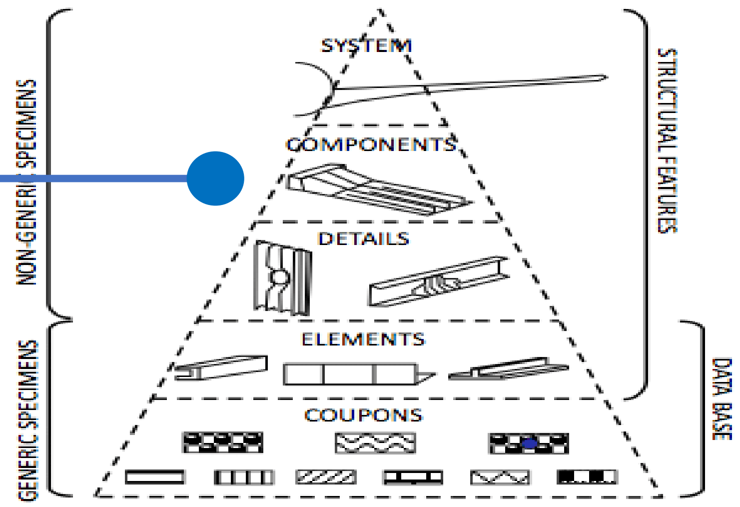
Manufacturing simulation
Moldflow, LS-Dyna, Hyperform, Abaqus, Aniform

Structural analysis
LS-Dyna, Ansys, Abaqus, Radioss, Optistruct, …

Material cards
Built-in models, Digimat, Genoa, Solvay proprietary (V)UMATs

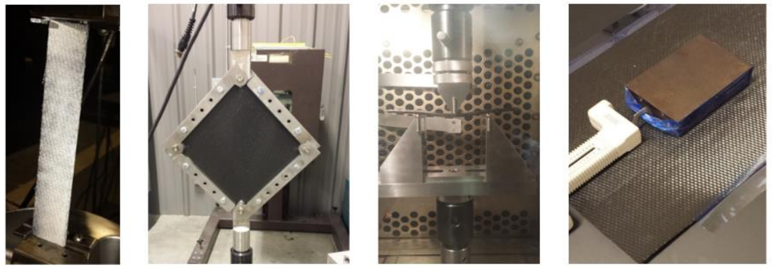
2. Material Card Development: Timeline

The BUILDING BLOCK approach applied to Material Card Development



Composite Materials Handbook 17 (CMH-17) MIL-HDBK-17

1. Laboratory coupon tests – molten state



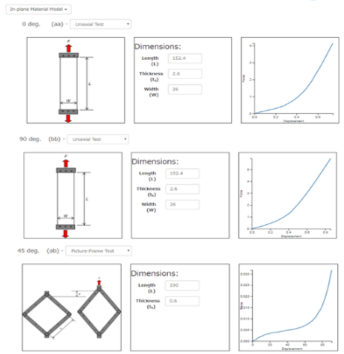
Tensile Modulus

Shear Modulus

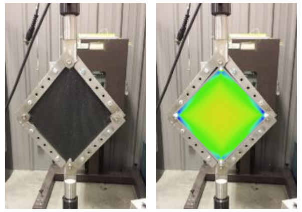
Bending Stiffness

Friction Coefficient

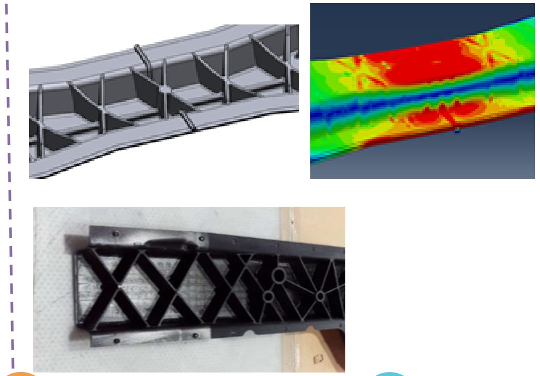
2. Virtual Laboratory models



3. Calibration

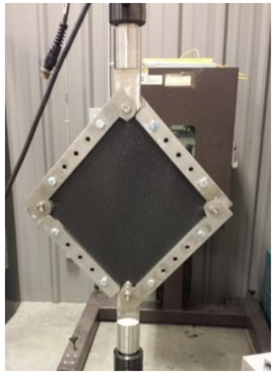


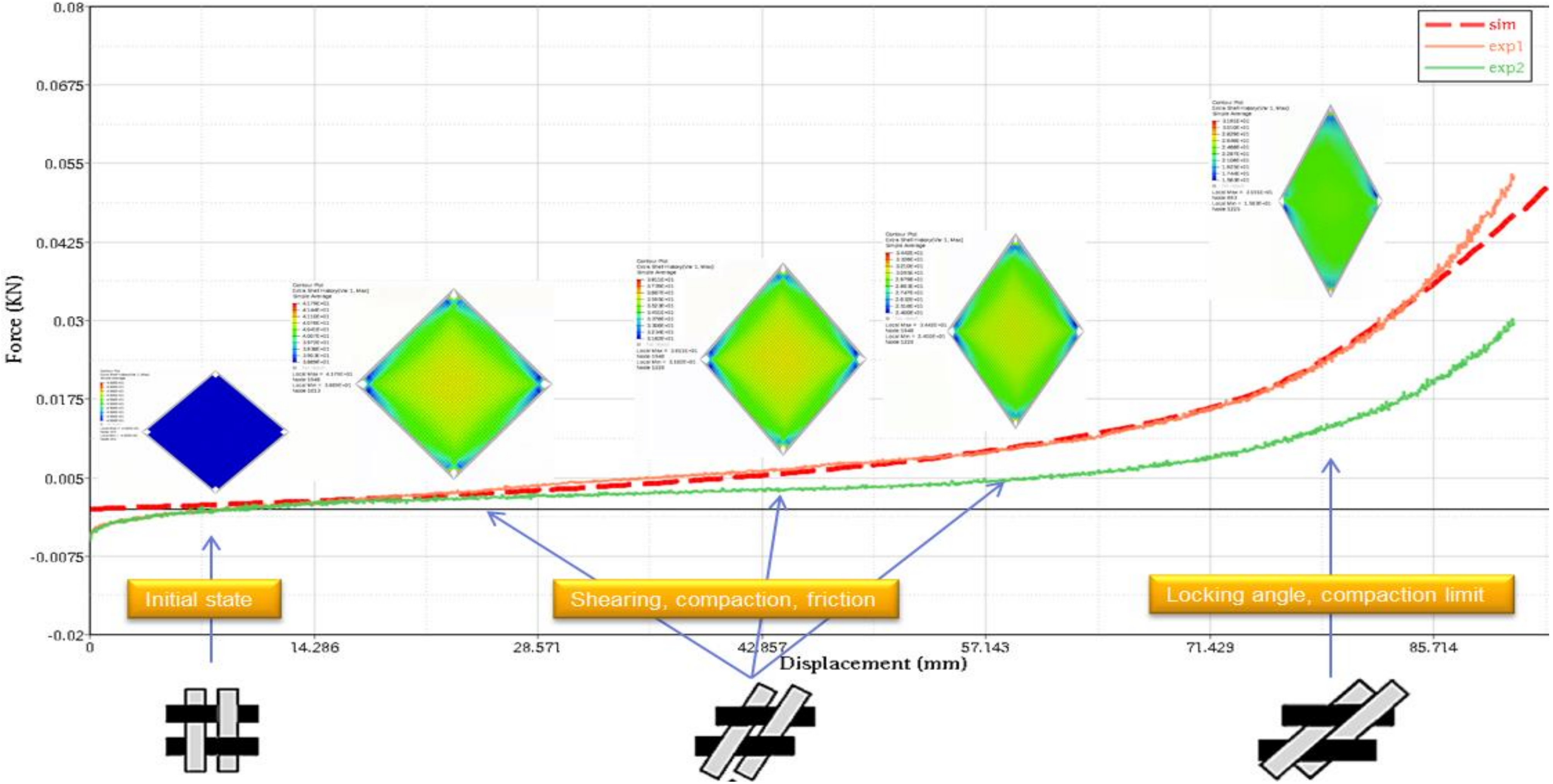
4. Validation



START — **Month 1** — **Month 2** — **Month 3** — **Month 4** — **Month 5** — **END**

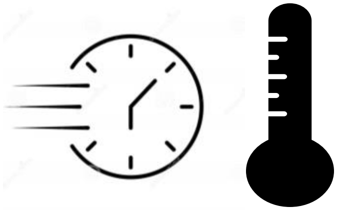
Picture Frame: Experimental Test vs Virtual Test



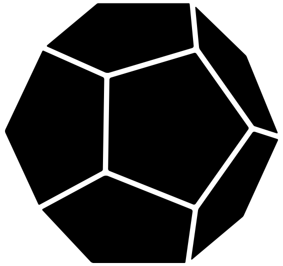


Finite Elements Method:
Manufacturing Simulation Challenges

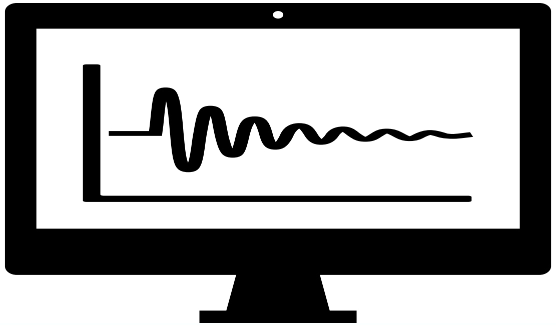
1. Manufacturing Material Card (in-plane shear and interface) must include rate and temperature dependence



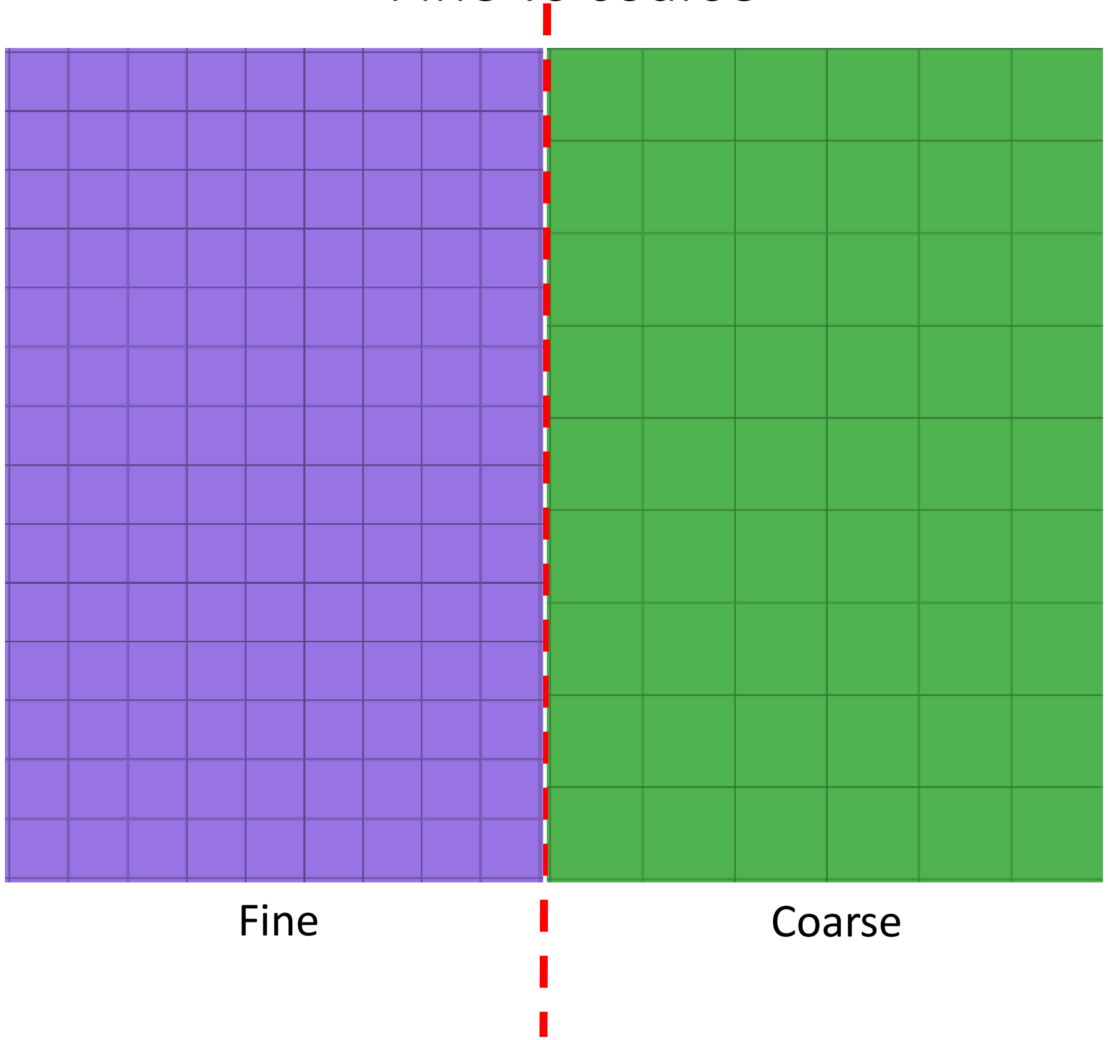
2. Manufacturing Material Card accuracy is achieved when mesh is aligned with the material fiber direction and with appropriate mesh size.



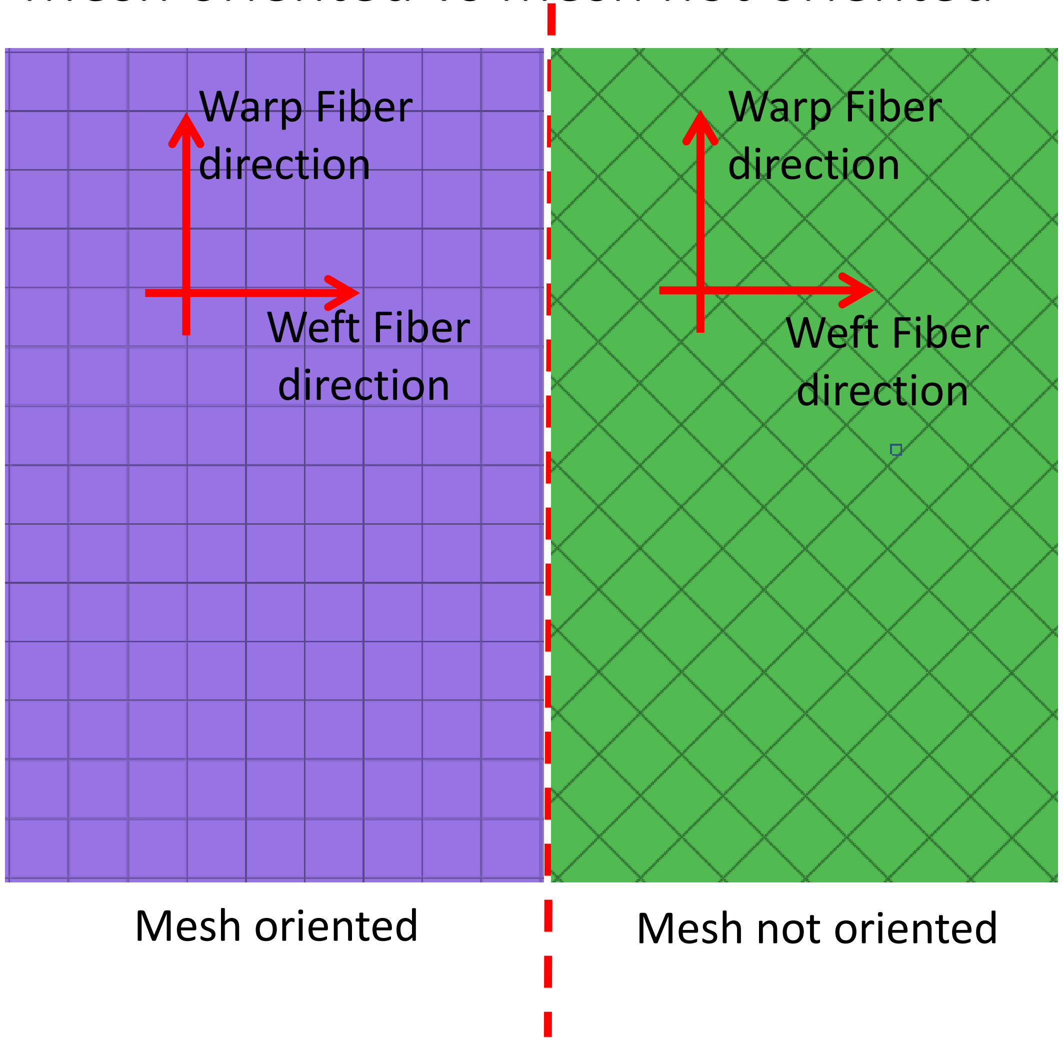
3. Solvers must handle large, complex 3D geometries, with multiple contacts between many layers and highly materially non-linear problems



Fine vs coarse



Mesh oriented vs mesh not oriented

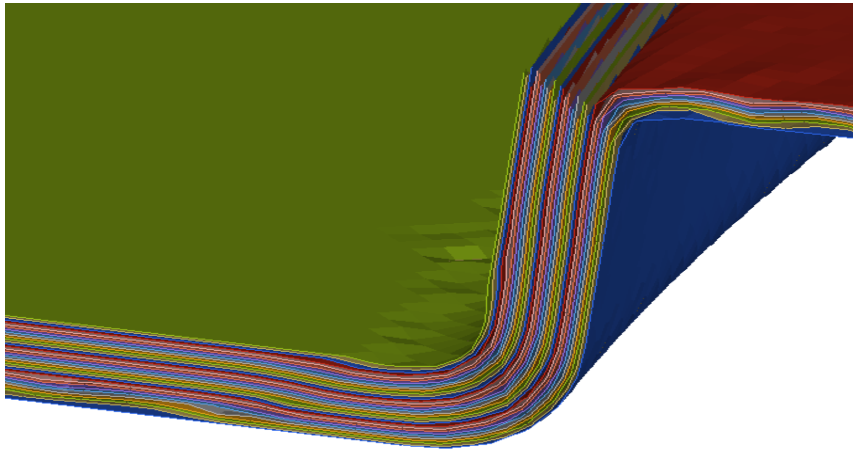


In some cases parallel explicit solvers appear to be very effective to handle press forming problems with many plies, complex geometries and large number of elements and contacts

- Thick composites, large number of plies
- Mutual contact between all different layers, as well as between plies and mould surfaces (to account for ply slip)
- Bottom and top faces of the same layer are in contact

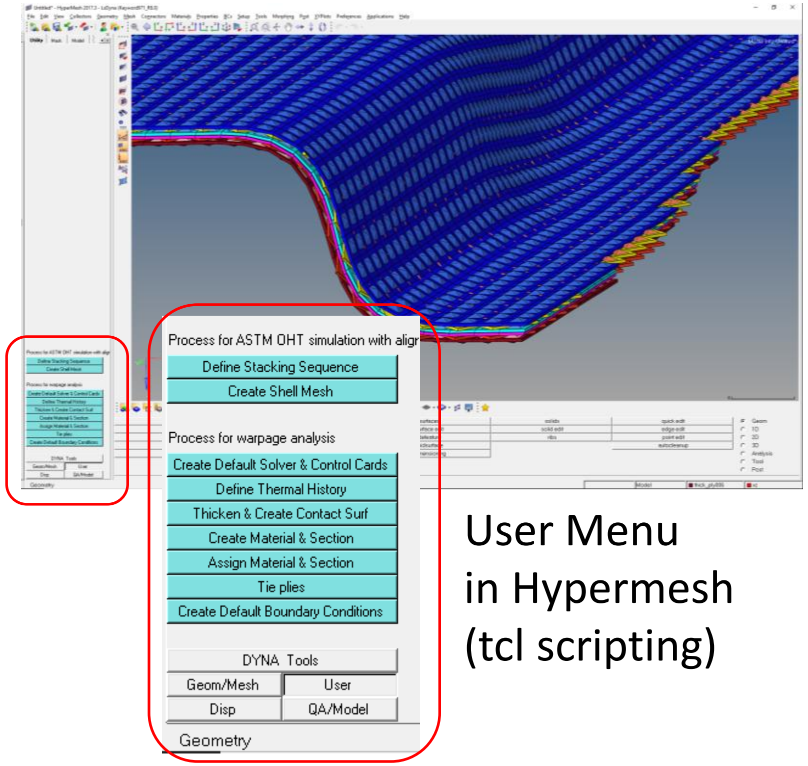
Illustrated:
Thick, complex lay-up showing wrinkles, slip bewteen plies of different orientations

Simulation was performed with LS-Dyna on 40+ cores in less than 7h

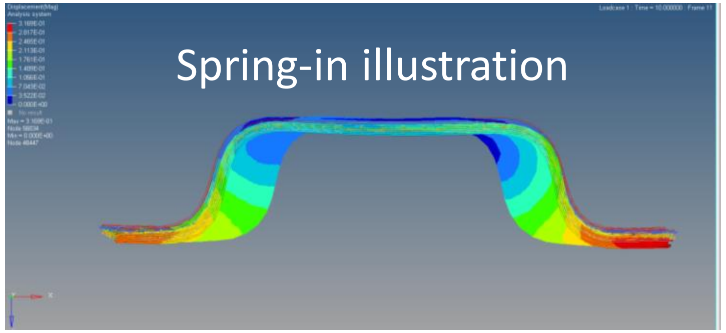


Warpage simulation steps

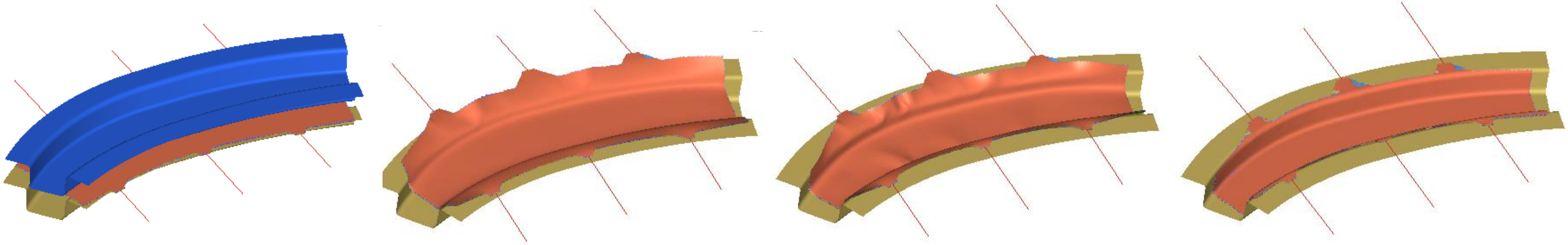
1) Manufacturing simulation mesh is retrieved and inflated
2) Tie constraint is set between plies
3) Boundary conditions are set (free, blocked or contact-friction with tool)
4) Cooling is simulated using three different approaches:
    1) Built-in orthotropic thermoelastic plies (built-in LS-Dyna or Abaqus card)
    2) Pseudo-viscoelastic orthotropic plies (UMAT)
    3) Thermo-viscoelastic plies (Digimat)



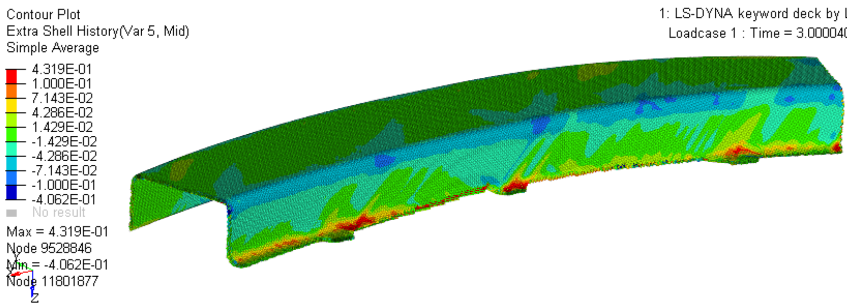
User Menu in Hypermesh (tcl scripting)

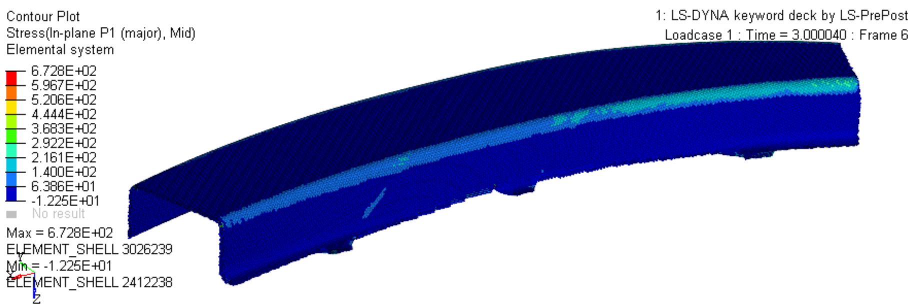


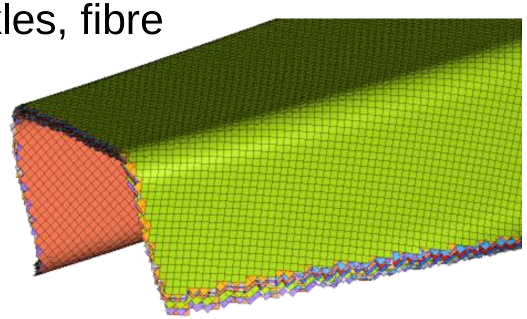
- Simulation Steps:

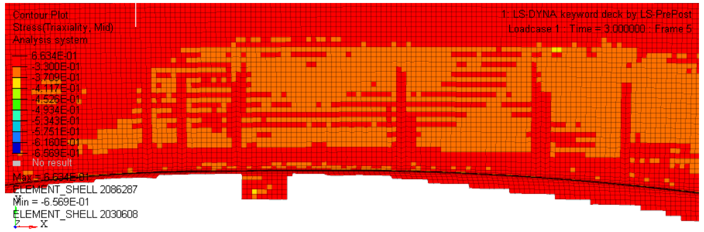


- Results:
  - Identify and design for regions of defect e.g. fibre deviation, ply-slip, wrinkles, fibre tension, resin bleeding, in-plane waviness, ply split , thickness change

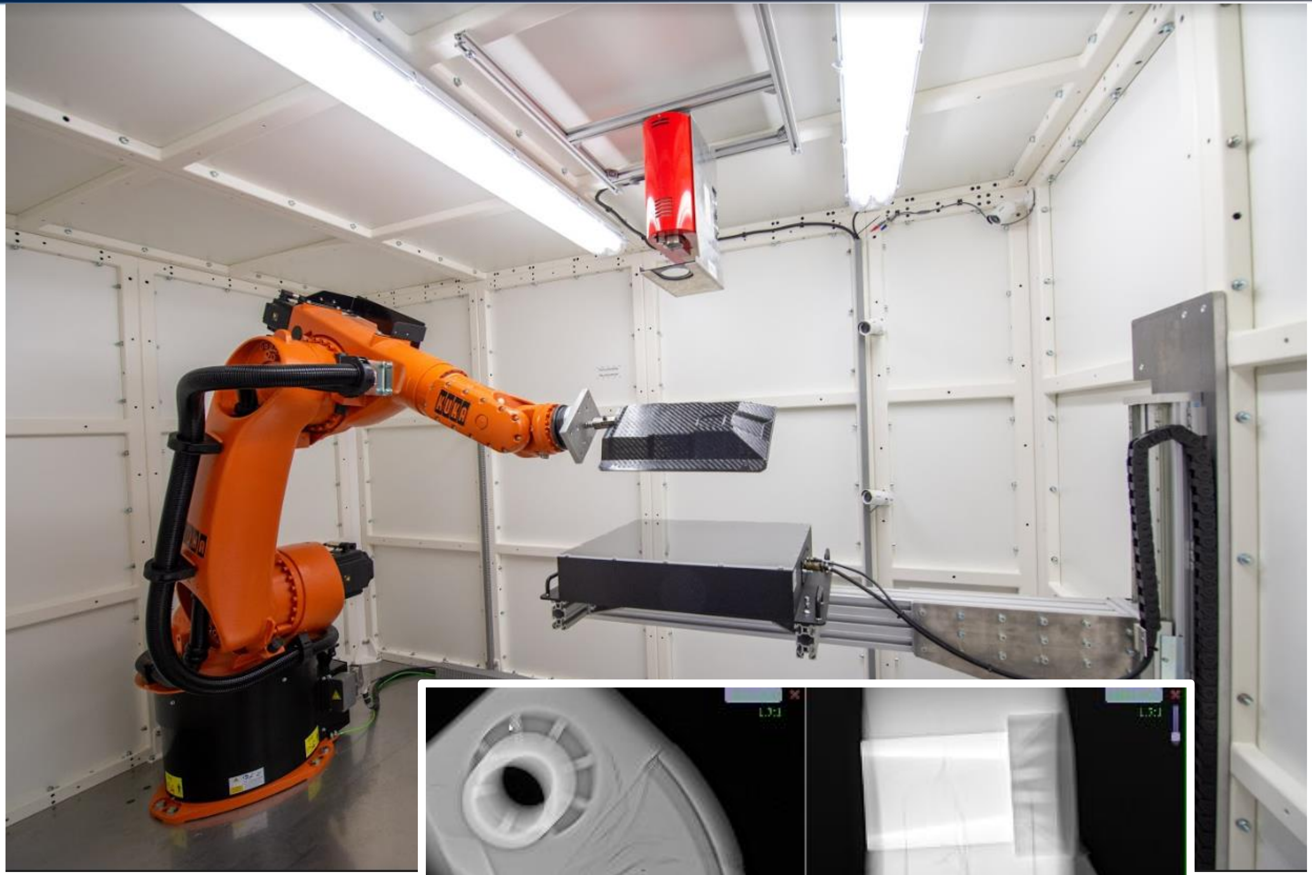






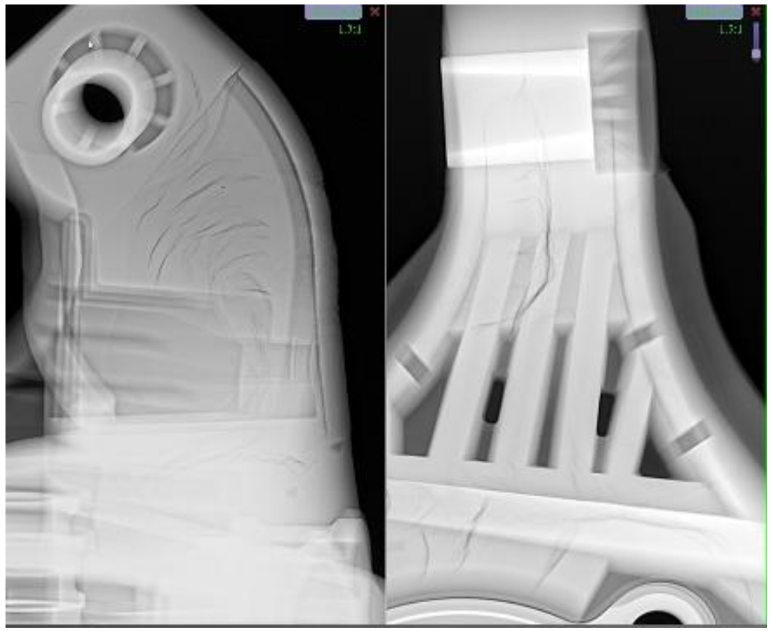


- Robotized specimen handling for small and medium size parts
- Micro-focus X-ray source (150 kV, 75W)
  - Size: 7 to 50 µm with divergent beam of 43°
  - Magnification (from 1 to 10) depends on the position of the test specimen between the source and the large digital detector
- 14-bit digital detector:
  - 43 cm X 43 cm
  - 3072 px x 3072 px (pixel size: 139 µm)
- **Computed Tomography (3D scan):**
  - voxel size between 20 µm and 120 µm
  - CT-scan time: 30 min



Example

Evidence of Internal cracks in a thick part



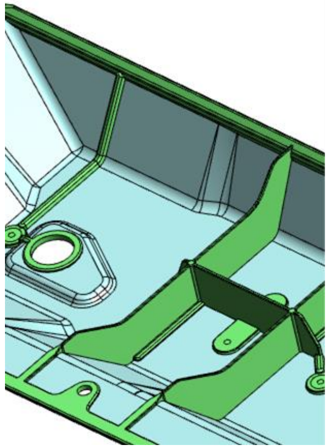
Conclusions

Step 1
Design

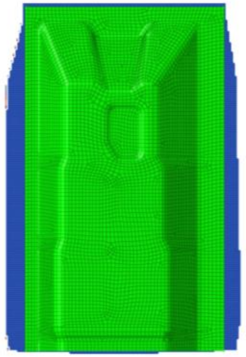
Step 2
Simulation

Step 3
Correlation

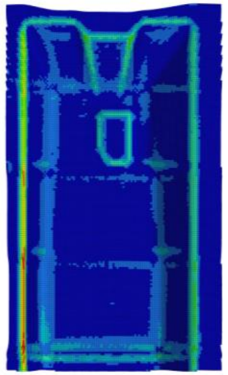
Step 4
Structural test & NDT



Generic Demonstrator

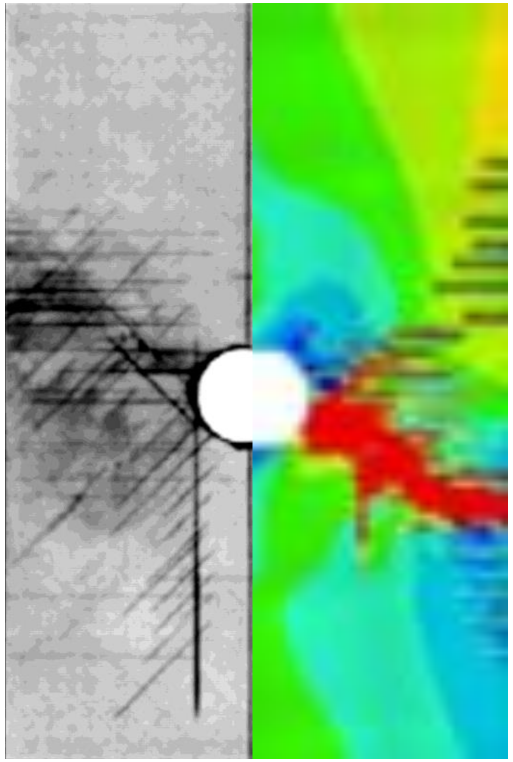


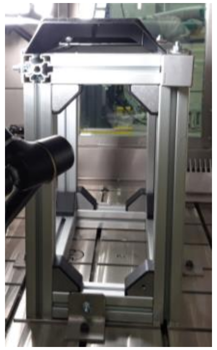
Inverse Drape Analysis



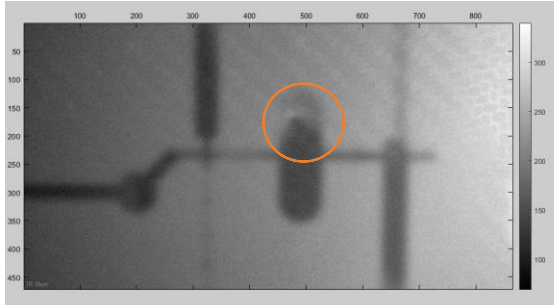
Fibre stresses

Shear angles





Impact test on part with high speed camera



Infrared thermography showing debonding of overmoulded rib