mid Moulding Innovation Day 2023

RADICI GROUP

RadiciGroup High Performance Polymers

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Moldex3D

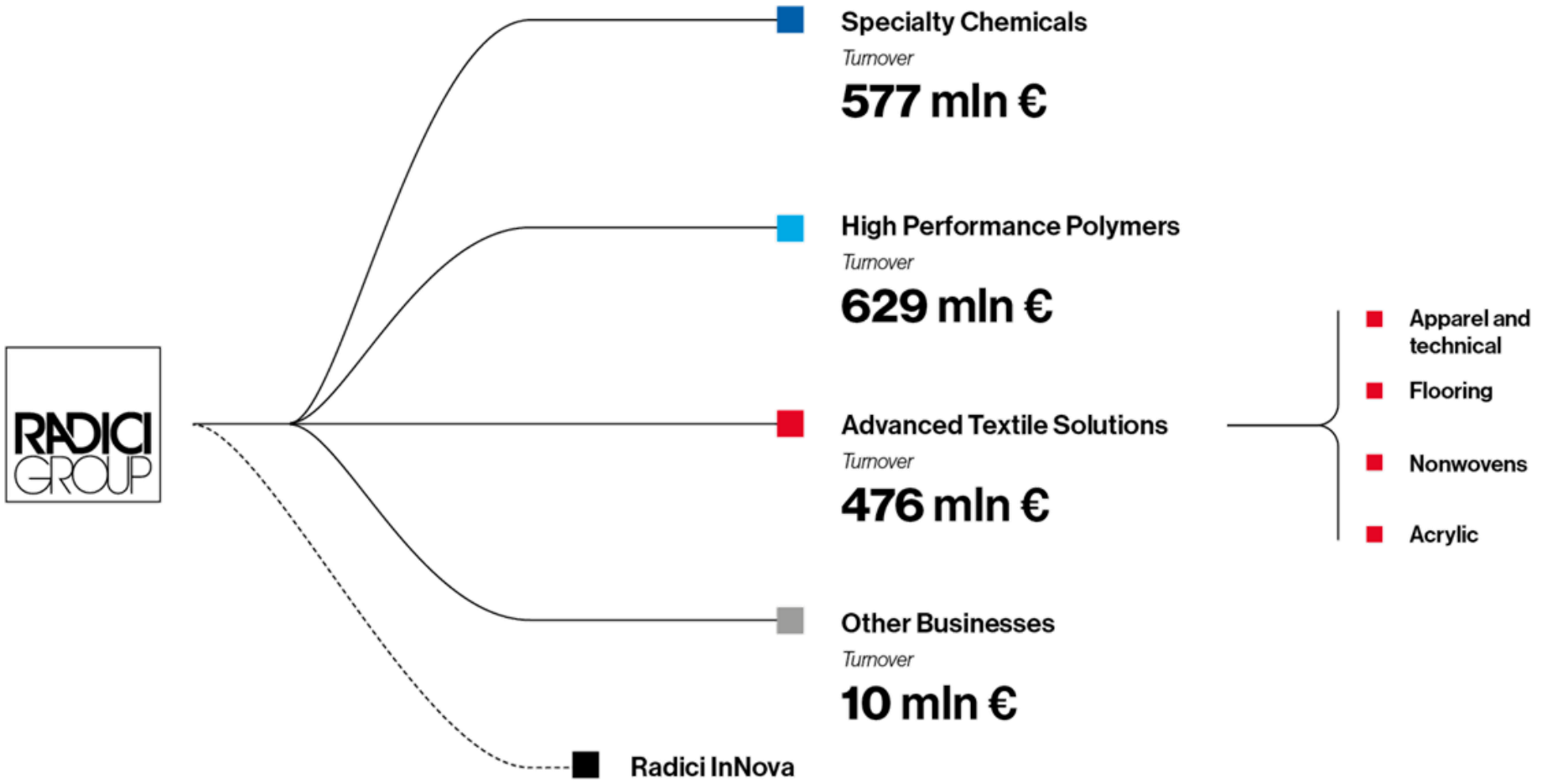
Metal Replacement with high-performance polymers: the use of Moldex3D solutions for success in an innovative sports project

mid Moulding Innovation Day 2023

Agenda

- RadiciGroup High Performance Polymers at a glance
- Metal Replacement: Key Concept and Materials Portfolio
- Engineering Service: CAE Support
- Successful case history: Rear Swing-Arm for E-Bike

RadiciGroup



2022 turnover, consolidated at Business Area level. The figure related to the single Business Area includes sales made to other Business Areas within RadiciGroup.

RadiciGroup High Performance Polymers

RadiciGroup HPP – Main Brands

radilon®	Polyamide engineering polymers (PA 6, PA 6.6, copolymers, PA 6.10, PA 6.12, PPA and other specialty PAs for high temperature resistant applications) for injection moulding, extrusion and blow moulding. Filaments for 3D printing.
radiflam®	Polyamide and polyester flame-retardant engineering polymers, including a complete range of halogen and red phosphorous-free products.
radistrong®	Specialty PA 6.6 engineering polymers. The main distinguishing features are high mechanical properties, better property retention with moisture absorption and an excellent surface appearance. Suitable for injection moulding of high mechanical resistance parts.
raditer®	Polyester (PBT and PBT copolymers) for injection moulding.
raditeck®	High-performance PPS compounds, characterized by their exceptional chemical/thermal resistance and dimensional stability.
RENYCLE®	New sustainability-oriented engineering polymers, from post-industrial and post-consumer sources, targeted at meeting the growing needs of the market that requires products with a low and measurable environmental impact without compromising on quality, reliability, traceability, safety

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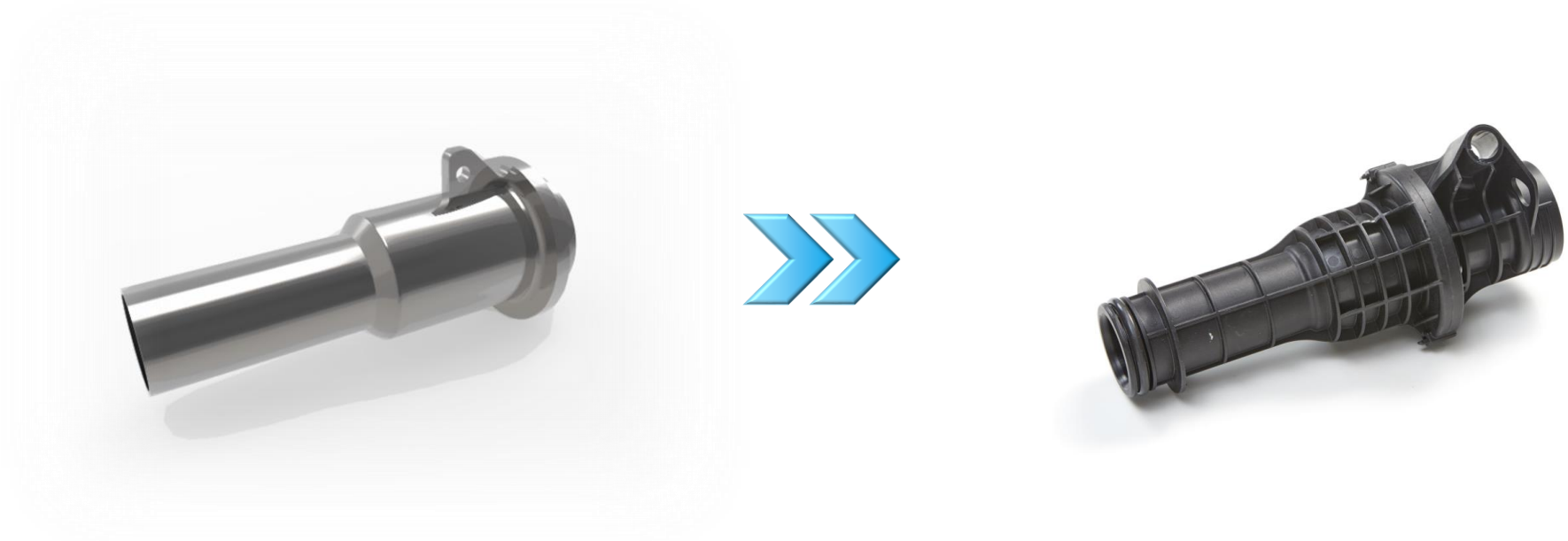
Metal Replacement: Key Concept

Substitute one or more parts currently made in metal with a part having the same **Functionality**, made with a different material (namely, Engineering Plastics).



Metal substitution with **engineering polymers** on demanding applications started successfully more than 30 years ago.

Metal Replacement: Macro Trends

There are still **big opportunities** in all industrial sectors, even on parts that were never considered for metal replacement. Macro drivers are:

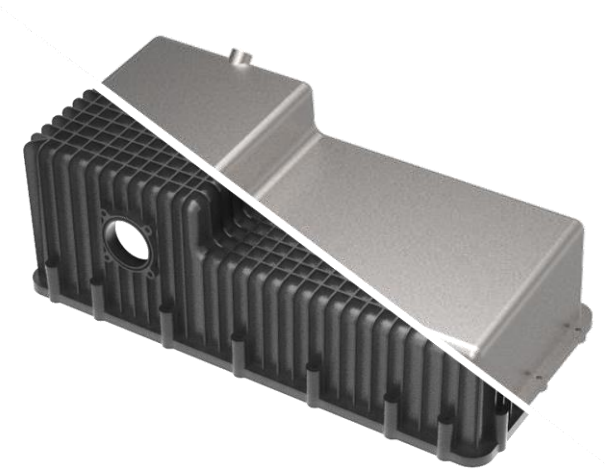
Reduction of the production **costs**

Lower Environmental Impact of the products
(LCA - Life Cycle Assessment)

Light-Weighting,
in particular for **Transportation sector**: new regulations on CO_2 emission limits (less weight > less fuel consumption)

Metal Replacement: Advantages

- **Weight** reduction
- Form and design **freedom**
- Environmental **Sustainability**
- **Integration** of functions
- Reduction of **assembly** and post-processing (machining…)
- **Aesthetics**, colorability
- Total **cost** of part (≠ cost of material per kg!!!)
  - Material cost per liter
  - Part count, Number of operations, Assembly
  - Cost of Injection Molding technology
  - Productivity
  - Tool life (vs Diecasting)



RadiciGroup HPP: Materials Portfolio

Product Name	Polymer Type	Key Features	Typical Applications
RADILON S RV300W	PA6-GF30	• Very high stiffness and strength • Good surface appearance	• Automotive • Consumer Goods • Industrial
RADILON S RV500W	PA6-GF50		
RADILON S URV300W	PA6-GF30	• Very high stiffness and strength • Easy flowability • Good surface appearance	
RADILON S URV500W	PA6-GF50		
RADILON A RV350W	PA66-GF35	• Very high stiffness and strength • Developed for demanding applications	• Automotive • Consumer Goods • Industrial
RADILON A RV500RW	PA66-GF50		
RADISTRONG A RV500W	(PA66+PA)*-GF50	• Very high stiffness and strength • Excellent surface appearance • Lower moisture absorption	• Water Management
RADISTRONG Aroma RV500RKC2			
RADILON D RV500RKC	PA610-GF50	• Improved dimensional stability • High chemical resistance • Partially obtained from renewable sources	• Industrial • Water Management
RADILON DT RV300RKC2	PA612-GF30	• Excellent chemical resistance • Improved dimensional stability • Very high stiffness and strength	• Industrial • Consumer Goods • Water Management
RADILON DT RV500RKC2	PA612-GF50		

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engineering service

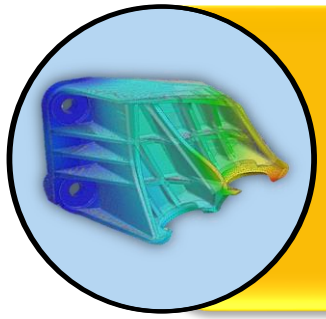
Simulate. Collaborate. Innovate.

From “material supplier” to “partner for innovation”

- **RadiciGroup High Performance Polymers** can rely on a global team including *Sales, Marketing, Applications Development, Technical Service and R&D*, to provide our customers with the highest professional support throughout **all project phases:**

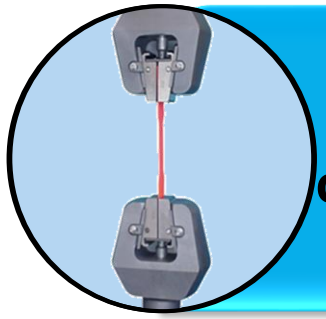
Simulate. Collaborate. Innovate.

RadiciGroup HPP: Engineering Service



Perform internally **CAE simulations** in support of application developments involving RadiciGroup products, with the purpose of:

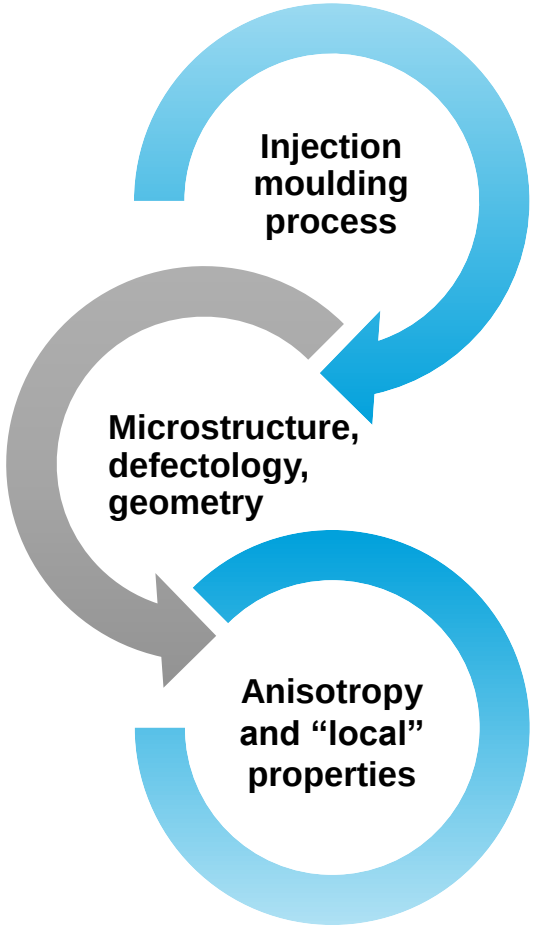
- Assessing **projects' feasibility**
- Validating **material selection** and part **(re-)design**
- **Troubleshooting** in prototyping or in regular production

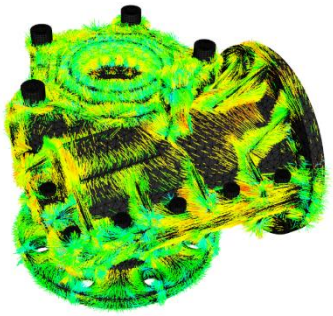


Coordinate with R&D, external suppliers and software producers so to ensure that fresh and reliable **material cards** for RadiciGroup products are made available for use to the simulation communities

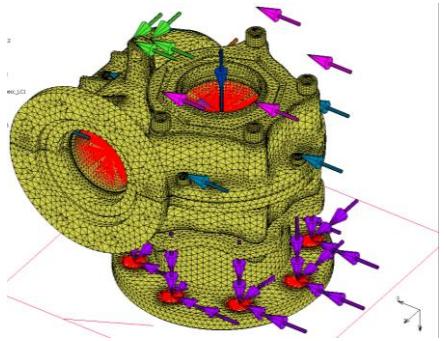
Communicate with customers' **Designers, Engineers and CAE experts** in order to facilitate a positive exchange of information in material selection and modelling

Integrated approach to Simulation

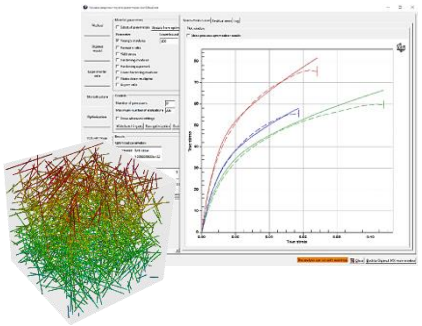




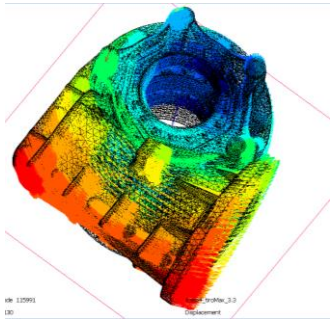
Injection simulation: Warpage, GF orientation, weld lines…

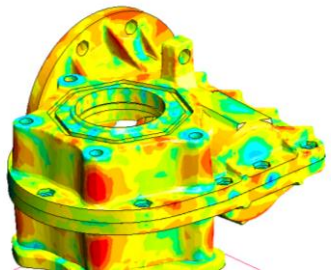


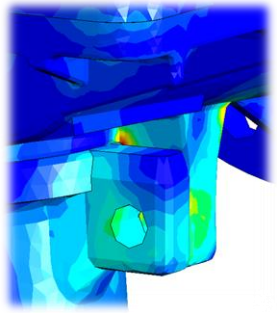
FEA model: Loads, boundaries



Multi-scale material modelling



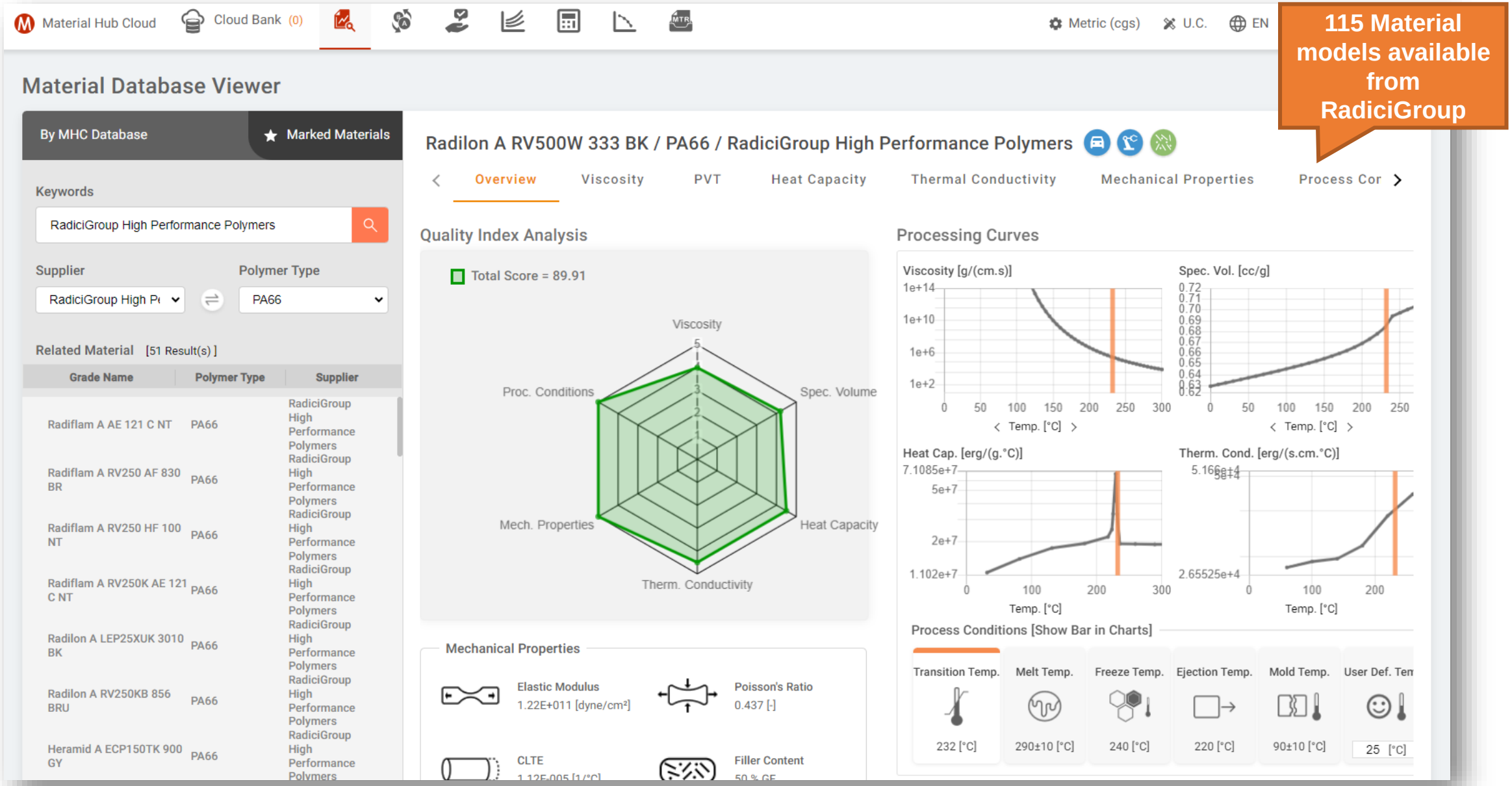




INTEGRATED STRUCTURAL SIMULATION

- Higher **accuracy** and **reliability** in predicting elasticity and failure
- More in-depth understanding of the **material behavior**
- Reduce tendency to **overengineering** and use of high **safety factors**
- Less need for **prototype testing**

RadiciGroup HPP database in Material Hub Cloud



Agenda

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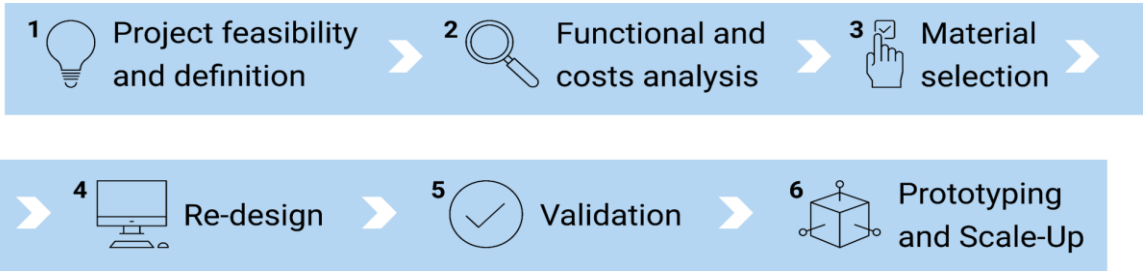
Metal Replacement: Design Approach

Metal Replacement: Substitute one or more parts currently made in metal with a part having the same **Functionality**, made with a different material (namely, **Engineering Plastics**).

…**Not** "make the part out of plastics" assuring the same **Properties** > **rather, consider how to take advantage of plastics peculiarities: Plastic is not metal!**

- A correct approach to metal replacement must take into due consideration, from the very beginning:
  - The **Functional requirements** of the part, including the implicit ones and the way it interacts with other parts and operating environment.
  - The **Intrinsic properties** of plastic, which are strongly different compared to metal: the part must be designed to "use" them properly.
- It's necessary to have an **overall view** of all the aspects related to the project to pre-select the material and then to re-design the part.



Case History: Rear Swing-arm for E-Bike

Courtesy of

ACERBIS FANTIC

Original material: Aluminium 6061 alloy

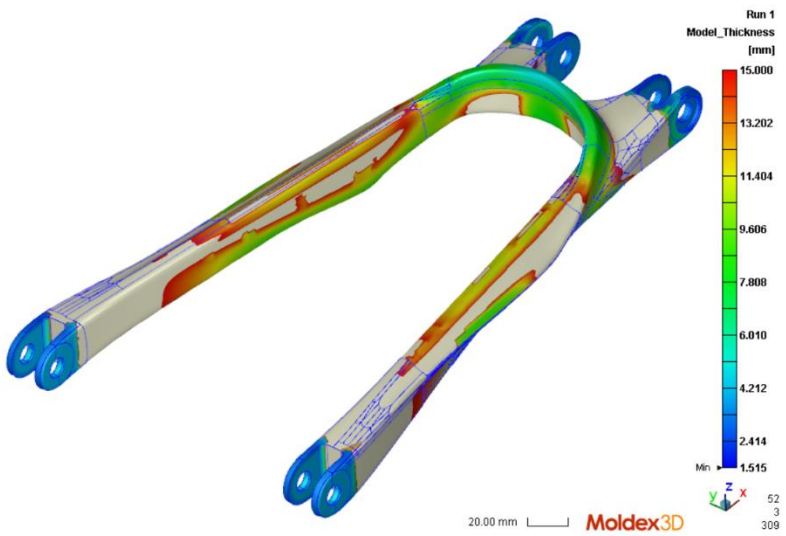
RadiciGroup proposal: radistrong®

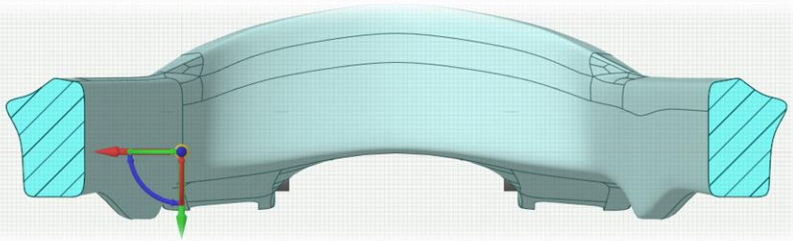
Requirements:

- Stiffness and mechanical resistance with static loads;
- Low moisture sensitivity;
- Fatigue resistance;
- High surface appearance and colorability;
- UV stabilization.

Rear Swing-Arm: Design Optimization

Thickness Analysis



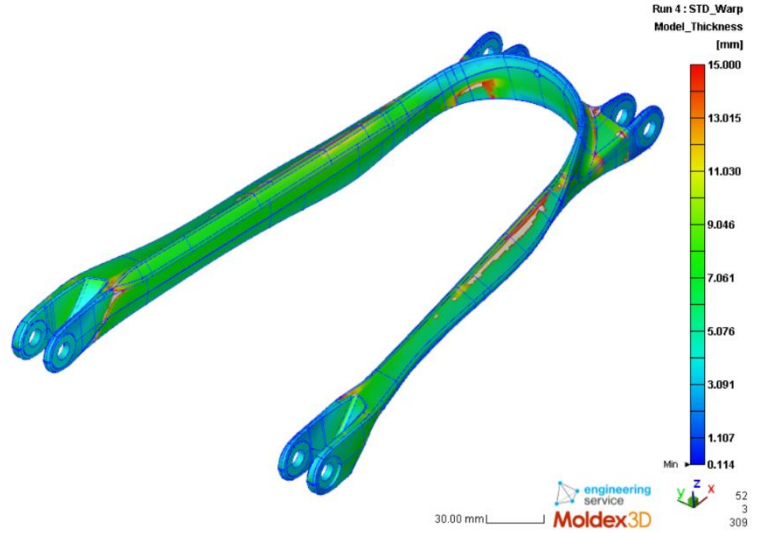


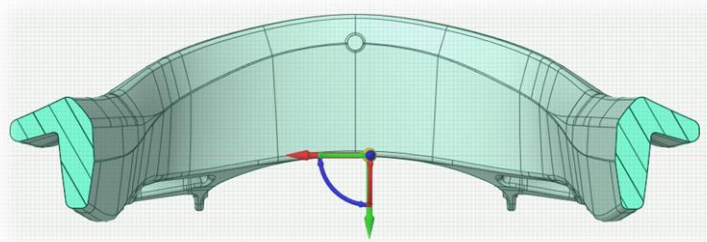
Re-Design ACERBIS

Process Simulation

Structural Simulation

Thickness Analysis





First Design
(Proposal)

engineering service
Simulate. Collaborate. Innovate.

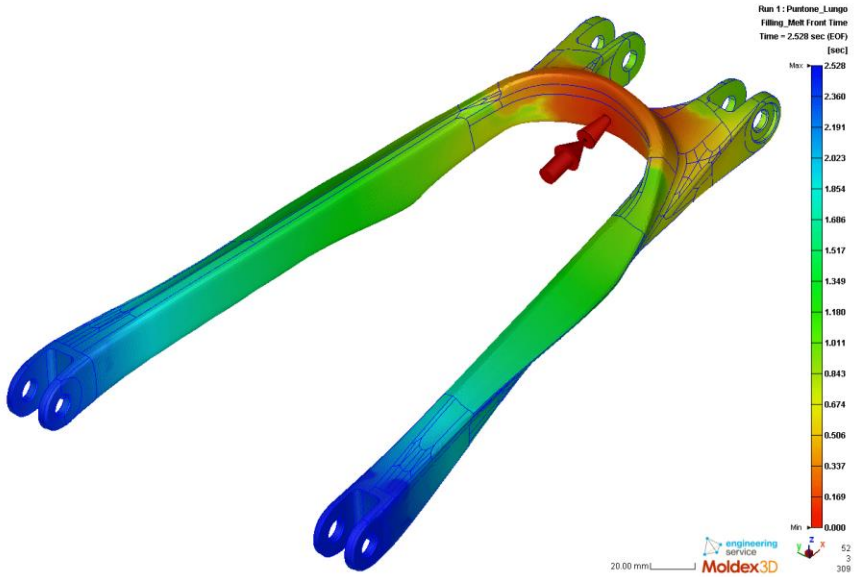
Final Design

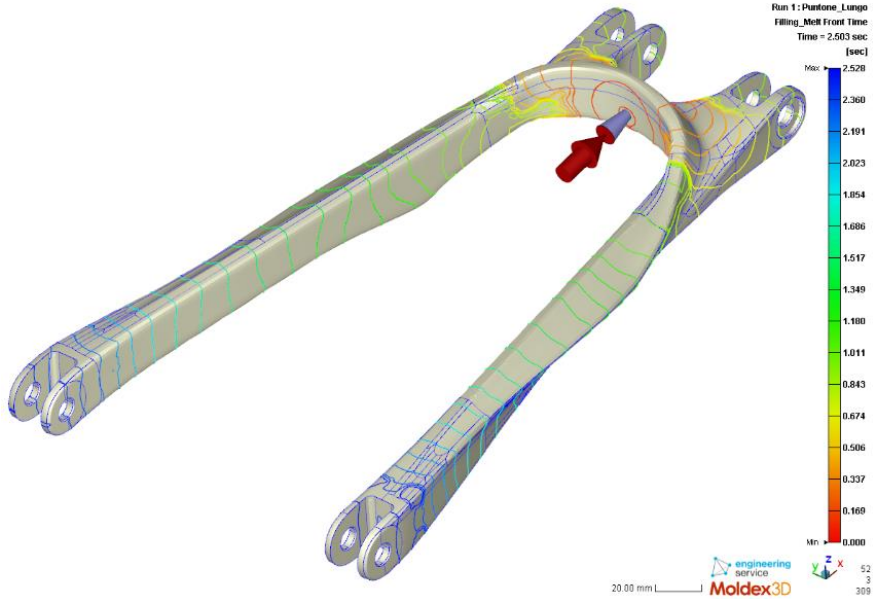
Process Simulation - Filling

Moldex3D
MOLDING INNOVATION

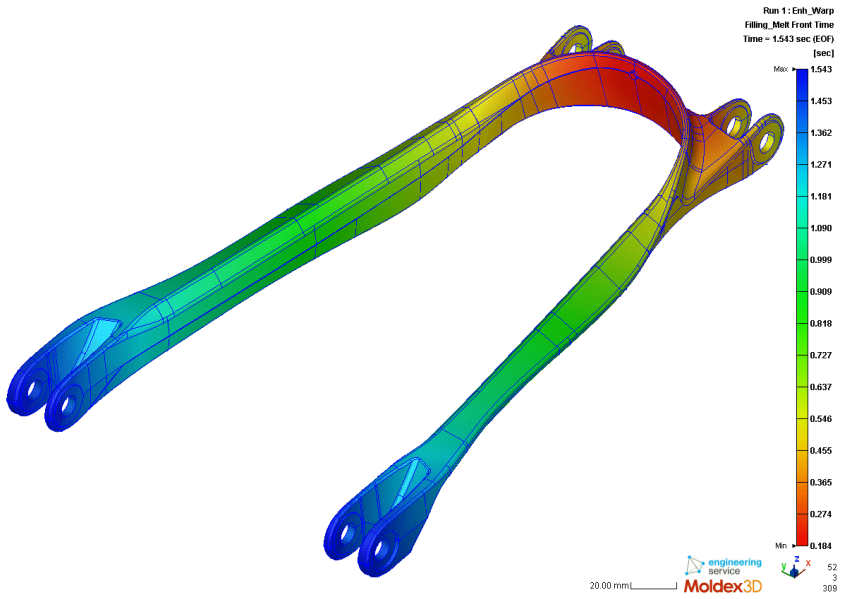
RADICI GROUP

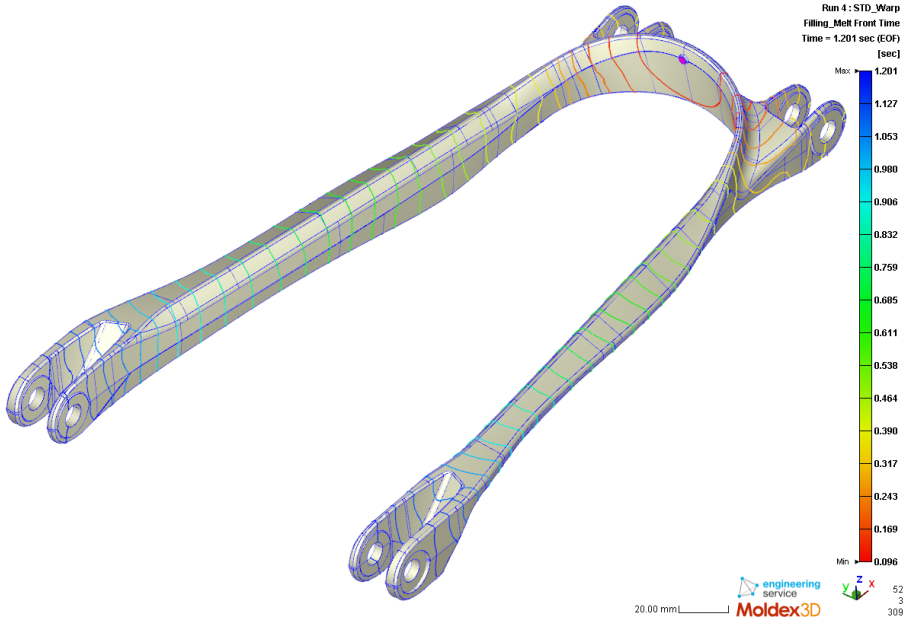
First Design
(Proposal)





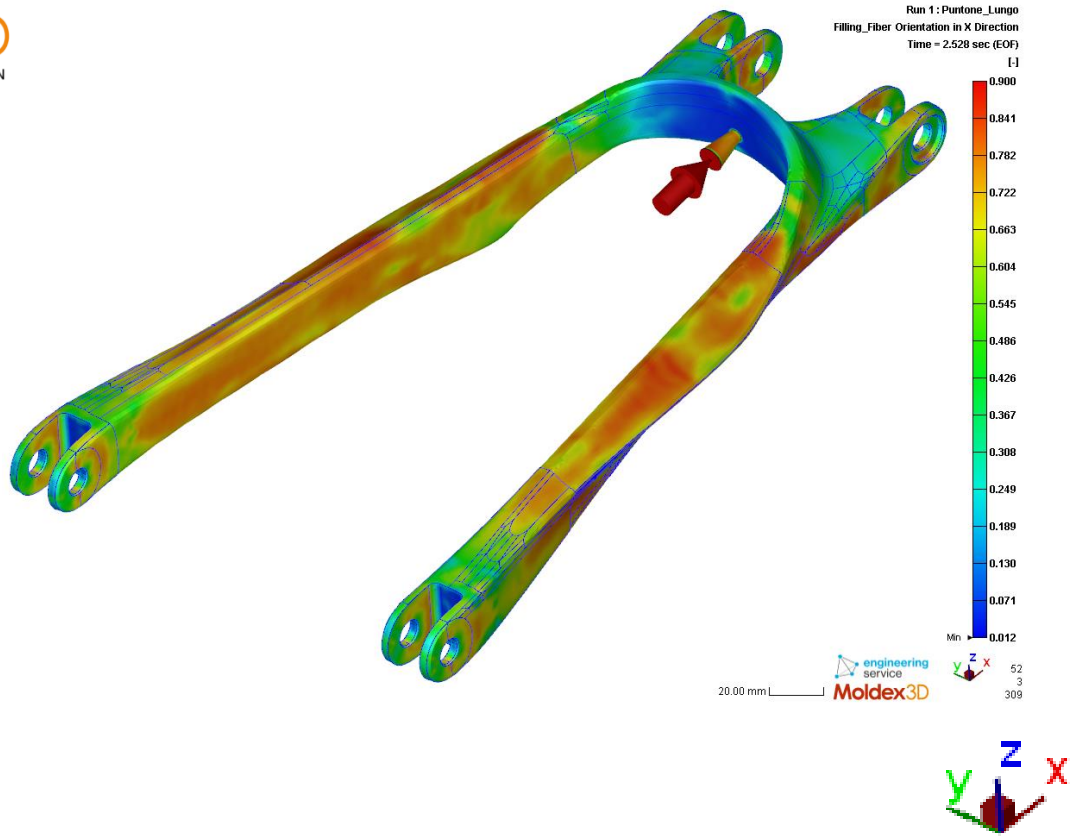
Final Design



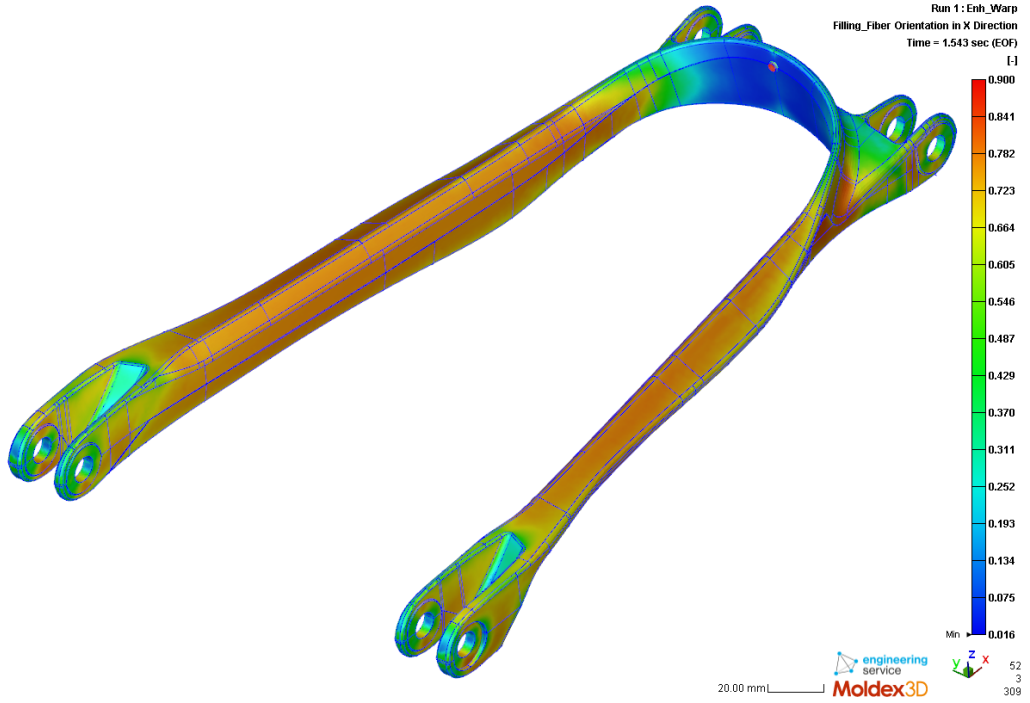


Process Simulation – Fiber Orientation Tensor X

First Design
(Proposal)



Final Design



Process Simulation – Packing Phase

Moldex3D
MOLDING INNOVATION

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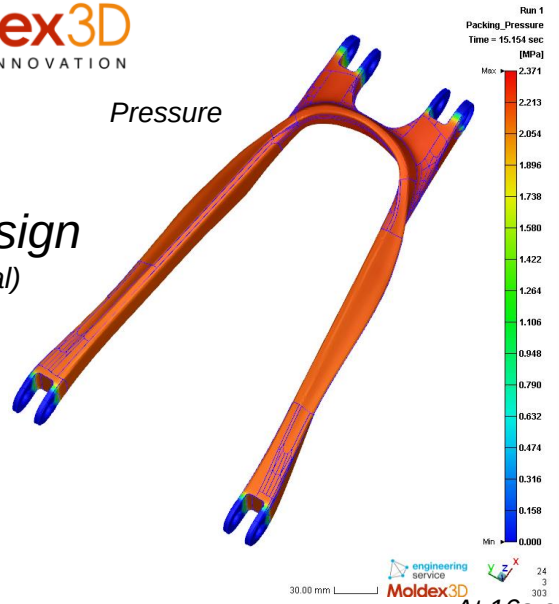
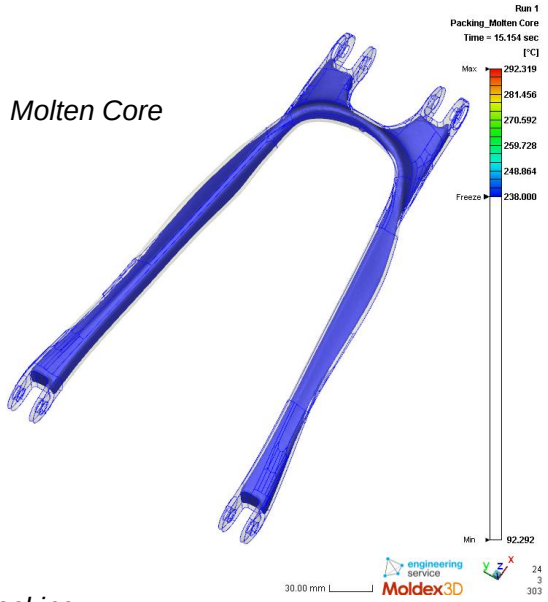
First Design
(Proposal)

Pressure

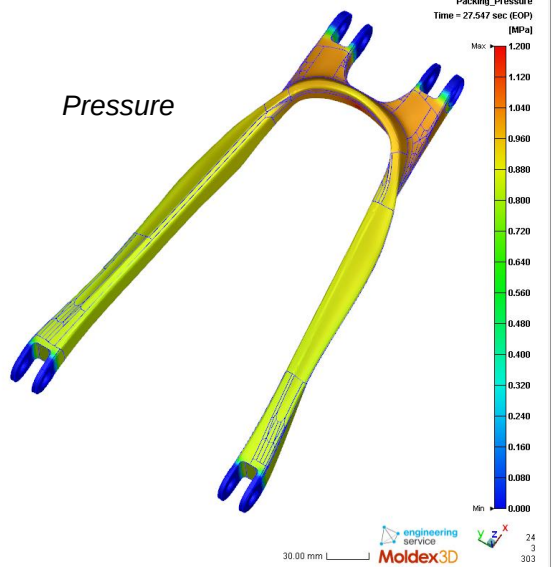


Molten Core

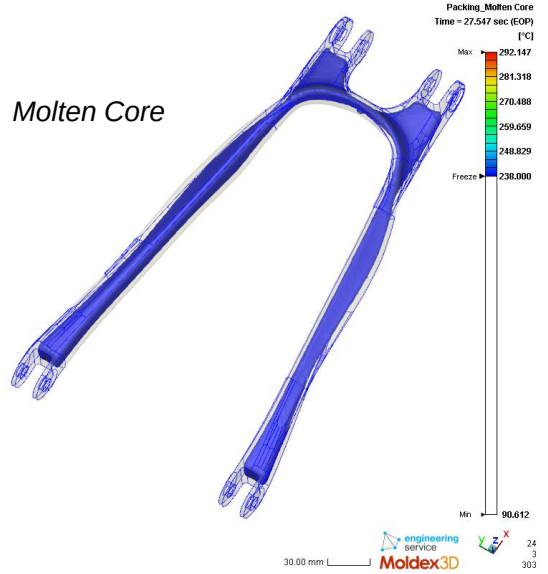


At 16s of Packing

Pressure



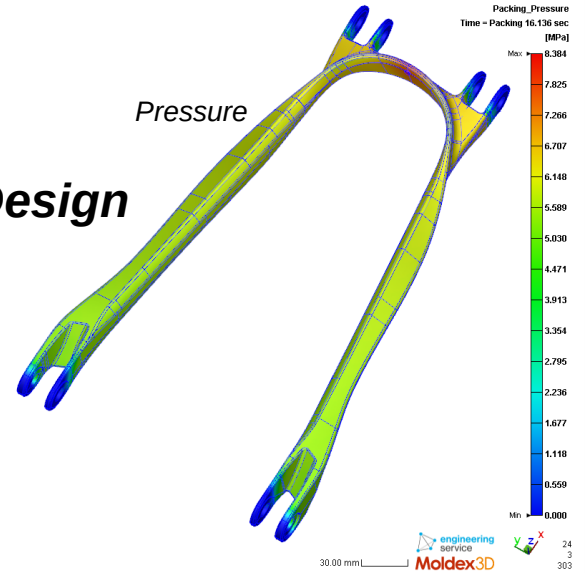
Molten Core



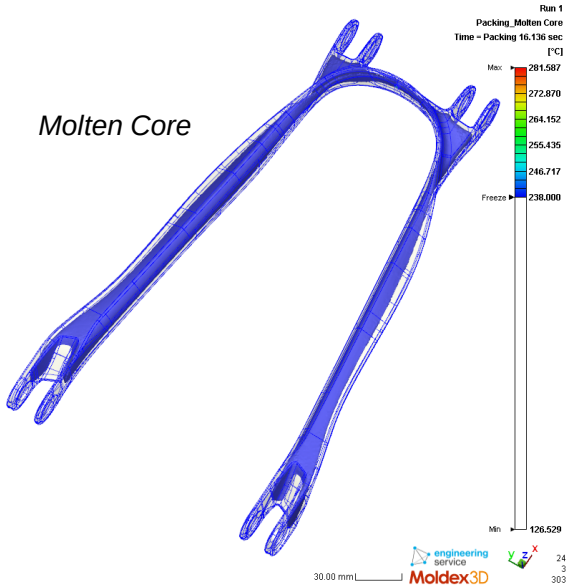
End Of Packing

Final Design

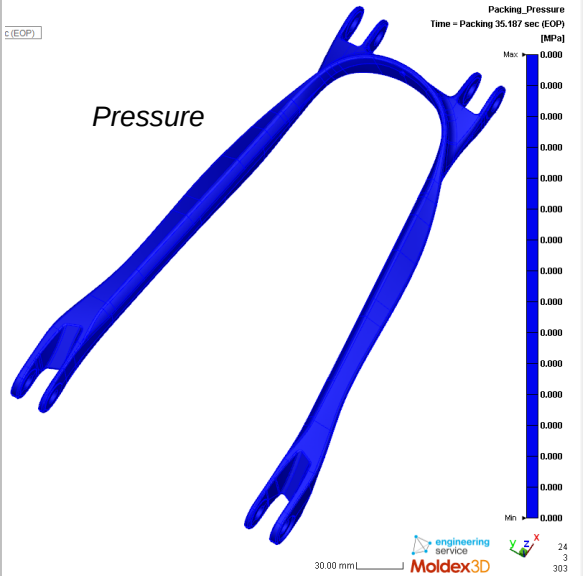
Pressure



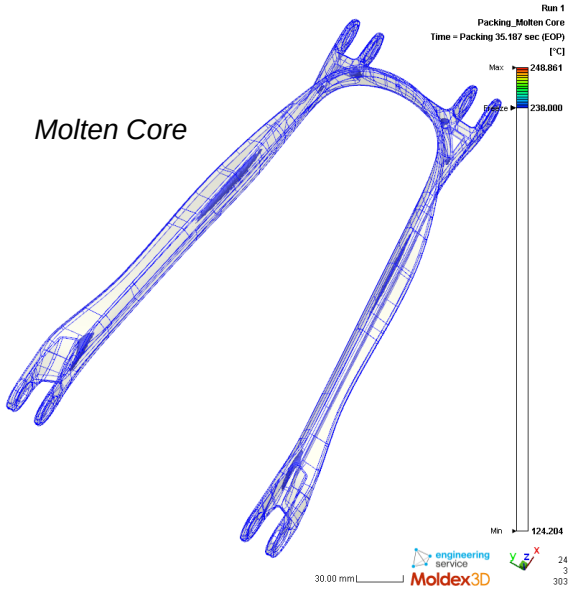
Molten Core



Pressure



Molten Core



Process Simulation – Cooling Phase

Moldex3D
MOLDING INNOVATION

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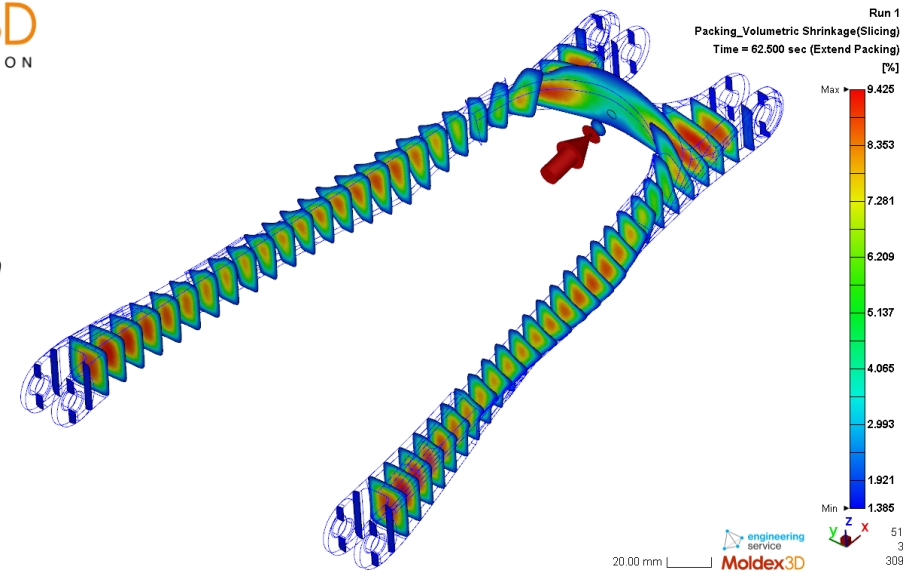
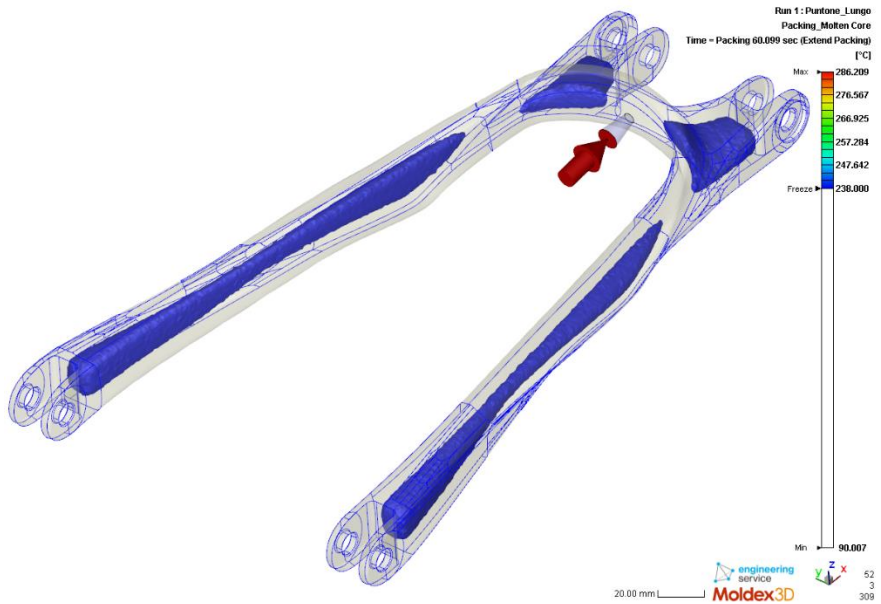
First Design
(Proposal)

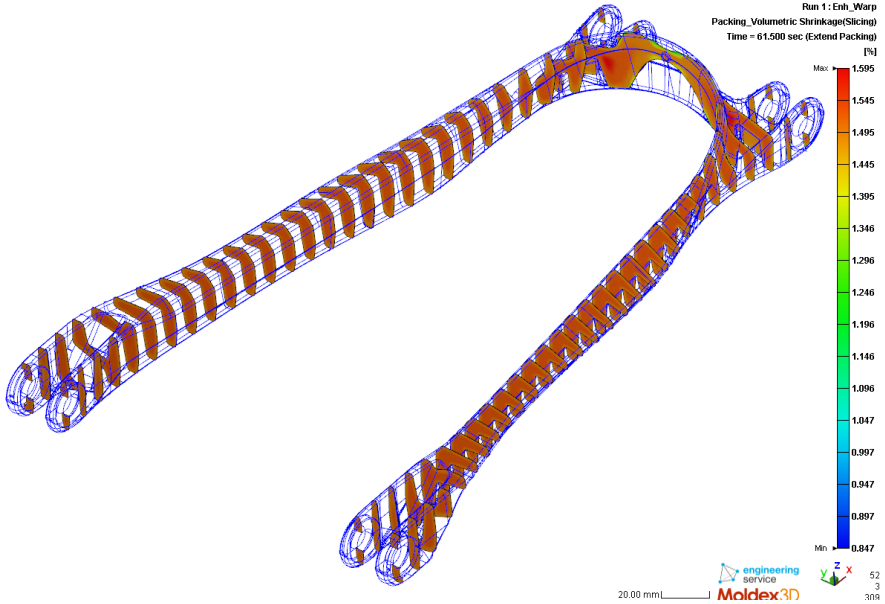


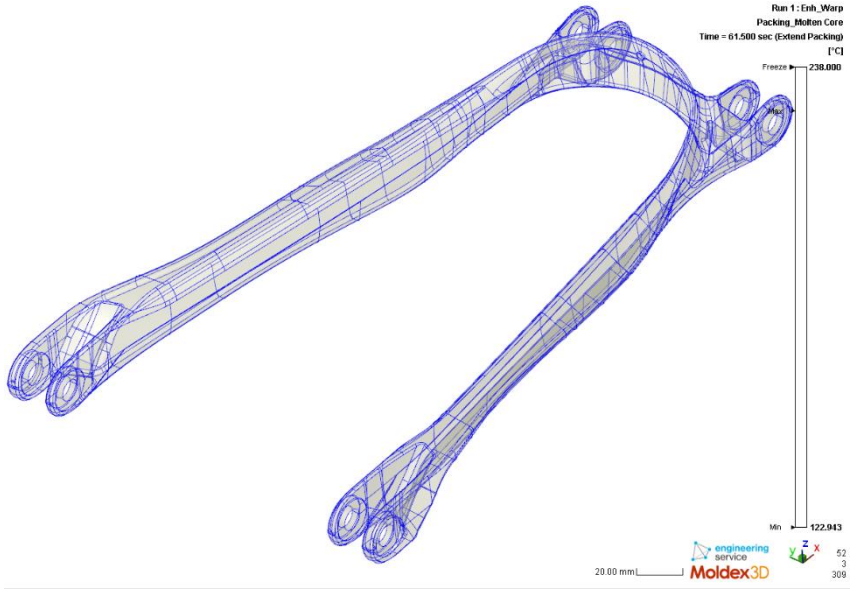
Volumetric Shrinkage



Molten Core after Cooling

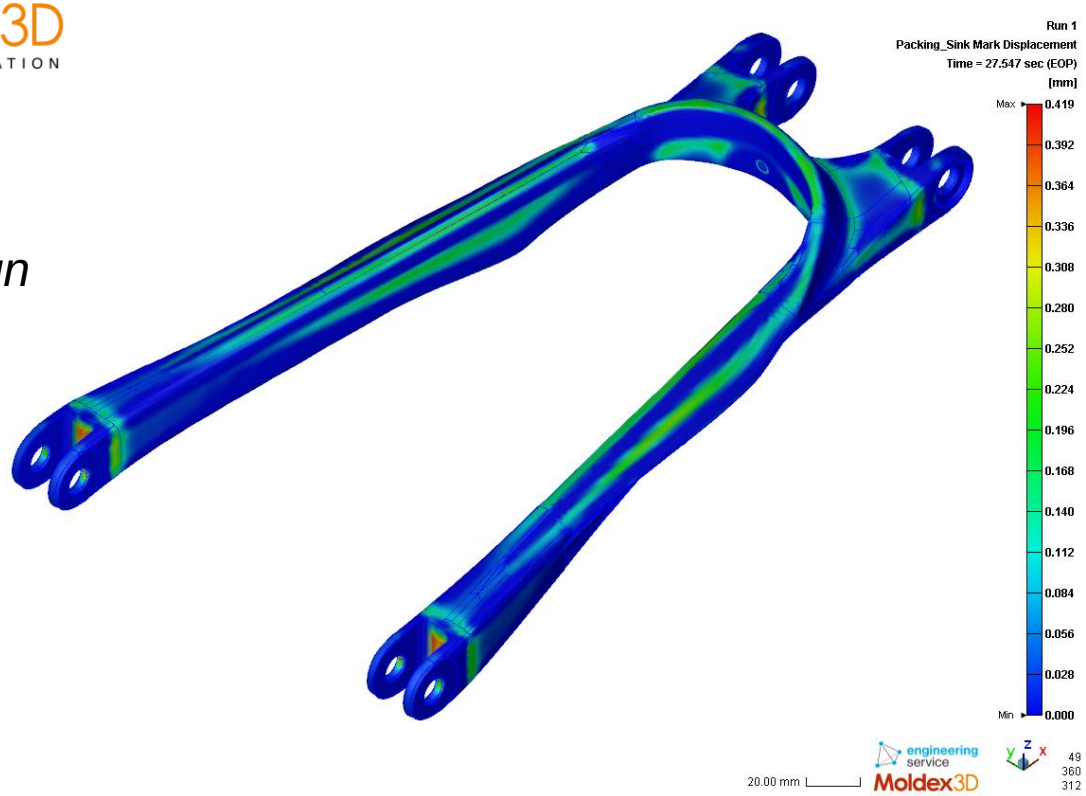
Final Design



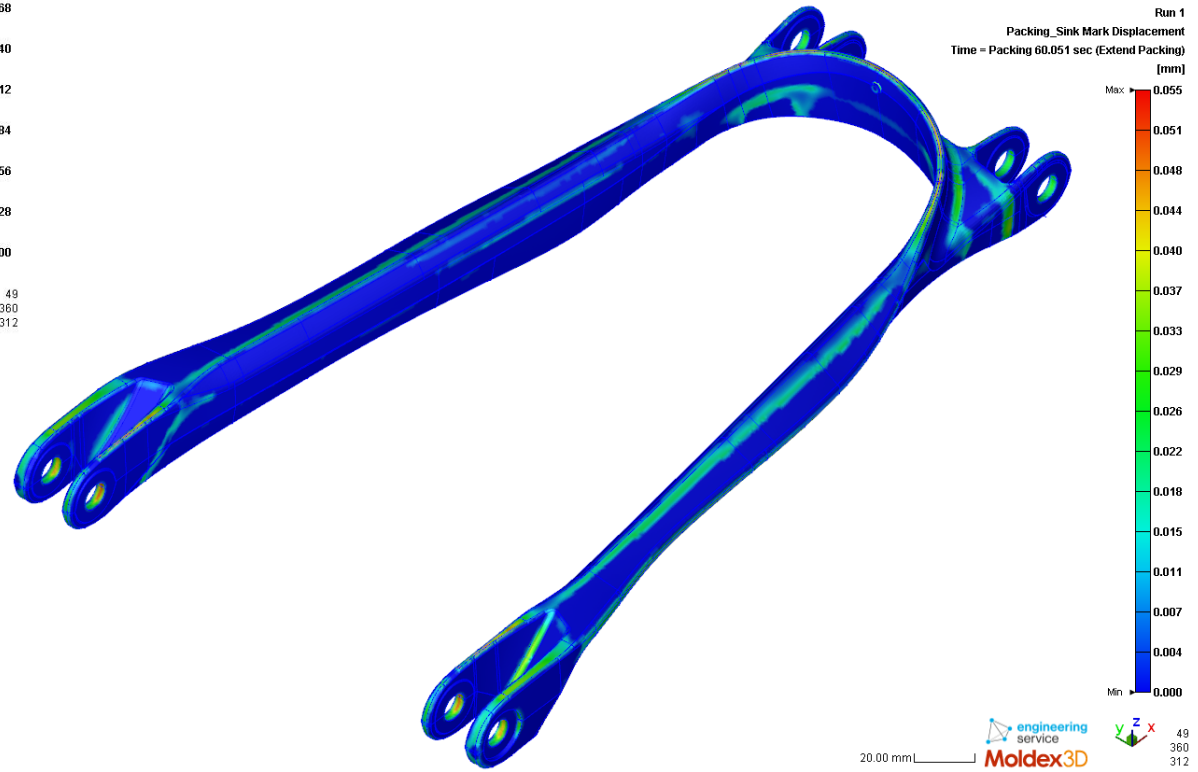


Process Simulation – Sink Mark Displacement

First Design
(Proposal)



Final Design

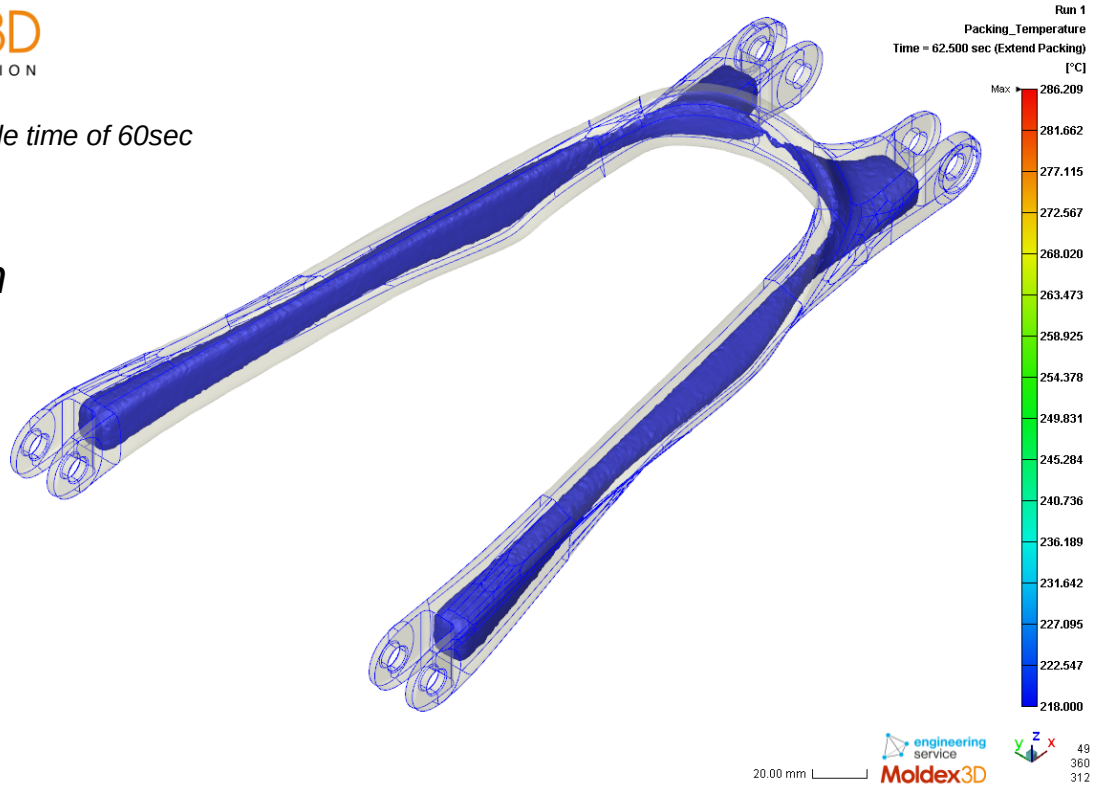


Process Simulation – Temperature at Ejection

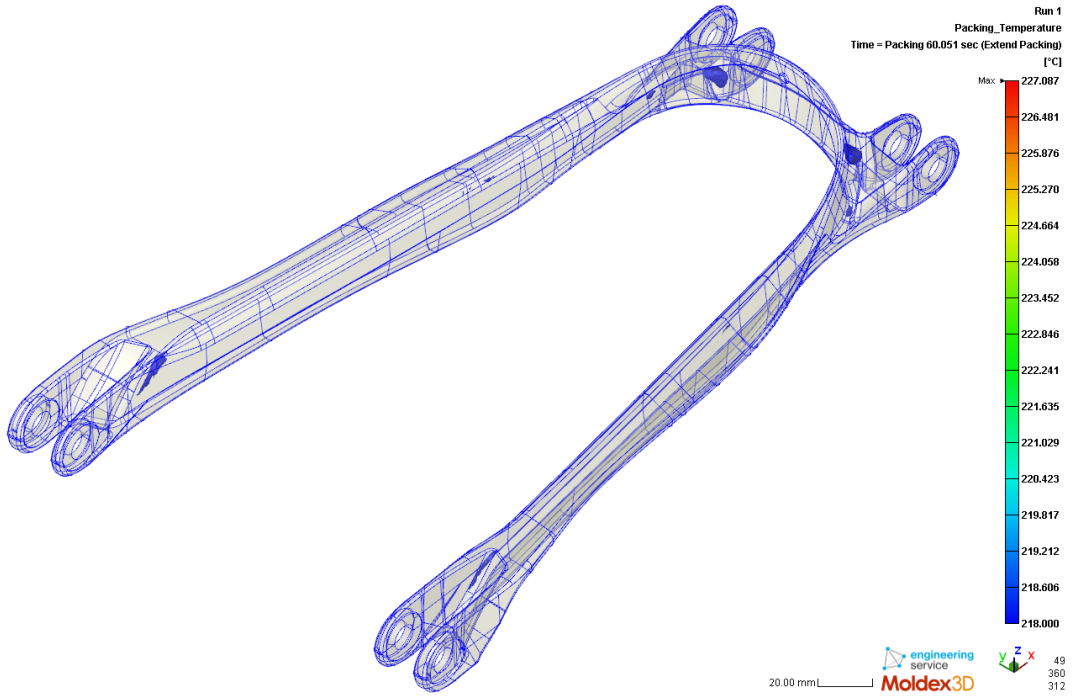
Moldex3D
MOLDING INNOVATION

Considering a cycle time of 60sec

First Design
(Proposal)



Final Design



Process Simulation – Warpage

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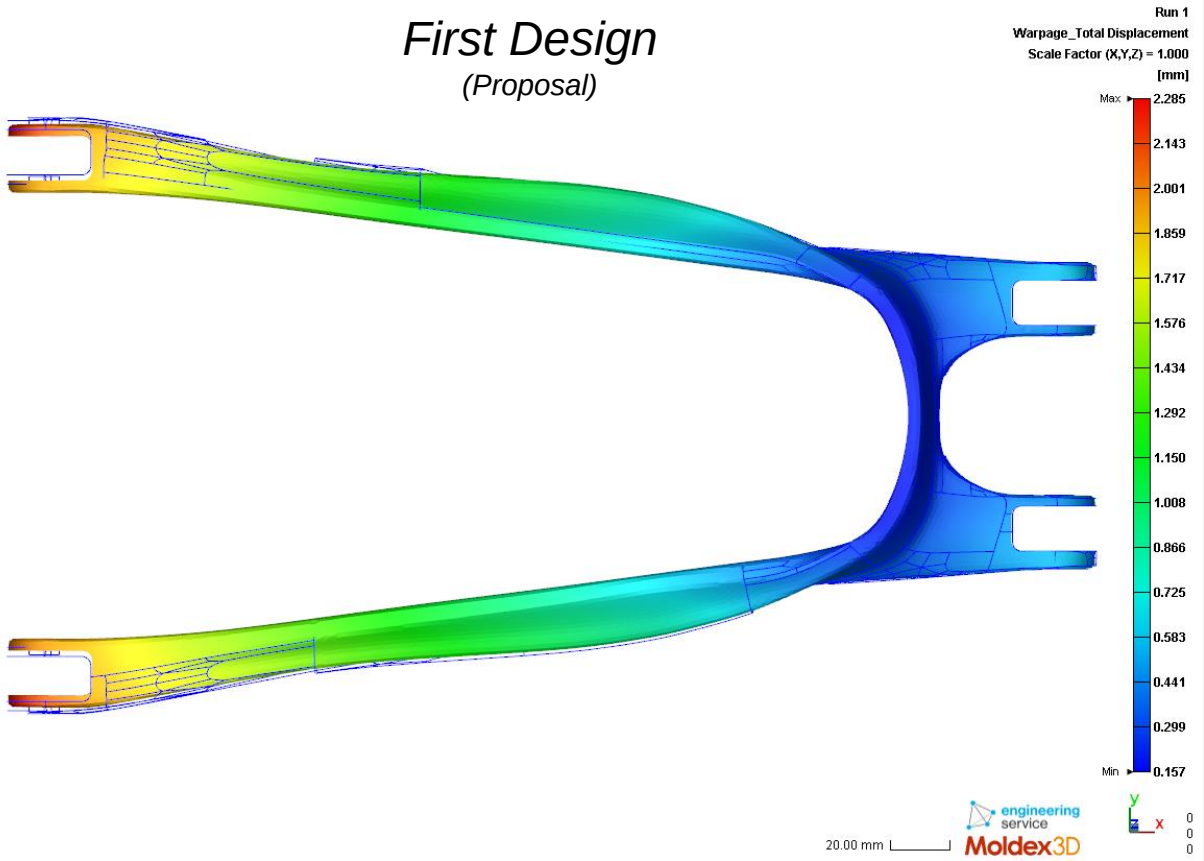
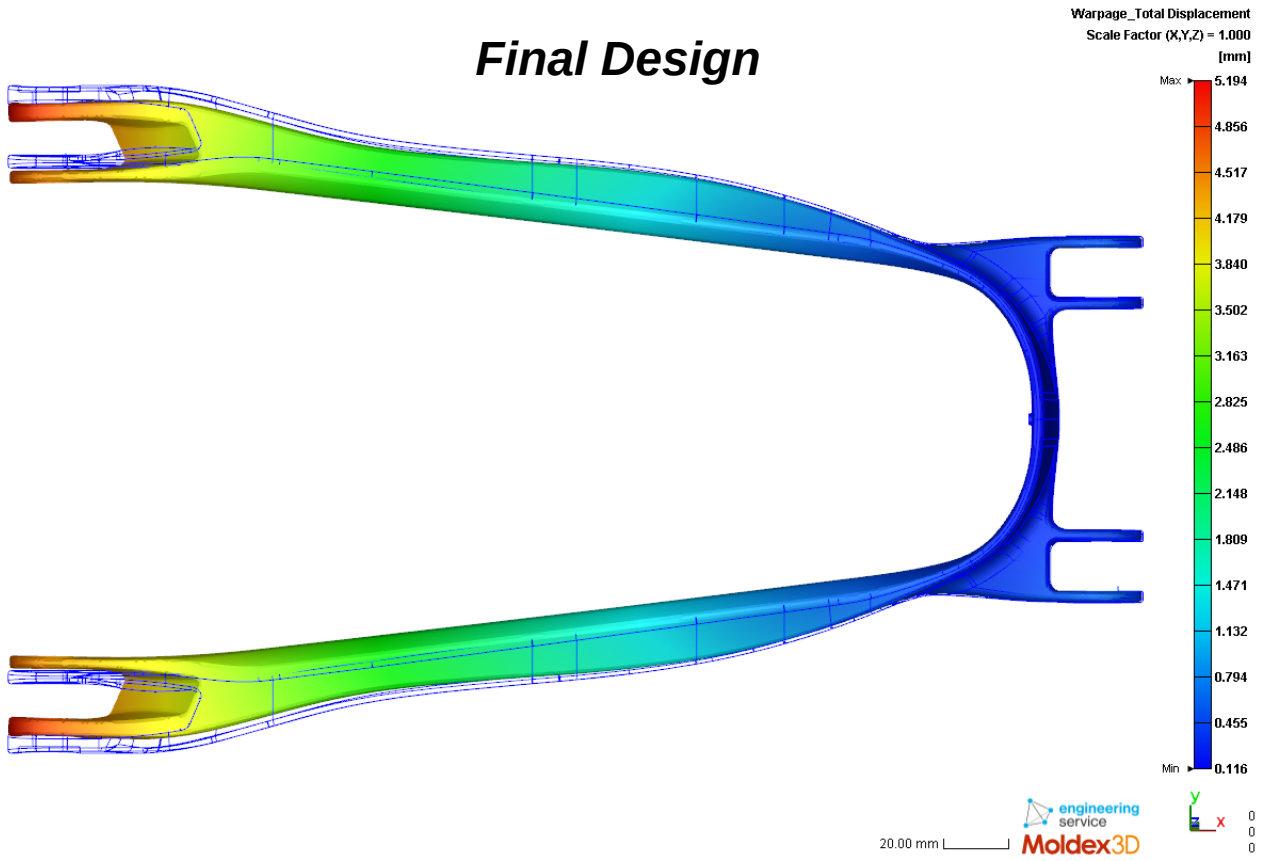
First Design
(Proposal)

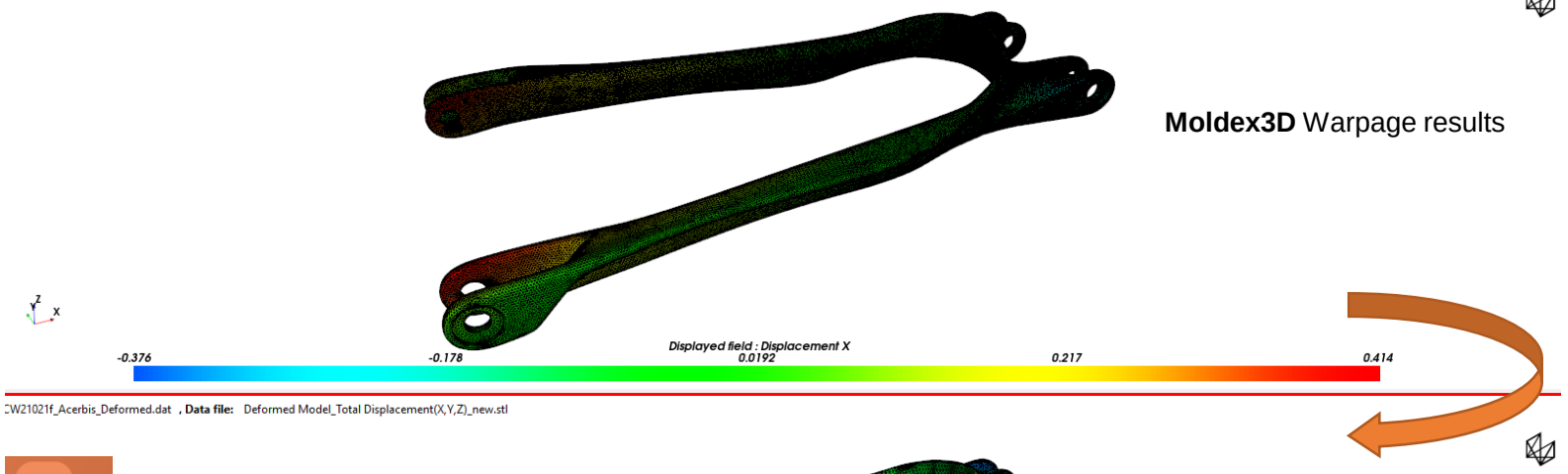


Final Design



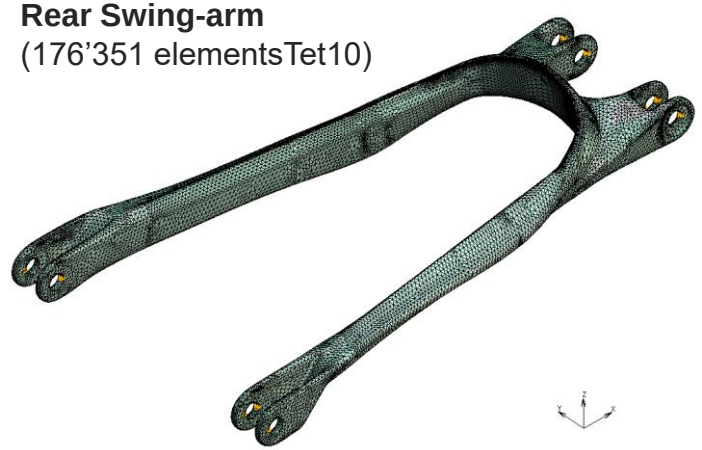
Mapping of Warpage from Moldex3D

Moldex3D
MOLDING INNOVATION



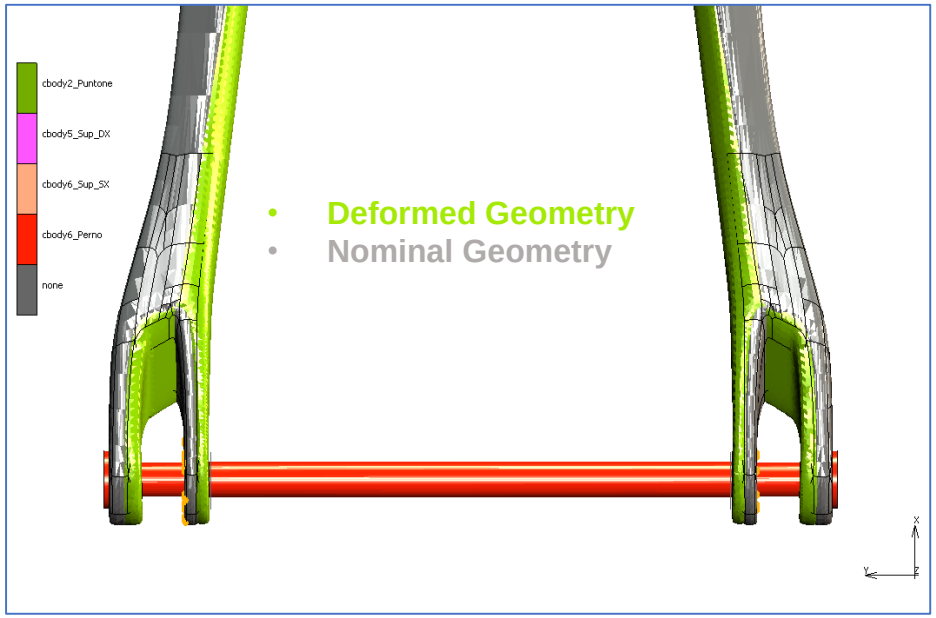
Moldex3D Warpage results

Rear Swing-arm
(176’351 elementsTet10)



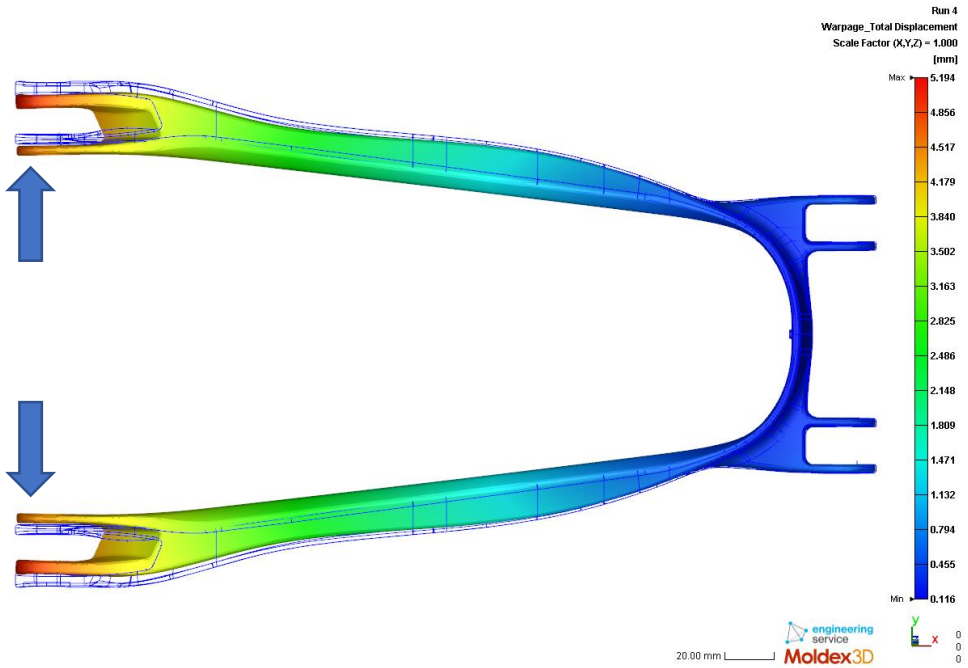
Digimat

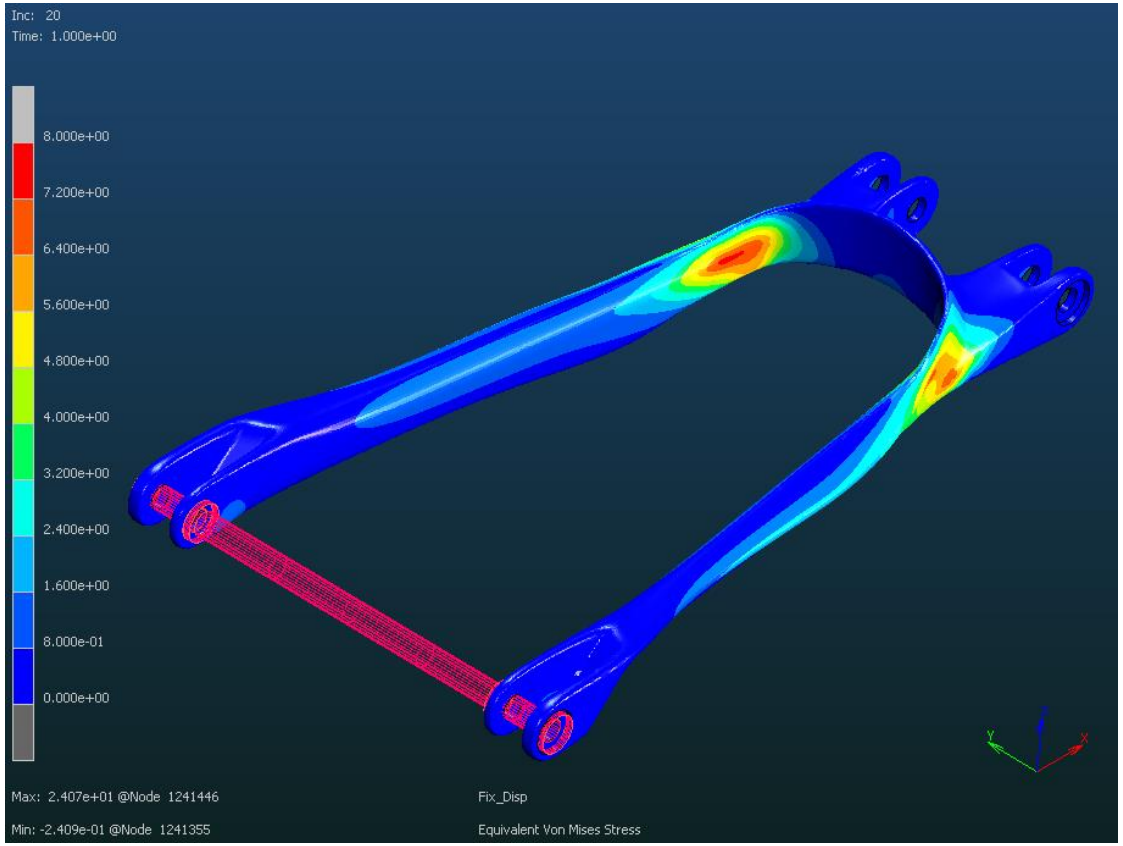
Deformed (stress-free) Structural Mesh



Considering the geometry with the post-moulding deformations, the simulation is more accurate and adherent to reality and to quantify, in the first phase, the force required to allow correct assembly of the component with the other parts of the system.

Structural Simulation: Spreading for assembly



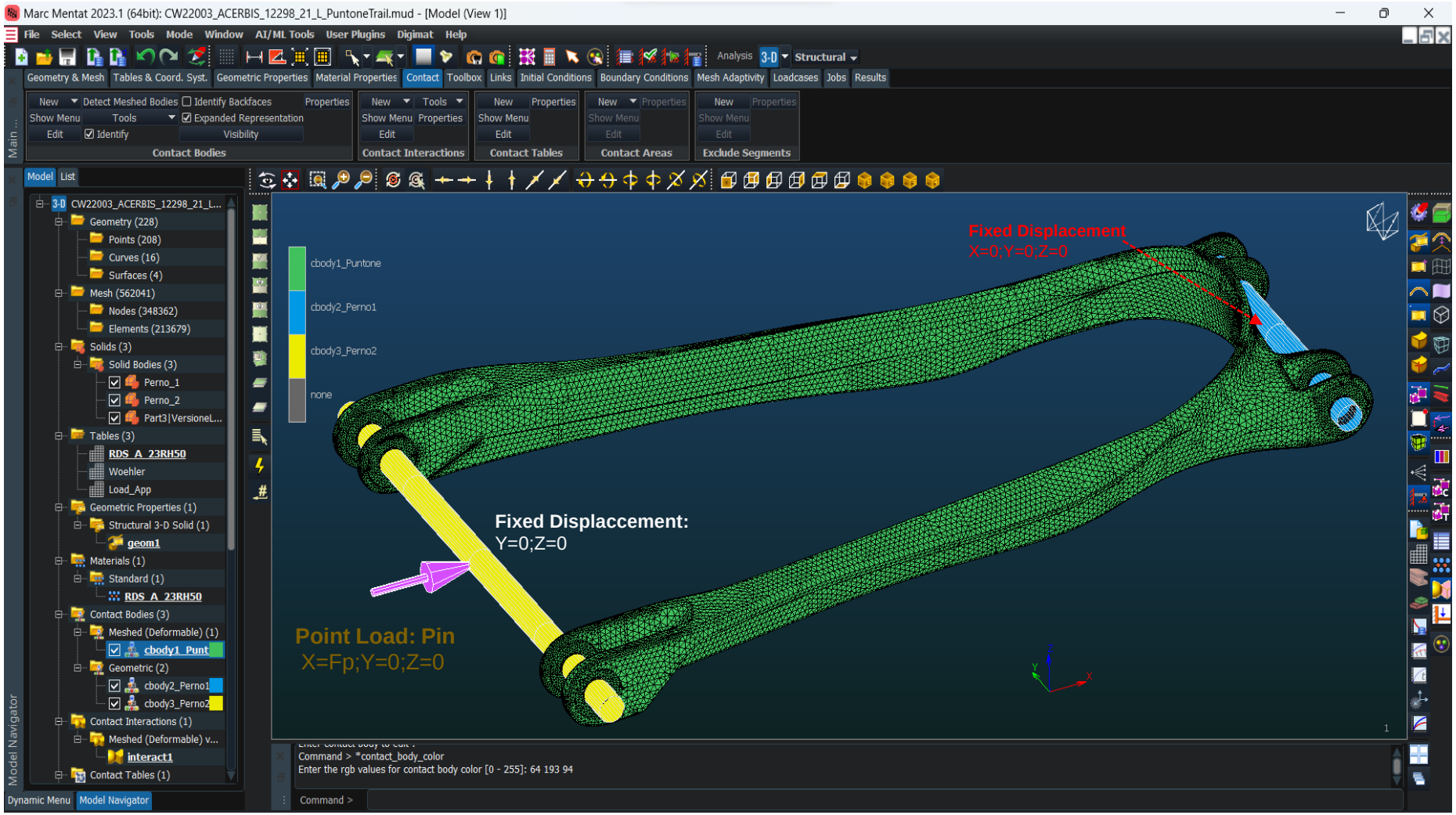


Max. expected value of Eq. Von Mises Stress: 8 MPa

No breakage foreseen

Structural Simulation: Model Set-up

MSC Apex | Marc



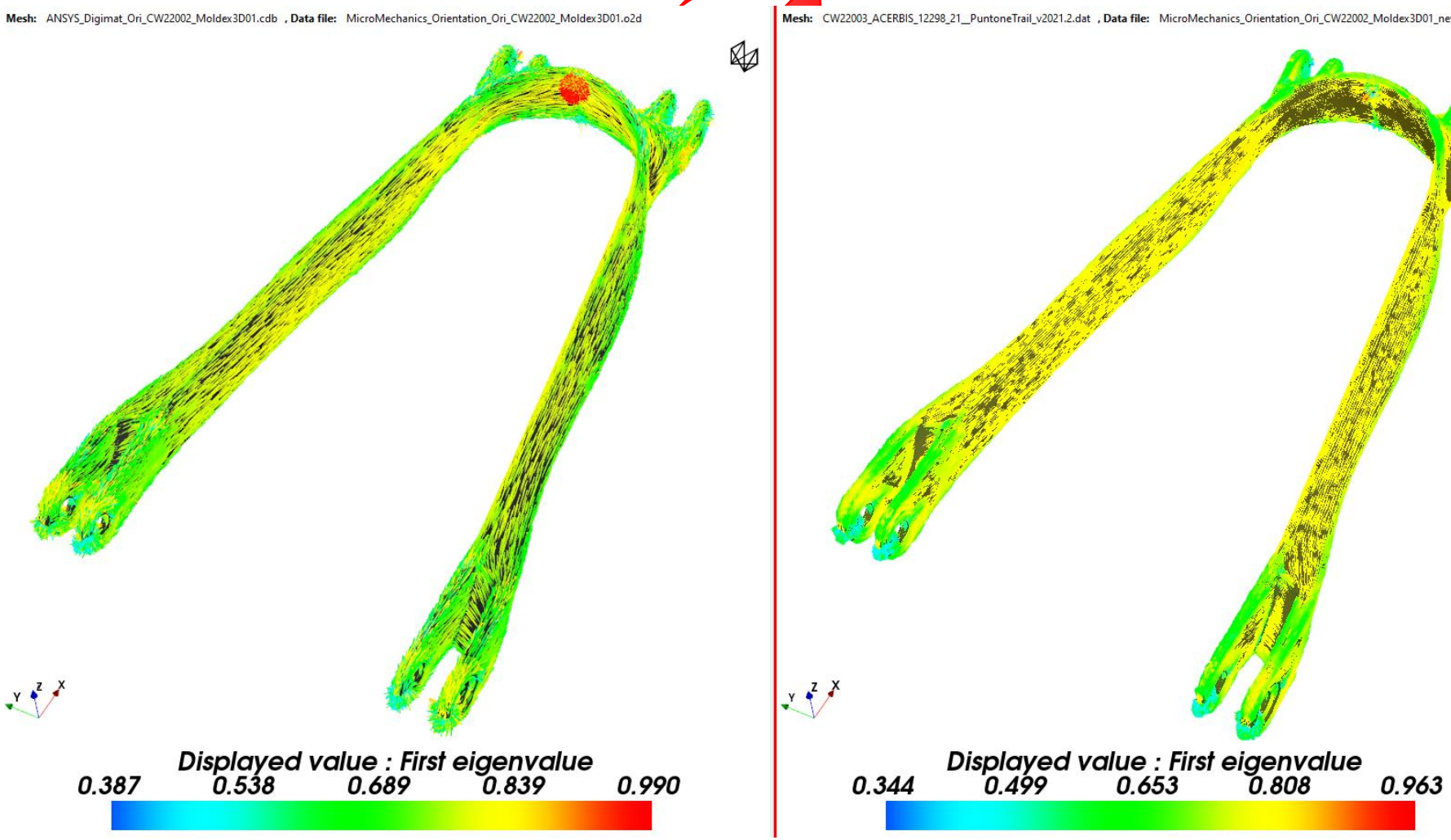
Number of Cycles	Force (N)
50.000	0.4xFp
37.500	0.7xFp
12.500	0.8xFp
1.250	Fp

Mapping of Fiber Orientation from Moldex3D

Moldex3D
MOLDING INNOVATION

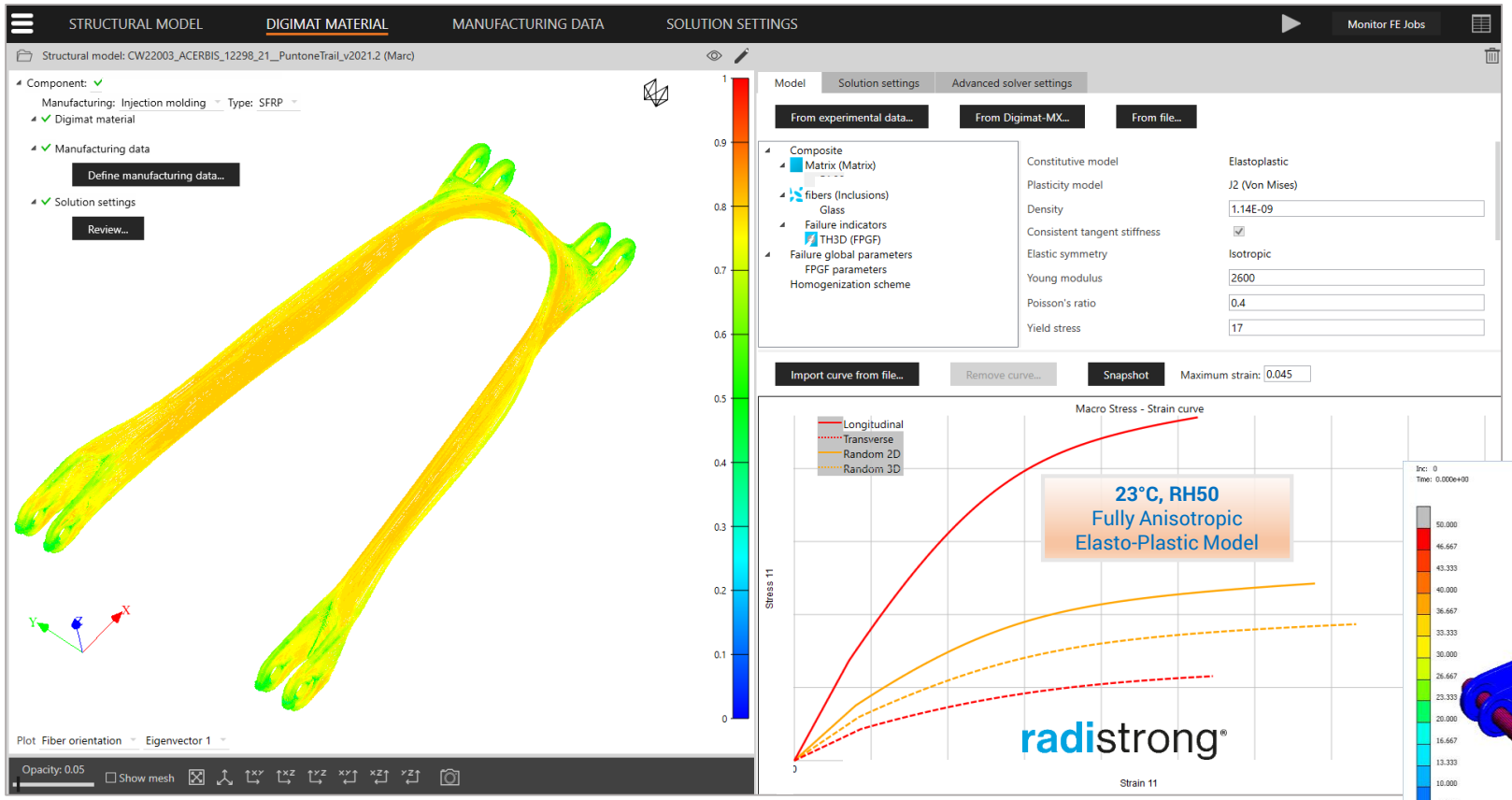
The microstructural properties obtained from the process simulation (Moldex3D) have been mapped onto the structural mesh using the Hexagon-Digimat software.

Digimat

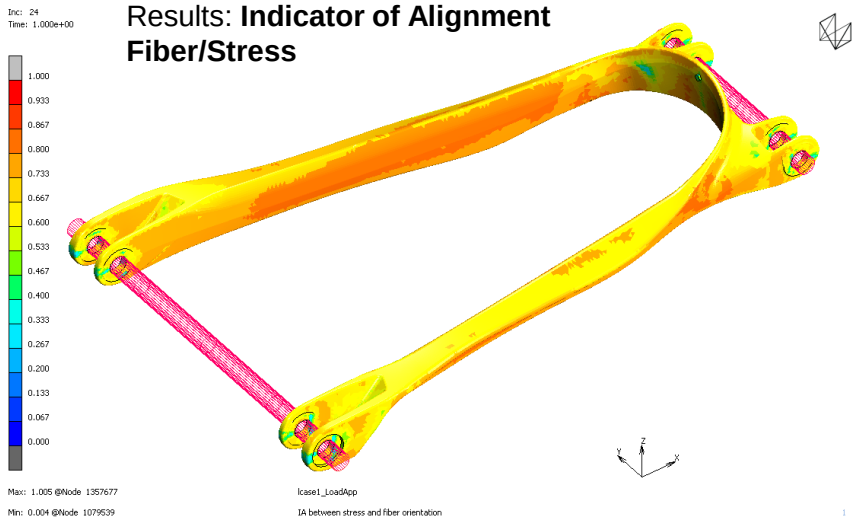


Advanced Quasi-Static Simulation – Digimat RP

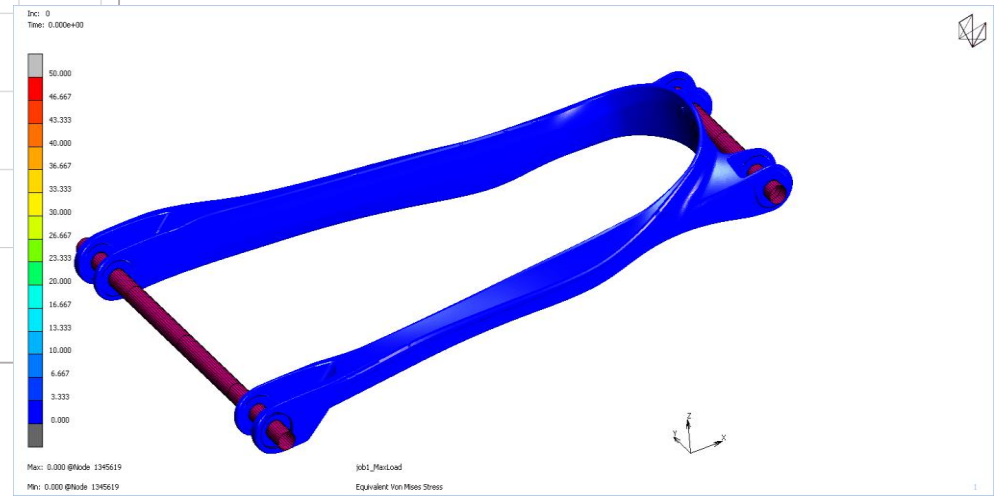
Advanced quasi-static simulation is performed to foreseen stress levels at maximum application load, evaluating, if present, potential failures or criticalities



Results: **Indicator of Alignment Fiber/Stress**



Results: **Eq. Von Mises Stress**

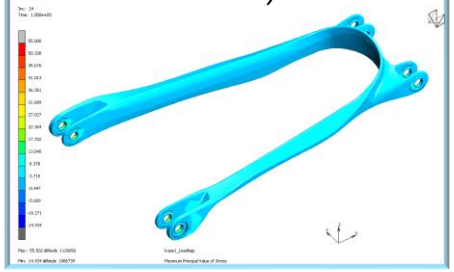


Scale Visualization factor:5x

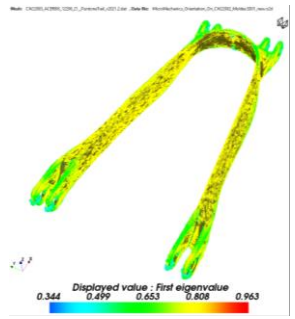
Advanced Fatigue Simulation – CAEfatigue

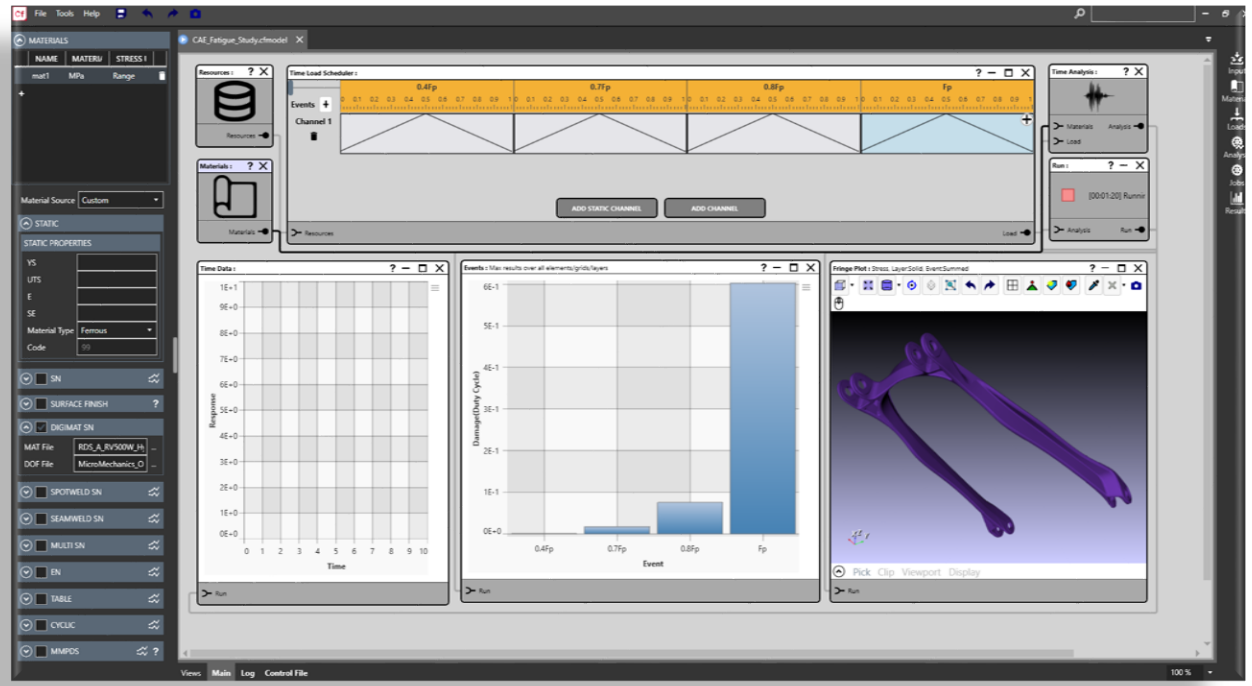
CAEfatigue

INPUT: Advanced (QS) Structural Simulation Marc-Digimat results (H5 or OP2 format)



INPUT: Fiber Orientation





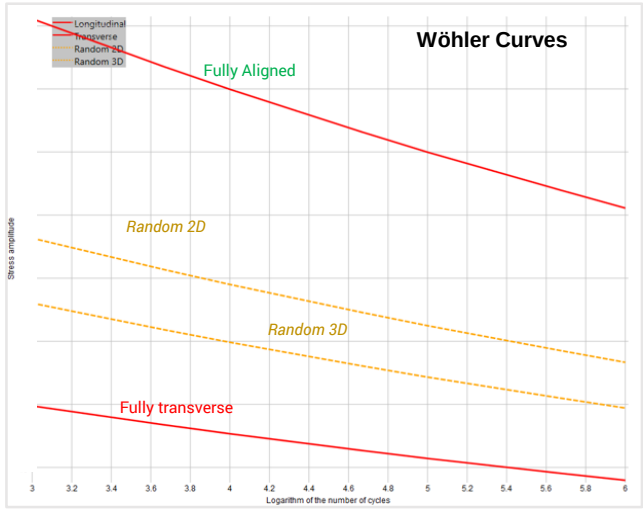
INPUT: Events

Number of Cycles	Force (N)
50.000	0.4xFp
37.500	0.7xFp
12.500	0.8xFp
1.250	Fp

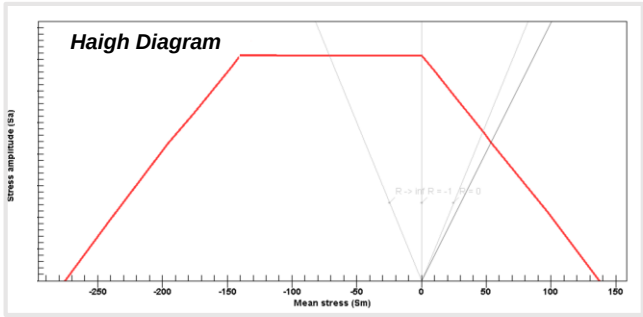
Miner's rule operates on the hypothesis that the portion of useful fatigue life used up by a number of repeated stress cycles at a particular stress is proportional to the total number of cycles in the fatigue life, if that were the only stress level applied to the part.

INPUT: Advanced fatigue Material Model

radistrong®



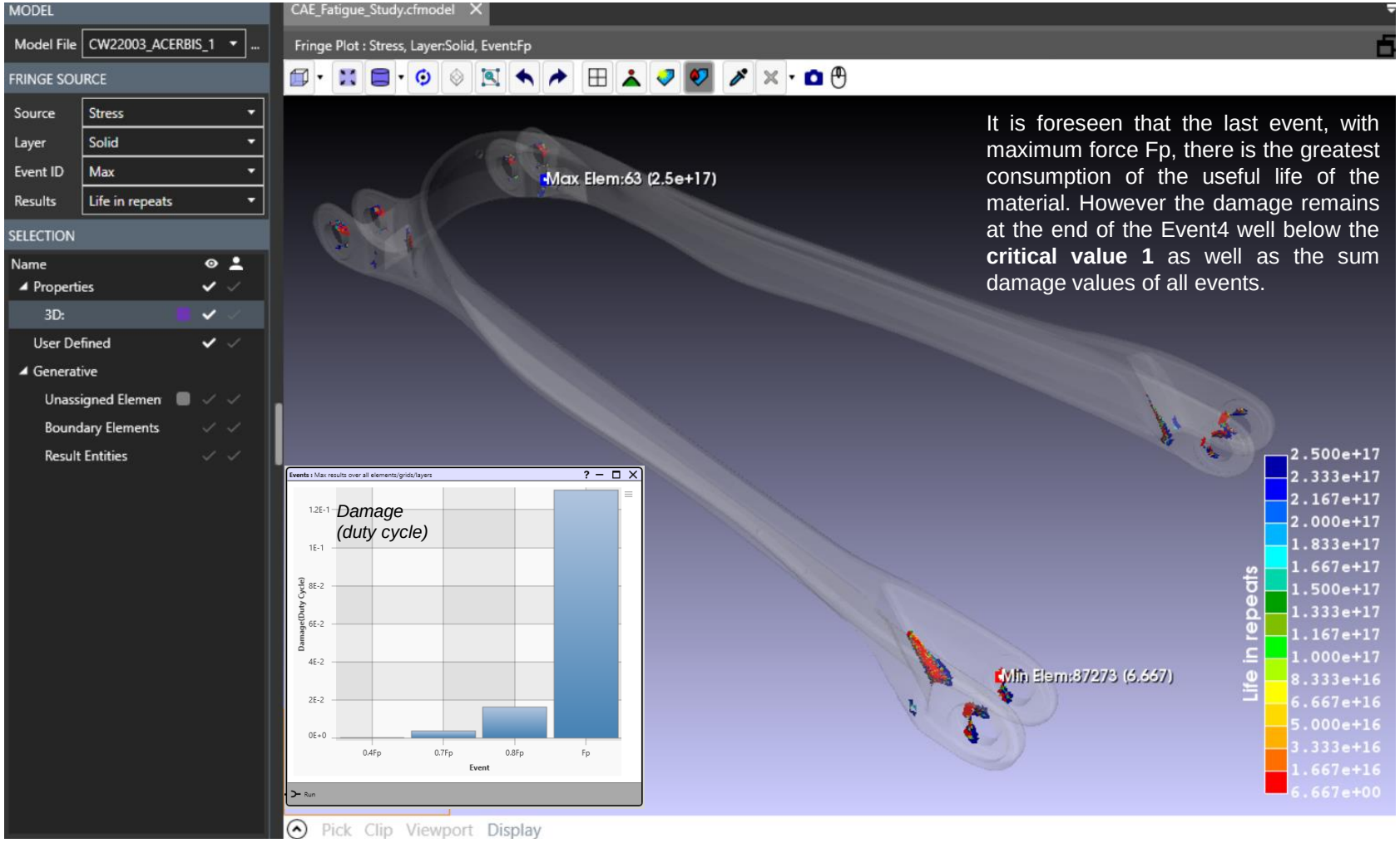
23°C, RH50
Fully Anisotropic Elastic Model



High-Cycle Fatigue Failure Indicator
(Considering mean stress effect, tension/compression differentiation, spatially variable R)

Results: CAEfatigue – Life in repeats

CAEfatigue



The estimated **fatigue life** of the component, through the **advanced structural simulations**, **fully satisfies the fatigue resistance requirements** requested by the customer (Life in repeats>1).

Physical tests were also performed on the first samples campaign verifying their durability and they confirmed the **outstanding mechanical performance of the material**.

Conclusions

Benefits: Thanks to the use of the **materials modelling tools and advanced engineering calculation**, the performance was accurately predicted and the project was brought to success.

- **Weight reduction**: -10% compared to the Al version
- **Mechanical Performances**: Real tests performed on the parts confirmed the outstanding fatigue resistance of the material predicted by the simulation
- Form and **design freedom:** Completely new Design in the sector
- Reduction of **assembly** and post-processing: No welding and painting process
- Environmental **Sustainability**
- **Aesthetics**, **colorability**: Material with high surface aspect, black coloured. Mould Texture applied for aggressive look of the parts
- Total **cost** of part
  - ✓ Part count, Number of operations
  - ✓ Cost of Injection Moulding technology
  - ✓ High productivity

Acknowledgements

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Special thanks for the valuable support and effective collaboration to:

- **FANTIC SpA** and **ACERBIS SpA** for the trust and collaboration in the Metal Replacement project and for the willingness to share its images and history.
- **Hexagon** and **Moldex3D** for active support in CAE procedures definition and problem solving
- **Carlo Grassini** and **Riccardo Galeazzi** for operational support, material modelling and CAE simulation execution

Thank you

RADICI GROUP
HIGH PERFORMANCE POLYMERS

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