VOLKSWAGEN

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PROCESS SIMULATION IN THE AUTOMOTIVE INDUSTRY

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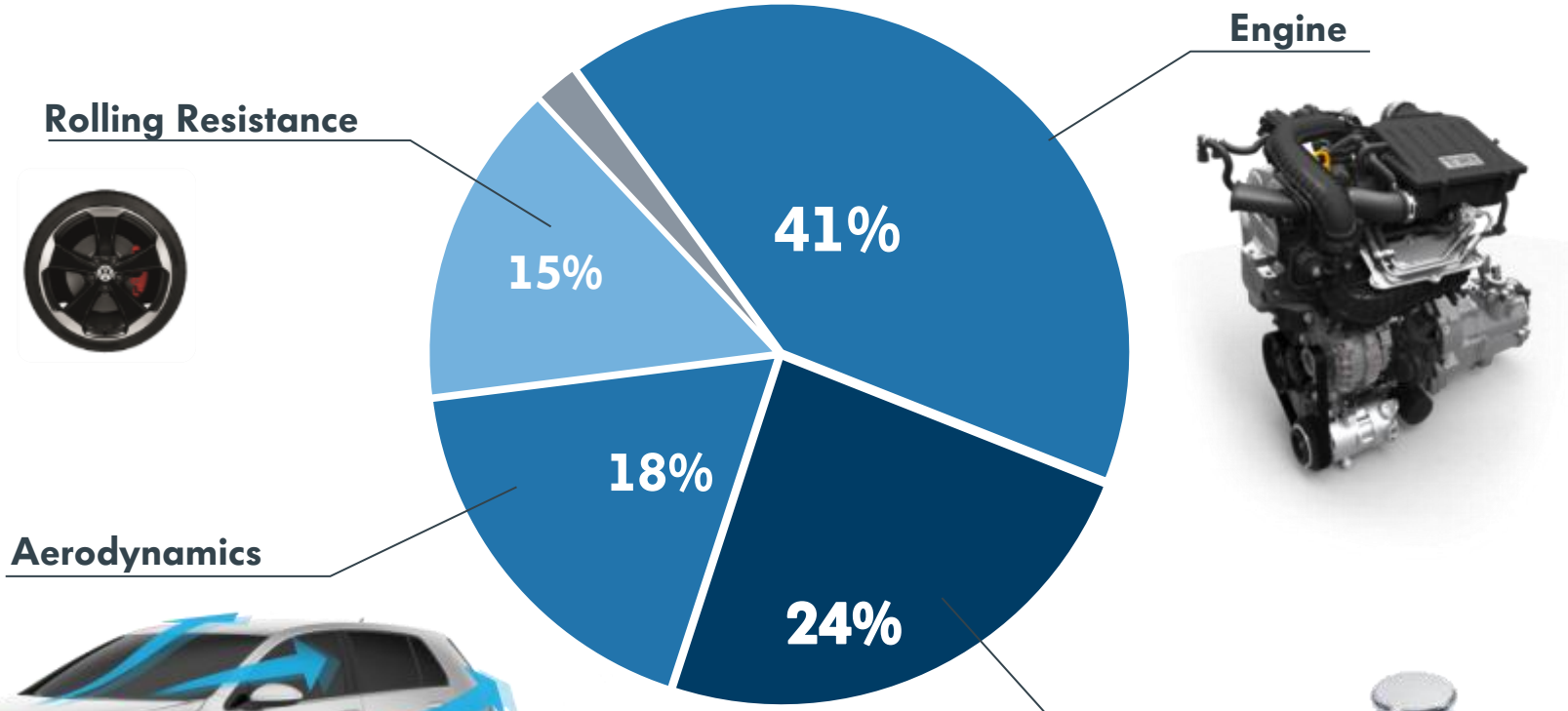
4A ENGINEERING DAY | SCHLADMING

AGENDA

- INTRODUCTION & MOTIVATION
- LIGHTWEIGHT MATERIALS AND PROCESS SIMULATION TOOLS
  - LONG FIBER REINFORCED PLASTICS
  - FOAM STRUCTURES
  - INTEGRATIVE SIMULATION
- CONCLUSION & OUTLOOK

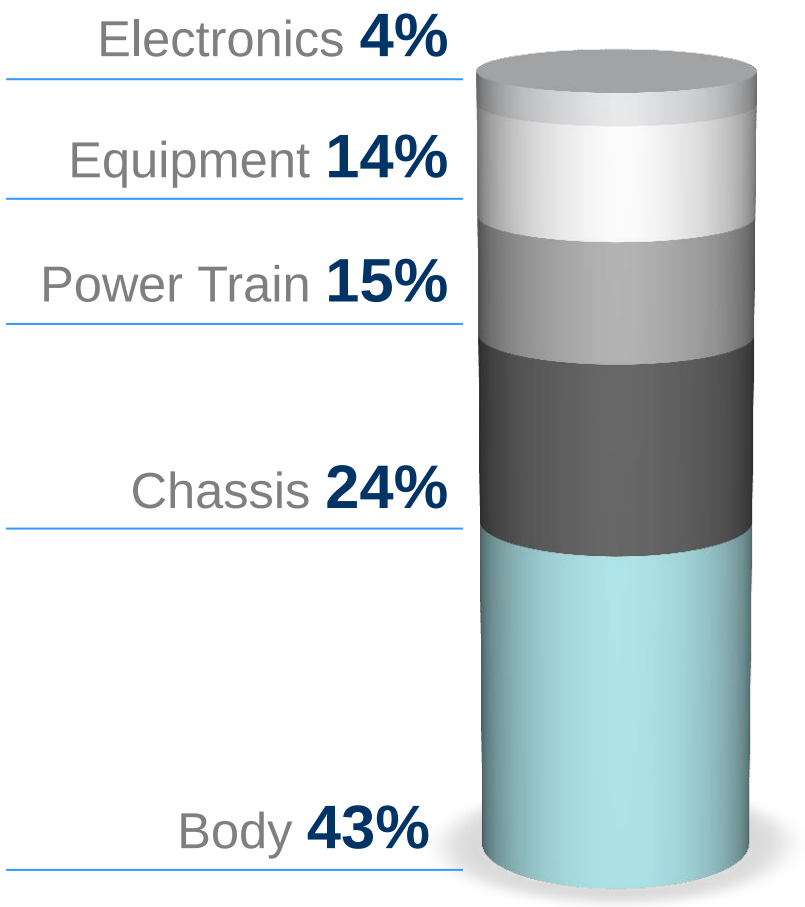
INTRODUCTION

SHARES ON OVERALL CONSUMPTION



DISTRIBUTION OF VEHICLE WEIGHT

COMPACT CLASS



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Conclusion:

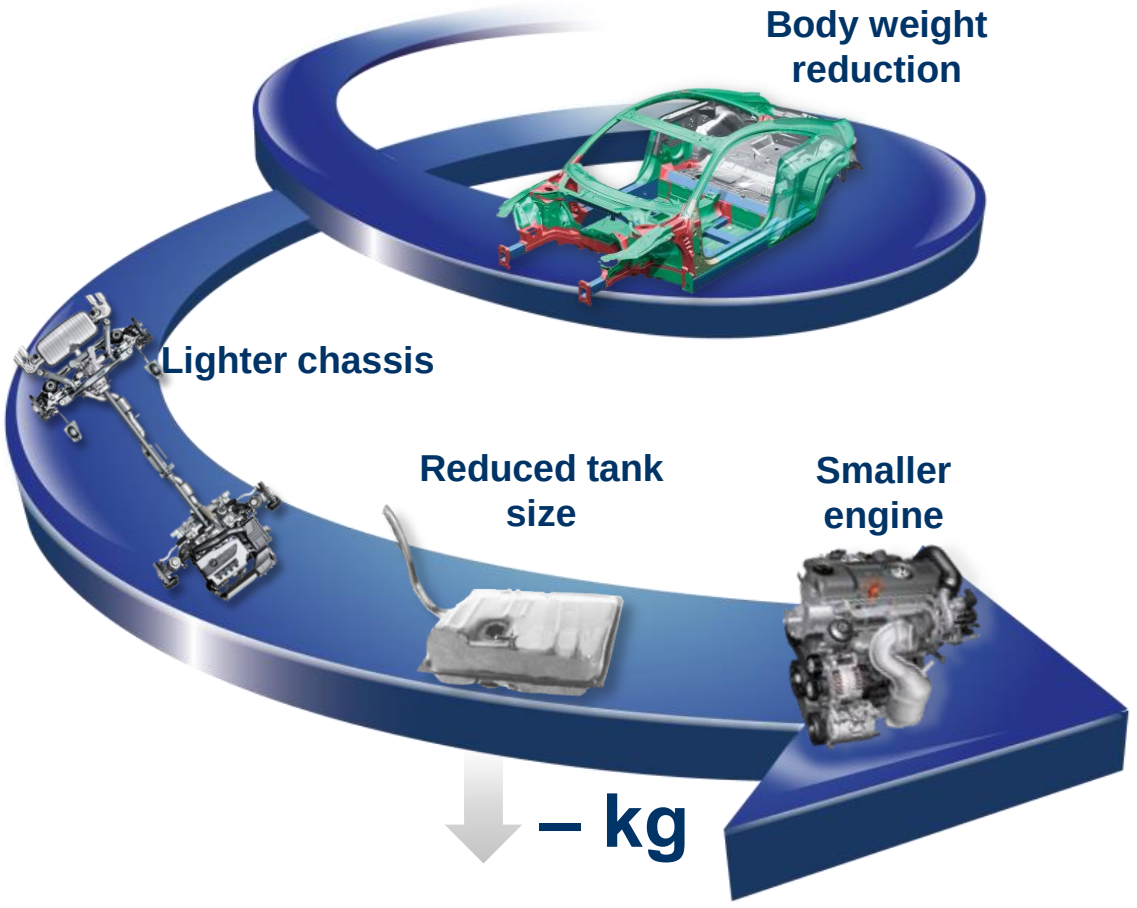
Weight optimization

is necessary!

REVERSED WEIGHT SPIRAL

INFLUENCE OF BODY WEIGHT REDUCTION

- Component and functions integration
- New materials and processes
- Costs and weight optimization



Initial weight reduction in the body lead to secondary effects in the vehicle.

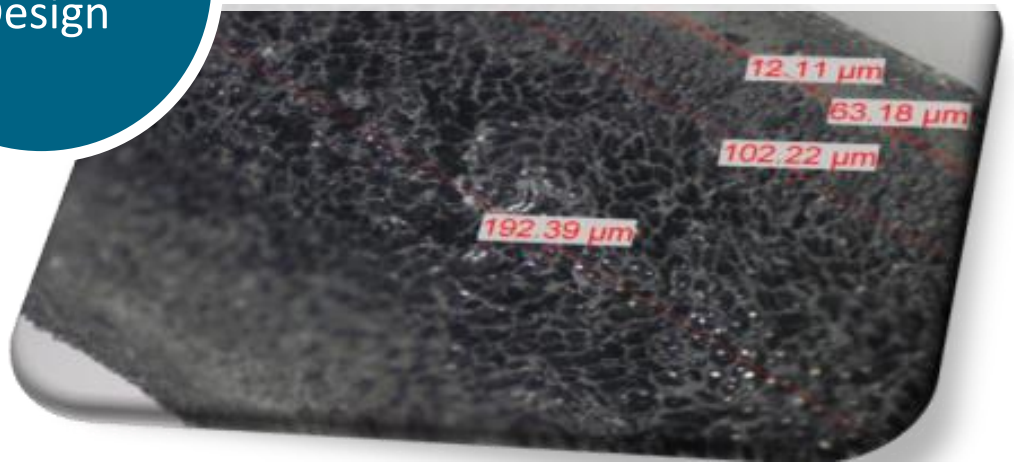
TECHNOLOGIES FOR WEIGHT REDUCTION

FOR THE AUTOMOTIVE INDUSTRY

Long Fiber Reinforced Plastics (LFRP)

Lightweight Design

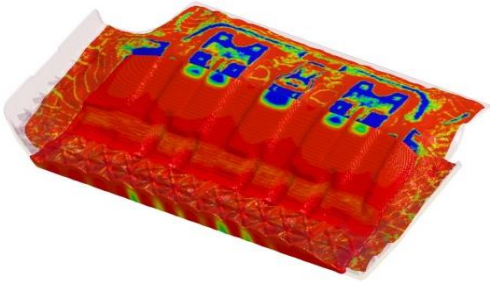
Foam Structures



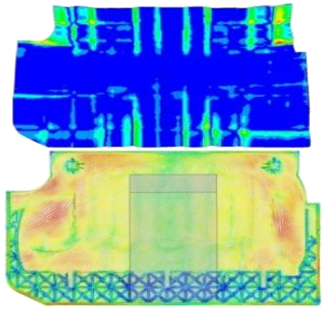
PROCESS SIMULATION

VIRTUAL PROCESS CHAIN

CAD Geometry



Process Simulation



Structural Simulation

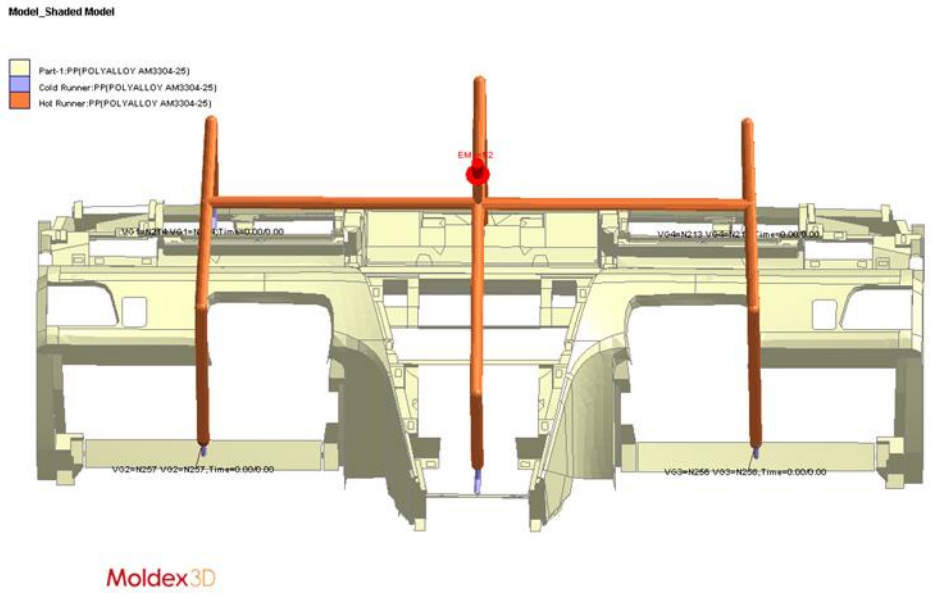
(Crash, Creep, Warpage, etc.)

Complex Material Behavior

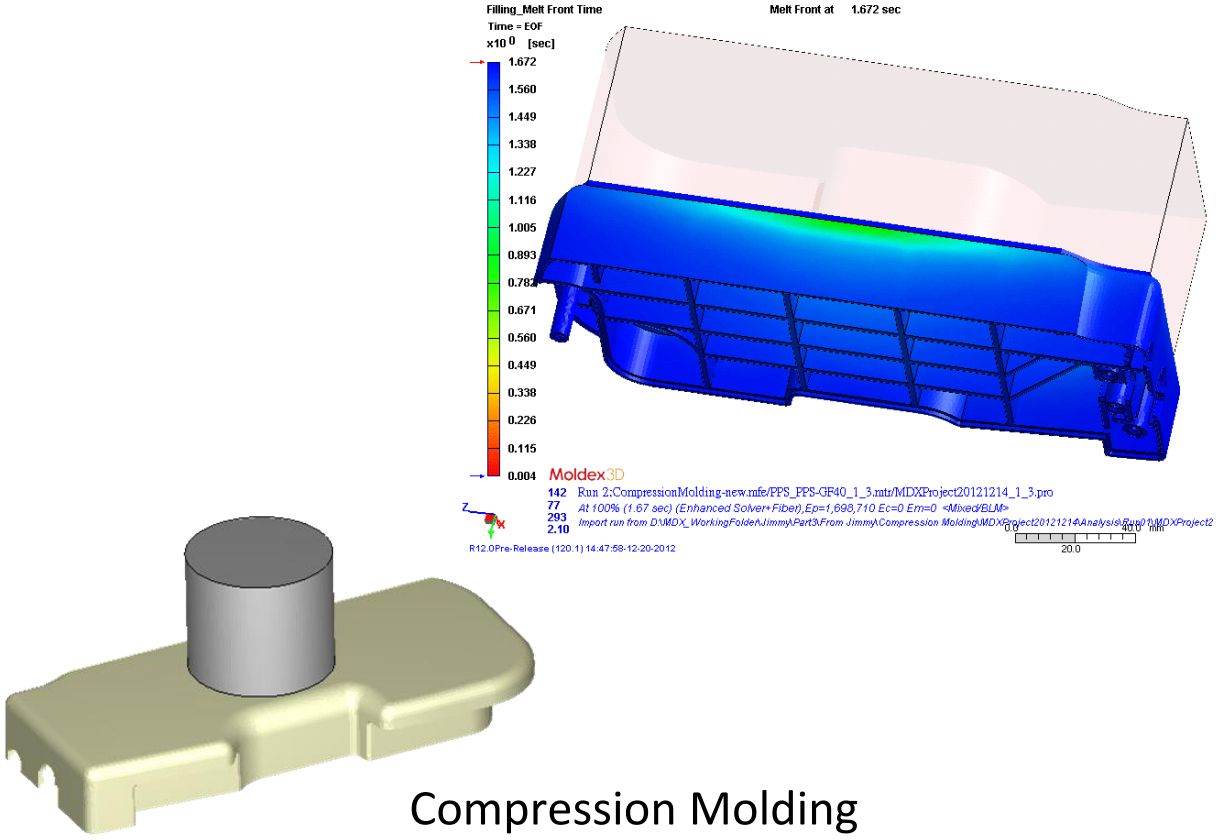
+ Optimized Part Geometry
+ Process and Structural Optimization
+ Shorter Development Cycles

PROCESS SIMULATION

INJECTION AND COMPRESSION MOLDING



Injection Molding

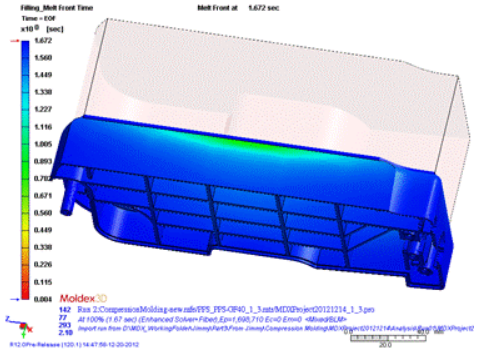


Compression Molding

PROCESS SIMULATION RESULTS

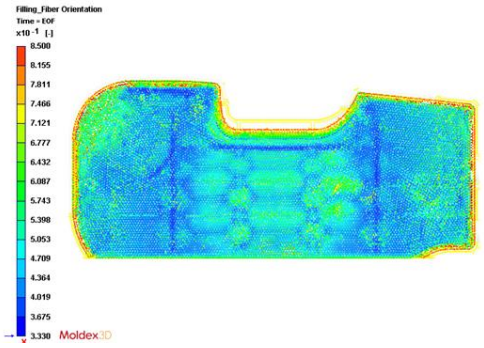
FOR COMPRESSION MOLDING

Filling ✓



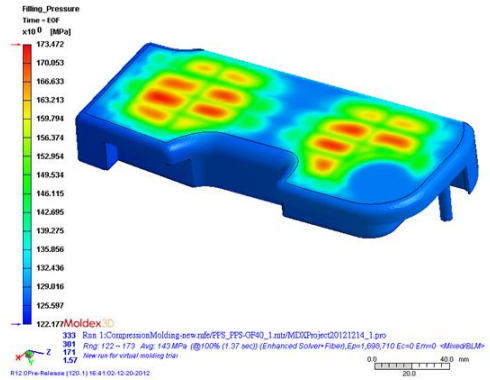
- Mold Filling, Air Traps, Weld Lines
- Temperature Distribution
- Curing (Thermosets)

Fiber Orientation ✓



- Prediction of Fiber Orientation
- Reorientation of Fibers due to Changes in Polymer Flow and Part Geometry

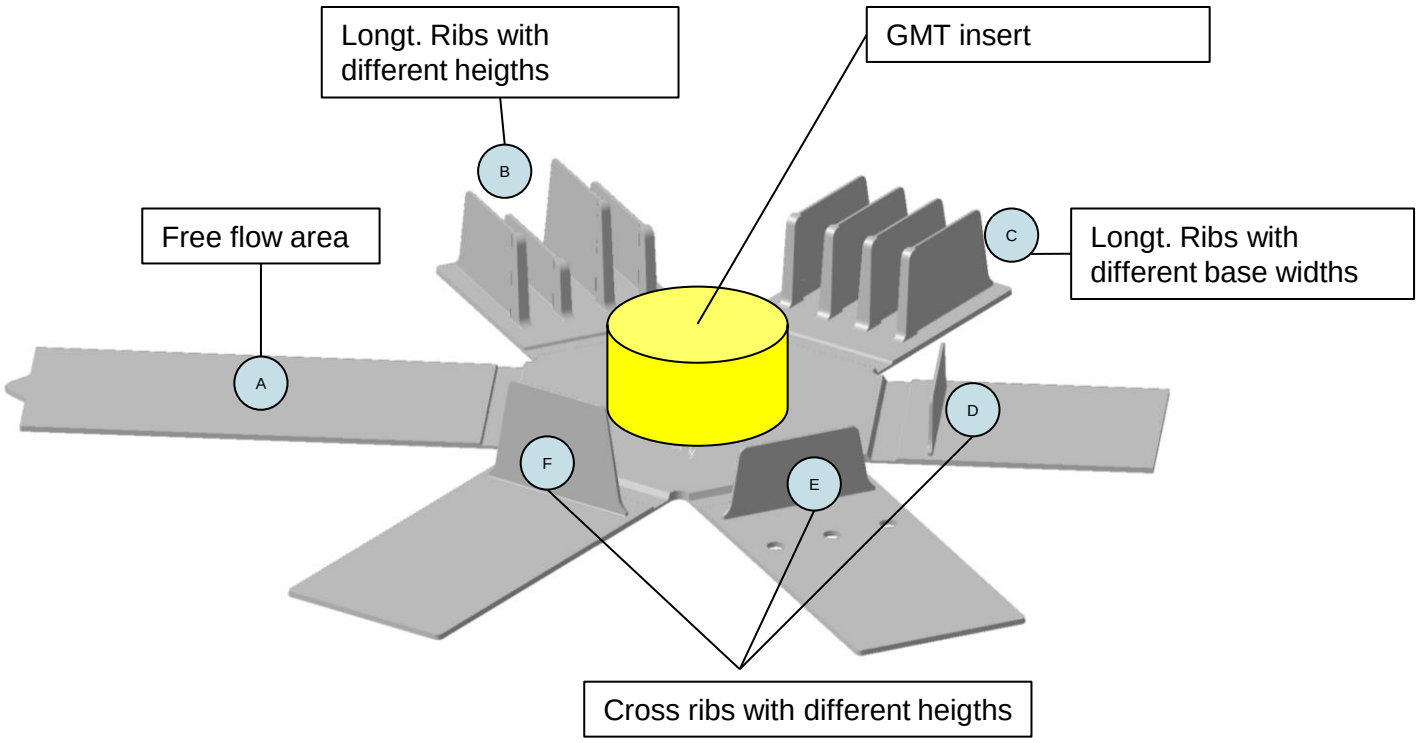
Fiber Length Distribution ✓

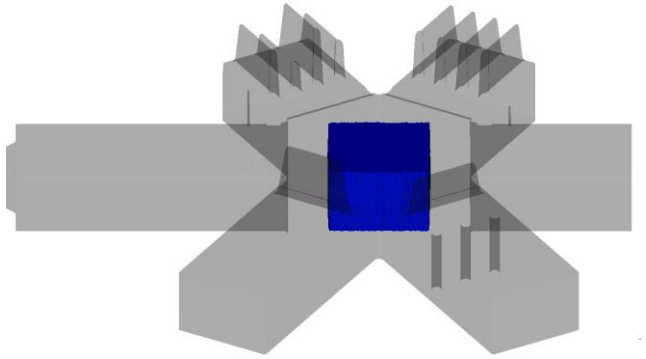


- Prediction of Fiber Length Distribution in various Sections of the Mold
- Breakage Statistics based on Initial Fiber length and Stress during Filling

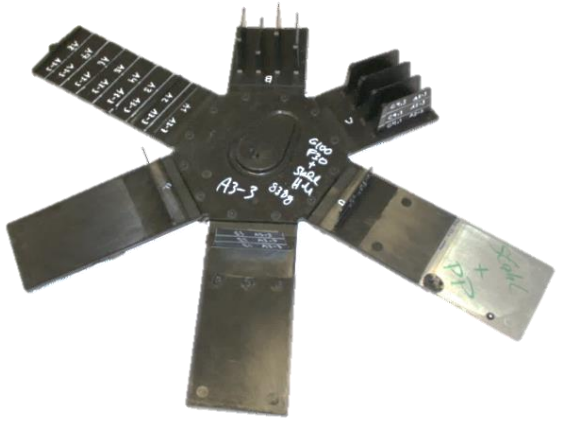
EXPERIMENTS ON LONG FIBER REINFORCED PLASTIC

COMPRESSION MOLDING





Simulation



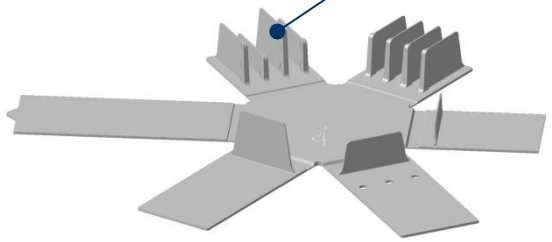
Real component

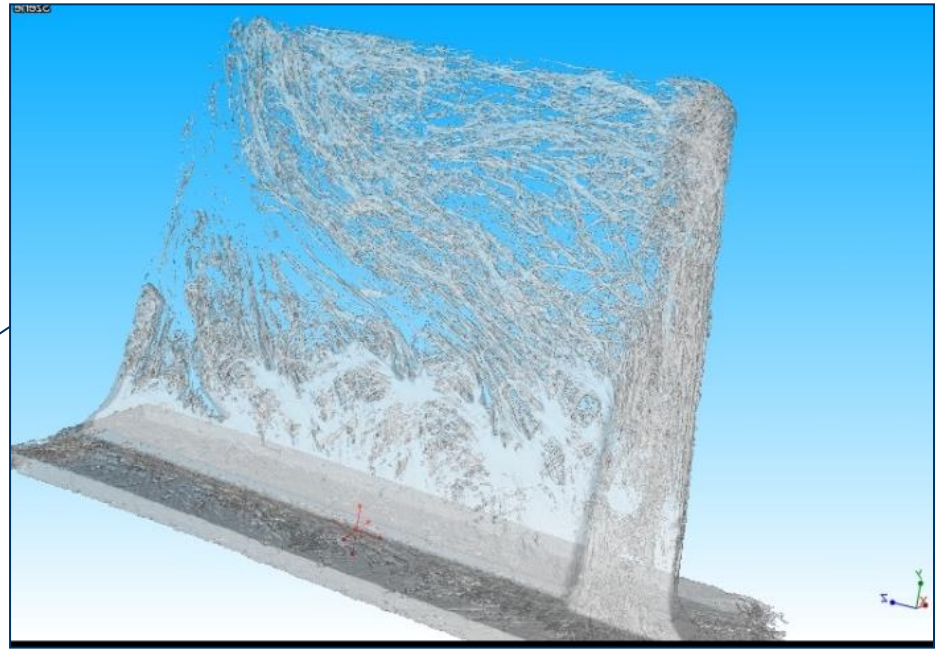
CT ANALYSIS

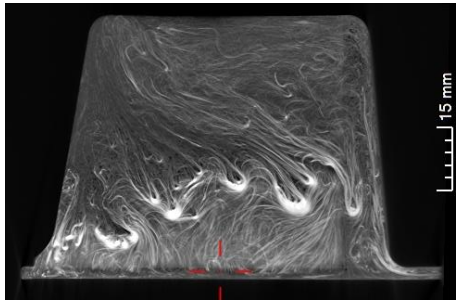
STAR SHAPED GEOMETRY

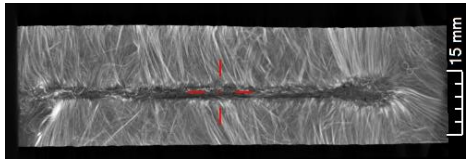
Experiments show deviations to process simulation results

- Fiber Orientation
- Fiber Breakage
- **Fiber Content Distribution**









FIBER MATRIX SIMULATION

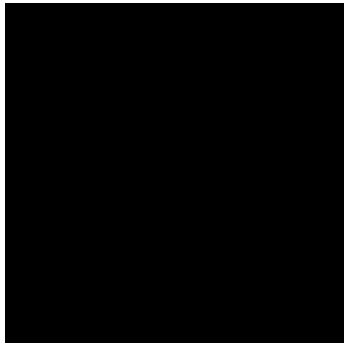
EXAMPLE

Quelle: Polymer Engineering Center, Prof. Tim A. Osswald

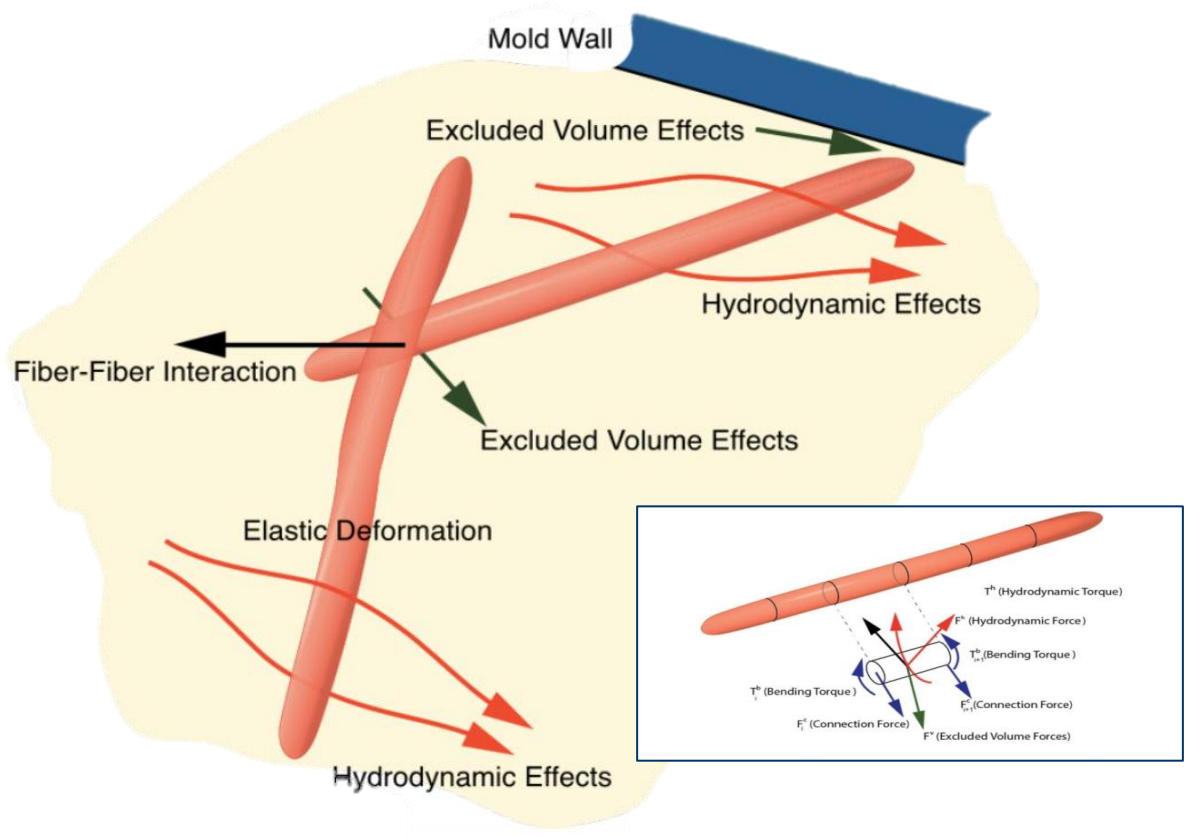
DIRECT FIBER SIMULATION (DFS)

GENERAL PRINCIPLE

- Fibers are simulated as multi-beam elements inside the polymer flow
- Complex interactions and fiber behavior can be simulated
- Fiber properties are free to chose (e.g. geometry, flexibility, breakage conditions)
- Detailed information on fiber orientation, fiber breakage and fiber content distribution



Fiber Interaction in DFS



DIRECT FIBER SIMULATION

RIBBED COMPONENT

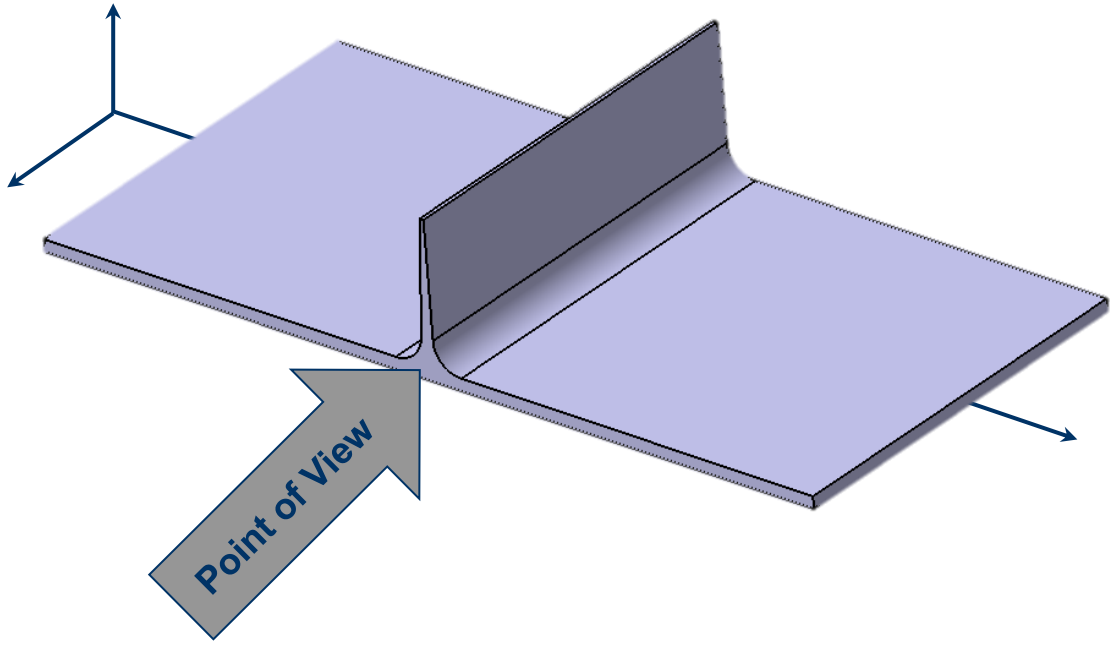
- Simple Compression Molding Experiments with Cross Rib

- Mapping of DFS into Moldex3D Filling Simulation

Input of Fiber Properties:

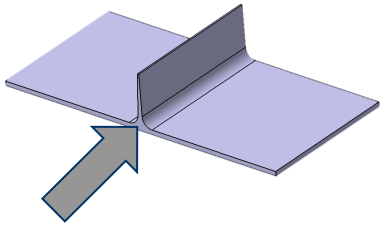
- Fiber Length
- Number of Segments / Flexibility
- Fiber Content

Evaluation of Boundary Conditions, Fiber Movement & Interaction at Rib Entrance



UPSCALING

DFS RIB FILLING SIMULATION



POLYMER FOAM STRUCTURES

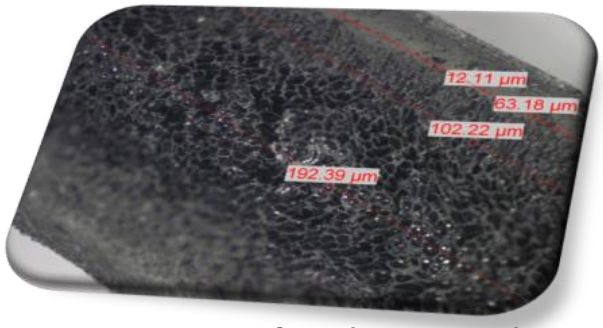
FOR AUTOMOTIVE APPLICATIONS

Benefits for Polymer Foam Structures

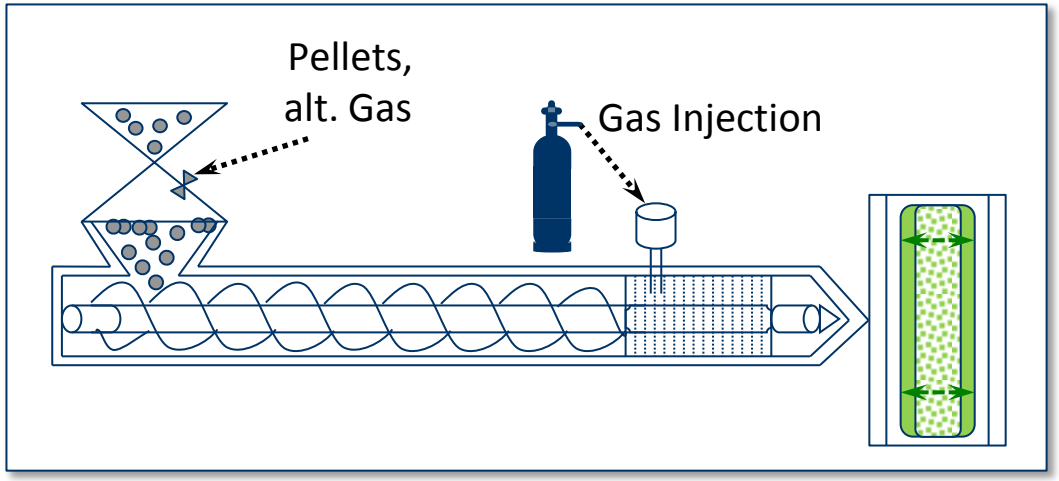
- Significant Weight Saving & Costs Reduction Potentials regarding material and processes (>10 %)
- Physically Foamed components comply with Volkswagen Surface Quality requirements for visible components
- Adaption of physical foaming with other lightweight technologies possible (e.g. hybrid materials, multi-component injection molding)

Available Technologies

- Mucell®
- Cellfoam ®
- *IQ Foam by Volkswagen*
- Pro Foam ®
- Smart Foam ®



Cross section of a thermoplastic foam plate with IQ Foam

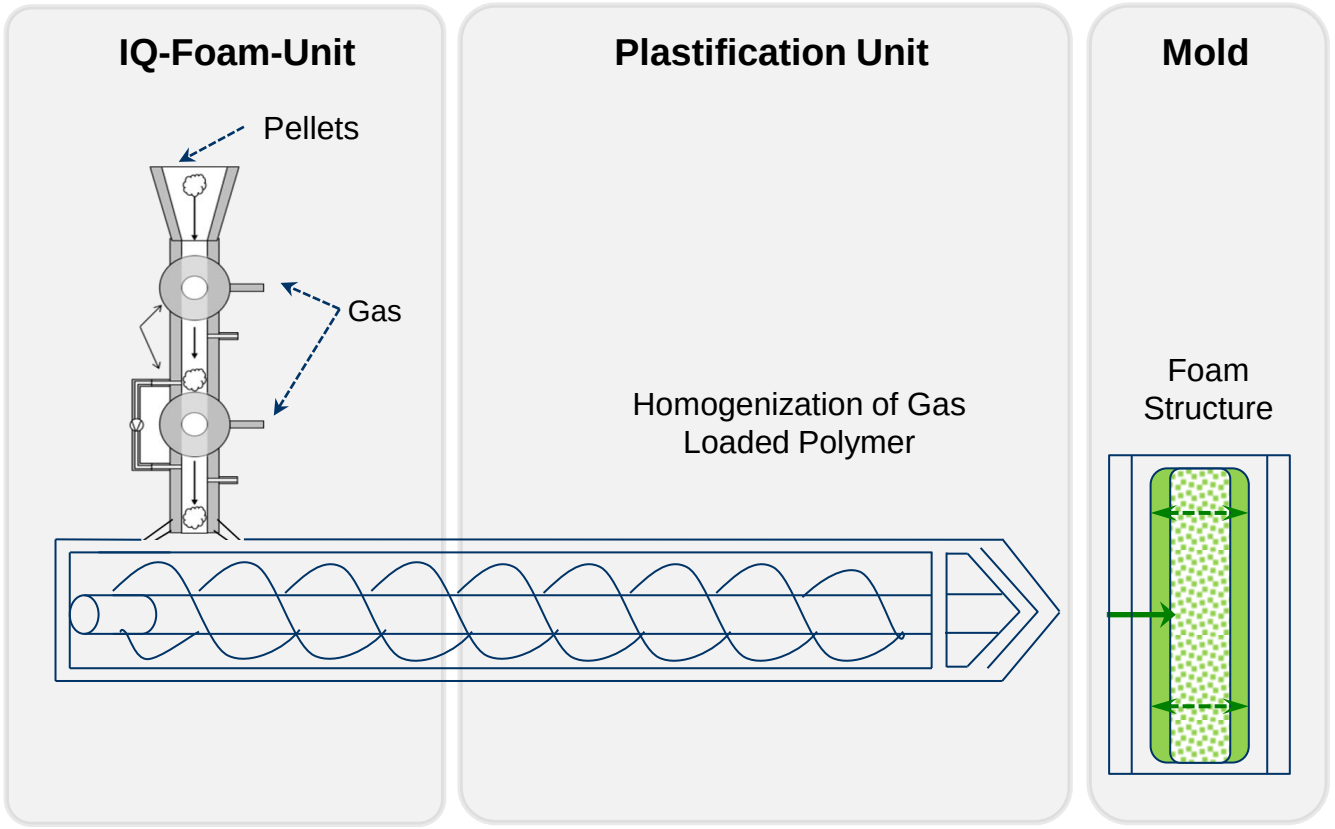


Physical Foaming Process

IQ FOAM

TECHNOLOGY

IQ Foam Process



IQ FOAM BENEFITS

FOAM INJECTION MOLDING

IQ Foam Process

IQ Foam Unit - Benefits

- Adaptable to most injection molding machines
- Very Low investment costs
- No integration into machine control system necessary
- Easy switch from foaming to solid injection molding
- Large variety of polymer / gas combinations possible

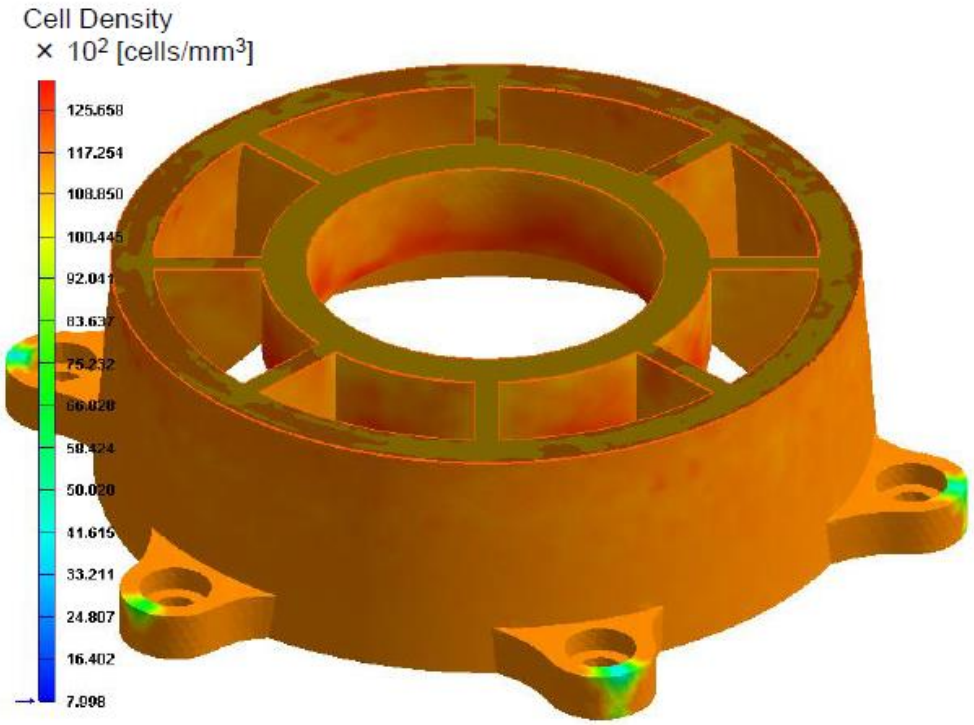
Component Benefits

- Significant weight reduction while maintaining mechanical requirements
- Material and cost savings
- Lower clamp forces
- No gas counter pressure inside mold necessary
- Decreased mold wear due to reduced injection pressure
- Increasing weight reduction possible with precision mold opening
- Both partial and large-scale foaming possible with core pull technology

FOAMING PROCESS SIMULATION

FOAM INJECTION MOLDING

- Foaming Tools available in Moldex3D
- Prediction of Foam Structure (Cell Density, Size Distribution, etc.) depending on processin parameters
- Application of Core Pull, Gas Counter Pressure & Variothermal Temperature Settings
- Forwarding of Cell Structure to Structural Simulation



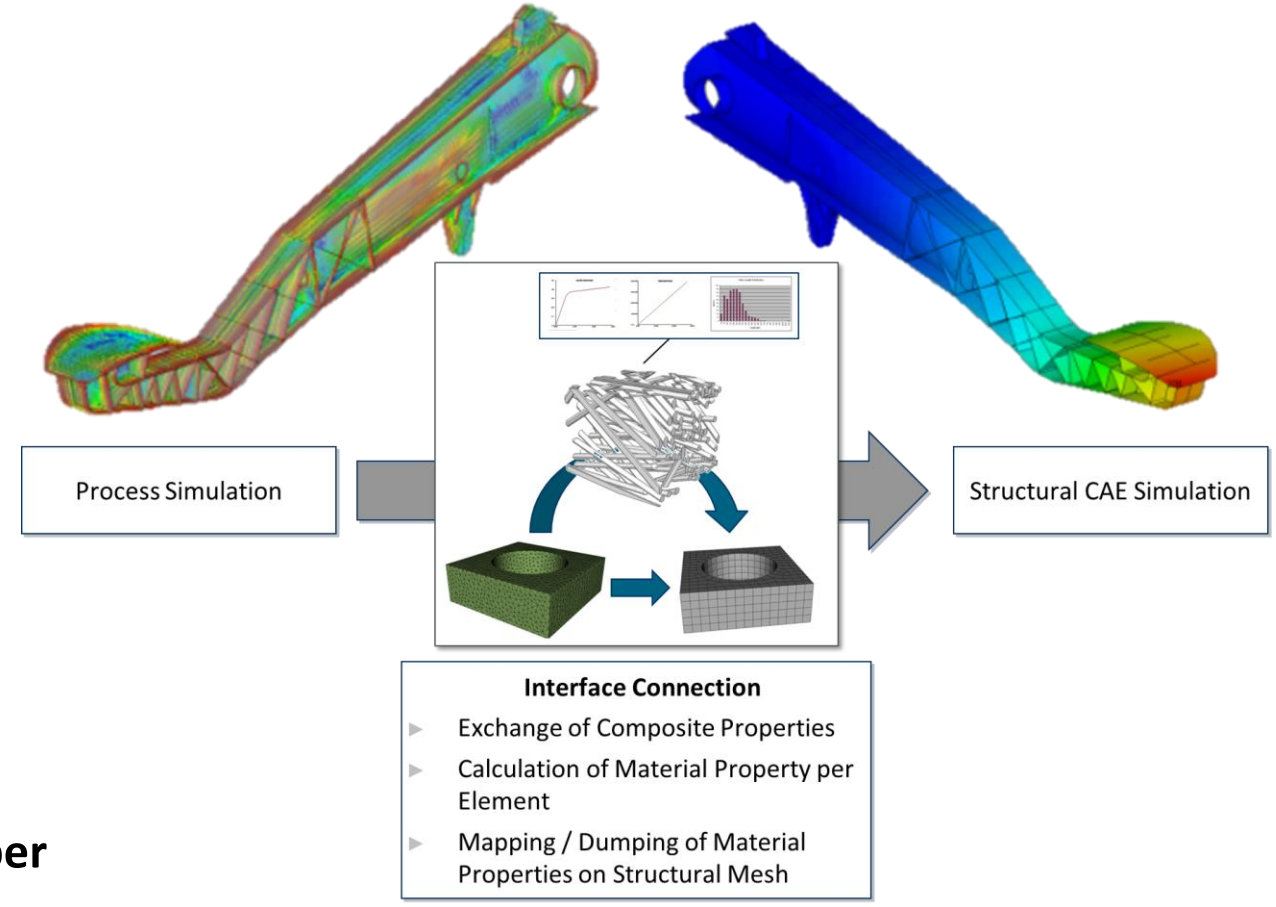
Cell Density Prediction

INTEGRATIVE SIMULATION CHAIN

CONNECTING PROCESS AND STRUCTURAL SIMULATION

Interchange of Process Simulation results with Structural FEA Simulation

- „Mapping“ of Processing results (Donor Mesh, e.g. Tetra) onto Structural Simulation Mesh (Receiver Mesh, e.g. 2D-Shells, Hexa, Tetra)
- Calculation of element properties based on local microstructure (e.g. Fiber Orientation, Foam Strucutre) with Homogenization Theories (e.g. Mean Field)



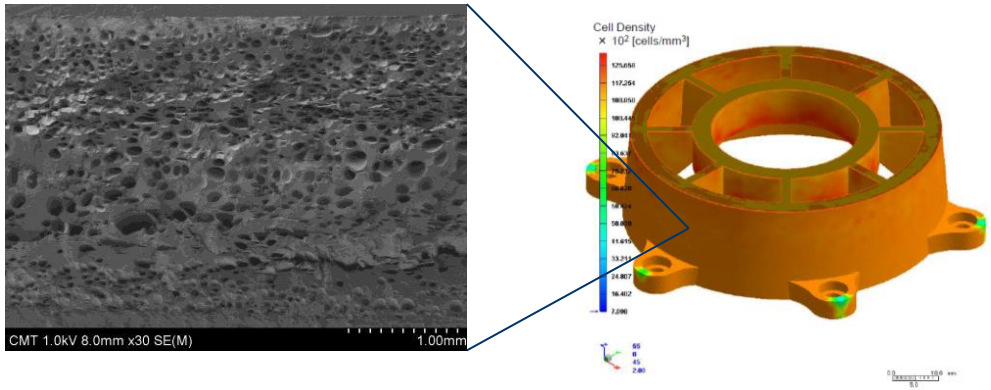
Increasing Accuracy of Structural Simulation with Fiber Reinforced Plastics & Foam Structures

CONCLUSION & OUTLOOK

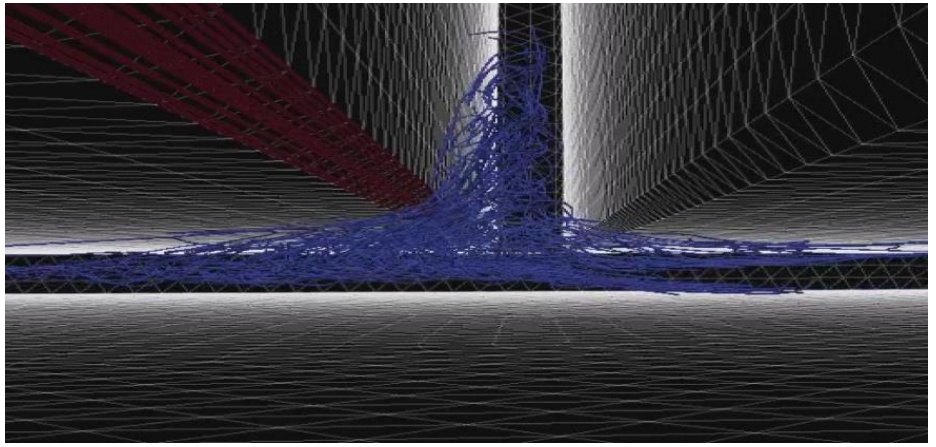
DIRECT FIBER SIMULATION

- Process Simulation Tools are vital for process understanding and prediction
- Tools for fiber reinforced plastics and foam structures are available
- Adjustments for long fiber application are in operation

- Forwarding of Process Simulation results to process simulation are important
- Evaluation of results with real components is key!



Foaming Process



Long Fiber Compression Molding

Thank you for your attention!