Polymertechnik Powertrain

Multiphysical Simulation of the Material State with Consideration of Process Parameters in a Single-Screw Extruder

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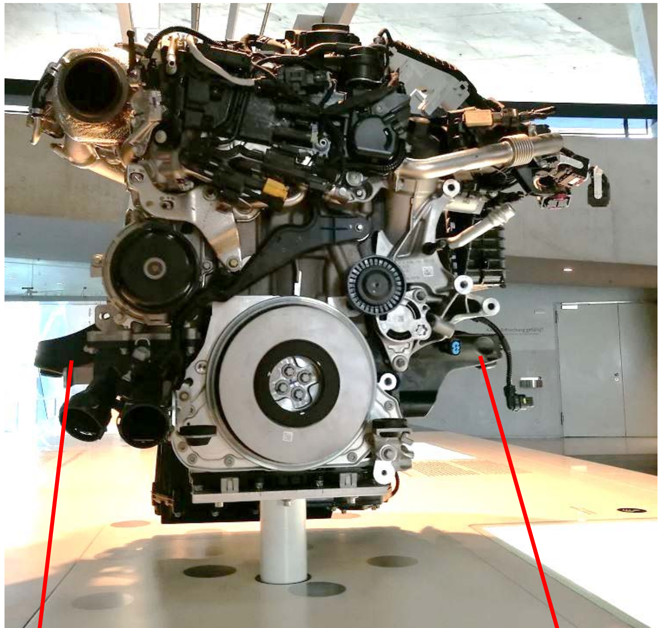
Agenda

- Background
- Motivation
- Schematic sketch of the injection molding process
- Plastification phase
- Conclusion

Background

First Application in the M-Class



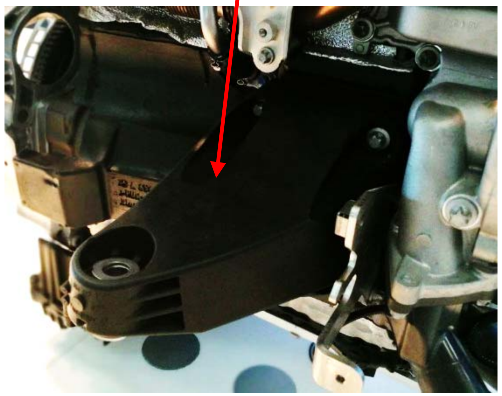
V6 Cylinder Diesel Engine

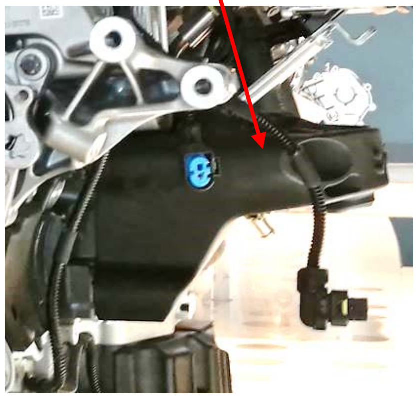
Development project between:

Daimler Company

BASF

Joma Polytec

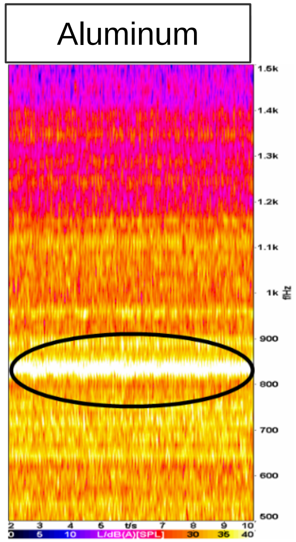


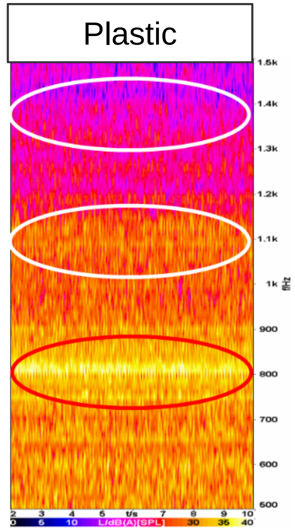


Right Engine Bracket Left

Background

The reason why substitution of aluminum by plastic material is to improve the NVH-behavior



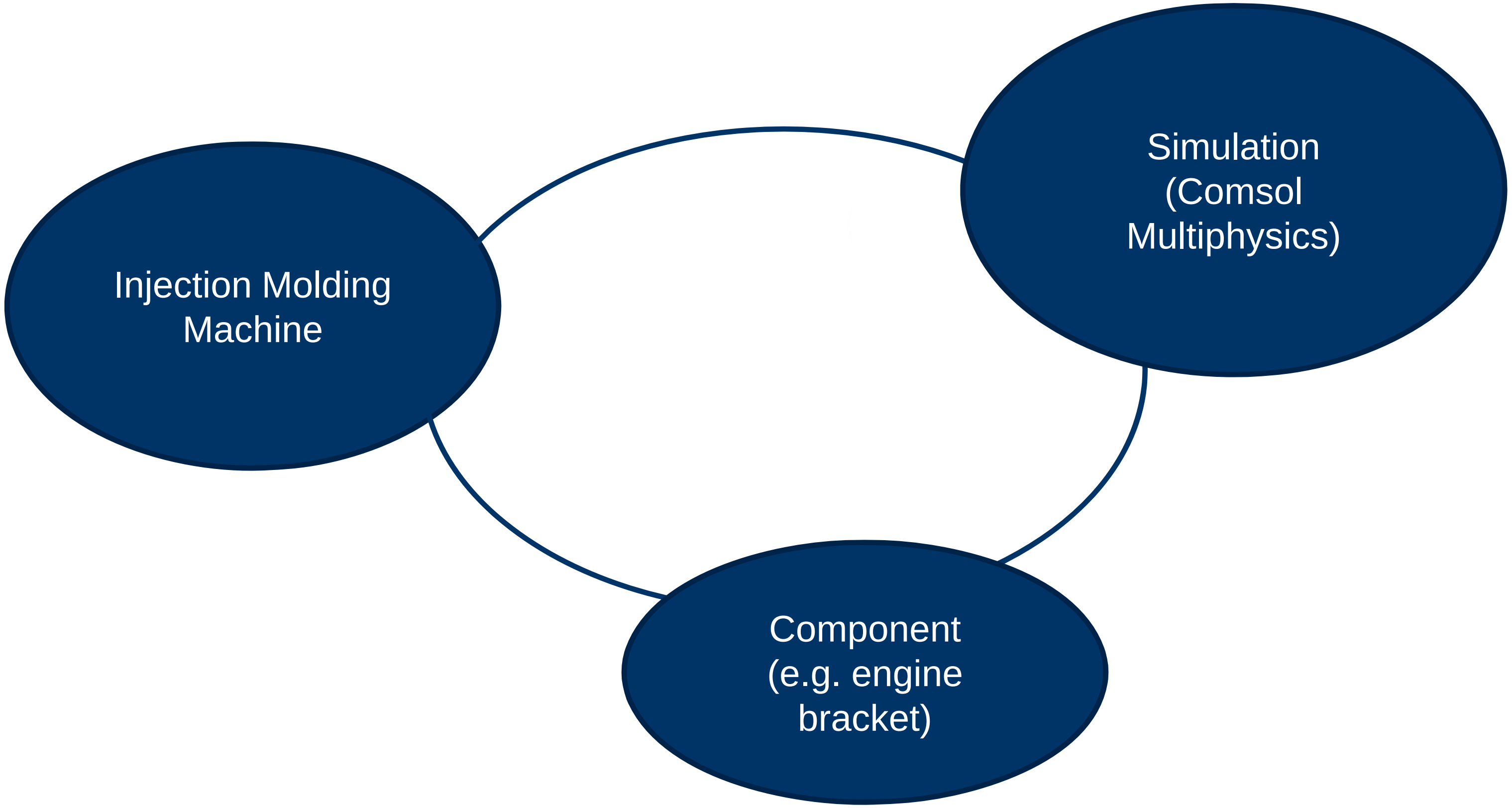


- Engine brackets now are made in thermoplastic material
- Increasing temperature and mechanical properties require duroplastic materials
- To guarantee constant quality needs a stabel injection molding process with cross-linked plastic material
- To understand the injection molding process in detail we need to simulate the state of material

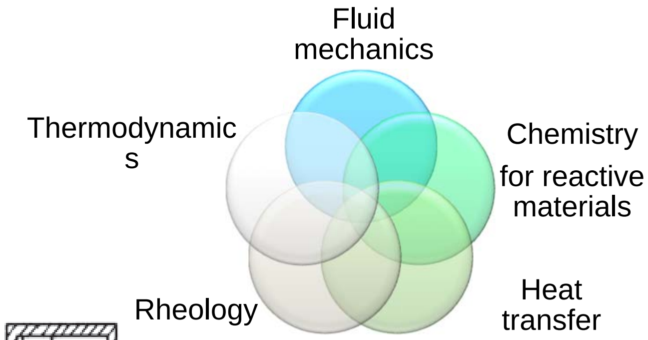
- **The first step is the simplification of the plastification unit for the injection molding process by a single-srew-extruder.**

Motivation for using Comsol Multiphysics

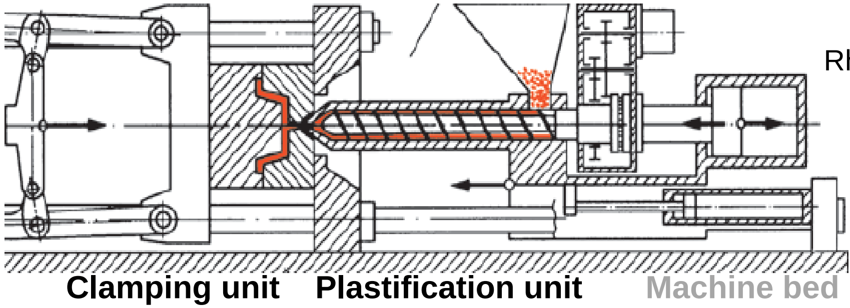
- Application of the reactive material in the vehicle component
- Simulation and analysis of the material state in the injection molding process
- Optimization of the injection molding process for better component quality



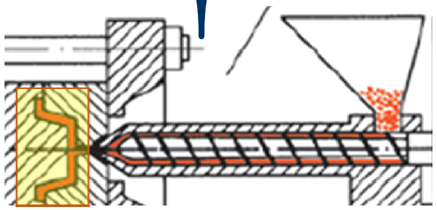
Schematic Sketch of the Injection Molding Process



Comsol Multiphysics: Coupling of multiphysical simulation



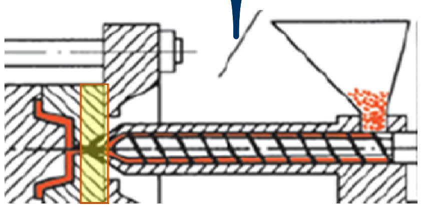
Mold ← **Nozzle** ← **Cylinder + Screw** — **Filling zone**



Mold

- Holding-pressure phase
- Cross-linking

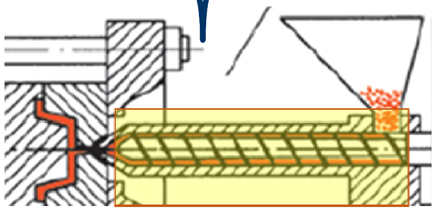
- **Chemistry**
- **Thermodynamic**
- **Heat transfer**



Nozzle

- Injection phase

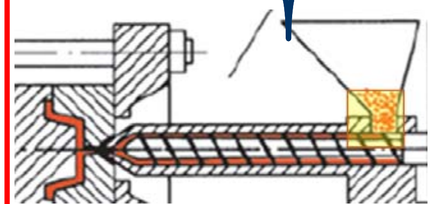
- **Fluid mechanics**
- **Heat transfer**
- **Chemistry**
- **Rheology**



Cylinder + Screw

- Encourage
- Plastification
- Dispensing

- **Fluid mechanics**
- **Heat transfer**
- **Chemistry**
- **Rheology**



Filling zone

- Filling

- **Heat transfer**
- **Rheology**

Plastification Phase:
Simplification of the Complex Plastification Unit in the Injection Molding Process

The simulation of the plastification unit for the thermosetting materials

The complete modelling of the plastification process is too complex

Therefor a simplification of the model is necessary

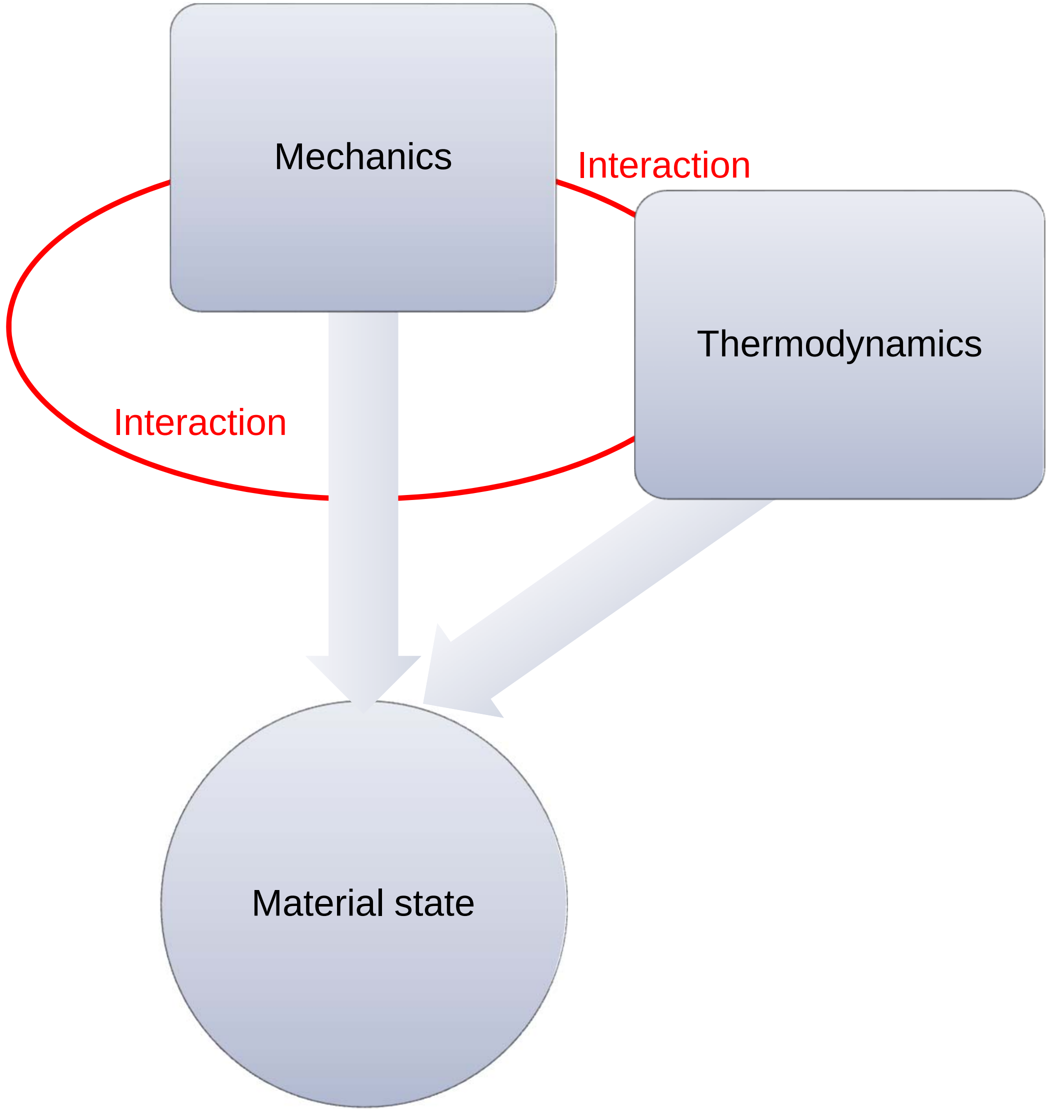
Instead of the plastification process:
Simulation of a single-screw extruder that processes a material, which is similar to a reactive resin

Similarities?

Similar design between the injection molding unit and the extruder, but the extruder has a simpler construction and geometry

Similar functions: material is sheared, homogenized and plasticized

Plastification Phase:
Influences of the Mechanics and Thermodynamics on the Material State



Plastification Phase:
Description of the Material State in a general Single-Screw Extruder

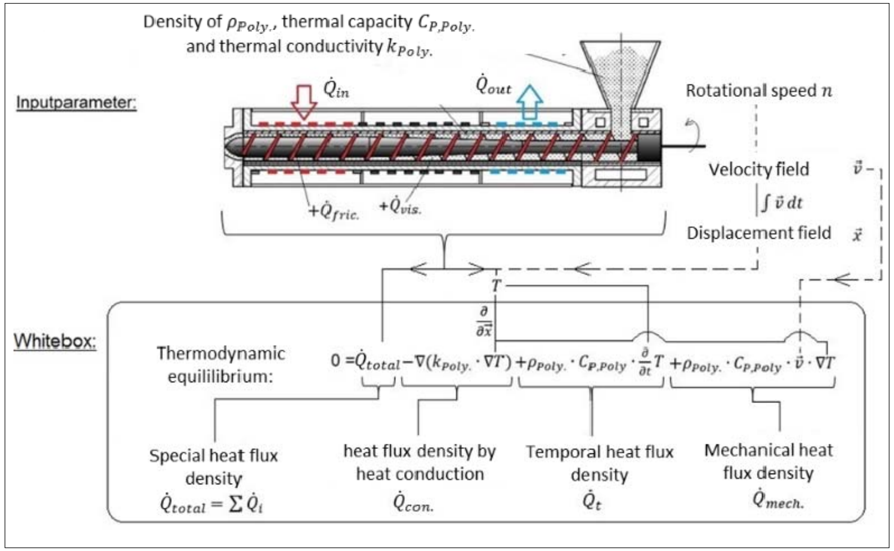
Material state in the single-screw extruder
Thermoplastic polymer system in the extrusion process :

1. Granulate is filled and transported by rotating screw
2. Energy dissipation (mechanical friction, viscous friction, etc.)
3. Variation of the process parameters (rotation speed, pressure, temperature)
4. Changes of the material state (viscosity, density, temperature)

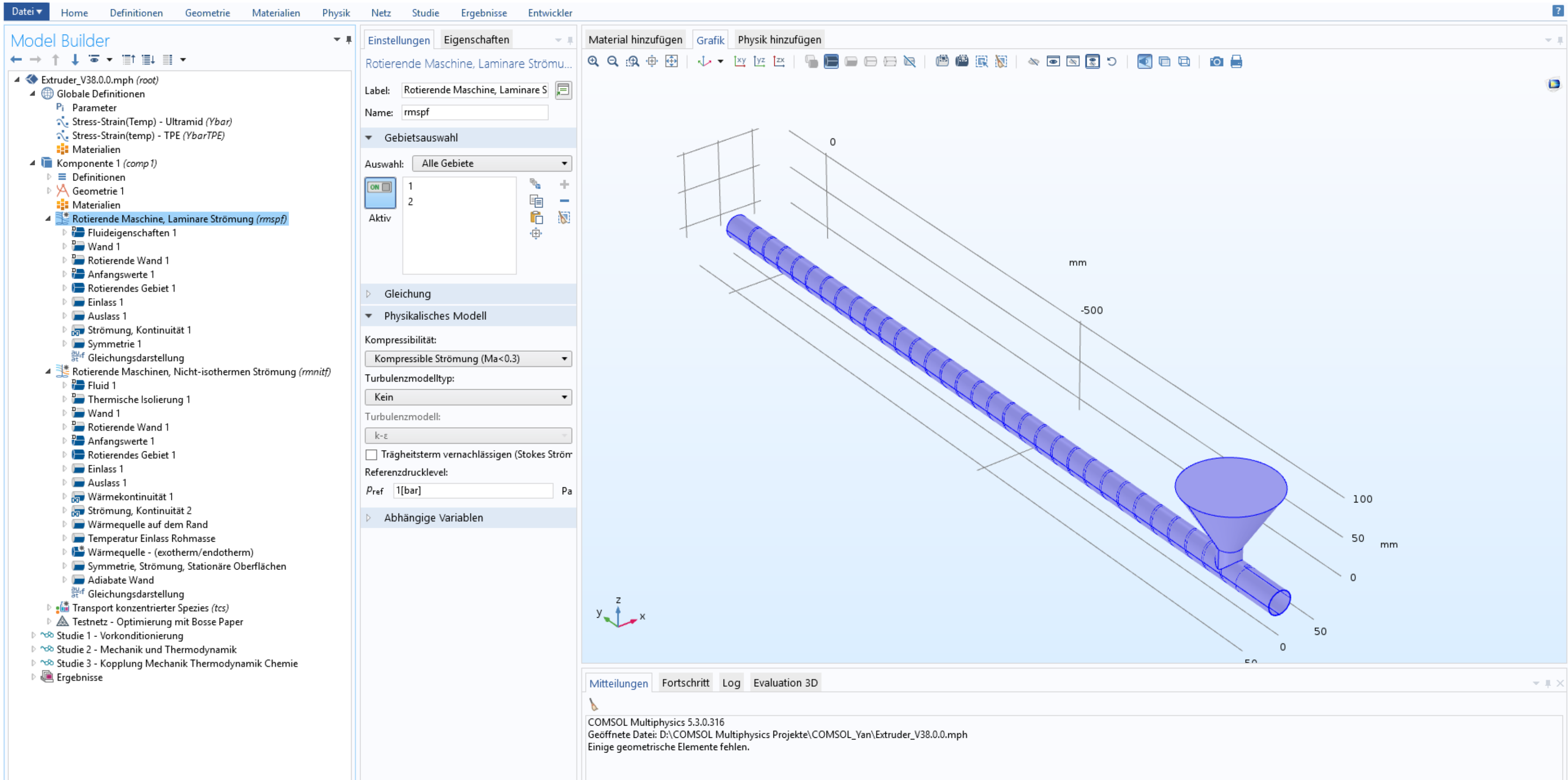
Summary of the influences of the extrusion process

Summary of the influences of thermodynamics

In the consideration of the heat flow balance



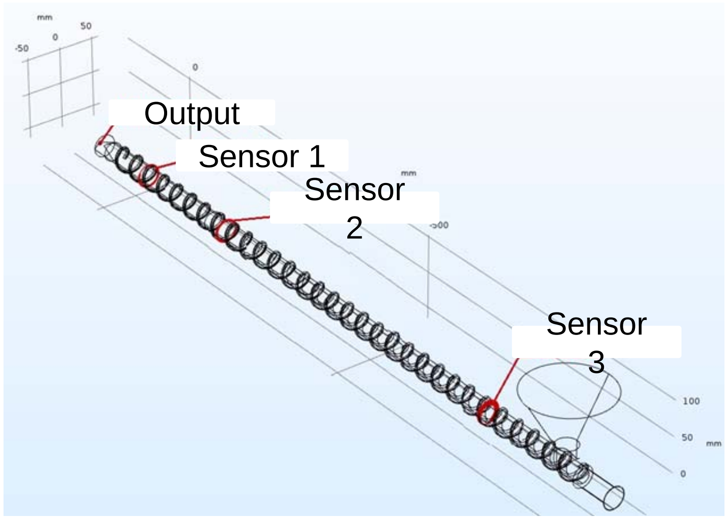
Plastification Phase: Modeling and Simulation



Plastification Phase:
Evaluation of the Numerical Results

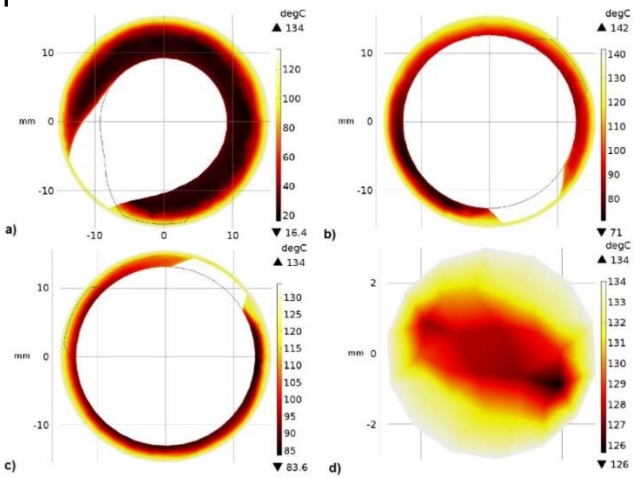
- Cross-sections in 4 meaningful regions are chosen to evaluate the results:

Cross-section 1 (Sensor 1): conveying section
Cross-section 2 (Sensor 2): melting section
Cross-section 3 (Sensor 3): feed section
Cross-section 4 (Output): output section

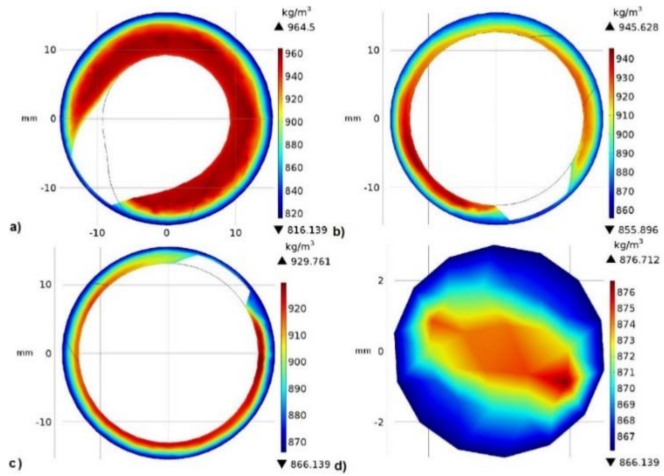


- Output parameter in the simulation:
  1. Mass flow at the output
  2. Temperature distribution
  3. Density distribution
  4. Viscosity distribution
  5. Pressure distribution

For example temperature and density distribution

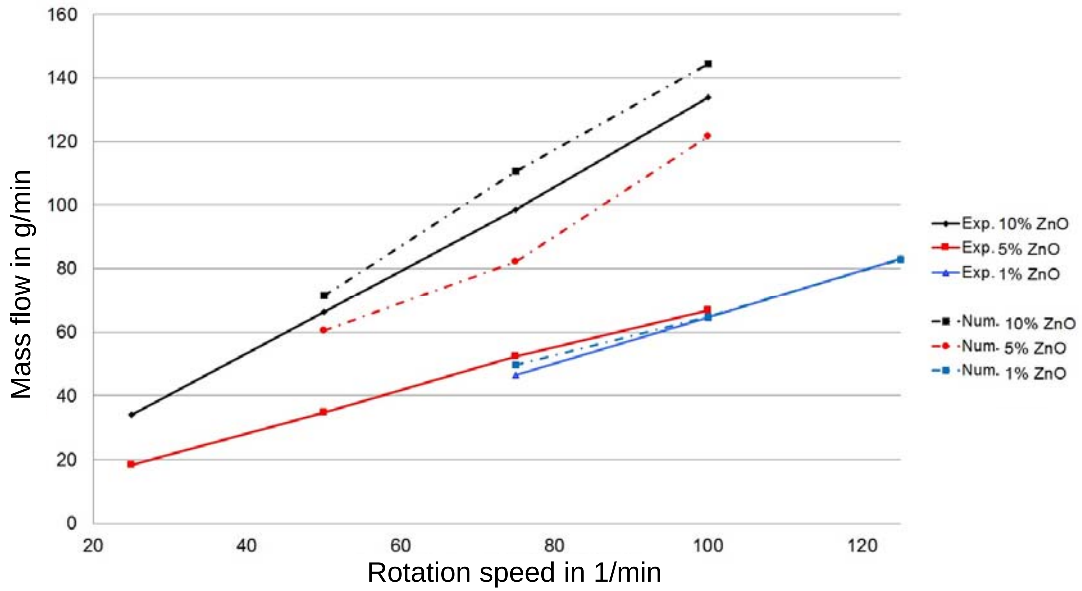


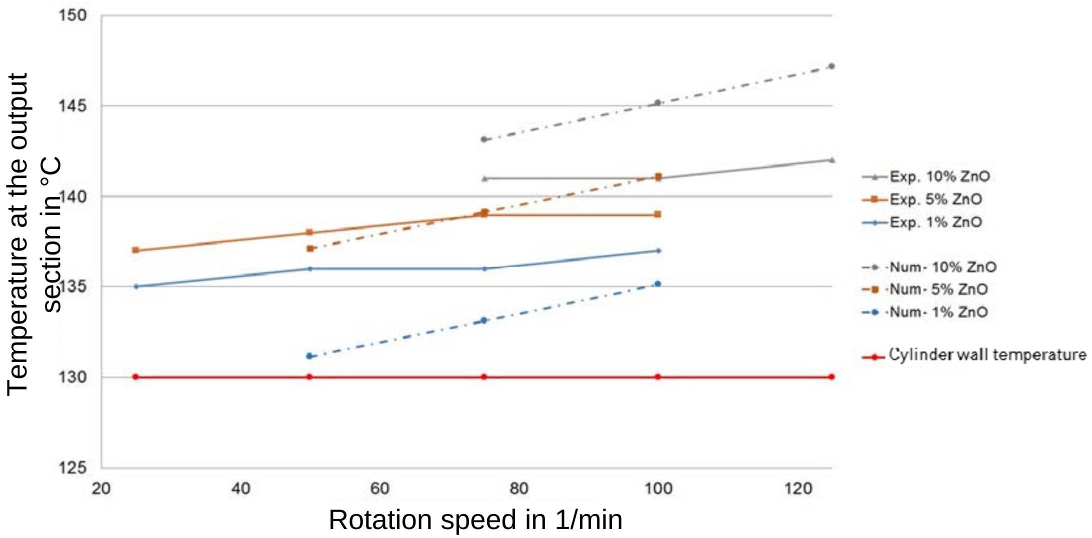
Temperature distribution



Density distribution

Plastification Phase:
Comparison between the Results from the Simulation and the Experiments





Conclusion

- The direct comparison of the experimental and numerical results show a good correlation
- In the simulation the non-directly measurable parameters of the material state in the extrusion process can be calculated and evaluated with good results

- The temperature influence in different zones on the material state (melt temperature, pressure, and mass flow) should be analyzed.
- Optimization of the physical model for better simulation accuracy (linear -> nonlinear)

Thanks for your attention!

Questions?

Plastification Phase:
Experiments on a Single-Screw Extruder

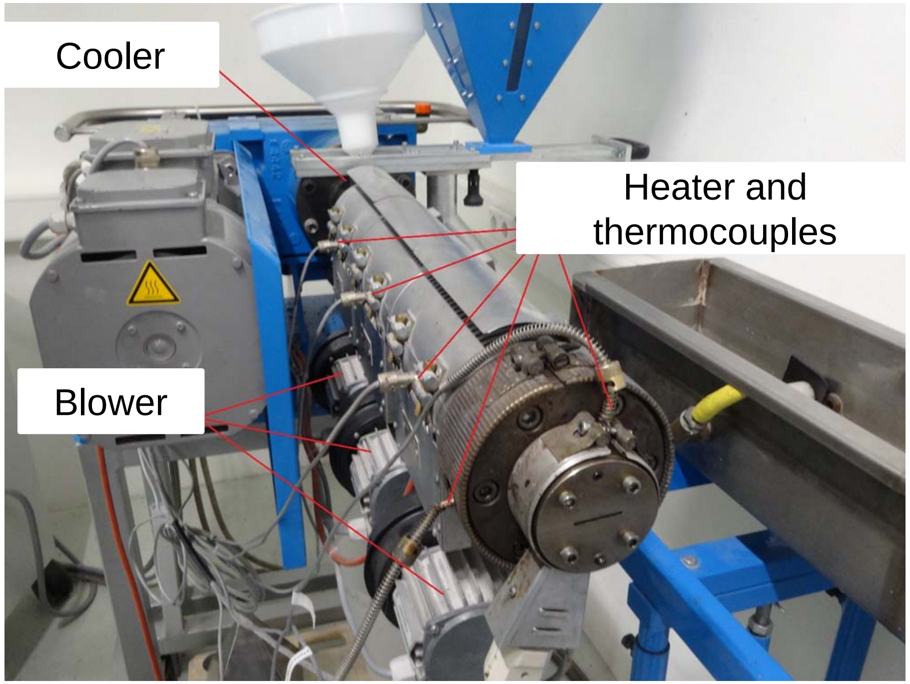
- Aims of the experimental investigations:
  1. On the one hand, the necessary parameters for the simulation model could be extrapolated from the experimental data.
  2. On the other hand, the numerical and experimental results will be compared.

- Input parameter:
  1. Material: TPE-zinc oxide compound

Compound 1: 99 mass-% TPE, 1 mass-% zinc oxide
Compound 2: 95 mass-% TPE, 5 mass-% zinc oxide
Compound 3: 90 mass-% TPE, 10 mass-% zinc oxide

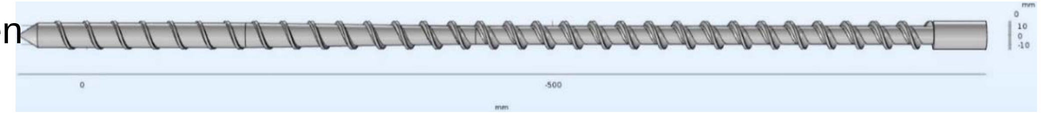
  2. Rotation speed (25, 50, 75 und 100 1/min)

- Output parameter:
  1. Mass flow at the output
  2. Temperature of the mass flow at the output
  3. Current of the engine

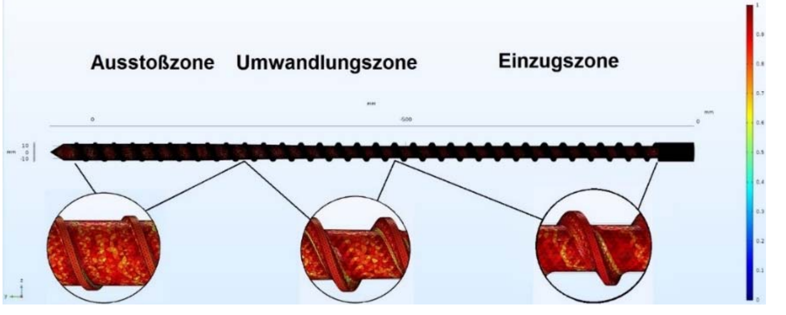


Plastification Phase:
Modeling and Simulation

- Implementation of the volume geometry between the worm-shaft and the cylinder wall



- Input
  1. System is adiabatic
  2. Material composition (TPE+zinc oxide)
  3. Thermal capacity
  4. Thermal conductivity
  5. Viscosity
  6. Etc.
- The mesh is adjusted until the convergence is reached (computing time, accuracy)



- Solver:
  1. First step: Mechanical pre-calculation for a better convergence
  2. Second step: Uses results from the first step as initial values to couple the calculation of the mechanics and thermodynamics