Moulding Innovation Day 2025

# Rubber Injection Molding Challenges: Case Study on Piston Rod Protector Bellow

SILIKO
**Marcel Hribernik**

Moldex3D

# More than 30-year tradition

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WE KEEP GROWING
IN THE GREEN

## Company basic data

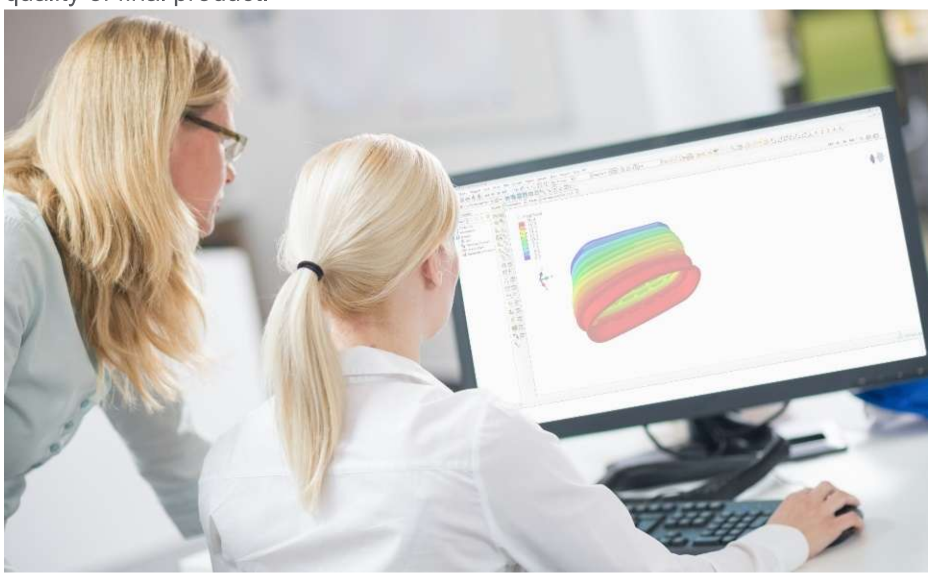
| | |
|---|---|
| **Main activity** | Rubber, plastic technical parts and tools |
| **Establishment** | 1993 |
| **Turnover** | 103 mio € in year 2024 + Neustadt H2 2024 28 mio€ |
| **No. of employee's** | 900+ |
| **Quality system** | IATF 16949, ISO 14001, ISO 9001, TISAX |
| **Locations** | Vrhnika, SI (development, tool shop, mixing hall, small series production)<br>Sevnica, SI (production)<br>Sombor, SRB (production)<br>Neustad in Sachsen, Germany (production) |

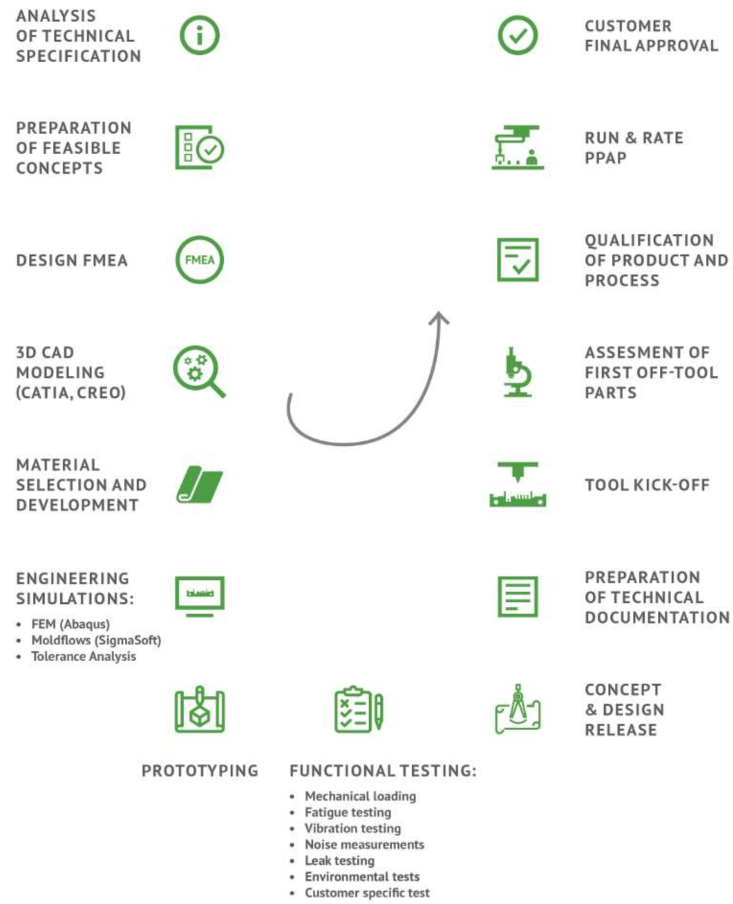
| ONE STOP SHOP | | | | | |
|---|---|---|---|---|---|
| **Design** | **Numerical Simulation** | **Material** | **Tooling** | **Technology** | **Validation** |

# Development capabilities

## Product development

The main task of our **R&D department** is to prepare and undertake **feasible technical concepts**, select suitable material or **develop tailored made elastomers** if needed, **validate** those concepts by using **engineering simulations**, select optimal technical solution and prepare complete technical documentation according to the available costs and timing to achieve optimal quality of final product.






IATF 16949 | ISO 9001 | ISO 14001 | ISO 45001 | ID PRFH80

## Laboratory

The main tasks of laboratory is support for the **elastomer development team** from mechanical and chemical requirements and the **technology development** team from material processability. Laboratory also covers the test **controlling the serial product quality**.

- Rheological properties
- Hardness
- Tensile properties
- Abrasion resistance
- Rebound elasticity
- Compression set
- Aging (ozone, media, autoclave)
- Salt spray test
- Dimensional measurements: Camera, CMM, 3D scan

- Thermogravimetric analysis
- Infrared spectroscopy
- Fogging test
- Cleanliness

IATF 16949 ISO 9001 ISO 14001 ISO 45001 ID PRFH80

## Functional testing

Our functional testing laboratory is equipped with high-end testing equipment that allows us to carry out full-stack functional testing of products we develop according to OEM specifications. The laboratory is equipped with equipment for measurement of basic physical properties (forces, displacement, pressure), environmental chambers and chambers for high pressure leakage tests acc. to IPx9K specification.
The latest equipment includes the leak testing device in order to test electric vehicle battery sealing, the 3D scanner Atos 5 for evaluation of surface quality of the A-class surfaces, the 8m3 environmental chamber and a dedicated test rig for dynamic testing of steering columns. The test ring includes two environmental chambers for simulation of conditions on engine and passenger side of the vehicle. On engine side we can also simulate dust and water conditions. We have also finished the a semi-silent room for measuring the acoustic properties of the products.

- Mechanical loading – static & dynamic
- Vibration testing
- Leak testing (dust, water, air)
- Noise measurements
- Environmental test
- Customer specific tests






IATF 16949 ISO 9001 ISO 14001 ISO 45001 ID PRFH80

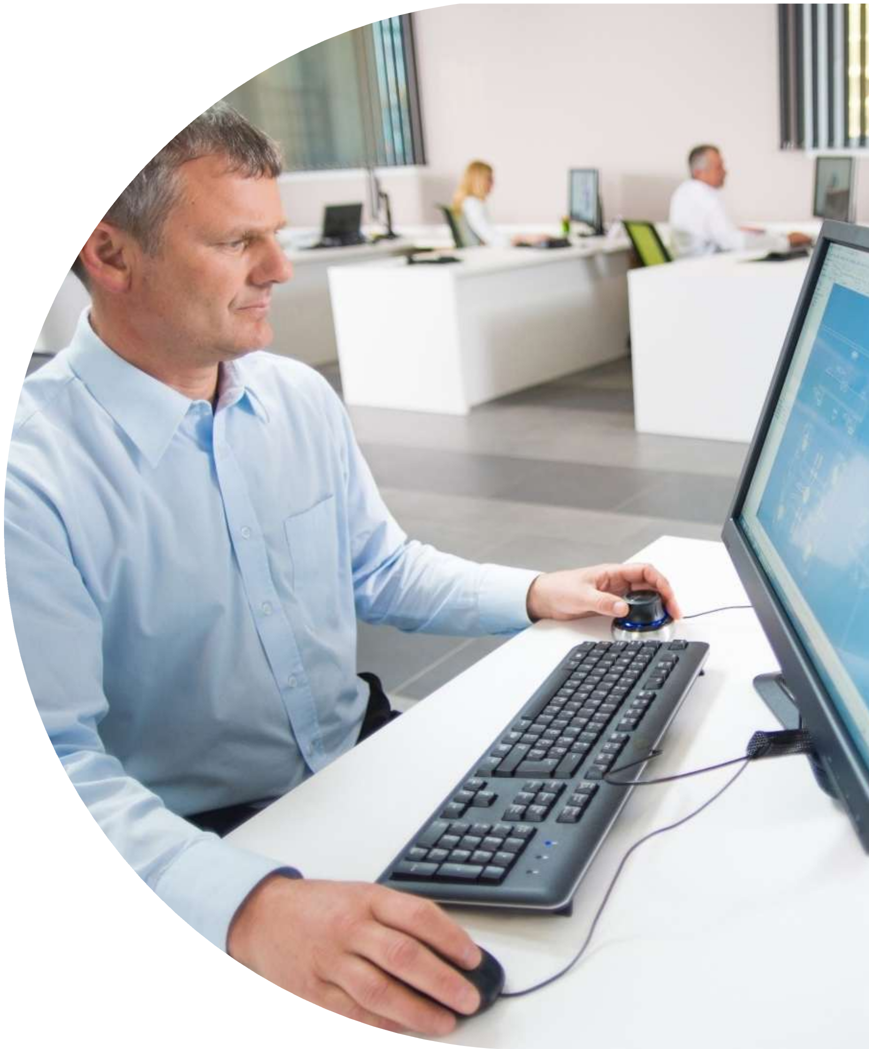
# Toolshop

## Key figures

- Approximately 50 employees
- 250 tools per year manufactured
- Prototype and serial tools
- Tools up to 2500x 1500 mm
- Specialized for IM tools for rubber, plastic and multicomponent moulding

## Internal know-how

- Tool design
- Proprietary cold runner systems
- Advanced injection moulding simulations
- Cavity filling
- Temperature distribution
- Cavity pressure sensor integration



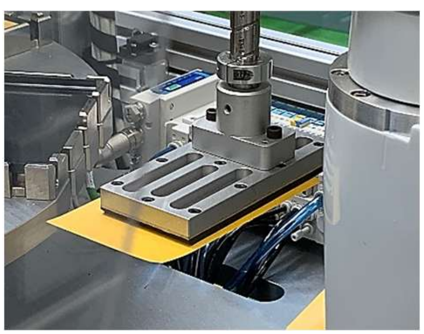
# Automation

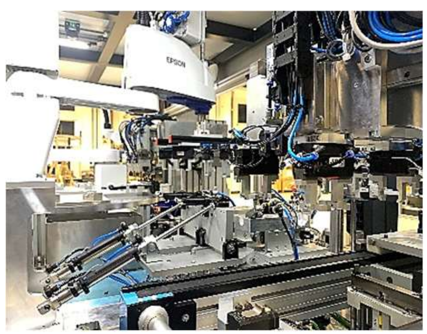
## Key figures

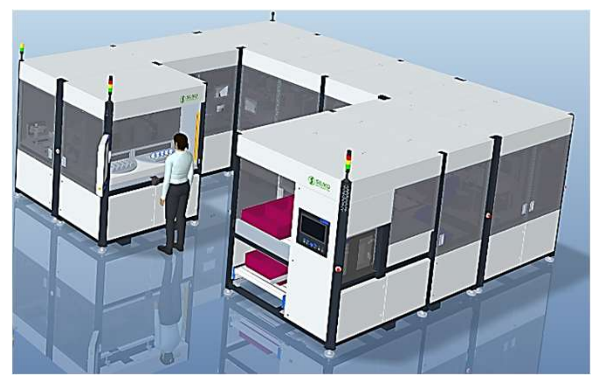
- High flexibility and state of the art internal technology development
- Technology and automation experts, machine designers, programmers, mechanical and electrical assembly engineers
- Streamlined and efficient machine building process
- High maintenance efficiency and know-how driven support to internal serial production

## Capabilities

- Internal machine development, assembly and deployment
- Inline quality control (AI supported machine vision, leak testing, precise dimension measurement, 3D scanning,...)
- OT network (MES, SPC analysis, remote access, data storage,...)
- Traceability control (laser marking, DMC application with process history, RFID worker access control,…)
- Advanced assembly (ultrasonic, hot plate, hot gas, IR & vibrational welding, adaptive position control, servo feedback control,…
- Cleanliness control (overpressure assembly cell, ionization, automatic packing system,…)
- Smart handling (3,4 and 6 axis robotic manipulators, material feeders and camera assisted feeding system,…)



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# Compounding and mixing

## Development

- In-house compounding capabilities
- Know-how for development of elastomer compounds (AEM, ACM, EPDM, NR, SBR)
- Customer-oriented services and tailor-made solutions
- Optimization of flowability and processability of elastomer compounds
- Environmentally friendly behaviour

## Laboratory (4L) and production (90L) mixer with extrudor



# Production

## Summary in numbers

- **4** production locations in 3 countries
- **50.000 m$^2$** covered surface; **50.000 m2** land available for building
- **15-21 shift/week** operation

## Injection molding technologies

- **102 machines** for elastomer IM with clamp force in range **30t – 850t**
- **80 machines** for IM of thermoplasts and LSR with clamp force **50t – 1500t**
- **10 machines** for compression IM of duroplasts with clamp force **130 – 140t**
- **1 machine** for thermoplast Compression IM with clamp force **320t**

## Secondary operations and assembly

- Post moulding operations
- Automated vision inspection
- Manual assembly
- Full automatic assembly
- Ultrasonic welding
- Mirror plate welding
- Pad & Screen printing
- Laser marking
- Packaging

# Solutions for E-Mobility

## TECHNOLOGIES

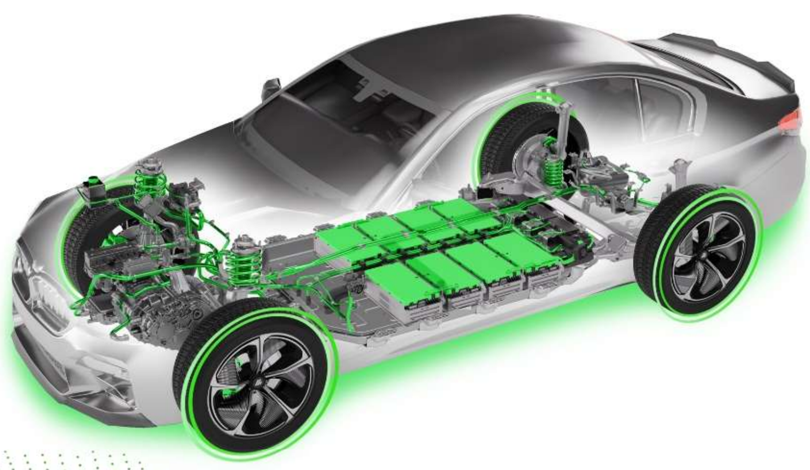
One-Component IM

Elastomers | Thermoplast | LSR

Multi-Component IM

Elastomer–thermoplast–metal

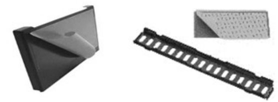
Manual – Semi Automated - Automated



**VENTING UNITS:**
Emergency degassing
Pressure compensation

**CHARGING MODULES:**
Charging pot housings
Flaps with seals
Socket holder
Firewall grommet

**DEGASSING HOSES:**
Degassing hoses for 48V or Hi-Voltage batteries



**INSULATION PLATES:**
Rubber plates
Insulation Carriers with MICA
Self-adhesive cell stack plates

**BATTERY PACK SEALINGS:**
Elastomer sealings
Sealings with metal bushes
Sealings with metal inserts

**CABLE ENCLOSURES AND GROMMETS:**
Housings
Grommets

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# Solutions for Body, Chassis and Comfort

## TECHNOLOGIES

One-Component IM

**Elastomers** | **Thermoplast** | **LSR** | **Duroplasts**

Multi-Component IM

**Elastomer–thermoplast–metal**

Assembly

**Manual – Semi Automated - Automated**

**STEERING SYSTEM ELEMENTS:**
Steering shafts sleeves
Fire wall bearings
Belt pulley

**PEDAL COVER PADS:**
Rubber cover pads
Cover pads with alu inserts

**PLUGS AND PROTECTION ELEMENTS GROMMETS ASSY:**
Dash wall crossing rings
and fire wall cable grommets

**STABILISER BUSHES:**
Rubber bushes Bushes
with metal inserts Bushes with
plastic inserts Plastic hybrid
clamps

**ANTIVIBRATION SYSTEMS FOR SUSPENSION:**
Rubber spring pads
Hybrid (Plastic&rubber) springs pads

**ANTIVIBRATION BUFFERS AND OTHER ELEMENTS:**
Bump stops
Exhaust system hangers & gaskets
Buffers

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# Solutions for Air, Fluid and Thermal management

**AIR-DUCTS:**
Air Ducts
Air & Fluid hoses
Air intakes

**WATER AND CONDENS REGULATION:**
Condensation drainage hoses
Water regulation systems

**PLUGS AND PROTECTION ELEMENTS GROMMETS ASSY:**
Assy parts for 4WD
Gaskets for drivetrain
Oil plugs&oil covers

## TECHNOLOGIES

One-Component IM

**Elastomers** | **Thermoplast** | **LSR**

Multi-Component IM

**Elastomer–thermoplast–metal**

Assembly

**Manual – Semi Automated - Automated**

**PARTS FOR TRANSMITION:**
Assy parts for transmition
Gaskets for transmition

**WATER REGULATION:**
Water nozzles
Draining valves
Grommets

**SCR TANKS:**
Tanks for AdBlue

# Case Study: Federunterlage BaC

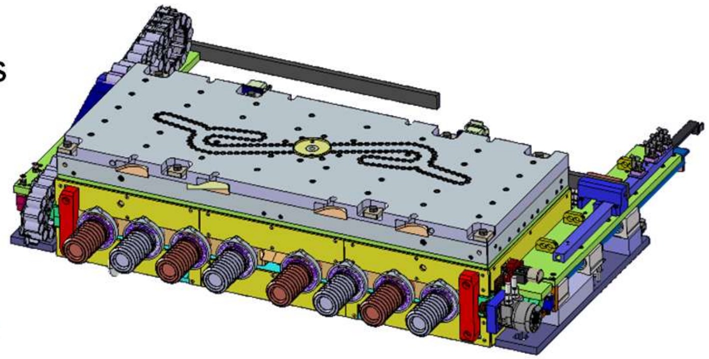
- **Part:** Elastomer bellow, mounted inside car suspension coil springs
- **Material:** Elastomer
- **Function:** protector for piston rod in all spring positions
- SOP in 2017
- 1 240 000 pcs/year
- Existing tool redesign due to carry-over project

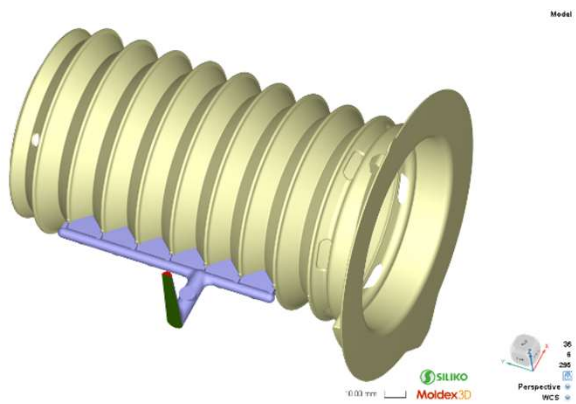
**Difficulties on existing tool:**

- Uneven part thickness
- Air traps
- Unbalanced fill
- Old material inclusions in part
- NOK bellow stacking

**Goal:**

- Reduce scrap (around 10%)



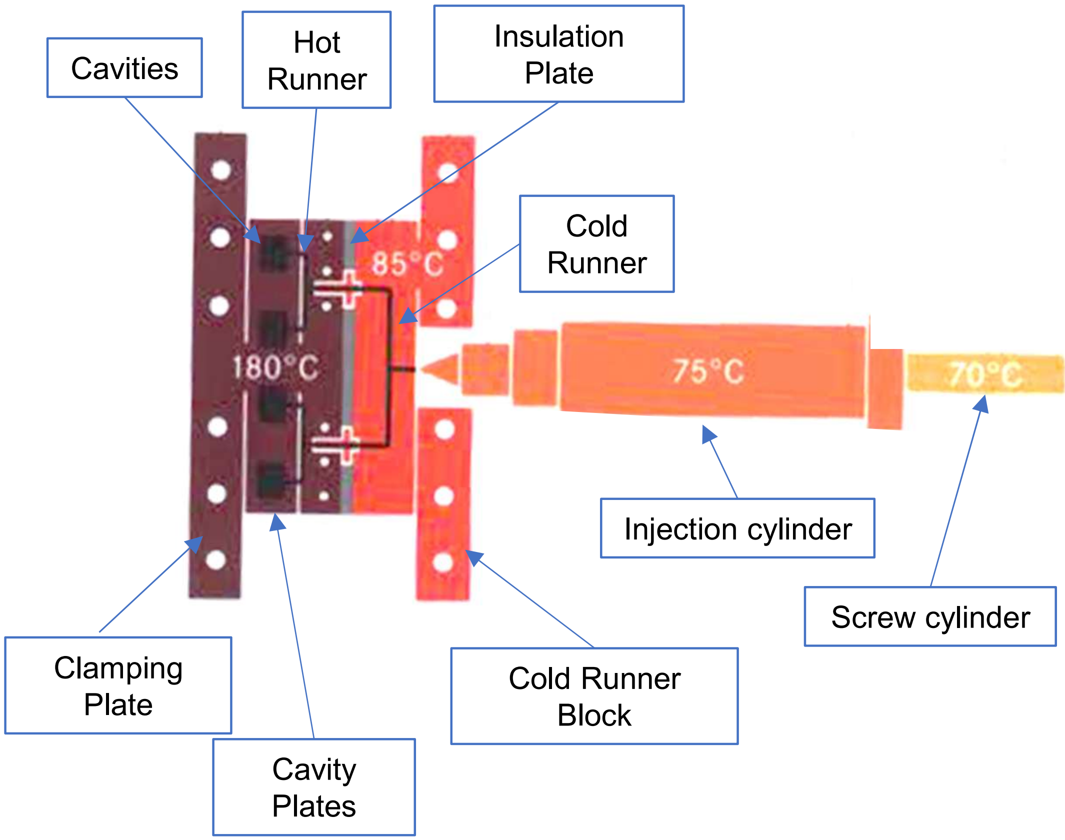


# Rubber Injection Mold Basics

Rubber injection mold is very similar to thermoplastic injection molding

Key differences:

1. Lower temperature screw and higher temperature mold
2. Runner System is cooled instead of heated (Cold Runner instead of Hot Runner)
3. Insulation plate between Cavity plates and cold runner block
4. Cavity and Clamping plates are heated instead of cooled
5. Cavities are under vacuum
6. Curing phase instead of packing phase



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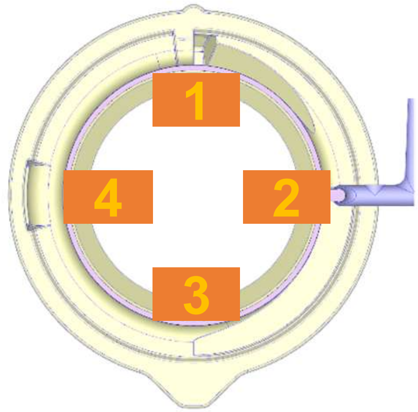
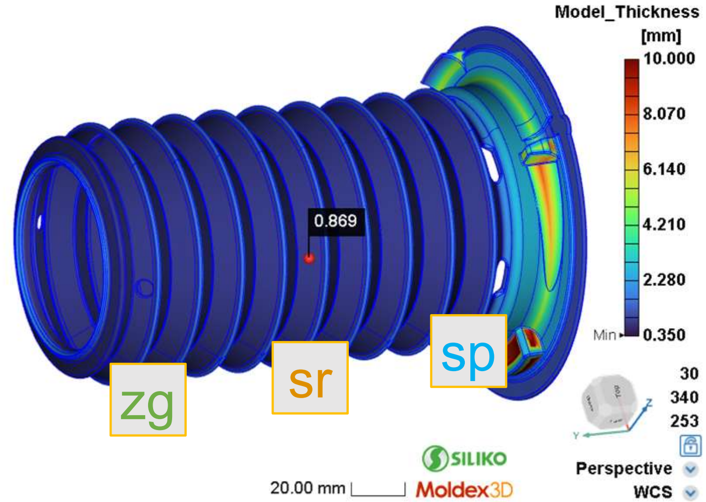
# Current Tool Issues

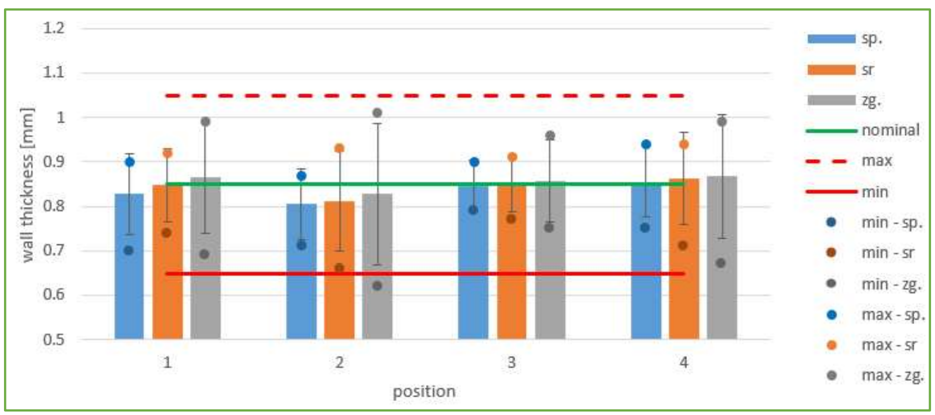
**Difficulties on existing tool:**

- Uneven part thickness
- Air traps
- Unbalanced fill
- Old material inclusions in part
- NOK bellow stacking

- ***Core fixation issues***



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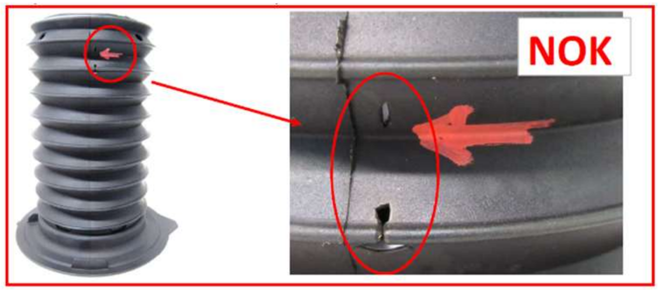
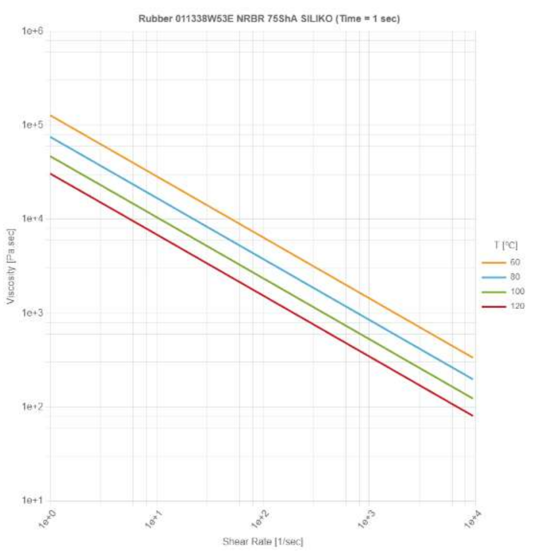




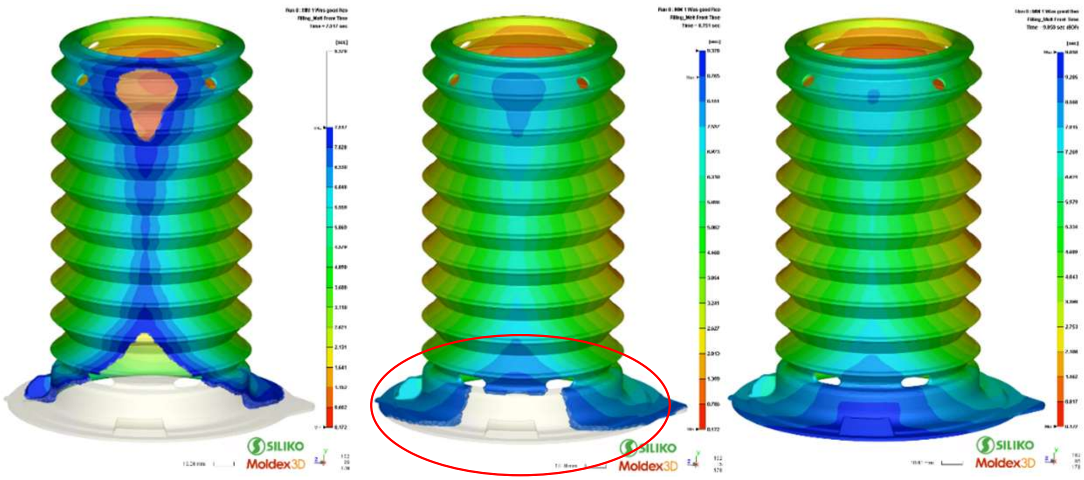

# First Iteration FLOW Simulations

Power law viscosity model




**Actual filling**

**First simulations**

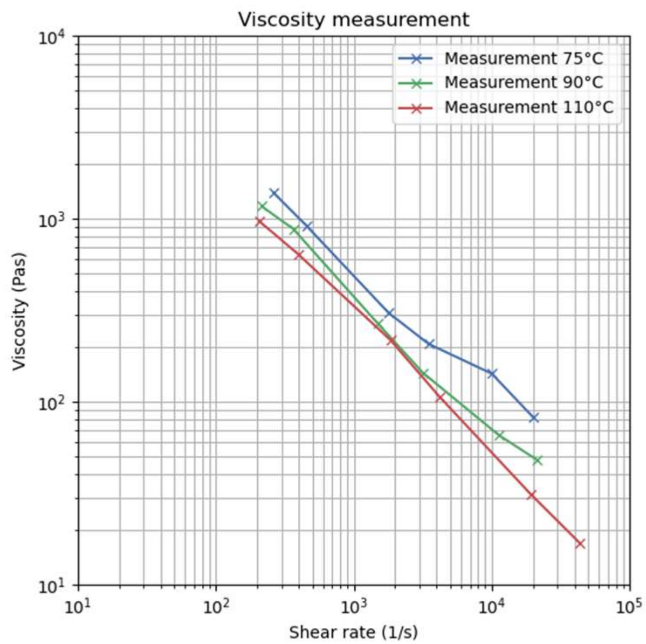


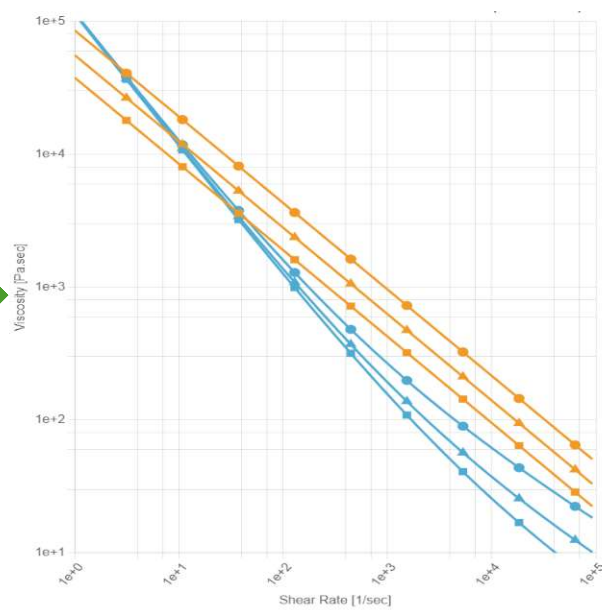
# Viscosity Measurement – Mold rheometer

Mold based capilary rheometer trial + shear heating correction simulations
***Pressure, Flow rate , Temperautre***

Measurement calculations
***Shear rate, Viscosity, Corrected temperature***

Material model
***Orange = generic***
***Blue = measured***

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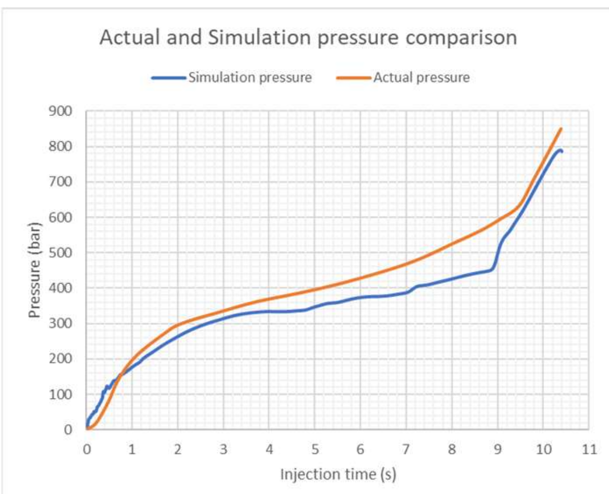
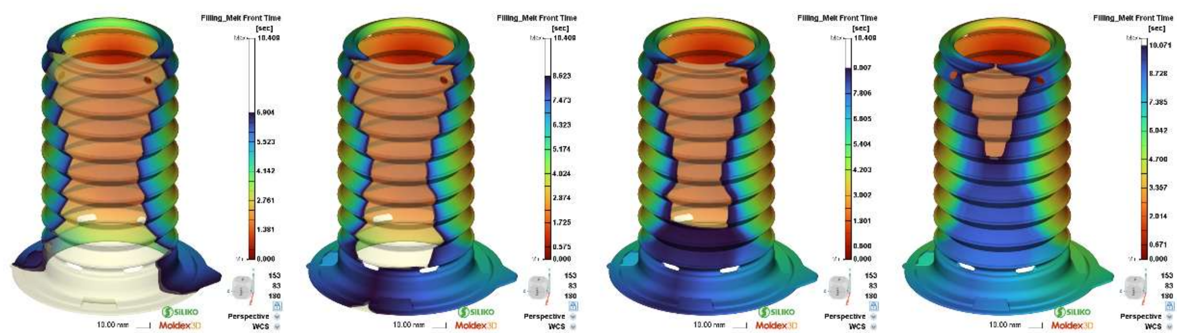
# Second Iteration FLOW Simulations

- Pressure curve is very close to actual
- Some differences in flow remain > Core Shift?



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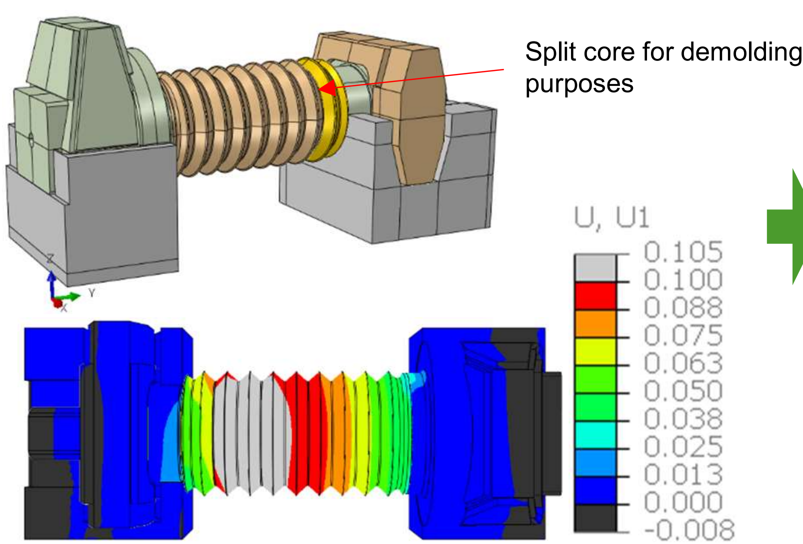
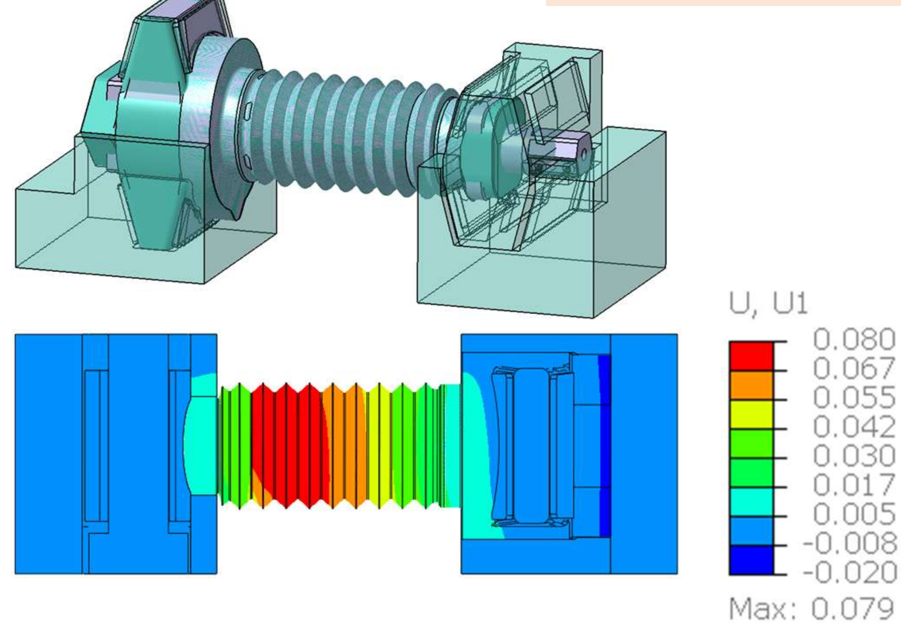
# Core Shift Simulations

- 2 Way Core Shift Simulation in Moldex3D is not realistic due to split core geometry
- Pressure on insert is taken from Moldex3D and applied to Abaqus FEM simulation
- Displacement result with pressure of 600 bar: 0.1 mm

Displacement remains high, but the design is more robust in the long term.

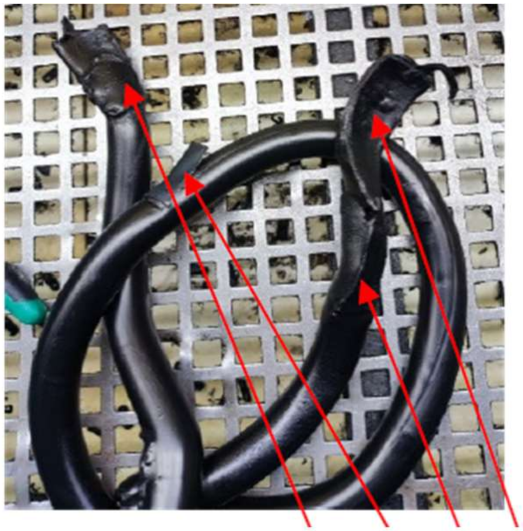
- **Core optimization with FEM simulations**



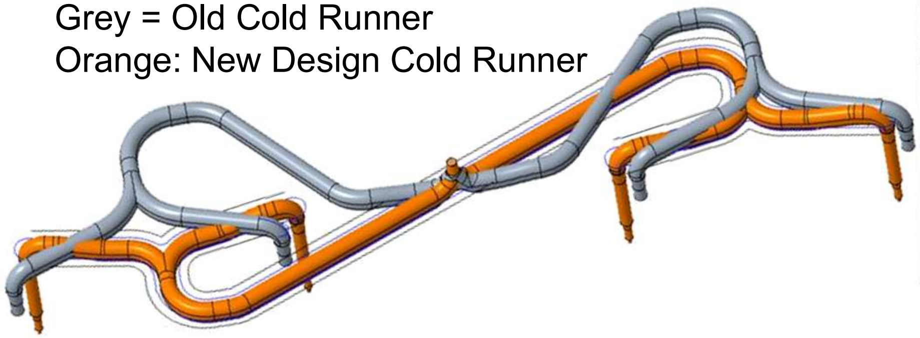



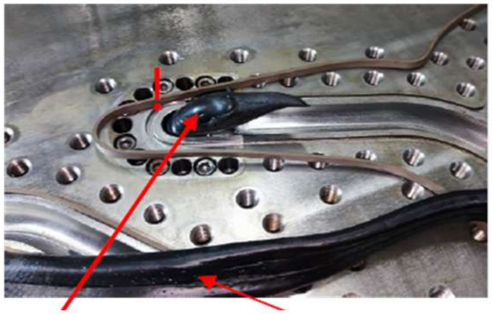
# Cold Runner Simulations

- Vulcanized material in Cold Runner system
- Old material inclusions in part
- Cause is combination of heat conduction from cavity plates and slow material velocity



Grey = Old Cold Runner
Orange: New Design Cold Runner

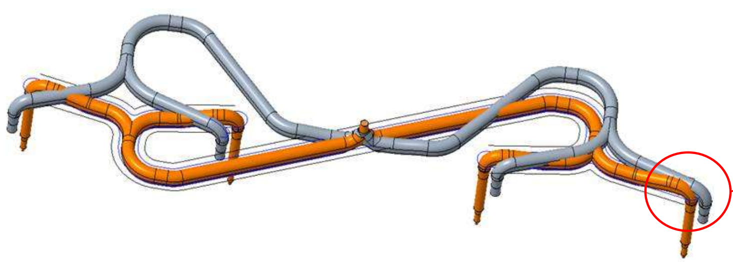


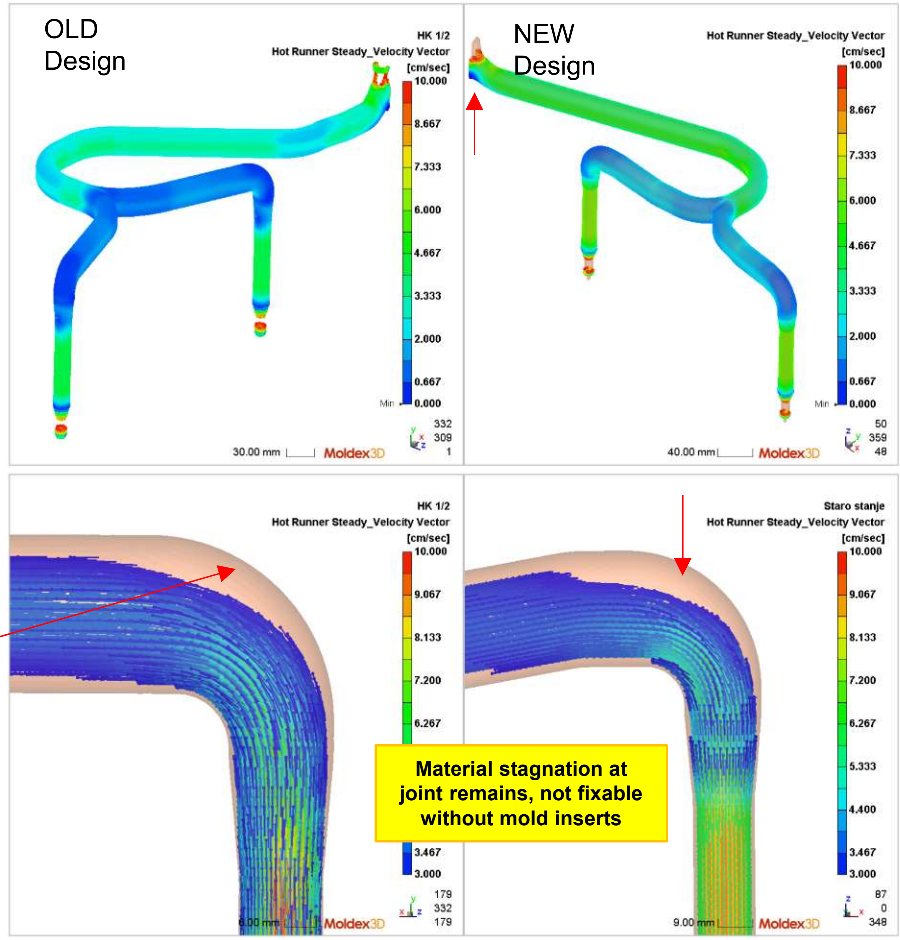


# Cold Runner Simulations

Old Design: 15 vol.% of material stagnation
New Design: 10 vol.% of material stagnation
Better, but could still be improved

- Hot Runner Steady
- T = 75°C
- Q = 60 ccm/s
- Symmetry ½

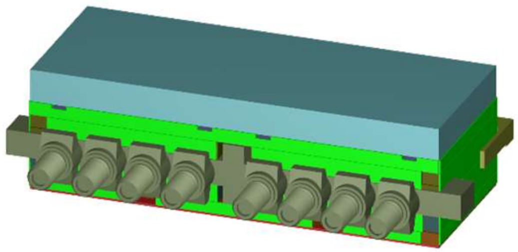





Material flow below U = 3 cm/s is not shown, regarded as too low.

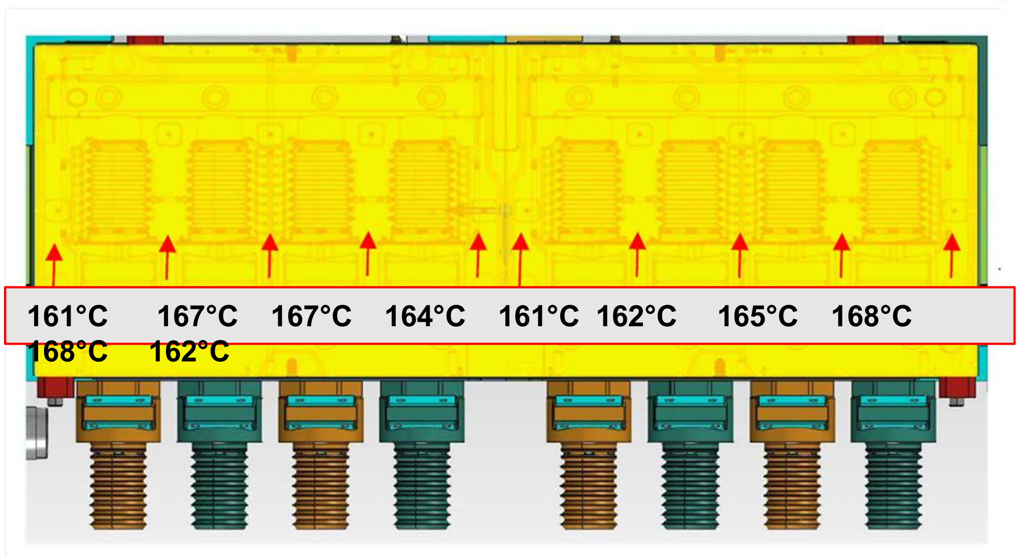
# Mold Heating Simulation

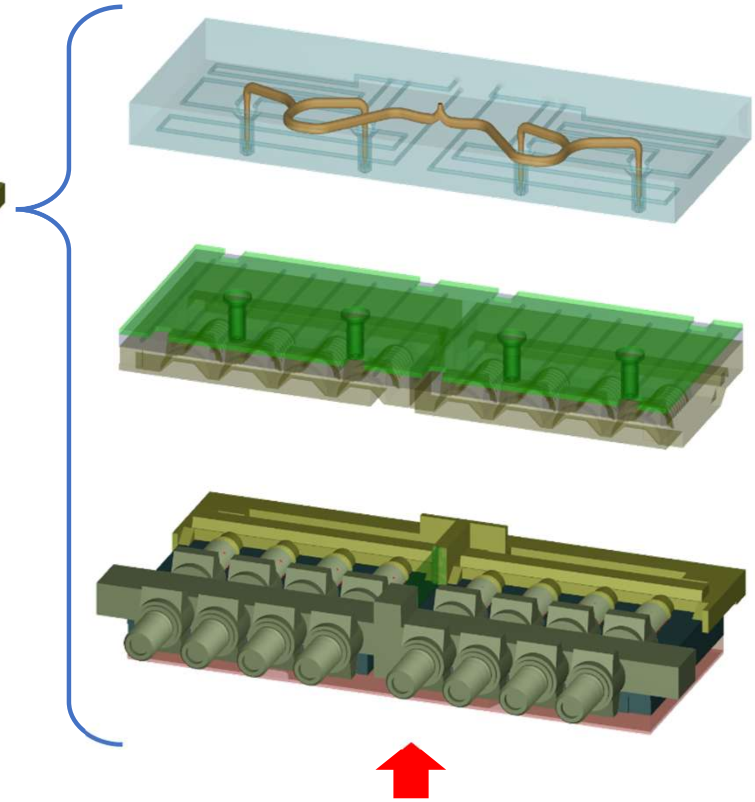
- Simplified numerical model:
- Water cooling in cold runner block
- 48 heating rods, controlled by 4 thermocouples
- Constant machine plate heating 170°C



Mold temperature measurement after first trial

MIN T = 161°C
MAX T = 168°C



Constant machine plate heating B.C.

# Mold Heating Simulation

## Overall Heating results

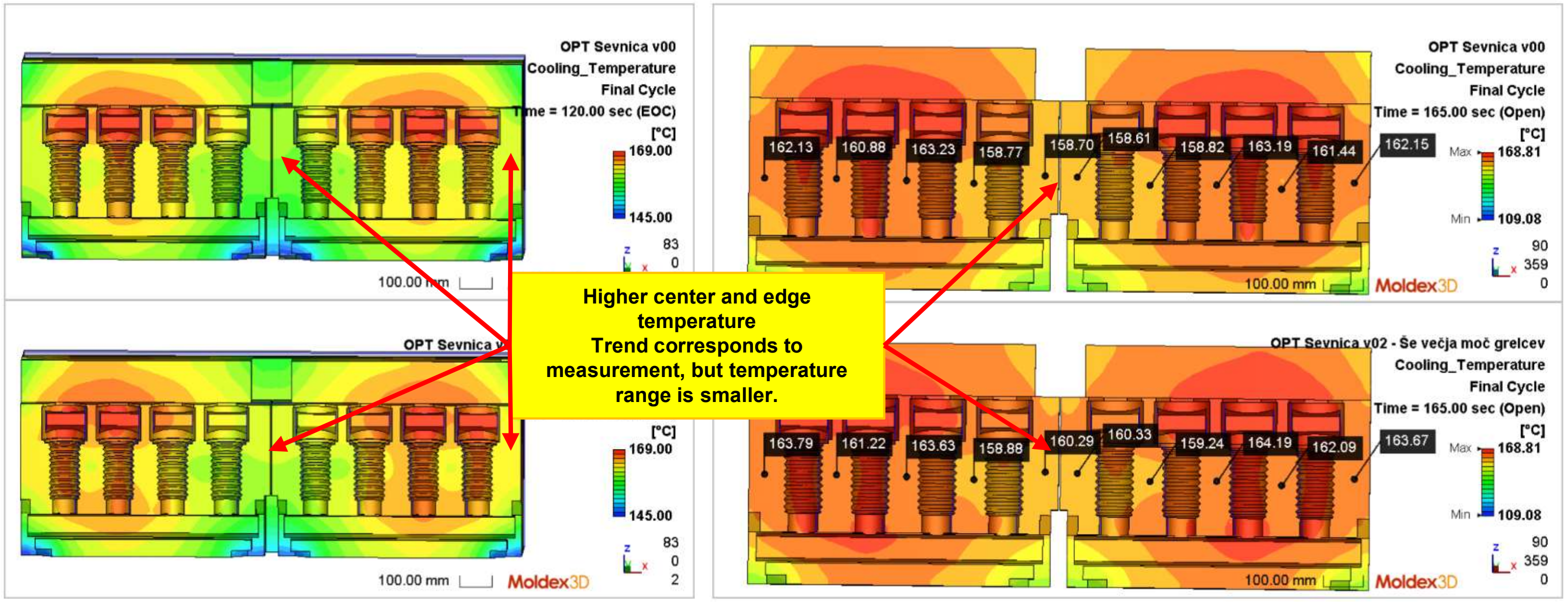
First Heating Design

Changed heater positions and increased power of heating rods at mold edges

Optimized Design

Upper Cavity Plate

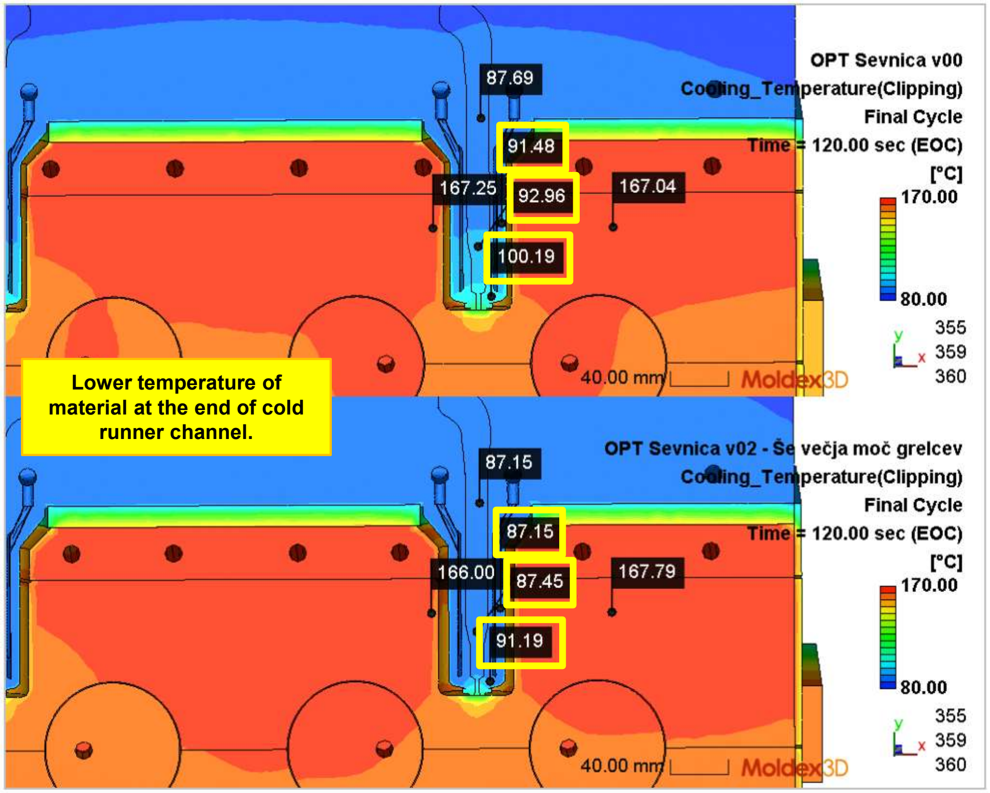
Lower Cavity Plate

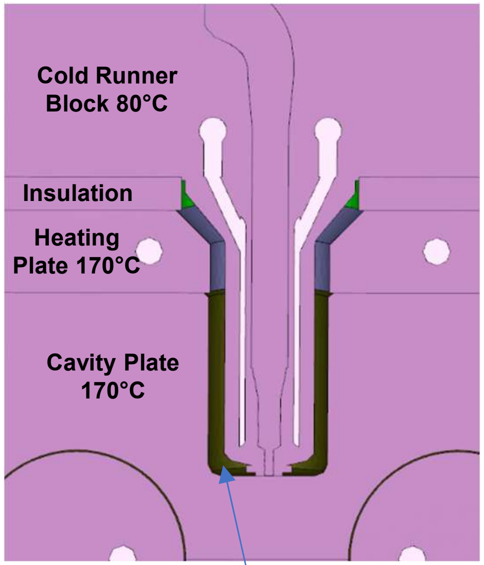


# Mold Heating Simulation

First Heating Design

Optimized Design




Increased air gap at cooling channel sprue

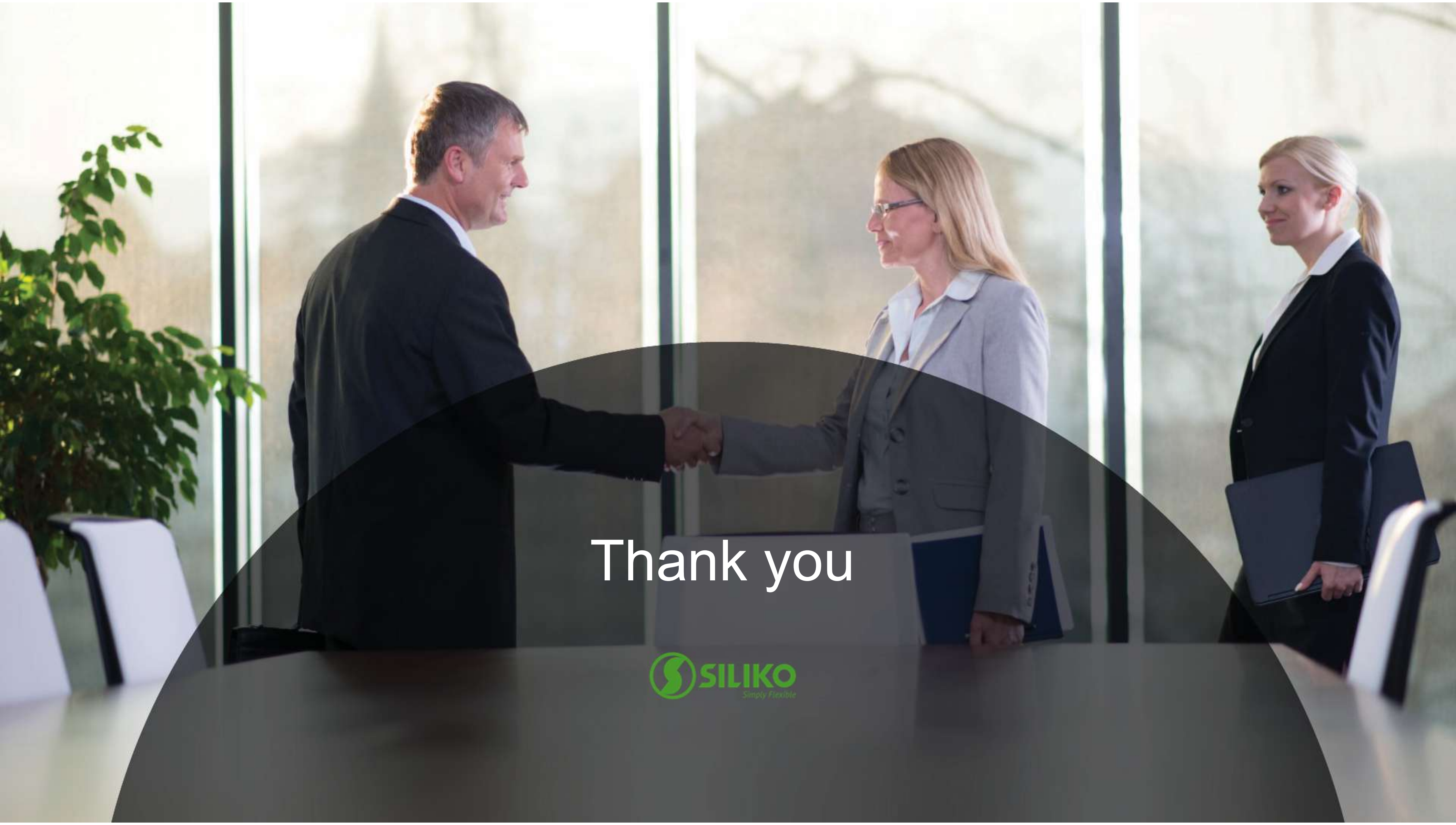
# Conclusions

Moldex3D simulations were used to validate and optimize the tool in all production stages:

- Validate current mold design
- Correct viscosity measurement of our rubber material
- Use pressure on core from injection molding simulation for FEM simulations in Abaqus
- Optimize Cold Runner channel with HRS simulation
- Improve mold tempering and reduce temperature differences in mold

- New tool is already running for roughly 1 year

- Overall scrap was reduced from ~10% down below 1%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