PART B:
Thermal and Rheological Design of Thermoset Molds

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Contents

- ISK GmbH
- Demands on Mold Tempering
- Simulation of Mold Tempering
- Simulation of Cavity Filling
- Examples
ISK GmbH

- Established 1996 as a Spin-Off from the University “Fachhochschule Südwestfalen” in Iserlohn / Germany
- 10 employees, 2 counselors, students
- Our customers: automotive, electrical engineering, medical engineering, household appliances
- Focus:
  - product development
  - mold design (CAE)
  - process optimization
  - research and development
  - industry projects
  - advanced trainings
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Demands on Mold Tempering

„Theory“

Technical quality of molded parts as a result of constant temperatures in the mold

Economical cycle times by fast heat supply into the cavity filled with cold resin

Main task of mold tempering
Demands on Mold Tempering

„Practice“

heating time
Rule of thumb: 25 W/kg steel

Mold functions
Inserts, runners, sliders, venting, parting lines, ejectors, costs

Main task of mold tempering
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How do we start?

Heat Balance on Mold:

\[ \dot{Q}_H = \dot{Q}_L + \dot{Q}_K + \dot{Q}_{Str} + \dot{Q}_F - \dot{Q}_{Exo} \]

Heat flows:

- \( \dot{Q}_H \): needed heating
- \( \dot{Q}_L \): conduction
- \( \dot{Q}_K \): convection
- \( \dot{Q}_{Str} \): radiation
- \( \dot{Q}_F \): “cold” thermoset
- \( \dot{Q}_{Exo} \): exothermic reaction

- How much energy for heating up?
- How much energy for production?
- Where to put the heat cartridges?
- Where to put the temperature sensors?
Heat Balance on Mold: one example for a useful solution

for heating up: frame heater

for production: heat cartridges
Thermal simulation: a simple example
Thermal simulation:

Poor design: two circuits

better design: four circuits
Thermal simulation

Poor design: 2 circuits  

better design: 4 circuits

Temperatures after heating up
Thermal simulation

best design: 4 elektrical circuits; plus oil heating circuits around the cavities

Temperatures after heating up
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Rheological simulation: Flow behavior of thermosets
Rheological simulation: Viscosity/Cure behavior of thermosets

a: viscosity decrease by temperature
b: viscosity increase by cross linking
c: viscosity curve of thermoset moulding materials

\[a + b = c\]
The viscosity data of the material is measured in a Rubber Capillary Rheometer.
The curing data of the material is measured by Super Sonic.
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Example: Electric Motor over molding by thermoset

Advantages of thermosets vs. thermoplastics:
- lower processing temperature
- lower processing pressure
- lower shrinkage
- better electrical isolation
- higher conductivity
- water tightness
• Heating of mold

• Filling of mold

• Curing time
- Heating of mold
- Filling of mold
- Curing time
Example: Electric Motor / Heating of mold

- Heating of movable side with in one hour
• Heating of mold

• Filling of mold

• Curing time
Example: Electric Motor / Filling

Result:

- Tracers are theoretical particles without mass, which allow a look on the things which happens behind the flow front.
Example: Electric Motor / Filling

Result:
• Pressure inside cavity by filling
Example: Electric Motor / Filling

Result:

- Areas where the state of curing after filling is more than 35%.
- Precuring of resin was 30%.
- No problems by curing while filling.
Example: Electric Motor / Filling

Result:

- Orientation of glass fiber. Degrees by color, direction by strings.
• Heating of mold
• Filling of mold
• Curing time
Example: Electric Motor / Curing

Result:

- Temperatures in resin and overmolded electrical devices during curing time
Example: COR – Compressor for air

Demands:
• Diameter 115 mm
• Tolerances in friction surface ± 0.02 mm
• Temperatures -25 – 120 °C
• Rotations 8000 U/min
• Lifetime 8000 hours
• Friction speed 6.4 m/s
• Surface pressure 150 N/mm²
• No oil or grease
Example: COR – Compressor

Wave rotor 2 K-Technology: compensation of shrinkage by thin cover layer => tolerances in range of +- 0,02 mm
Example: COR – Compressor:

Filling of second component:
=> no weld lines friction surface
=> no air traps

Measurement of part:
=> tolerances in range of  ± 0,02 mm
Conclusion:

Simulation of thermoset injection molding is possible. MOMENTIVE and ISK know what is needed, how to do it, and what we can get from it. So we have a powerful tool to improve:

- Number, capacity and position of heat cartridges
- Number and position of thermo couples
- Heating time of mold
- Filling of cavity, position of weldlines, pressure profiles, orientation of fibers
- Pressure and temperature on over molded devices by injection and while curing time
- Curing rate in cavity

So we can find problems, improve part and mold design before building the mold.

In the end it helps our customers save money and time!!!
Thank you very much for your attention!

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