Glass bottle forming process modeled in STAR-CCM+

Presented by:
Ferrari Simone
Structural and Fluid Dynamic Simulation Department
R&D Bottero Group

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Company profile

Italy
- Cuneo – (Headquarter)
- Trana
- Vicenza
- Treviso
- Pesaro

France
- St. Jeannet

Germany
- Grevenbroich
- Donauwörth

United Kingdom
- Rochdale
Bottero business and products

Business and products

- Hollow Glass
- Flat Glass
- Special trailers
  COMETTO industries
Hollow Glass

Offers a complete range for glass forming from fore-hearths to lehr

- Glass Conditioning
- Gob Forming
- Container Forming
- Ware Handling
Focus on Hollow Glass Division

Glass Conditioning

Gob Forming

Container Forming
Press & Blow process

1. The gob is guided into a blank mold
2. A plunger rises from the neck side and presses the gob forming the “Parison”
3. The mold opens and the partially formed container is released and inverted through 180 degrees
4. The container is transferred to the blow mold
5. Air is injected to blow the container into shape
6. Finished container
Bottero E-MOC

E-MOC Project

Blank and Mold Mechanism

Innovation in glass industry

Top mounted
Parallel Molds motion
Retrofittable
IS mold compatible

360° Axial and Radial Cooling

Bottero Glass Technologies
Glass Viscosity vs. T

- Elastic Solid
- Newtonian Liquid
- Viscoelastic transition

- Strain point: $10^{14.5}$ P
- Annealing point: $10^{13.0}$ P
- Softening point: $10^{7.63}$ P
- Working point: $10^4$ P

- Temperature (°C)
- Log$_e$ $\eta$ (pascal-seconds)

- Melting
- Forming
- Glass
Glass Bottle Forming

IR Thermo-Measurement

Forming steps

Simulation Steps

Step 1
Blank Side
Parison Forming

Step 2
Invert Mechanism
Reheating

Step 3
Blow Side
Stretching

Step 4
Blow Side
Bottle Forming
**Step 1) Blank Side – Parison Forming**

**Conjugate Heat Transfer Simulation:**
- Input: T Glass Gob
- Conduction and Radiation
- Physical Material Properties
- Unsteady: Time = Machine Timing

**Equipment Thermal Images**

**Volume Temperature Distribution**

Steady State Simulation
Step 1) Blank Side – Parison Forming
Step 2) Invert Mechanism – Reheating

Conjugate Heat Transfer Simulation:

- T Glass from Step 1
- Air Convection: T Air
- Conduction and Radiation
- Unsteady: Time = Machine Timing
Step 2) Invert Mechanism – Reheating

From Blank Side...

Rotation 180°

... to Blow Side

Parison surface Temperature

Ready to stretch…
Step 3) Blow Side – Stretching

VOF Simulation 3D

- 2 Phases: Glass and Air
- Conduction and Air Convection
- Gravity
- Unsteady: Time = Machine Timing

Input:
3D Temperature Distribution from the Reheating Step

Input:
Viscosity (T)
Step 3) Blow Side – Stretching

Physical Interpretation

Gravity, Conduction, Temperature, Viscosity…
Step 3) Blow Side – Stretching

Stretching extremely depends on:

- Parison Design
- Process Variables (e.g. Molten Glass T, Molds Contact time)
Step 4) Blow Side – Bottle Forming

**VOF Simulation**

- Blow Pressure
- Vacuum Pressure
- Unsteady: Time = Machine Timing
Step 4) Blow Side – Bottle Forming
Final Bottle Results

**Thickness Profile**

- Compromise between structural properties and bottle weight
- Stretching is the Key-Step
Conclusions

• Simulation is based on physical parameters in both thermal and dynamic properties

• The VOF model handles glass viscosity from liquid (100 P) to solid ($10^9$ P) with high time-steps

• The simulation variables are the machine settings (e.g. cycle timing, molten glass $T$)

• Application cases:
  - Parison Design to reduce the trials on molds and on machines
  - Effects of non-idealities on process variables

Next goal is the optimization of the entire forming process to reach faster production and lighter bottles
Thank you very much for your attention