Glass Industry 4.0: new technologies and developments

Changes out of the combination of physics and intelligent process control: thermal toughening as an example

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1. Presentation institute

2. Current technology status

3. Experiments, results and knowledge

4. New control value

6. Outlook
1. Presentation institute

TU Bergakademie Freiberg
Institute of ceramic, glass and construction material

• 1950 founded by Theodor Haase as Institute of Ceramic
• 1954 renaming in Institute of „Silikathüttenkunde“
• 1954 university lecture „Glashüttenkunde“ by Paul Beyersdorfer
• 1990 new formation as Institute of silicate technology
• 1995 the appointment of Dr.-Ing. Heiko Hessenkemper as professor of glass and enamel technology
• 2002 renaming in institute of ceramic, glass and construction materials
1. Presentation institute

Technology oriented industry-related research and consulting

**Fields of activity**
- Increasing durability of refractory material for glass melting facility
- Glass fibre reinforced materials
- Optimizing the glass melting process
- Surface treatment of glass
- New concepts for the thermal use solar energy
- Glass fibers
- Thermal and chemical toughening
- Foam glass

**Spin-offs**
- LubriGlass GmbH – Hall 12 / D03
  Surface Treatment Technology of Glass
- Ancorro GmbH - Hall 12 / C03
  Refractory and Melting Technologies
2. Current technology status

Industrial production of safety glass (facility example)

Influence variables

➢ Heating, temperature distribution
➢ Glass thickness, type of glass
➢ High use of energy because of insufficient measuring options

source: Tamglass; www.glaston.net
2. Current technology status

Schematic overview of the production process of safety glass

- Glass temperature (surface → linescan)
- Sampling control (destruction, fracture pattern DIN EN 12150-1)

Furnace temperature

Empirical management by sampling control

source: Glaströsch; www.glastroesch.ch
2. Current technology status

Glass properties

- Specification: DIN EN 12150-1; december 2015
  → First time regulation for 2 mm safety glass
- Increase the strength by compressive stress in the surface
- Fracture pattern caused by high tensile stress in the core
- Bending tensile strength minimum 120 MPa (DIN EN 1288-3:2000)
- Minimum count of fracture pattern [field (50±1) mm x (50±1) mm]

Extract from DIN EN 12150-1:2015

<table>
<thead>
<tr>
<th>Glasart</th>
<th>Nenndicke, d (mm)</th>
<th>Mindestanzahl an ausgezählten Bruchstücken</th>
<th>Mindestanzahl an ausgezählten Bruchstücken für Duschabtrennungen (siehe EN 14428)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alle Glasarten</td>
<td>2</td>
<td>15</td>
<td>nicht anwendbar</td>
</tr>
<tr>
<td>Alle Glasarten</td>
<td>3</td>
<td>15</td>
<td>40</td>
</tr>
<tr>
<td>Alle Glasarten</td>
<td>4 bis 12</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Alle Glasarten</td>
<td>15 bis 25</td>
<td>30</td>
<td>30</td>
</tr>
</tbody>
</table>
3. Experiments, results and knowledge

Measurement of glass – core temperature

**Experimental setup**

![Experimental setup image]

**Graph**

- **Tg**
- **T [°C]**
- **t [s]**
- **2 mm**
- **3 mm**
- **4 mm**

- **Measurement of glass – core temperature**
  - Temperature measurements at different times for glass samples of 2 mm, 3 mm, and 4 mm thickness.
3. Experiments, results and knowledge

Determination of the bending strength DIN EN 1288-5:2000

- 100 mm x 100 mm
- Thickness 1,85 mm
- Contact cooling

Strength [MPa]

- Float glass
- Safety glass
Measurement of stress - profile

Stress [MPa]

Glass thickness [mm]

-200 -150 -100 -50 0 50 100 150 200

0 0.5 1.0 1.5 2.0 2.5

Stress (contact cooling by IKGB)
Stress (air cooling by company)
3. Experiments, results and knowledge

Result of heating and the influence on the quality of thermal toughening

Measurement:
- Line scan directly after heating zone
- Direct relationship between homogeneous heating and fracture pattern

→ Important quality aspect

Real sample patterns for hand out.

Please return the samples after the presentation.
4. New control value

stress - temperature - time - correlation
in case of contact-cooling 2 mm soda-lime-glass

- stress - core (measured)
- stress - surface (measured)

* dilatometrically measured

temperature [°C]
stress [MPa]
time [s]

Tg
225 MPa
350 MPa
526°C - 557°C

stress - temperature - time - correlation
in case of contact-cooling 2 mm soda-lime-glass

- temperature - core (measured)
- temperature - surface (measured)

* dilatometrically measured
Schematic overview of the production process of safety glass

- **Glass temperature** (surface → linescan)

- **Sampling control** (destruction, fracture pattern DIN EN 12150-1)

- **Furnace temperature**

- **Empirical management by sampling control**

- **Loading** → **Heating** → **Cooling zone** → **Unloading**

source: Glaströsch; www.glastroesch.ch
4. New control value

Schematic overview of the production process of safety glass

Glass temperature (surface → linescan)

Sampling control (destruction, fracture pattern DIN EN 12150-1)

> 650 °C

Furnace temperature

Empirical management by sampling control

source: Glaströsch; www.glastroesch.ch
4. New control value

Schematic overview of the production process of safety glass

- Glass temperature (surface → linescan)
- Furnace temperature
- ΔT – measurement
  - Online cooling management
  - Quality assurance

Source: Glaströsch; www.glastroesch.ch
4. New control value

Key findings

ΔT as process variable
- Significant measurable value for process control
- Measurement adaptable to existing plants

Dependency of ΔT
- Thickness of glass
- Optical properties of glass (glass composition)
- Thermal conductivity of glass
- Cooling capacity
5. Outlook

Potential benefit

Essential shortening of process times
- By variation the cooling power
- Stop quenching after core temperature is lower than $T_g$
→ Saving energy and increasing throughput

Documentation for quality assurance
- Recording production data batch by batch
- Marking by individual silk screen
- Complete traceability

Further options
- Heating zone as bottle neck: new concepts
Thank you for your attention!