How the Industrial Revolution 4.0 will impact the Glass Industry

Image analysis part of ES 4.0 a key component towards Industry 4.0

GLASS SERVICE

January 2018
• Introduction GS
• What it means to be Industry 4.0
• Present Automation of Glass Production
• Furnace melting automated by Expert System III and 4.0
• GS Furnace Camera Identification Techniques
• Outlook
Glass Service Company Structure Worldwide
HQ Vsetin, Czech Republic (total approx 100 employees)

Glass Service USA
USA

Glass Service B.V.
The Netherlands

GS ACT
Slovakia

GS Russia
Russia

GS CHINA Ltd.
China

CERAMIC FORUM
Japan

Divisions of Glass Service Inc. :
- R&D
- GFM Furnace & Forehearth Simulation
- Glass Forming Simulation (GS ACT)
- Physical Modelling
- Advance Furnace Control ESIII
- Glass Defects Analysis
- Furnace data analysis & Inspections
- Furnace Engineering (spec. furnaces)
- Raw Materials Deliveries
- Burners (FlammaTec)
- Electric heating systems (F.I.C., UK)

THERMOJET
Brasil

HEM Engineering Consulting Company Ltd.

QUIIMICA QMASSO
France

KUK DONG INTERNATIONAL CO. LTD.

CHIEF UP INTERNATIONAL CORPORATION

Ms. Ann Shing LIEW

MULTIBUSINESS ALLIANCE CO., LTD.

CERACON ENGINEERS PVT. LTD.
1. Industrial revolution
   Introducing mechanical production machines powered by water and steam
   Industry 1.0
   End of the 18th century.

2. Industrial revolution
   Introducing mass production lines powered by electric energy
   Industry 2.0
   Beginning of the 20th century

3. Industrial revolution
   Through the use of electronics and IT further progression in autonomous production
   Industry 3.0
   Beginning of the 1970s

4. Industrial revolution
   Based on cyber-physical systems
   Industry 4.0
   Today

Level of complexity

Steam

Electricity

Computers

Cyber-Physical

Source: DFKI/Bauer IAO
Industry 4.0

A collective term for technologies and concepts of value chain organization. Based on the technological concepts of cyber-physical systems, the Internet of Things, it facilitates the vision of the Smart Factory.

Within the modular structured Smart Factories of Industry 4.0, cyber-physical systems monitor physical processes, create a virtual copy of the physical world and make decentralized decisions.

Over the Internet of Things, Cyber-physical systems communicate & cooperate with each other & humans in real time. Via the Internet of Services, both internal & cross-organizational services are offered & utilized by participants of the value chain.

- Builds on the Digital revolution
- Ubiquitous internet
- Smaller & powerful sensors
- Artificial Intelligence (AI)
- Machine Learning
- Labor & Energy Cost
Container Glass production

Adding value versus Process Control

Raw Material delivery
Mixing raw Material
Melting
Forming
Cooling
Quality Inspection
Packing

Level of automation

70% 90% 40% 60% 70% 95% 90%

Missing is automatic interpretation & interconnection of info exchange & feedback
New trends in early data processing (Xpar)

- Hot End IR-D Inspection (Xpar)
- XMIS xpar Process data analysis
- Or Swabbing Robots from eg Heye
Additional PC computer with OPC/DDE communication is only necessary HW addition to run ESIII. Original control equipment is used:
• Standard PID control loops are used for fast processes with single input/output variables (almost entire glass production line).

• Strong correlations between multiple input and output variables, incl. disturbance variables.

• GS ESIII state of the Art with about 5% of glass furnaces worldwide installed
MPC PROCESS MODELS EXAMPLES

<table>
<thead>
<tr>
<th>Gas</th>
<th>Boosting</th>
<th>Cullet Ratio</th>
<th>Pull</th>
<th>Bubbling</th>
</tr>
</thead>
</table>

[Graphs showing various process models for gas, boosting, cullet ratio, pull, and bubbling.]
Data sample 2 months

**ESIII™** was in control for 96% of the time

Data sampling 5 minutes

**ESIII™** setpoint zone ± 1°C for TBX control

<table>
<thead>
<tr>
<th>TBX tolerance</th>
<th>Operator</th>
<th><strong>ESIII™</strong> (old furnace)</th>
<th><strong>ESIII™</strong> (new furnace)</th>
</tr>
</thead>
<tbody>
<tr>
<td>± 2 °C</td>
<td>19.6%</td>
<td>64.8%</td>
<td>74.4%</td>
</tr>
<tr>
<td>± 4 °C</td>
<td>44.5%</td>
<td>91.6%</td>
<td>97.4%</td>
</tr>
</tbody>
</table>

Percentage of time TBX is within tolerances ± 2 °C and ± 4 °C during entire process control, including pull changes

Temperature stability Improvement, with energy savings 3%
• Present Trend of Industry 4.0 is motivating glass production for further automation of the glass melting process with less need of operators

• Part of the glass melting process such as the batch blanket spread in most furnaces and Glass Ribbon in Tin Float baths relies on operator visual regular inspection and his personal interpretation, followed by some decision making

• Even your TOP management understands that this cannot continue like this in the near future
• GS IP HD Visual & Infrared cam with electronic retraction system
• Monitoring
• Input to the ES 4.0

Picture 2: Camera(s) in furnace process control
ES III™ CAMERA - OVERVIEW

Measured data, statistics, analysis

Correspondence between the real world and the images

Image processing

Projection
Analyzing via picture archive easy long term video
• Bubblers position and size detection
• Batch flow direction and velocity
Analyzing via picture archive (easy) long term video
• Batch coverage / Batch periphery = Batch fragmentation

Picture 7: Container furnace measurement
• TCP/IP client integrated in ES IV
• Might be used separately also
• Viewing and history browsing pictures and videos
• Fast playing forward and backward possibility
• Multiple monitors and screens can be defined
New GS Augmented-Sens camera provides 2 video streams: regular vision information plus calibrated temperatures using Infrared parallel
Using IR camera for spread detection, improved detection

Picture 12: Ribbon Spread detection IR camera
Adding Intelligent “Vision” to the process in the near future

New (available) sensors
- Batch/Cullet Humidity
- LIBS (Laser Induced Breakdown Spectroscopy)
- Batch Line
- BTU
- Oxygen sensor
- Mass Spec (Fuel & Flue gas)
- Corrosion
- ESIII Feedback
- Oxygen sensor
- Viscosity sensor
- Gob Image
- Mould temp
- Thermo vision
- Online stress
- Defects Mass Spec

Existing standard sensors
- Temperature sensor
- Glass level sensor
- Disturbances
- Operators
- Neural Network
- Defect recognition
- ESIII Feedback
- Defects imaging
Final HMI process overview for advanced control, 2 melters and 6 forehearths example

<table>
<thead>
<tr>
<th>ES III Ready</th>
<th>ESH ON</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Furnace 1</strong></td>
<td>cross fired</td>
</tr>
<tr>
<td><strong>Furnace 2</strong></td>
<td>and fired</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Temperature</strong></th>
<th><strong>Preconditioning ON</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>SP 1525.0 °C</td>
<td>SP 1525.0 °C</td>
</tr>
<tr>
<td>US 1525.0 °C</td>
<td></td>
</tr>
<tr>
<td>T 140.7 tpd</td>
<td>New T 151.2 tpd</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Energy Management</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas ON</td>
</tr>
<tr>
<td>Max 3000 Nm³/h</td>
</tr>
<tr>
<td>Electrolyte ON</td>
</tr>
<tr>
<td>3304 kW</td>
</tr>
<tr>
<td>Max 4000 kW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Furnace 2</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>ES III Ready</strong></td>
</tr>
<tr>
<td>ESH ON</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Feeder 1.1</strong></th>
<th><strong>Feeder 1.2</strong></th>
<th><strong>Feeder 2.1</strong></th>
<th><strong>Feeder 2.2</strong></th>
<th><strong>Feeder 2.3</strong></th>
<th><strong>Feeder 2.4</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Actual Tonage</strong></td>
<td>86.3 tpd</td>
<td>54.4 tpd</td>
<td>81.4 tpd</td>
<td>111.4 tpd</td>
<td>99.4 tpd</td>
</tr>
<tr>
<td><strong>New Tonage</strong></td>
<td>76.8 tpd</td>
<td>64.4 tpd</td>
<td>76.2 tpd</td>
<td>113.0 tpd</td>
<td>71.0 tpd</td>
</tr>
<tr>
<td><strong>Jsh Change</strong></td>
<td>08.05 2016 17:15</td>
<td>11.07 2016 06:18</td>
<td>04.07 2016 07:00</td>
<td>25.06 2016 04:55</td>
<td>26.05 2016 09:30</td>
</tr>
<tr>
<td><strong>Preconditioning time</strong></td>
<td>44 min</td>
<td>60 min</td>
<td>45 min</td>
<td>50 min</td>
<td>20 min</td>
</tr>
<tr>
<td><strong>New Datum</strong></td>
<td>SP 1188 °C</td>
<td>SP 1200 °C</td>
<td>SP 1189 °C</td>
<td>SP 1195 °C</td>
<td>SP 1188 °C</td>
</tr>
</tbody>
</table>

**Start**

**Preconditioning**
**ESIII™ Advanced Process Control for Glass Production**

1. is a comprehensive supervisory advanced control tool – keeps existing PID loops
2. Models are made in most cases from historical database or step testing
3. is designed for glass melting and conditioning processes
4. stabilizes long and short term processes
5. provides full automatic control of glass production temperatures
6. brings consistent furnace operation to furnace – 24/7 independent on operator
7. uses energy sources efficient – saving energy and costs
8. stabilizes glass forming conditions – increase yield
9. optimizes combustion – emission control
10. stable furnace operation – impact on furnace lifetime
11. Customer can use just Runtime License or Developer License
ES/// References till mid 2017

GS EXPERT SYSTEM INSTALLATIONS WORLDWIDE: 1996 – 2017

Total number of GS ADVANCED CONTROL SYSTEMS: 185
THANK YOU FOR ATTENTION!

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