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Digitalisation of the glass melting process

Volker Scharnagl considers the possibilities and limitations of digitalisation of the glass container melting process, asking whether the '4.0 glass furnace' is possible.

Industry 4.0 is an approach to solve problems within production processes. Presently, the glass container industry faces the following challenges:

- Extremely high temperatures.
- An 'unexplored' chemical melting process.
- A huge number of dependencies for process results.
- Long reaction times.
- Collection of data more difficult than in other industries.
- Lack of experienced personnel.

Industry 4.0 means the implementation of self-learning and self-optimising systems. This means automation not only of the process but also of the process control. The basis behind the systems is data collected by sensors, stored in databases and evaluated by algorithms. Since there are already many sensors in the production process of glass melting, the main challenge is to connect the different production steps with control loops (eg batch house, furnace and inspection machines), in order to create sufficient glass quality at the best price (see figure 1).

Industry 4.0 features

Currently, glass production factories are in the automation state of 3.0. Requirements for Industry 4.0 are, among other things, process models, interlinkage of data and a solid database. Furthermore, automatic process control is not free from maintenance. Setpoints and sensors have to be adjusted and checked.

Priorities and restrictions for model predictive control (MPC) have to be set. For stable process operation, predictive maintenance is obligatory and includes inspection routines, exchange of wear parts and documentation.

Current automation state of the melting process

- The batch house is automated.
- The furnace is mostly automated (burner adjustment manually → actuators available).
- Forehearths are partially automated (chimneys adjustment manually → actuators available).
- IS machines are mostly automated (swabbing robots have become more common).
- Quality control is mostly automated (inspection machines have become more common, while seed count is often manual).
- Current control loops between the furnace and forehearth.
- Simple control loops like temperature regulation by natural gas amount or glass level by batch charging amount.
- Slightly advanced control loops incorporating more than one variable like natural gas amount and cooling power in forehearths in order to maintain optimum combustion.
- Model Predictive Control (MPC) considering most variables, a self-optimising system based on data and model of the furnace/forehearth.
- No exchange between different process steps like furnace and distributor/forehearth, eg lower energy input in order to reduce glass temperature in riser or vice-versa.

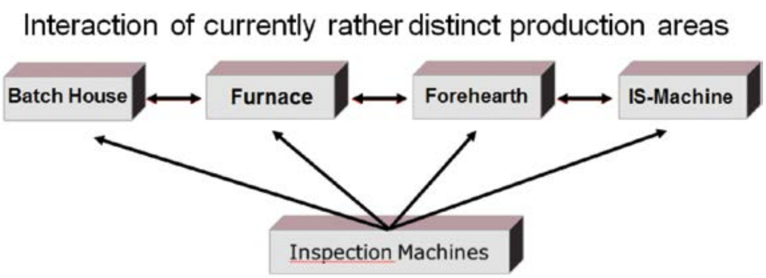

Figure 1: Interaction of current rather distinct production areas.

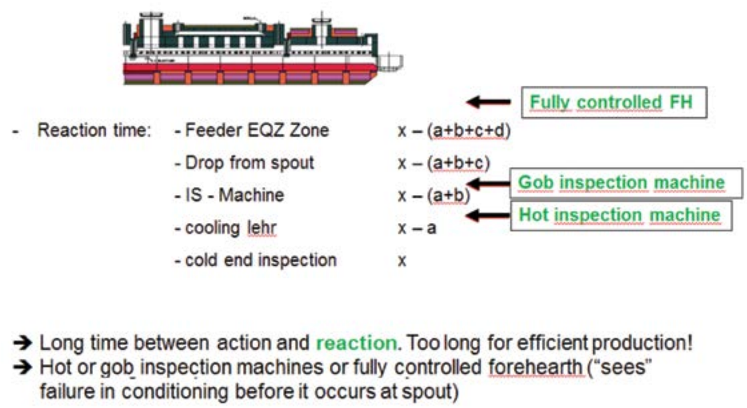

Figure 2: Reduction of rejects.

Possible control loops in the near future (without MPC)

- Cascade control loop, eg in forehearths: Adjustment of gob temperature, subsequent automatic adjustment of all zones of the forehearth.

Future goals

- Faster reaction time for less production loss.
- More precise regulation for optimum performance.
- Less manpower for more time for innovation.
- Same control strategy for the whole day for stability.

Solutions

- More control loops.
- Self-optimising systems.
- Interlinkage between single production units. ▸

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This article is based on a paper presented by Ulrich Imhof at the 42nd ASEAN Glass Conference in Yogyakarta, Indonesia, held in September 2018.

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Ulrich Imhof, who leads the container and speciality glass business unit at HORN, addresses the 42nd ASEAN Glass Conference.

Tools

- More sensors for better resolution?
- Better sensors for higher accuracy?
- Different sensors for additional information?
- More sophisticated control methods/algorithms?

A good example of a goal is to reduce rejects during production. In figure 2, the reaction time in relation to inspection method is shown. The optimum solution would be not to start the production of rejects, so the reaction does not depend on the results gained from inspection machines after production. If it was possible to foresee production failures by forehearth data, an increase of pack-to-melt ratio would be possible.

In order to improve control aspects, it is possible to apply on the one hand more, better and new sensors, resulting in higher costs. On the other hand, it would be possible to use more sophisticated control methods or connect available sensors to other parts of the production process (table 1).

Sensors that might be applied, for example, are redox or SO_x probes in glass, as well as a natural gas and flue gas analyser or a thermographic camera. Of course, all these sensors are currently too expensive in relation to the benefit realised but this might change due to additional benefits (eg increased pack-to-melt).

Information similar to redox probe is already available in some plants performing a colour measurement for flint glass. So again, the connection of currently distinct parts of the glass melting process might be an alternative.

Delegates at the 2018 ASEAN Glass conference in Yogyakarta, Indonesia.

Melting end	Batch house
Energy consumption	Batch humidity
	Cullet content
Foam on furnace	Sulphate/carbon amount
Inspection machine	**Batch house**
Colour	(de)colouring agent, redox
Inspection machine	**Furnace**
Glass quality	Energy consumption
Inspection machine	**Forehearth**
Bottle shape	Setpoint gob temperature

Table 1: Possible connections between currently distinct production steps.

The latest sensors for faster reaction time would be eg more direct thermocouples in glass or hot inspection machines, instead of cold inspection machines.

In order to improve automation of the process and enable self-optimising systems, innovative actuators have also to be applied, like automatic burner angle adjustment, motor-driven chimneys and residual oxygen measurement also at the forehearths.

Predictability of the glass melting process

Since glass melting also depends on uncertain factors like the weather and natural raw materials, prediction is quite difficult. Energy balance models are currently used for the design and evaluation of furnaces, distributors and forehearths. They are relatively simple but the information gained is also limited (eg forehearth homogeneity is not an output). To establish a totally working predictive model of a furnace or forehearths is quite time-consuming and needs a lot of data. Since every furnace is unique, every model has to be adjusted individually.

Cyber maintenance

Cyber maintenance is already performed for process control systems software. Furthermore, data is sent to furnace suppliers so they can decide whether maintenance is necessary (eg electrode pushing).

In the future, probably the control system suggests the order of a maintenance crew or even orders automatically when necessary.

Conclusion

Many industrial branches already use the benefits of Industry 4.0, so glass manufacturing companies can use existing experience and apply reliable technology. Ultimately, the fourth industrial revolution will most probably result in:

- More sensors for data collection.
- More actuators (robots) in order to be able to install more sensors.
- Other qualification needs for employees.
- Less physical work and more brainwork.
- Different company structures.
- Higher efficiency of production.

The glass industry has to be prepared for these tasks.

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