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Glassmaker employs the benefits of process control

Arc International's site near Lille, Northern France, operates glass furnaces for which energy is an important part of its budget. Model Based Predictive Control (MBPC) has proven to be an efficient technique for handling processes where the dynamics are heterogeneous and varied. François Famchon and Joël Cardon of Arc International* and Olivier Gerbi and Jacques Papon of Sherpa Engineering** report.

Arc International's production site in Arques, France hosts the research and development of the group where one of the targets is the optimisation of production working conditions. This optimisation includes energy savings.

The implementation described here is about the dynamic control of a feeder – part of the glass process. The feeder is a channel through which the glass flows out of the furnace and is distributed to the different forming machines (moulds, centrifuges etc).

It is crucial that the glass reaches the tools with the specified viscosity and therefore the right temperature. Since the feeder is the last stage of material processing, the targeted quality is the responsibility of the feeder (of its actuators, burners and coolers).

Requirements

Improvement is desired on two aspects: Dynamic control performance and reduced gas consumption.

Specified temperatures during the steady state are not difficult to achieve. However, as in most other places, shortening transition phases represent an important potential gain during production changeover.

The other objective concerns gas consumption. The effects of heating (gas flow rate) and cooling (air flow rate) on temperatures are heterogeneous in terms of dynamics (pure time delay and time constants).

This is why difficulties are experienced with regards to computation of co-ordinated actions. This has led operators (until now) to maintain a constant cooling amount in order to act dynamically only on the gas flow rate for controlling temperatures. The target is therefore to handle both actions in a coherent way, use them in an exclusive manner and particularly, to use the air flow only when cooling is necessary.

Added to the different dynamics between heating and cooling actions, these parameters vary with the production rate (glass flow rate). They may in fact double.

Control technology

The selected technology is based on the use of a dynamic model of the plant which is to be controlled: Model Based Predictive Control (MBPC). MBPC relies on the following principles:

- The use of a model of the process: This model is embedded in the control algorithm and makes possible the prediction of the behaviour of the process output(s).
- The definition of a future desired trajectory for each process output on which a target is defined (set point or zone control). The user defines each time response: It is the mean to specify the closed loop trajectory for each process output.
- The use of a solver algorithm. This performs the computation of the manipulated variables (actions) to be applied to the process (or to the set points of basic controllers) in such a way that the predicted behaviours fit with the specified future trajectory.

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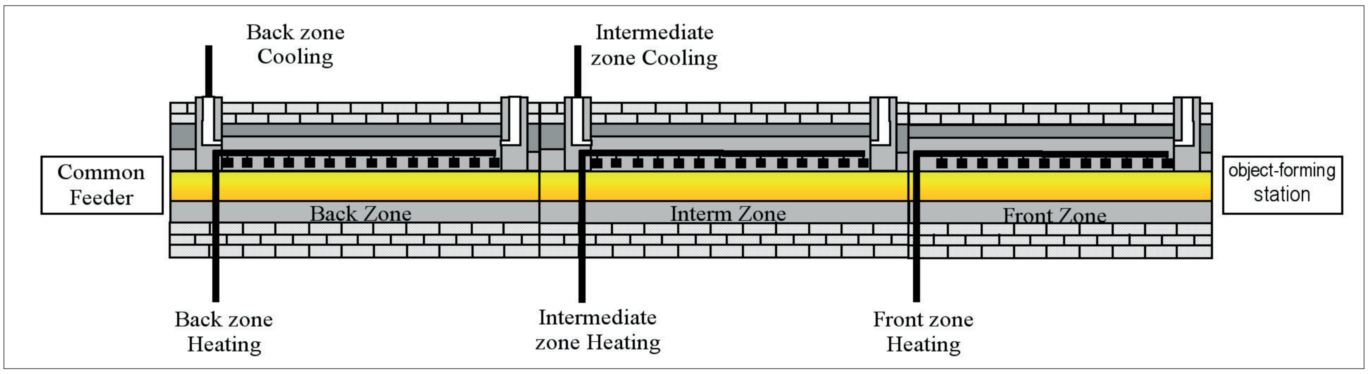

Fig 1. The feeder consists of three zones along which are spread 100 burners and equipment for adjusting cooling air flow rate.

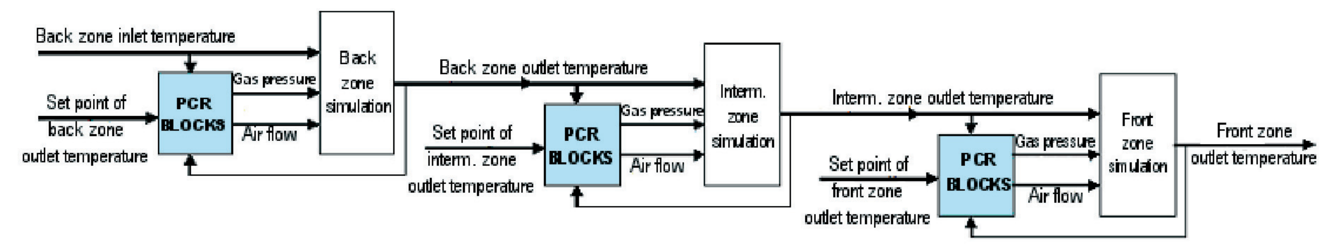

Fig 2. The control architecture consists of a cascade of three similar control structures. Each of them is composed of a 'Split Range' and 'Feed Forward' set.

The PCR software library belongs to this process control technology and is well adapted to 'diagonal' process architecture. The effects of the actions (heating and cooling) do not propagate against the glass flow. PCR was designed in order to be embedded easily into PLCs or DCS boards. The process control team at Sherpa Engineering performed this project with the PCR product through close collaboration with Arc International.

The efficiency of the split-range stems from two properties of the PCR module:

- The control models in the PCR split-range module are in line with the heterogeneous dynamics of the actuators.
- The inertia of the effects of the actions. The computation takes into account passed actions which continue to effect temperatures.

Project phases

An introduction to the methodology was provided for the site team. This was achieved through a light training session including some practice of the CAD tools attached to the PCR library. Thanks to this training, Arc International is now in a position to follow up the project and will be able to maintain the application after start-up.

Regarding the control aspect, the controller model is a 'black box' model (transfer function) and its parameters are estimated from recorded experiments. The plant tests consist of voluntary moves applied successively to the actuators of each feeder zone.

Considering the probable relationship between these parameters and the production rate, experiments were performed around three different operating rates.

The parameters of the models were identified (estimated) for each of the three zones of the feeder and for two operating rates of the furnace.

The models can be used for building a simulator of the whole system in closed loop, including three zones and the full control architecture based on PCR control blocks. That simulator is built in the MATLAB/SIMULINK environment on PC under Windows – an environment also used by the Arc team.

The control architecture consists of a cascade of three similar control structures. Each of them is composed of a 'Split Range' and 'Feed Forward' set as described in ***fig 2.***

In this environment, the user may specify and tune the control in order to find an acceptable trade-off between performance (closed loop time response) and robustness (capability of the controller to work correctly even if the process behaviour differs from the control model).

As an example, the tests performed on the closed loop simulator show good robustness when the time response varies with the production rate. Consequently, it is not necessary for the control model to follow-up the variations of the time response of the process. This was verified by experience after start-up.

The source code of the control software was embedded into the Siemens S7 PLC by the Arc team.

After systematic validation of integration, the PCR predictive control blocks were tested on the first zone of the feeder before being extended to the whole system.

Fig 3 shows an example of the first closed loop tests performed on the back zone of the feeder.

Performance evaluation

The improvements could be evaluated quickly thanks to fast appropriation of the new control by the operators. The improvements were of three main types:

- Energy savings: Manipulating, heating and cooling in a coherent way avoids simultaneous actions which are sources of calorie waste.
- Faster move back to steady state after production or rate changes.
- Repeatability of glass conditioning and improvement of yields.

The pay-out-time, estimated only from energy savings, is less than 10 months. ■

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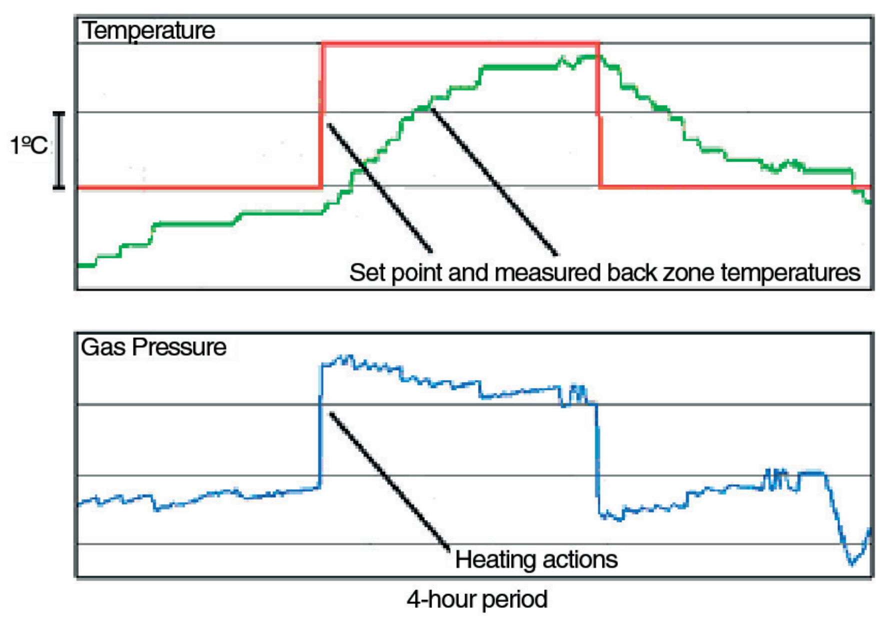

Fig 3. An example of the first closed loop tests performed on the back zone of the feeder.