The march in glass process control

The site of Arc International, close to Lille (in the North of France), runs glass furnaces for which energy is an important budget item. The Model Based Predictive Control (MBPC) turns out to be an efficient technique for handling a process whose dynamics are heterogeneous and varying.

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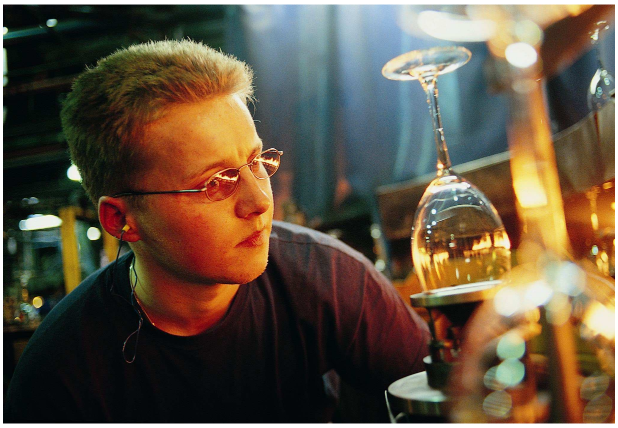
Scope of the application

Arc International employs 16,500 persons of which 8,500 in France. The Group, originally from Arques located in the Pas-de-Calais department, had a 1.4 billions euros turnover in 2006. The Group supplies table service items in more than 160 countries, among others with the brands Luminarc®, Mikasa®, Cristal d'Arques® Paris, Arcoroc®, Pyrex® [1] et Studio Nova®.

The production site at Arques hosts the R&D of the Group whose one of the targets is the optimization of the production working conditions. This optimization includes necessarily the energy savings.

[1] Pyrex ®, owned by Corning Inc, is exploited by Arc International Cookware SAS under an exclusive licence in Europe, Middle-East and Africa.



Description of the process

The implementation described here is about the dynamic control of a feeder qui is 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 gets to the tools with the specified viscosity, therefore with the right temperature. Since the feeder is the last stage of the material processing, the respect of the targeted quality is the responsibility of the feeder, i.e. the responsibility of its actuators, burners and coolers.

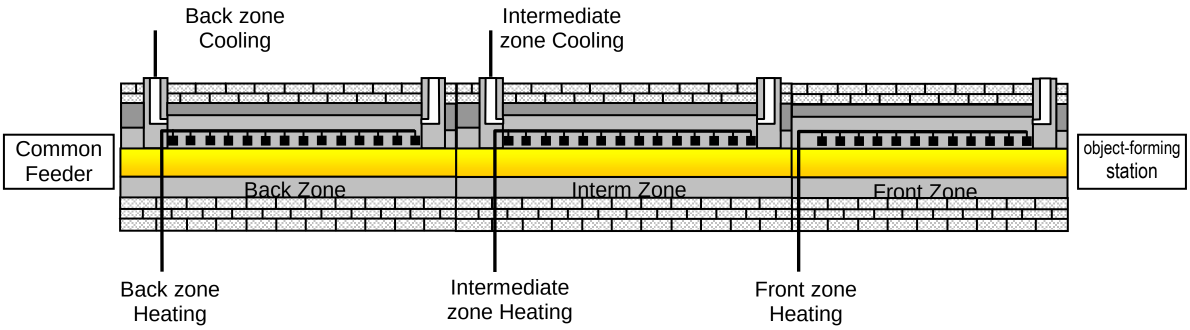


Figure 1

The feeder consists here of 3 zones along which are spread some one hundred burners and equipments for adjusting cooling air flowrate.

Requirements

The improvement is desired on two aspects: the dynamic control performances and the reduction of gas consumption.
The respect of the specified temperatures during steady state is not much difficult. However, like in most other places, shortening transition phases represents an important potential gain during production changeover.

The other objective concerns the gas consumption. The effects of heating (gas flow rate) and cooling (air flow rate) on the temperatures are heterogeneous in terms of dynamics (pure time delay and time constants).
This is a reason which makes difficult the computation of coordinated actions and lead the operators, up to now, to keeping a constant cooling amount in order to act dynamically only on the gas flow rate for controlling the 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.

Difficulties

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

Control technology

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

Model based predictive control 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 performing 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 the predicted behaviours fit with the specified future trajectory.

The PCR software library belongs to this Process Control technology and is well adapted to the "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 a tight collaboration with the team at Arc International.

Appropriate split-range

L'efficacité du split range tient ici à deux propriétés du bloc PCR :
The efficiency of the split-range comes from two properties of the PCR module:

- The controller 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 the passed actions which keep on having an effect on the temperatures.

Project phases

An introduction to the methodology made possible for the site team to get familiar with the principles here above through a light training session including some practice of the CAD tools attached to the PCR library. Thanks to this training, Arc International is in position to follow up the project and will be able to maintain the application after the 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 its 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, environment also used by the Arc team.
The control architecture consists of a cascade of three similar control structures, each of them composed of a ‘Split Range’ and ‘Feed Forward’ sets as described below.

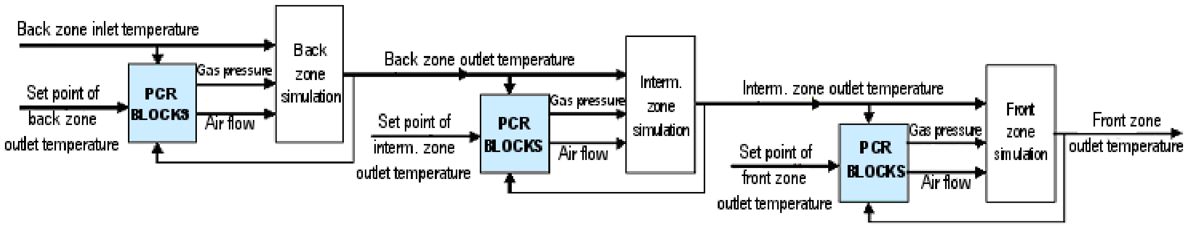


Figure 2

In this environment, the user may specify and tune the control in order to find an acceptable trade-off between performances (closed loop time response) and robustness (capability for the controller to work correctly even if the process behaviour gets different from the controller model).
As an example, the tests performed on the closed loop simulator showed a good robustness when the time response varies with the production rate. A consequence is that it does not look necessary, for the controller model, to follow-up the variations of the time response of the process. This was verified by the experience after the start-up.

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

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

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

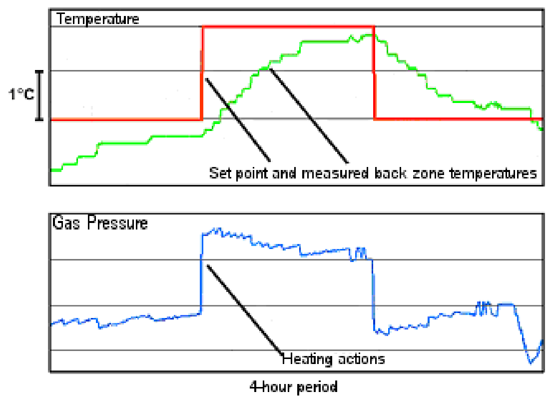


Figure 3

Evaluation of performances

The improvements could be evaluated soon thanks to a fast appropriation of the new control by the operators.

The improvements are of three main types:

- Energy savings: manipulating heating and cooling in a coherent way avoids simultaneous actions which were sources of calories wastes.
- Faster move back to steady state after production or rate changes. (figure 4)
- Repeatability of the glass conditionning, improvement of the yields.

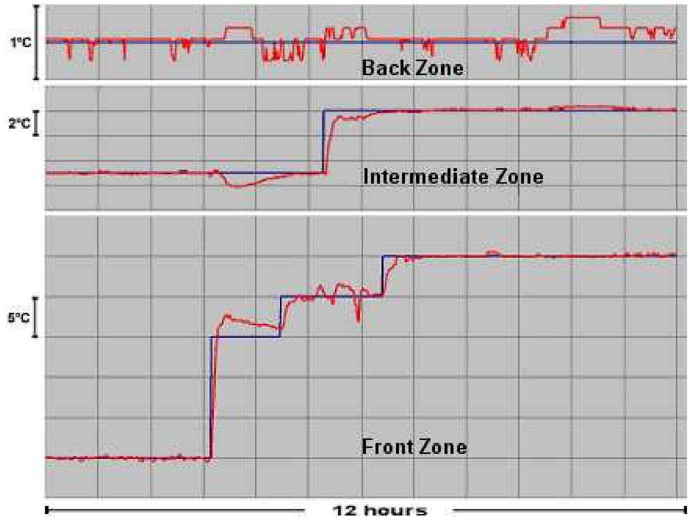


Figure 4

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

Other feeders of the site can easily take benefit of the same control architecture thanks to their instrumentation and control system.

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