Advanced feeder and furnace control, a pragmatic approach

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Introduction

Advanced control is a very powerful tool to increase glass production in furnaces and forehearth. This paper describes a method of how advanced control has been applied on a distributor and 2 forehearth systems at a container glass furnace of BSN glass pack. The real practical experience of advanced control is shown and explained. This new software concept called Expert System II, allows to build knowledge and empirical predictive models about the process into an interactive control strategy. It is the authors' believe that this concept can contribute to further improvement of glass production efficiency. Following text will review control tasks of the forehearth at BSN glass pack in Leerdam, discuss main control technologies, explain advanced control concept and present practical examples of its application.

1.EXISTING FOREHEARTH CONTROL

PID is a fundamental technology used to control production process. It is typically used to control primary single input single output loops for gas and air flows, levels or temperatures. The control action of PID controller, also called control output, is described using 3 tuning constants: P – proportional, I – integral and D – derivation constant. Usually behaviour of PID results in constant oscillation around SP (Setpoint) in typical PID deregulation. Reason for limited ability of PID to provide stable and very accurate control is caused by long dead time, interacting dynamics and non-linearity of processes in glass furnaces and forehearth systems.

A forehearth represents a great challenge for control, because it requires coordination of several zones including heating on sides and cooling of middle part of glass surface. At the same time temperature of glass has to be decreased from throat temperature to forming temperature. Thermal homogeneity just before the spout is very important for successful forming process. It is difficult to control because there is a stream of hot glass in the middle of the forehearth due to the fast parabolic flow in the central plane. At the same time there is a cold glass in the bottom corners of the channel caused by combination of the heat losses through the bottom and sidewalls of the channel.

Current control uses single zone control where PID loop maintains manually set temperature by operator. Ratio between heating and cooling is linear or often only heating or only cooling is used inside the PID loop.

In the forehearth with about 3 zones a combination of local zone SP´s and appropriate ratios of heating/cooling have to be tuned in order to bring thermal homogeneity for the forming process. It is possible, however the tuning of the forehearth is difficult and requires very good experience and constant attention by a good operator. As a result of human factor and unknown disturbances majority of all forehearths are tuned only occasionally just after start up and then thermal gradient drifts depending on ageing of the equipment and skills of operator.

2. ADVANCED CONTROL CONCEPT – EXPERT SYSTEM

2.1. Control Algorithm

In order to overcome difficulties of PID control new control algorithm has to satisfy several key conditions:

- Solve situation when dead time T_D (dead time) is long
- Predict functionality (proportion) of the process
- Allow to combine several inputs and outputs in one control action
- Optimise control action
- Solve situation when system is non-linear and its functionality is very difficult to be determined by numerical model
- Use logical information about physics and chemistry of the process

New control algorithm has several important features:

Multi Input – Multi Output (MIMO)
This concept allows to specify not only one SP which is influenced by one parameter (for example maximal temperature in the melter and total fuel flow), however several SP's can be defined being influenced by several other parameters. The temperature profile in the forehearth can be defined as several set points together with gob temperature. The SP´s will then be kept by combined action of all heating/cooling zones in a forehearth.

Model-Based Predictive Control (MPC)
Fundamental part of this control is dynamic numerical model of the process. The model can be expressed as time transient function, which has typical shape as is shown on Fig. 1.

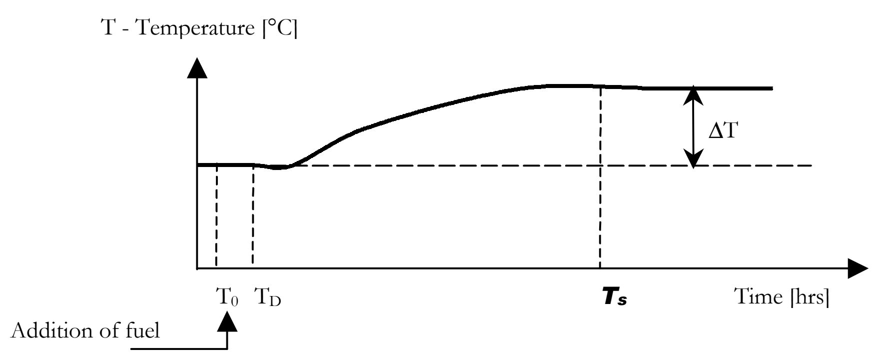

Fig. 1 Example of time transient function of temperature dependence on thestep increase of fuel flow. T_D is dead time or time delay, ΔT is gain of temperature, T_s is time to set new equilibrium

Above mentioned time transient function can be described as mathematical formula for dynamic change of temperature T: **T = F (Time, Fuel)** allowing to calculate temperature at

any time as a function of fuel addition or removal. Such function is called model and can be used for Predictive Control.
In both cases model describes outputs (e.g. temperatures, flows or levels) based on a set of input (e.g. gases, valve openings) parameters. The model knows what will happen with temperatures based on past changes in gasses. The control problem is solved using model inversion. The controller has to know what is the optimal setting on gasses to get stable temperatures. So it knows current or predicted temperatures and the question is what is the gas setting.

In general the controller will solve a dynamic optimisation problem to find the control plan (what are the movements on gasses) that will minimise the difference between predicted (future temperatures) and desired behaviour across some time horizon into the future.

2.2. Forehearth Control

The incoming gob temperature should be as stable as possible over time, but also as homogeneous as possible. To achieve this goal, better control over the forehearth, which conditions the glass and delivers it to the forming process, is needed. Next to this the container glass industry has to switch quite frequently between products. It is of high interest to reach stable and good quality for the new product as fast as possible. This requires usually lots of manual tuning on several parameters at the same time. Also when there are more than 1 forehearth it is important that a job change on 1 feeder does not affect the production on another feeder. The following figure shows examples of practical models derived at BSN glass pack, see figure 2. This shows that spout heating has no effect on bottom!

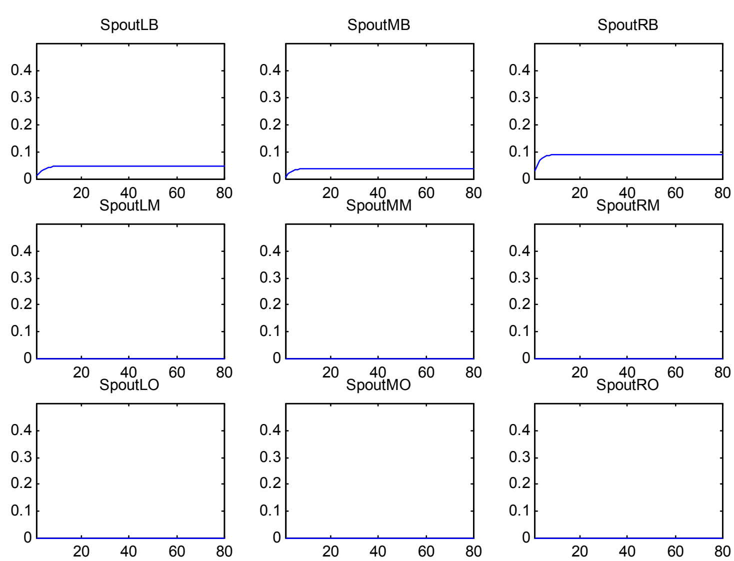

Fig. 2 Example of MPC models of spout heating showing effect of increased heating in last zone on 9 grid, only affect on top temperatures. Eg. 1% results in about +0.05 till 0.1 ºC.

3. CONCLUSIONS

The following list gives some overview about what can be expected:

- Stable temperature for glass delivery to forming (even bottom temperature)
- Increased homogeneity and again consistency to the forming process
- Reduced time and production losses for product changes up to factor 2
- Fuel savings by continuous optimised heat/cool input distribution
- Direct control over major outputs and not intermediate variables

To give some hard numbers from installed furnace/forehearth applications we have seen for instance energy savings up to around 5-10%, improved yield in range of 0.2-2%, which means payback times are reasonable short. The other effect is the increased insight and helpful tool for the operators. The presentation will show more practical details from the BSN glass pack installation.