Minimising annealing costs

Henning Katte explains how the costs associated with annealing can be reduced by the automatic and objective measurement of residual stresses

When container glass is formed, strong mechanical forces are generated in the glass due to the fast cooling rate. These must be reduced in the annealing lehr by defined heating up and slow cooling down. The energy consumption necessary for this can be clearly reduced by the selective optimisation of the annealing lehr settings.

To achieve the necessary stability for further processing, glass containers in the IS machine are cooled from around 1200°C (gob temperature) to around 600°C. Mechanical stresses in the glass are caused because of the inhomogeneous temperature distribution, which without further treatment would lead to glass breakage, even under the lowest mechanical or thermal loading.

OPERATING THE ANNEALING LEHR

Annealing of the glass is only possible between the annealing point and strain point, as the glass still has sufficiently low viscosity (log(η) = 13 to 14.5 dPas) in this range to facilitate relaxation. As thin-walled glass in particular is cooled down further during transport from the IS machine to the annealing lehr (to around 450-550°C), the glass must be initially heated in the lehr to approximately 550°C and held at this temperature level for a certain time. The glass is then cooled down slowly to the out-feed temperature of around 120-140°C. (Subsequent cold-end coating requires a minimum temperature in this range.) The containers are then further cooled to 30-40°C on the out-feed conveyor.

For the same chemical glass composition, the dwell times and temperatures depend mainly on the infeed temperature, the article weight, the glass thickness and the throughput. Thus the process time can vary strongly according to article, e.g. from around 20 minutes for a beer bottle to around 60 minutes for a champagne bottle, and so

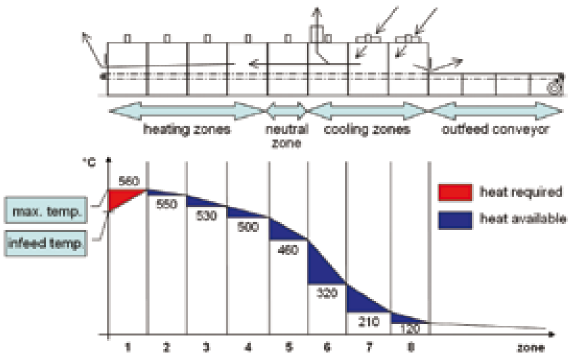

FIGURE 1: SCHEMATIC REPRESENTATION OF AN ANNEALING LEHR WITH EIGHT ZONES, DRIFT CONTROL AND COOLING CURVE *(IMAGE COURTESY OF PENNEKAMP)*

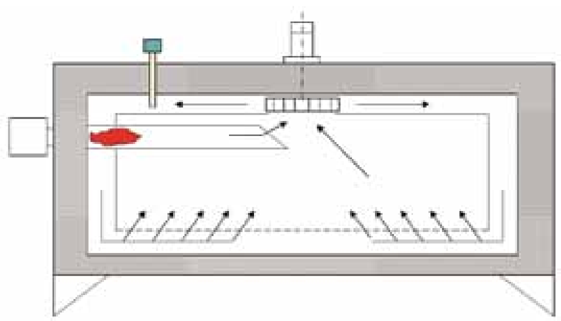

FIGURE 2: CROSS-SECTION THROUGH A HEATING ZONE – THE AIR HEATED BY A GAS BURNER IS DISTRIBUTED HOMOGENEOUSLY BY AIR RECIRCULATION *(IMAGE COURTESY OF PENNEKAMP)*

FIGURE 3: THE STRAINMATIC M2 POLARIMETER SYSTEM IS FOR AUTOMATIC AND OBJECTIVE MEASUREMENT OF RESIDUAL STRESSES IN CONTAINER GLASS ITEMS

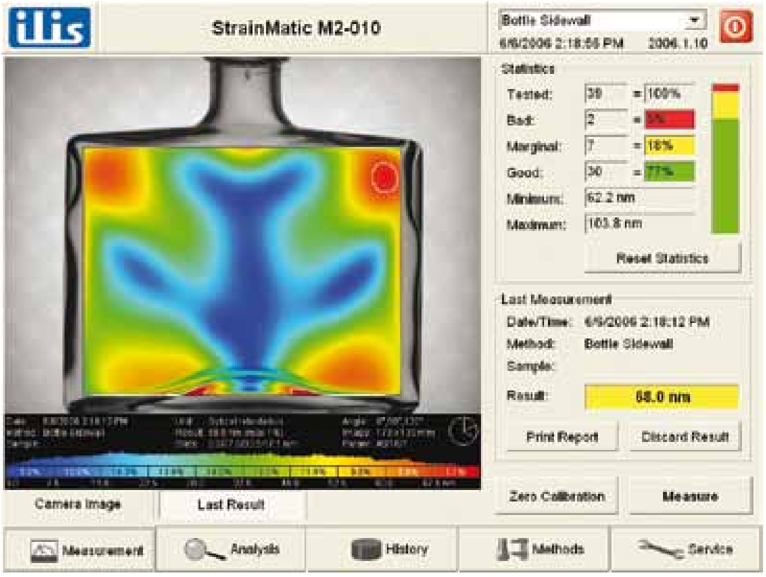

FIGURE 4: THE STRAINMATIC'S OPERATOR INTERFACE WITH MEASURING RESULT

does the energy consumption (gas or electricity).

Figure 1 shows the schematic construction of an annealing lehr and a typical temperature curve, and Figure 2 shows the cross-section through a heating zone. The containers are heated up from below in a recirculation heating system; it is important that the air flow is set as homogeneously as possible over the width of the lehr to guarantee uniform relaxation. As this condition can be achieved only approximately, the containers often have a different residual stress level at the edge of the conveyor in comparison with the middle. The infeed temperatures may also differ from each other according to IS station because of different mould temperatures and different lengths of transport path. Temperature differences at the in-feed ranging from 50-100°C are typical, which also leads to different residual stress levels.

STATEMENT OF THE PROBLEM

The goal of annealing lehr optimisation is to achieve a sufficient and homogeneous quality of relaxation with minimum energy consumption. As the optimum setting depends on the article, the temperature curve must be reset at every change of article. Accurate measurement of the residual stresses is not reliably possible with manually operated polariscopes or polarimeters. In ASTM C148-00, the measuring uncertainty of polariscopes is stated with a temper number of 1 (= 22.8 nm); at a typical measured value of temper number 2, the measuring uncertainty is therefore 50% of the measured value.

For this reason the annealing lehr is usually operated in a safe range so that the glass is relaxed more than is necessary, so more energy than necessary is often expended. A slight reduction of the setpoint temperatures – by 10°C, for instance – has a considerable effect on the heat supply required and therefore on the energy consumption.

A prerequisite for such limiting value optimisation is the presence of reliable measured values. Especially in coloured glass, due to the high dependence of the measured value on the operator who performs the measurement, manual measurement does not always give a reliable indication.

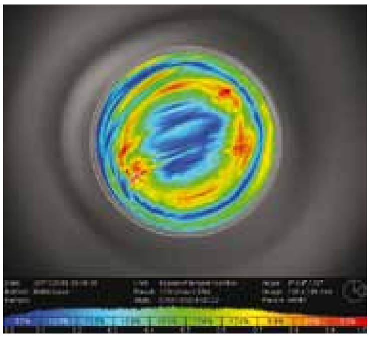

FIGURE 5: RESIDUAL STRESSES IN THE BASE OF A CONTAINER GLASS ITEM

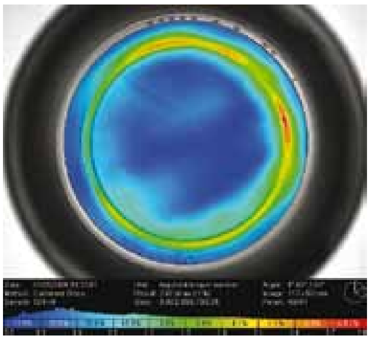

FIGURE 6: CHORD STRESSES IN THE BASE OF A CONTAINER GLASS ITEM

OBJECTIVE MEASUREMENT OF RESIDUAL STRESSES

The automatic StrainMatic polarimeter system has been developed to eliminate the influence of the operator on measurement results to obtain reliable measured values (see Figure 3). Measurement and evaluation are fully automatic – the operator only has to select the suitable programme (in which parameters such as bottle height and diameter are defined) and start the measurement. Figure 4 shows the measuring result on a bottle sidewall in false colour display (blue shows low values, green to yellow indicates medium and red is for high values). The area with the highest residual stress is detected automatically and compared with predefined limiting values.

With container glasses, usually only the base is measured as residual stresses are most critical there due to contact with the conveyor belt. To enable non-destructive measurement, the camera is automatically moved close to the neck finish for this purpose. Figure 6 shows a typical measuring result for the base of a food jar. The measured values are usually displayed in the unit of apparent or real temper number (according to ASTM C148).

Measurement with the StrainMatic is independent of the rotation angle of the sample in the measuring field. The reproducibility of the measurement is in the range of one-tenth of a temper number, which facilitates an accurate differentiation of the results depending on the position in the annealing lehr and in the IS machine. The high resolution of the measured values enables chord stresses in the glass to also be visualised, apart from the annealing stresses (see Figure 5).

RESULTS

Energy consumption could be reduced by consistent optimisation of the annealing lehr settings on the basis of accurate StrainMatic measurements; in production, the saving was 20-50% of the initial value. For an average gas consumption of 200 m^3 per day and lehr and an assumed gas price of €0.50/m^3, a 30% reduction gives a saving of nearly €11,000 a year. ■

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