Old Zebra Boards Give Way to New Roller-Wave Gauges.
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Years ago, the topic of roller wave measurement in architectural glass aroused little interest among glass manufacturers and fabricators. Windows were small enough to make distortion in reflected images hardly noticeable under most conditions and “roller wave” (a deformation caused by the soft glass passing over the conveyor rollers) was not a parameter that needed to be quantified. More recently, as larger glass became common in building exteriors, fabricators have been relying on so-called Zebra boards (Figure 1) to detect any major flatness defect as the lites of flat glass emerge from the tempering furnace.

With the advent of modern structures that feature large areas of glass and highly reflective “window walls,” optical distortion has become a real aesthetic concern to architects and civil engineers (Figure 2). In fact, glass with minimal roller wave distortion is now a sign of premium product quality to most building professionals (complete elimination of roller wave is unavoidable).

Unfortunately, many glassmakers still use Zebra boards, which rely on a totally subjective evaluation of the degree of roller wave distortion present in the glass. The result is glass “slipping through” that is not only out of specification for roller-wave, but inconsistent from batch to batch – and even lite to lite. Any architect will tell you that the only thing worse than bad roller wave is different roller wave between adjacent panes. The inconsistency only serves to magnify the undesirable distortion effect.

Figure 1. A “Zebra” board like the one shown above is often mounted at the exit of a tempering furnace or at an off-line inspection table. The operator looks at the reflection of the lines in the glass and notes any significant flatness defect as unacceptable roller-wave distortion.
Figure 2. The effects of roller-wave in architectural glass are most apparent when reflected images appear distorted, as in a “fun-house” mirror.

Taking the Measure of Roller-Wave.
Today, many glass manufacturers and fabricators recognize that subjective operator inspection with Zebra boards does not provide the reliability or repeatability required to keep roller-wave distortion within acceptable limits. Fortunately, there are several inexpensive and practical methods for accurately measuring roller wave in flat glass. These instruments are the basis for a formalized test method for roller-wave distortion (TD 01 03-00) developed by GANA (Glass Association of North America). If a roller-wave problem is revealed, the glassmaker can adjust furnace parameters (usually excessively high temperature or out-of-round rollers) to solve it.

In the GANA recommended test method, devices called roller-wave gauges are employed. These simple instruments are designed for off-line bench inspection of heat-strengthened or fully tempered glass. While available in several different models (Figures 3-5), they all operate on the same principle: measuring the maximum “peak-to-valley” depth and length of the wave so that the optical distortion, or lens effect, can be easily calculated (a conversion chart is supplied with the instrument).

The peak-to-valley depth and wavelength values are usually stated in inches or millimeters, while the optical distortion is expressed in millidiopters (mdpt). The length of the roller wave usually, but not always, corresponds to the circumference of the conveyor rollers. Measurements should not be taken closer than 6” from the edge to eliminate normal edge kink.
Figure 3. Model RWG flat-bottom roll wave gauge features a 12-inch (305mm) Delrin® low-friction base and an analog micrometer dial readout, available in inches or millimeters. Resolution is 0.01 mm.

Figure 4. Model RWG-D three-point contact gauge offers a higher degree of accuracy, with an adjustable length between contact points and digital micrometer readout with a resolution of 0.001 mm. A PC interface is optional.

Figure 5. Model RWG-LVDT is a three-point contact gauge fitted with an LVDT sensor and digital panel meter with a 0-5 V analog output. This model may also be ordered with a motorized trolley and reel assembly that moves the gauge across the glass.
Welcome to the Age of Automation.
Strainoptic Technologies has introduced a new, fully automated system for high-speed, on-line measurement of roll-wave optical distortion in tempered glass applications. Installed at the furnace exit, the LIN-2003 system (Figure 6) uses a unique, non-contact optical technology, combined with proprietary and user-friendly Windows-based software and a PC workstation, to provide fast, accurate and repeatable readings of roll wave distortion. Because the process is almost entirely automated, no special operator training or skills are required.

Figure 6. Strainoptic’s LIN-2003 system automatically measures optical distortion in millidiopters, and displays it on a PC screen, with trend graphs for shift, batch, and individual lite measurements, as well as peak-to-valley depth and average wavelength data.

The ability to measure roll-wave distortion automatically and quantitatively offers glass fabricators the following benefits:

- Assured optical quality for architects and end-users
- High reproducibility
- Reliable data for better control of furnace temperature and other operating parameters
- Improved productivity, with less waste and lower energy costs
- Optimal furnace and roller maintenance
- Avoidance of excessively high surface stress
- QC Documentation for factory and trade certification programs
- Compatibility with statistical control and factory automation programs

The LIN-2003 system is self-calibrating using a traceable standard and measures optical distortion levels from 0 to 500 mdpt, with a resolution of 1 mdpt. A specially designed optical sensor and high-speed data acquisition allows for continuous measurements at normal furnace speeds. The flatness of each lite is monitored as it emerges from the
furnace and distortion values are displayed on a PC monitor in graphical and numeric formats. The system can also be configured to provide a measurement for lite length and/or thickness.

The on-line sensor head is mounted on a lightweight rail, and easily moved from one furnace lane to another. For 100% inspection, additional sensors can be installed over multiple lanes. The system can also be configured as a portable installation for use with more than one furnace, and a table-mounted version is available for performing off-line inspections.

Summary
As glass manufacturers respond to the growing demands of architects, consumers, and standards organizations worldwide for tighter control of roll-wave distortion, they no longer have to rely on visual inspection methods. Instruments currently available make cost-effective quantitative measurement possible, either off-line with roll-wave gauges or on-line with automated PC-based equipment. By adding roller-wave measurement to their QC process, glassmakers can make better glass and provide an assurance to the glass customer of consistent product quality.

References:


