

Accurately measuring cord stresses in container glass

Henning Katte* discusses equipment that provides fast, reliable measurement of cord stresses in container glass, using automatic imaging polarimeters.



▲ Fig 1. Ring section of a beverage bottle in a petri dish filled with immersion liquid.

Cord stresses can have a strong impact on the strength of container glasses. High stresses near the glass surface in particular can increase the probability of breakage when the bottle is filled in the bottling factory or handled by the end user. Continuous and objective control of cord stresses is, therefore, an essential precondition to ensure high quality.

In an ideal world, glass is homogenous in composition, i.e. there are no local variations in the chemical structure.

But time and cost constraints in commercial glass production mean this cannot be achieved perfectly. The reasons can be manifold: incomplete molten batch components, insufficient dwell times in the furnace or improper temperature distributions in the forehearth, to name a few.

As a result of fluid dynamics, these compositional differences appear as thin streaks in glass, so-called cords, which have a different thermal expansion coefficient in comparison to the surrounding glass matrix. This causes strong mechanical stresses.

As the tensile strength of glass is ten times lower than the compressive strength, tension cords near the glass

surface have a negative influence on container stability. This can lead to costly complaints if the glass breakage happens after leaving the factory.

Conventional technique

Since the cord streaks are rarely visible in a normal polariscope used to check the annealing stress in accordance with ASTM C 148, a different method is used to measure cord stress quantitatively.

In accordance with ASTM C 978, ring sections are cut from the cylindrical part of the container and analysed with a polarising microscope. To avoid time-consuming polishing of the glass surfaces, the ring is immersed in a liquid that has a similar refractive index as the glass, eliminating light scattering (**Fig. 1**). The polarised light sent through the ring section changes its polarisation state when interacting with stresses in the glass. The resulting optical retardation can be quantified by using a Sénarmont analyser or Berek compensator attached to the microscope.

The method described is labour-intensive and time-consuming because the ring section has to be scanned visually through the microscope to search for the maximum stress value. The results also depend a great deal on the skill of the operator and are therefore subjective.

Gage R&R studies have shown that the reproducibility achievable in practice is below the desired level. This is particularly true for dark-coloured glasses, since the contrast is often insufficient to generate a reliable measurement. The manual measurement does not provide automatic documentation of the measurement process and measuring result. In case of a complaint, it is therefore hard to prove that the quality was good with respect to cord stresses and that the measurements

were performed correctly.

As a result of the complicated, time-consuming and error-prone measuring technique, many glass factories do not perform cord stress measurements on a regular basis or have outsourced the analysis to external laboratories. The sampling frequency is often also too low to detect production problems quickly and react accordingly.

Fully automatic measurement

To make cord stress measurement faster and more reliable, ilis has developed two instruments – the StrainMatic M4/120 and the StrainScope S4/20 cord testers. The StrainMatic series of imaging polarimeter systems was originally developed to measure residual stresses in glass objectively and without operator influence. Like an ordinary polarimeter, the StrainMatic utilises the well-known Sénarmont compensation method to determine stresses in glass. However, in contrast to a normal polarimeter, which delivers a result only for a single observed measuring spot, the StrainMatic creates a two-dimensional result for a whole area with high lateral resolution and high accuracy and repeatability.

The StrainMatic M4/120 cord tester (**Fig. 2**) is a special variant dedicated to measuring the stress distribution in ring sections with a diameter of up to 120mm.

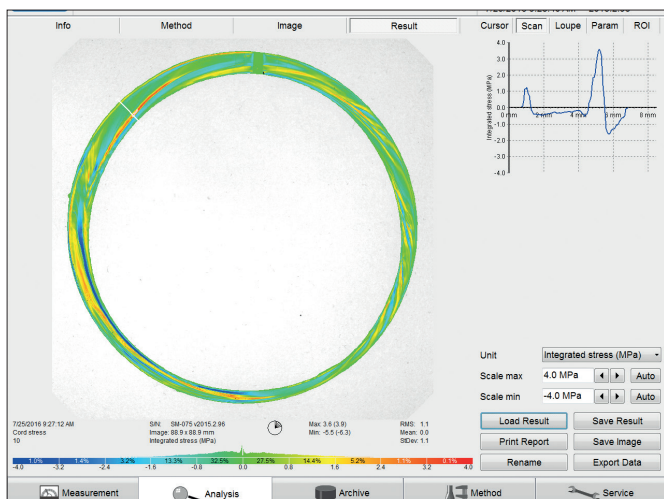
After placing the ring section into a petri dish filled with immersion liquid (e.g. dimethyl phthalate or simple vegetable oil), the operator only has to start the measurement. After less than a minute, the operator sees a colour-coded image showing the stress distribution for the whole ring section. The area

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◀ Fig 2. StrainMatic M4/120 cord tester for fully automatic measurement of cord stresses in ring sections of container glass.





▲ Fig 3. StrainMatic measurement result of a bottle ring with notable cord stress. Compression is shown in blue and tension in red. Neutral areas appear in green.

of maximum tension is identified, highlighted in the image and reported as a numeric value (Fig. 3). The results obtained can be stored in an integrated database and exported to production line monitoring systems.

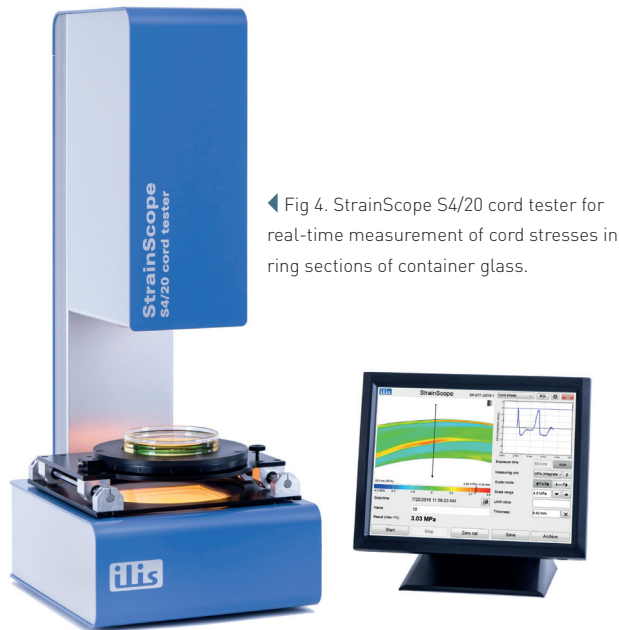
Semi-automatic measurement

As an alternative to the fully automatic measurement with the StrainMatic, ilis offers another solution to measure cord stresses based on its StrainScope series of real-time polarimeters. Many container glass manufacturers already use the StrainScope S3/180 to measure residual stresses in glass bottles and jars according to ASTM C 148 and other standards.

While the operator is still responsible for handling the bottle or jar during the measurement and selecting the region of interest, the measurement and evaluation is automatic and is carried out in real time. The operator gets a result immediately after positioning the bottle into the instrument's field of view and the colour-coded image makes it easy to assess the quality in a few seconds.

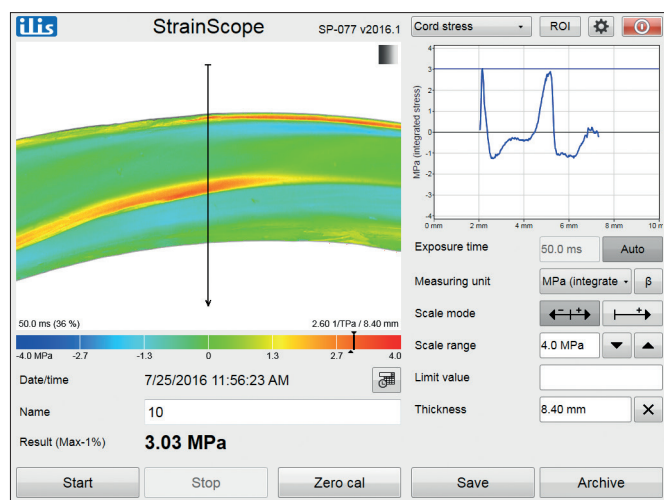
However, this instrument is not suitable for measuring cord stresses in ring sections, since it only has a spatial resolution of 0.25mm. This is not sufficient to detect cord streaks that can be much thinner. For this purpose ilis has developed the StrainScope S4/20 cord tester (Fig. 4), featuring a ten times higher resolution.

In contrast to the StrainMatic cord tester optics, which capture the whole ring section at once, the StrainScope cord tester's field of view covers only a portion of the ring section. Therefore, the operator has to scan the whole sample by rotating the petri dish containing the ring section. During this process, the software continuously shows the stress



◀ Fig 4. StrainScope S4/20 cord tester for real-time measurement of cord stresses in ring sections of container glass.

▶ Fig 5. Measurement result of the same bottle ring as seen with the StrainScope cord tester. The maximum tension value in MPa or psi is reported below the image.



profile over the wall thickness in a line chart and reports the maximum tension value along this line as a result value (Fig. 5). As with the StrainMatic, the results obtained can be stored and exported to other systems.

Comparability of results

While the result values obtained with the StrainMatic M4/120 cord tester and the StrainScope S4/20 cord tester are generally comparable, samples with high cord stresses often lead to higher values when analysed with a conventional polarising microscope.

This is due to the lateral resolution of the microscope which is much higher still. Since the desired value refers to a narrow peak with high slope angles, the measurement result very much depends on the lateral resolution.

This effect is similar to measuring the length of a coastline, which seems to get longer the closer one looks. However, the lateral resolution of both the StrainMatic and the StrainScope cord tester is sufficient to capture even thin cord streaks and distinguish easily between good and bad quality.

Summary

Cord stresses have to be monitored on a routine quality check basis to ensure a high level of glass homogeneity.

The manual method currently used is labour-intensive, user-dependent and requires adequately trained personnel. Both the StrainMatic M4/120 cord tester and the StrainScope S4/20 cord tester automate and accelerate the measurement and ensure highly reproducible results which can be documented.

Which instrument is better suited for this task depends – apart from budgetary considerations – on the preferred method of operation.

While the fully automatic measurement of the StrainMatic certainly leads to the highest reproducibility, some users favour the semi-automatic operation principle of the StrainScope because its handling is closer to that with which operators are already familiar. ■

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