Breaking new ground in accuracy

Grenzebach, in collaboration with Innomess, has developed a new optical method for the quality inspection of flat and bent glass based on the moiré effect in physics. As is demonstrated here, the technology enables extremely accurate assessment of the optical quality of glass through the detection of defects by their refractive power. More reliable than conventional systems, the new method also requires far less maintenance than the latest laser systems.

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The aim of this article is to present a new inspection system which basically measures optical distortions in glass. For flat glass, Grenzebach offers the *FloatScan Catcher & Optics* system, while the *ScreenScan Faultfinder* inspection system has been specially developed for bent automotive glass.

FLOAT AND FLAT GLASS APPLICATIONS

FloatScan is the name given to the product group comprising all Grenzebach's inspection systems for float lines or processing lines for flat glass. These are:

- the *Panel & Edge* camera system for measuring the size of glass plates, including the length, width and diagonals, and for assessing the quality of the glass edge;
- the new *Hotgauge* transversal thickness measuring system, by which glass thickness can be measured immediately after the tin bath and before the annealing lehr;
- the *Coldgauge* system for generating a thickness profile after the annealing lehr. An extension to this is the *Stress* feature, for measuring the glass stress.

The Catcher & Optics system, the latest addition to the FloatScan product range, detects small point defects such as bubbles and stones, and also measures the optical quality of the glass ribbon. In float lines this system is located before the cutting area, so that it can transmit the glass quality information to the cutting optimization system. It will then optimize the cutting and assign the cut plates to the various production tasks. The same system may also be integrated into an off-line cutting line, for example in front of a cutting table.

AUTOMOTIVE GLASS APPLICATIONS

ScreenScan is the name given to the product group comprising Grenzebach's inspection systems for manufacturing automotive glass. Part of this range is the *Curve*, a sensor for measuring the bending cross curvature profile of automotive glass when it is still in the bending furnace. At present, we are working on a series of new on-line inspection systems which can assess the quality of edge grinding and screen printing, or detect scratches on the finished product.

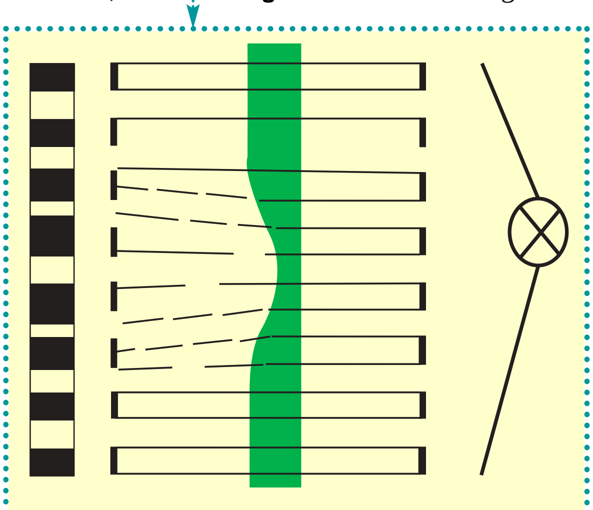
The ScreenScan Faultfinder can be located in the cutting area, at the start of the automotive glass production process. Alternatively, it can be installed behind the bending lehr, so that it not only detects defects in the raw glass, but also optical bending defects. First and foremost, though, the system should be situated in the final inspection line. Here it will inspect the quality of the raw glass and detect and monitor one hundred per cent of the bending defects, as well as the optical defects from bad lamination, that pass through the system.

DEVELOPING AN INNOVATIVE METHOD

Both measuring systems are based on a consistent technological evaluation of the physics of the moiré effect, combined with state-of-the-art PC and camera technologies. They are destined to replace both laser scanners, successfully used for many years now, for the on-line detection of point defects in float lines, and the latest camera systems for assessing glass optics.

The new technology was developed through an alliance between the two companies Grenzebach and *Innomess*. Grenzebach, a leading manufacturer of glass plant equipment, has been using the inspection systems of various manufacturers for many years now, and has always kept a look-out for new and improved technologies. Innomess is a group of metrology experts with a strong background in the glass industry. Originally founded as a glass manufacturer, the company decided to further improve glass measuring techniques by consistent market research and by developing new technologies. Innomess succeeded in this and obtained a new patent for the on-line application of the moiré principle in the inspection of glass. Grenzebach found this invention so pioneering, that it decided to merge with Innomess. Ever since, our two companies have been fully committed to bringing these systems to industrial maturity within the shortest possible time.

Fig. 1 Diagram showing how the moiré effect reveals defects in glass



HOW MOIRÉ TECHNOLOGY WORKS

In glass inspection technology, the moiré principle in itself is nothing new. Numerous glass laboratories use the moiré effect to analyse glass optics and the condition of the glass surface. The basic principle is that, depending on the relative position to each other, two fringes lead to clearly visible interference lines and figures. By changing the interference lines and using the Fourier transformation, several computations may be done.

For example, the position of both fringes to each other may be computed. And the other way round, if the fringes are in a fixed position to each other, the optical characteristics of a glass plate situated between the two fringes may be computed.

This can be done by using a light and a camera with the glass plate inbetween.

To generate the moiré effect, a grid is mounted in front of the light and a special camera is converted into a moiré head. If there are no defects in the glass plate, interference will be influenced by the position of the moiré head towards the grid in front of the light. However, as soon as there is refractive power in the glass, for example from small point defects, from undulations in the glass surface, or from inhomogenous glass, the interference will change. By computing these interferences we can qualify the optical quality of the glass.

On the right-hand side of the schematic sketch in Figure 1 you can see the light with the grid. On the left-hand side, you can see the reference grid of the Moiré head.

If the glass plate inbetween does not have any refractive power, as you may see on the top and bottom, this results in a uniform interference. However, as soon as refractive power appears in the glass, for example because of changing thickness, the generated interference will also change and will then also be seen by the moiré head.

HIGH ACCURACY

The on-line analysis of these interferences with current PC technology allows the detection of refractive power of one millidiopter (mdpt) for each surface spot of 0.1 mm^2. Millidiopter is the technologically correct unit of measurement for lenses to be measured in the glass.

The diopter is used as a unit of measurement by opticians for glasses. Our system is one thousand times more accurate.

To give you a better idea: if a beam of light is sent through a lens with a refractive power of one mdpt, the beam will be deflected by one micron over a distance of one metre.

This high level of accuracy is needed to allow the on-line measurement of values which are normally measured off-line in laboratories. A lower accuracy than this could not replace today's laboratory measuring.

In the zebra test, for example, an experienced quality inspector may detect quality divergences of ±1-2° zebra with full repeatability. The difference between 50° zebra and 48° zebra is about 1.5 mdpt.

This clearly shows that other optical measuring techniques presently under discussion, which allow refractive power to be determined at ±5 or ±10 mdpt, are insufficient for a one-hundred-per-cent on-line qualification of the glass.

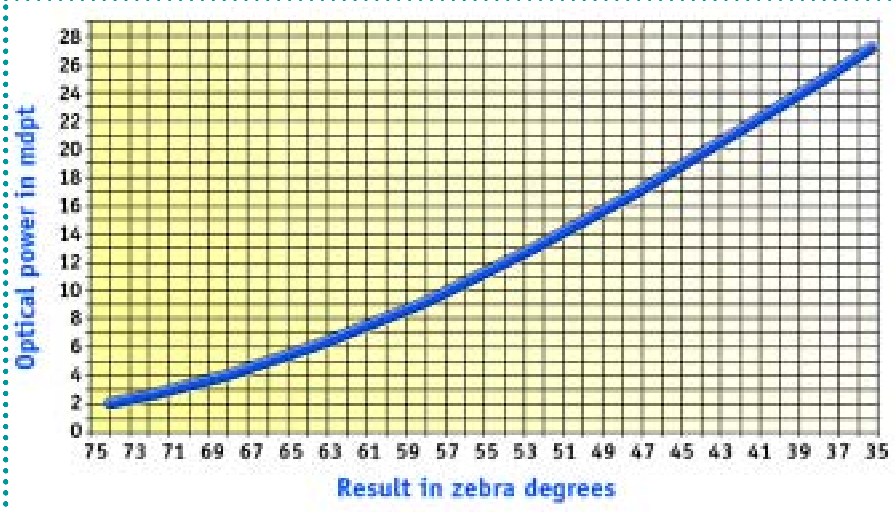


Fig. 3 - Correlation between zebra angle and optical power in mdpt

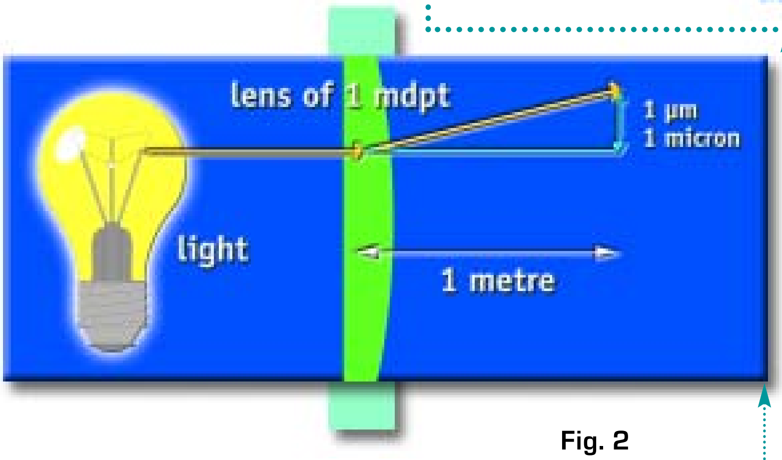


Fig. 2 Deflection of a beam of light through a lens with a refractive power of one mdpt

If we compare the detection performance of the moiré method with that of a laser scanner, we will find that the laser light is also deflected by the refractive power of a point defect. However, here a refractive power of 50 mdpt, or deflections of 50 microns per metre and even more are needed to generate a signal change at the receiver-multiplier.

This means that the superior physical detection capability of the moiré technology compared to conventional systems must be seen in terms of refractive power.

From this comparison, we can conclude that the moiré system is a real measuring instrument that not only detects defects of a certain size more or less reliably, but gives an exact measurement of the refractive power of the glass, or in other words, its optical quality.

For example, all the glass defects shown in Figure 4 generate their own specific refractive power. Such optical refractive power is caused by thickness changes, or by bent or inhomogenous glass.

The moiré system detects all of these as lenses in the glass.

THE MOIRÉ METHOD IN OPERATION

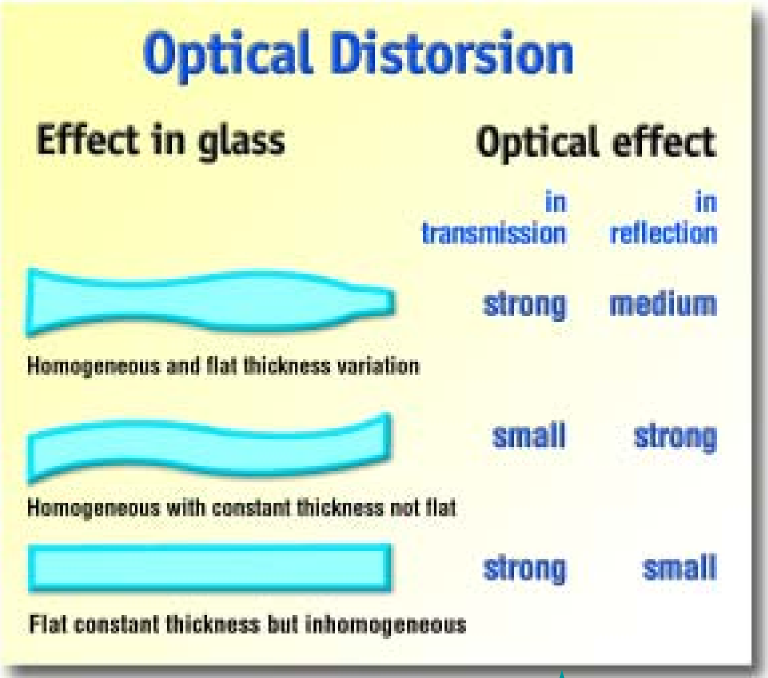


Fig. 4
Optical effects created by glass defects

Analysing float ribbon quality

A practical application in float lines is, for example, a long-term analysis of the glass ribbon optical quality. At the bottom of Figure 5 you can see the quality of a float ribbon under normal, good conditions. The refractive power peaks are situated at around ± 5 to 8 mdpt maximum. In the upper part of the picture you can see the same situation during a colour change in the glass melt. During such a colour change the glass is often eliminated into the crusher for hours. However, the on-line analysis of the glass also shows that about ten to twenty per cent of the glass is of excellent optical quality and can thus be stacked.

All data are stored in a data base together with that of other measuring systems, such as thickness and stress measurements. This then allows a statistical analysis of the quality of a production run. Moreover, the obtained measuring result can be compared or reproduced at any time and in any place.

Measuring intensity changes

Further analysis and evaluation is possible if the intensity or absorption channel is considered too. In addition to the refractive power, we also measure intensity changes by transmitted light.

This is in order to examine whether the defect spot or the defect corona is brighter or darker than the surrounding glass.

Other possible evaluations concern intensity changes by reflected light. This enables reliable classification of even the faintest spots or drops of tin, for example.

Even strongly coloured or tinted glass, or coated glass does not constitute a problem for the moiré method. Furthermore, it is rarely necessary to recalibrate the system even in the case of extreme changes in the glass.

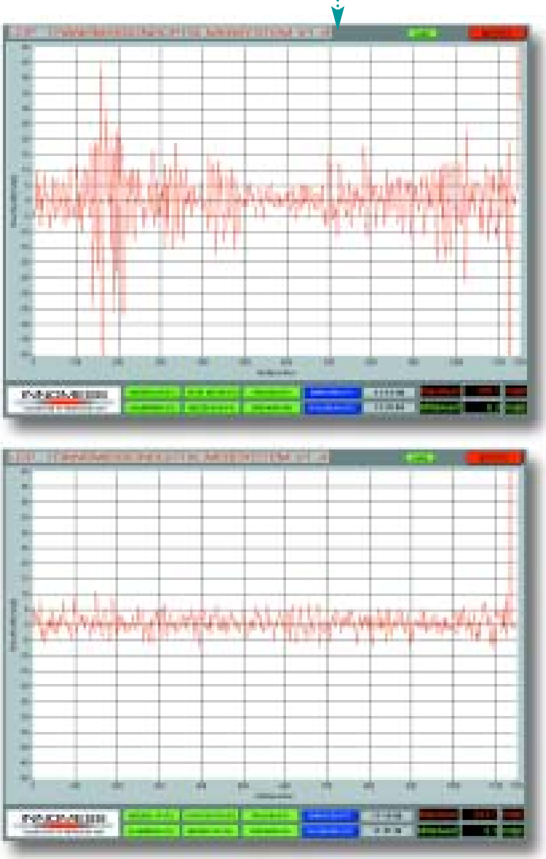
The LabScan test unit

We have constructed a special test unit, called *LabScan*, which allows glass samples to be scanned on-line.

The measuring result is immediately shown on the screen monitor. The LabScan system is used for presentations and for examining especially problematic defects.

Some of our autoglass manufacturing customers, as well as various car manufacturers, have a LabScan unit in their quality inspection shop to determine the quality of the glass and to define quality standards, which are then published for the automotive glass manufacturers.

Fig. 5
Monitoring glass ribbon quality in float glass



Detecting dirt and dust

Dirt causes no problems in the moiré method. So washing the glass in float lines to improve the detection of defects becomes superfluous, because dirt rarely generates refractive power. This is also the reason why moiré-based systems are less troubled by pseudo-defects or false hits than conventional systems, and remain reliable even with the smallest bubbles or stones.

Of course, dirt and dark shaded glass also deteriorates the intensity of our system. However, for the comparison of the signals with the “black” interference lines, even a small

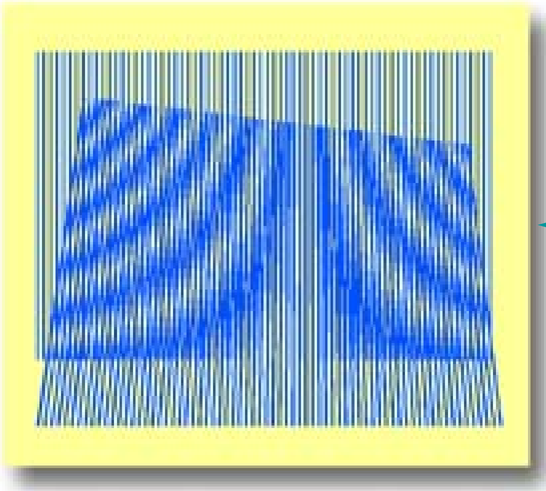


Fig. 6 The moiré effect with dirty or dark shaded glass

amount of light allows a reliable and correct analysis.

In Figure 7 we compare the refractive power signals of a point defect detected by the moiré method on clean glass, with the same glass sample in a contaminated condition. Both sides of the sample were soiled with dust, Lucite and fingerprints. The defect is clearly detected, and no pseudo-defects impair the measuring result. Only the defect classification is changed: the grease of the fingerprints influenced the effect of the refractive power of the lenses around the defect.

DURABILITY AND EASY MAINTENANCE

Another major advantage of the moiré method compared to conventional inspection systems is its easy maintenance. To make efficient use of this system and to service it, all that is necessary is a knowledge of PC and observation of the instructions in the operator's manual. The complexity of Grenzebach's Moiré-based system can be compared to that of a standard camera system.

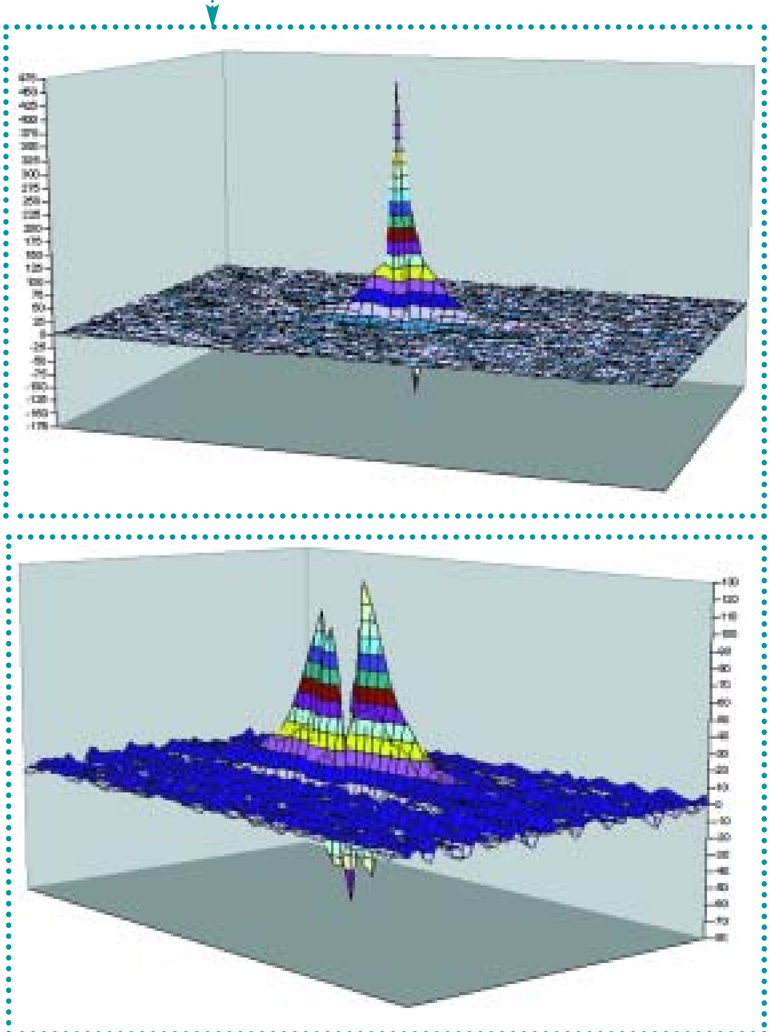
Furthermore, the cost for replacing parts due to wear and tear is insignificantly low. The light lasts one year, after which only simple and cheap fluorescent tubes need to be replaced. From time to time the air filter must be cleaned, but apart from this, little other maintenance is needed.

By contrast, with a laser system, the maintenance costs may, within ten years, even exceed the price of the equipment.

ADVANTAGES FOR AUTOMOTIVE GLASS MAKERS

All of the above applies both for the inspection of flat glass, as well as for bent automotive glass. However, with automotive glass, we not only inspect the quality of the raw glass, but also detect bending and laminating defects. Several car manufacturers, for example Audi, Chrysler, Opel and Volkswagen, use our system for quality assurance and even request their suppliers to use similar inspection systems. Figure 8 (overleaf) shows what a rejected windscreen with bending defects looks like. At the bottom, in red-green, is a so-called "burning" or focal line, an undulation in the glass caused by a different cooling of the screen-printed area and the surrounding glass. At the top is an even worse situation: concave bending defects of up to 300 mdpt. These lenses are extremely disturbing to the driver's field of vision. Yet this windscreen was actually sold to a customer and built into a car!

Fig. 7 Comparison of refractive power signals in clean and contaminated glass



PERFECTING THE SYSTEM

I hope that you now have a fair idea of what can be achieved with the moiré method. Yet the computers available on the market are still not fast enough to allow on-line real time evaluation of raw data. At the same time, we have not yet finalized all the software we have started working on. But we are making progress month by month towards satisfying the application needs of glass manufacturers. We are continuing to aim for a real glass defect evaluating system which will allow improvements in the melting and annealing processes in glass production. The first prototypes have already been in use in float lines for quite some time now, and the second generation is already being used by some of our customers. At Glasstec ‘98 we launched the third generation, which was demonstrated in full operation at the trade fair.

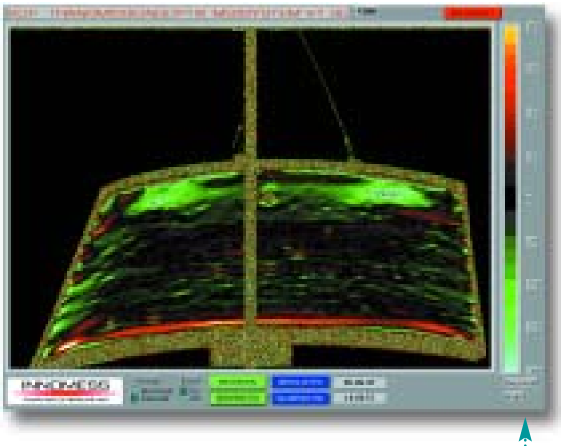


Fig. 8 - Inspection of a windscreen for bending defects

In the field of automotive glass, we have one off-line measuring system in operation and in 1998 we installed and started up the first prototype of an on-line final inspection system for windscreens.

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