Measuring tip of the extruder probe with a sapphire lens

In-Line Color Measurement Directly in the Melt

Process Control. Color shade differences result from a change in the process parameters, the material, or the material feed. Continuous in-line color measurement directly in the melt as it leaves the extruder permits gap-free control of the process as a whole, with the possibility of immediate intervention in the running process in the event of deviations.

FUAT EKER

Color measurement constitutes a means of verifying color quality. The measurement is generally conducted on the finished end product using samples that have been taken manually, directly from the production line, or by means of automated measuring methods.

A distinction is drawn between several different types of color measurement. With the off-line method, the measurement results are not available for a matter of hours, which is why this method is not suitable for intervening in the process. The online measurement method supplies the measurement results for the finished product after just a few seconds, but at a much later stage in the process sequence. The online method is thus only suitable to a limited extent for timely interventions in the process. With an in-line measurement, by contrast, the results are available within a matter of seconds and, since the measurement is taken directly in the melt upon output from the extruder, this method is particularly suitable when it comes to making immediate corrections to the process [1].

Translated from Kunststoffe 4/2009, pp. 54–56
Article as PDF-File at www.kunststoffe-international.com; Document Number: PE110032

Different Color Measurement Methods

Offline color measurement is a method frequently used in industry. This measuring method involves the following steps:

- Removing the sample from the production process,
- transporting the sample to the laboratory,
- converting the sample material into a measurable shape (e.g. color plaques, sheet),
- cooling the sample to room temperature,
- measuring the sample with a spectral photometer,
- notifying the measurement results to the production department,
- deciding on a potential modification of the process, and
- where appropriate, repeating the process for a further individual measurement.

It is clear from the different steps involved that several hours can elapse between the manual removal of the samples and the notification of the measurement results to the production department. A further drawback is that only one measuring point is established during this time. The color quality prior to this measurement point, or at a later point in time, still remains unclear. Color deviations can, however, occur abruptly as a result of one-off events and may also come about gradually (as happens in the majority of cases). Effects of this type are not taken into consideration by the off-line measurement method.

Online measurement systems make it possible to measure color quality – on sheets or semi-finished products, for example – at the intermediate stages during production. These systems are used to record the actual status of already-finished products. All the problems that have occurred in the process up until then which led to color deviations are simply documented here. Given the time lag in relation to the earlier process steps, this method is not suitable for supplying useful feedback for genuine process control. ▶

Manufacturer

Pausch Messtechnik GmbH
Nordstrasse 53
D-42781 Haan
Germany
Tel. +49 2129 9396-0
Fax +49 2129 9396-10
www.pausch.com

Fig. 1. The extruder probe (left) is screwed on at the side of the extruder exit opening

Fig. 2. The tip of the measuring probe extends into the extruder to ensure that the lens is covered with melt

Fig. 3. The Nema 4 box with its touchscreen holds all the measuring technology

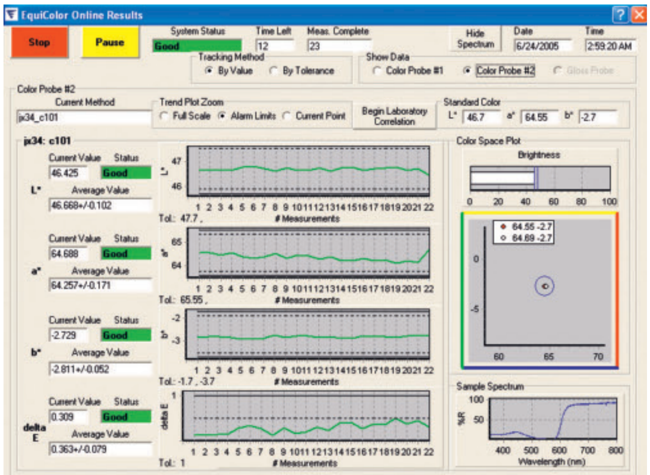

Fig. 4. The trend diagrams are compiled with the EquiColor software

An in-line color measurement performed directly in the melt upon output from the extruder not only permits consistent documentation but also offers the opportunity of intervening directly in the extrusion process in the event of color deviations. Direct in-line color measurement dispenses with the first six steps of the off-line method and does not involve a time lag like the online method. Measuring the color directly during the extrusion process supplies the decisive process information within just a few seconds, at the earliest possible time in the production chain.

The In-line Measurement Technique

To record the measured values for the color, the measurement probe (Title photo) is screwed into a threaded hole at the extruder exit (Fig. 1).

The so-called extruder probe comprises a sleeve with a robust head, which has a sapphire lens set in it. As the second-hardest material after diamonds, sapphire is particularly suitable for use in the extrusion process where it is subject to stressing through high temperatures and pressures and also to friction through a constant flow of material.

The probe is placed in the extruder housing in such a way that it does not touch any of the movable parts, such as the screw elements (Fig. 2). The melt, however, must cover the sapphire lens during the flow process. The sapphire lens is self-cleaning, which ensures that no material sticks to it.

The melt flowing over the lens is lit up by a xenon flash lamp. To do this, the light is transported to the sapphire lens via six flexible glass fiber conductors, arranged in a circle. The reflected light is fed back to the spectral photometer via a centrally-positioned glass fiber. This operation is repeated every ten seconds, and a continuous color measurement performed in this way.

Calibration and Structure

The special design of the extruder probe means that the spectral photometer can be calibrated without any interruption to production. To do this, the fiber optic is unscrewed from the probe sleeve and calibrated on the basis of the black and white standard. A green control standard is employed to check the validity of the calibration. The calibration is a function of the surrounding conditions. The system can retain its stability for up to three months before a renewed calibration is required.

The actual color measurement is performed in a spectral photometer using CCD technology. The spectral photometer employed covers the wave range between 360 and 780 nm, i.e. it includes the visible part of the spectrum. By combining a monochromator with the CCD technique, it is possible to achieve a finer resolution than with the standard color measurement units.

Process Error

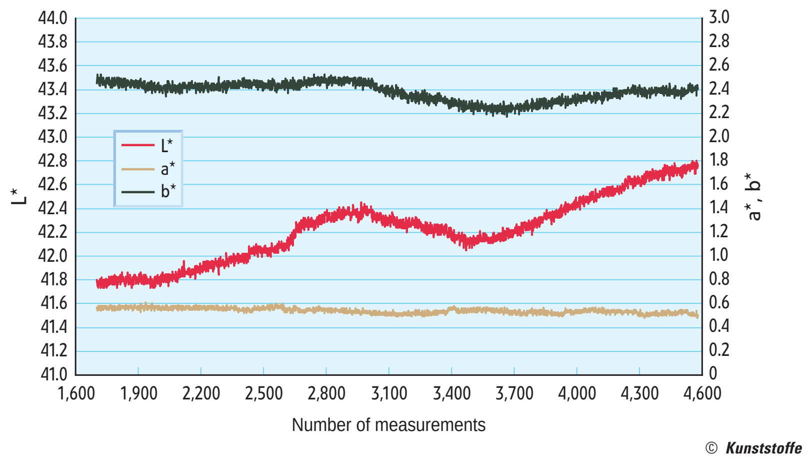

Fig. 5. The excessively high amount of titanium dioxide added causes the brightness value L* to increase for an identical color shade trend (a*, b*)

All the technology, i. e. the spectral photometer, xenon flash lamp, control unit, a full-fledged PC with Windows XP as the operating system and a touchscreen are housed in a so-called Nema 4 box (Fig. 3). This box is made of stainless steel and has been designed for use in industrial environments, with protection against dust and splashes of water. The built-in air-conditioning ensures stable running, even in production environments with greatly fluctuating temperatures.

Assessment of the Measurement

The measurement results are depicted in the form of a trend diagram (Fig. 4). This shows the measured color values by comparison to the standard color shade in a traffic-light display. The value currently measured is specified separately as a numerical value alongside the trend diagram. A measured color value that is within the tolerance is shown in green. A value shown in yellow has reached the warning limit for the permitted tolerance. And, if the permitted tolerance has been exceeded, the color will change from yellow to red. These clear-cut signals are not only displayed on the screen but can also be shown by signal lamps in these same colors.

On the screen presentation, it is possible to choose between four freely-selectable trend diagrams, i. e. those for dL*, da*, db* and dE*. All the standard color scales, and whiteness and yellowness formulae are available with the familiar light types (for 2° and 10° standard observers).

Process Control

The extrusion process is a highly complex operation with a large number of influencing factors that affect the final result. In addition to the process parameters of temperature, pressure and throughput speed, the extruder itself, with its individual components, has a major influence on the result. Added to this come differences in the material employed, such as raw materials from different batches, or different mixing ratios.

These influencing factors, taken both in isolation and together, have a direct influence on the color shade of the extruded product. By using the in-line measuring method to measure the color, it is thus also possible to draw conclusions regarding modified machine or process parameters.

Correlations between the color values and the causes of defects have become clear in practice. The addition of an excessively high amount of titanium dioxide, for example, can be established on the basis of the brightness value L* (Fig. 5). Fluctuations in the color shade can be attributed to a pump that is pulsating or to the settlement of pigment in liquid coloring agents. In addition to this, the color measurement can also be used to diagnose mixing problems in the extruder, problems with homogenization or metering, or other fluctuations in process stability.

Conclusion

The color shade does not necessarily have to be a key aspect of the final product, Measuring the color, however, is an excellent way of achieving stable process control. Any instability in the production process as a whole is reflected in differences in the color. These deviations can be eliminated straightaway through corresponding interventions in the production process.

Due to the continuous nature of the recording, performing inline color measurement directly in the melt constitutes a particularly good means of analyzing and optimizing the production process as a whole. It can be used to prevent rejects, avoid the contamination of quality products, keep defective batches down to a minimum, optimize formulations, save on raw materials/pigments, and ensure precise metering and compliance with production specifications, thus avoiding returned goods.

All of this leads to considerable savings on raw material and production costs. ■

REFERENCES

1 Kretschmer, K.; Hochrein, T.: In-line Messtechnik in der Compoundierung; Conference "4. Würzburger Compoundiertage"; Würzburg, Germany June 2008

THE AUTHOR

DIPL.-ING. (FH) FUAT EKER, born in 1965, has been with Pausch Messtechnik GmbH, Haan, Germany, since 2006, where he holds responsibility for in-line color measurement and new technologies, including thermal conductivity and image processing; feker@pausch.com