NIR Process for the Inline Inspection of Recycled Plastics

Testing Recyclates Directly during Injection Molding and Extrusion

Contaminants in recyclates can cause damage to injection molding machines and extruders. And they can also give rise to flaws in the manufactured products. This can be avoided by checking the quality of the recyclates directly during processing. A method adopted from the field of colorimetry for use in the NIR range is ideal for this purpose.

The Spectro-T-3–60-NIR/NIR-D20 NIR inline sensor is mounted on the sight glasses of metering systems and silos. © Sensor Instruments

The global plastics processing industry is converting recyclates more and more. In Europe, this trend is being fueled by, among other things, stricter regulations governing their use. In addition, plastics converters are increasingly striving to be perceived by the public as companies that engage in sustainable business practices. Consumers are increasingly asking for products that are more sustainable, yet are not prepared to accept inferior quality. However, users of recyclates need to be made aware that recycled plastics cannot be compared one-to-one with virgin material. There are certain parallels here with paper recycling, where some new stock has to be used if a certain quality standard is to be maintained.

What is needed is the right type quality control. Systems that can sense the color and monitor the moisture content of recyclates are now often found directly upstream of the injection molding machines and screw extruders, but they provide no information about the composition of the plastic contained in the recyclate. This is a problem because recycled plastics are not always single-resin products. Frequently, recyclate is subjected only to a color check before it is sold onwards.

This situation could end up causing more and more problems for screw extruders and injection molding machines in the future. For example, there is the potential for increased wear on injection molds. And contaminants can also cause problems with the

© Carl Hanser Verlag, Munich. Reproductions, even in extracts, are non permitted without licensing by the publisher.

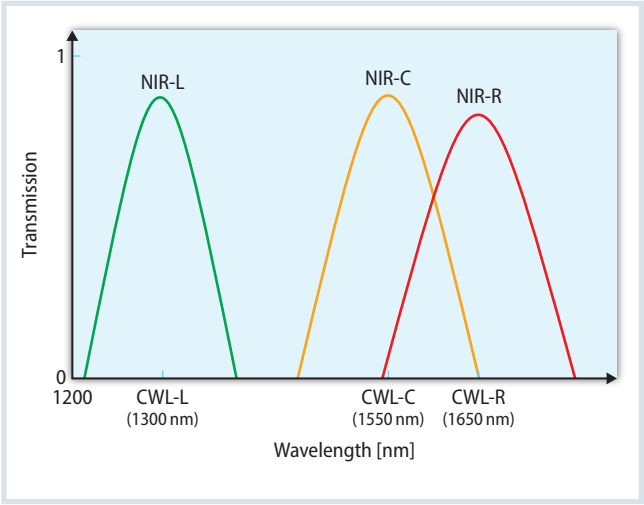

Fig. 1. The NIR three-range procedure is analogous to that used for the visible spectrum.

Source: Sensor Instruments; graphic: © Hanser

products themselves. One solution here is to install inline near-infrared (NIR) sensors in the production shop. The relevant sensor technology for this has been developed by the company Sensor Instruments. This technology applies the three-range procedure to the NIR range, more precisely at wavelengths between 1300 and 1700 nm. The vast majority of plastics can be reliably distinguished from one another in this range.

The principle behind the NIR three-range method has been adopted from the visible spectrum and implemented in the sensor technology. Instead of spectral evaluation, the NIR wavelength range is divided into three regions (**Fig. 1**), each covered by a group of NIR LEDs of specific wavelengths: 1350, 1550 and 1650 nm (NIR-L, NIR-C and NIR-R) that are switched on in sequence. Sequencing allows the use of a broadband receiver in the form of an NIR-sensitive photodiode, which is arranged perpendicularly to the surface of the pellet to be measured. The advantage of this over the use of an NIR spectrometer is that more light is available for evaluation because the detection area on the receiver measures around 4 mm x 1 mm and is larger than the diameter of the spectrometer's input aperture of < 0.1 mm. Measurement is therefore less noisy and, above all, faster. In addition, this type of sensor technology costs only a fraction of a spectral solution.

Suppression of Directed Light

The high sensitivity of the receiver also makes it possible to work with a frosted glass diffuser on the transmitter side that diffuses the light into almost all of the half-space. Thus only a small fraction of the NIR light actually reaches the receiver. As a result, directed light (reflected directly toward the receiver) is almost completely suppressed, and this in turn benefits the measurement result. The sensor technology is also compact and robust.

Analagous to the three-range color evaluation in the visible wavelength »

Fig. 2. A wide range of recycle samples was studied (see results in the **Table**).

© Sensor Instruments

© Carl Hanser Verlag, Munich. Reproductions, even in extracts, are non permitted without licensing by the publisher.

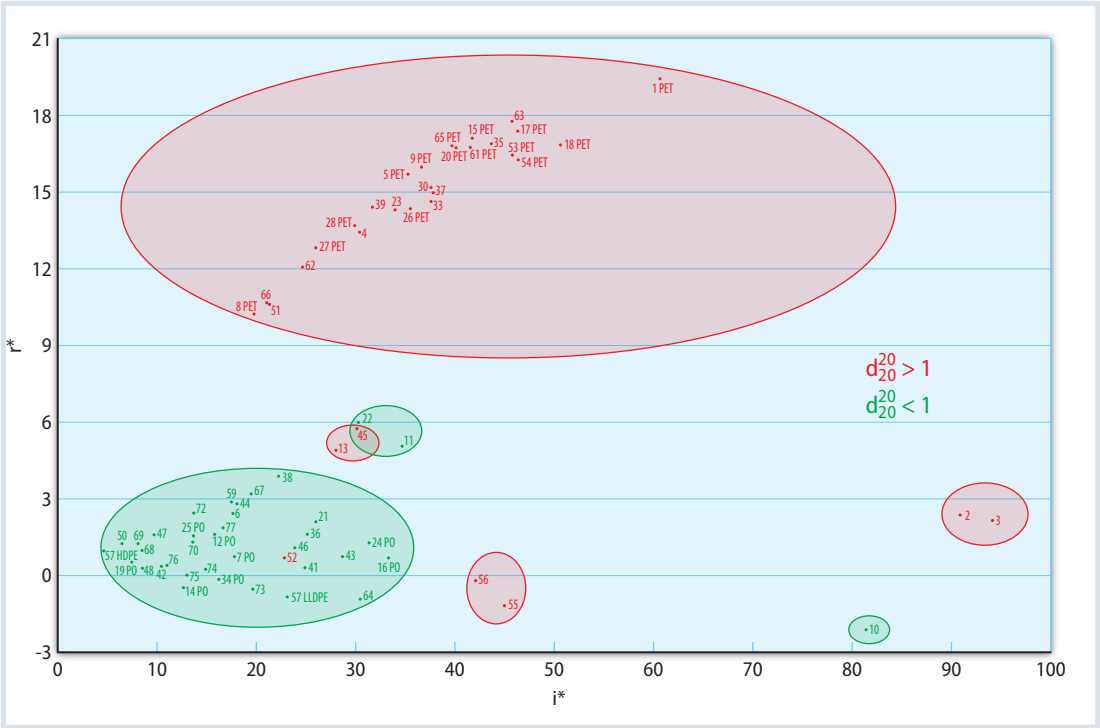

Fig. 3. i*r* diagram of the tested samples of recyclates: It can be clearly seen that clusters form.

Source: Sensor Instruments; graphic: © Hanser

range, the color values are also calculated from the raw color data NIR-L, NIR-C and NIR-R in this case: N*i*r* analogous to L*a*b*. N* provides information about the gray value of the pellets being examined. i* provides information about reflection behaviour between the central (NIR-C) and the short (NIR-L) NIR wavelength ranges while r* indicates reflection behaviour between the medium and the long (NIR-R) NIR wavelength ranges.

*L*a*b* Algorithms for NIR*

Initially, the decision to use the L*a*b* algorithms was just an idea, but it proved in retrospect to be highly advantageous and efficient. The designation N*i*r* was chosen arbitrarily, as no defined parameters existed for a three-range method in this wavelength range. The studies conducted showed that, as is the case for the visible range, reflection behaviour by an object in the NIR range can also be described by these three parameters.

First of all, pellets of virgin material were studied. Precise information about the origin and composition of the individual pellets was available. Measurements were taken in accordance with the diffuse 0° method. This is similar to the diffuse 8° method used in colorimetry. The only thing separating the NIR sensor and the pellets is a sight glass. The latter can easily be integrated into silos, for example, as well as into metering lines (**Title figure**). The diffuse incidence of the light suppresses interfering direct reflection to a large extent, with the result that it is primarily diffuse reflection which reaches the receiver. Nevertheless, measurement accuracy can be increased by taking measurements on the moving pellet stream. 20 different samples of

Fig. 4. The two laboratory instruments Spectro-T-3-DIF/0°-Lab-CMU and Spectro-T-3-DIF/0°-Mobile-P are based on the same technology and are also suitable for calibrating the inline sensors.

© Sensor Instruments

© Carl Hanser Verlag, Munich. Reproductions, even in extracts, are non permitted without licensing by the publisher.

virgin material and 70 samples of recyclate were available for the tests (**Fig. 2**). Prior to the actual tests, a sinking test was performed on the individual samples, which were then classified according to specific density of less than 1, equal to 1 or greater than 1.

Tests on Recycles Confirm Suitability for Use

The tests on virgin material revealed individual domains in the i*r* diagram. Furthermore, reliable distinction was reproducible within each domain. Subsequently, the available samples of recyclate were tested.

It was found that these exhibit very similar behaviour. Here, too, there was an accumulation of recyclates of specific density < 1 on one side and two significant areas of specific density > 1 on the other (**Fig. 3**). One of these had a very high positive i* value, while the other had a relatively high positive r* value. Unfortunately, the exact composition of some of the tested recyclates was not known, and so these samples were only labeled with a number and color. No evaluable measurement results could be obtained for the recyclates colored with carbon black, as the latter absorbs nearly all NIR light. Gray recyclates and dark-colored recyclates, by contrast, produced usable signal strengths (**Table**).

Experience gained with the colorimetric determination of recyclates shows that it is helpful for the user to have measuring systems available in the laboratory in addition to the inline sensors. Hence, for better comparability of the measurements, the same sensor technology has been integrated into existing laboratory systems. The Spectro-T-3-DIF/0°-Lab-CMU laboratory measuring system can be used to calibrate inline sensors, while the Spectro-T-3-DIF/0°-Mobile-P laboratory system is ideal for measuring larger quantities of 11 l or more recyclate in the laboratory (**Fig. 4**). Measurements are taken while the pellets are moving as well; this offers the best compensation for randomly arranged pellets. The measurements are evaluated with a PC. The individual NIR sensors can be calibrated with the Spectro3-MSM-Docal Scope V1.4 software, which is included in the scope of delivery. The change in dN*di*dr* over time is also displayed for a defined sample.

Designation (color)	Density relative to water	Polymer	N*	i*	r*
1 (white)	> 1	PET	83.04	60.67	19.04
5 (beige)	> 1	PET	75.19	35.34	15.37
7 (blue)	< 1	PO	59.54	17.91	0.71
8 (olive, transparent)	> 1	PET	52.7	19.87	10.01
9 (light blue)	> 1	PET	73.57	36.68	15.64
10 (beige white, semitransparent)	< 1	PO	52.86	81.39	-2.09
11 (light green)	< 1	PO	70.15	34.79	4.94
12 (gray)	< 1	PO	42.18	15.93	1.57
14 (oliv)	< 1	PO	51.69	12.79	-0.48
15 (white)	> 1	PET	75.05	41.81	16.76
16 (light beige)	< 1	PO	76.63	33.39	0.66
17 (light blue)	> 1	PET	78.82	46.39	17.03
18 (white)	> 1	PET	72.06	50.66	16.5
19 (dark gray)	< 1	PO	34.64	7.63	0.51
20 (light gray)	> 1	PET	77.56	40.16	16.39
21 (turquoise)	< 1	PO	61.02	26.12	2.05
22 (beige, transparent)	< 1	PO	63.61	30.4	5.85
24 (turquoise)	< 1	PO	76.34	31.46	1.25
25 (grayish blue)	< 1	PO	39.51	13.76	1.51
26 (gray)	> 1	PET	68.05	35.61	14.06
27 (greenish gray)	> 1	PET	65.69	26.09	12.56
28 (gray, transparent)	> 1	PET	63.24	30	13.4
31 (beige)	< 1	LLDPE	58.02	23.22	-0.83
34 (braun)	< 1	PO	52.78	16.36	-0.15
53 (gray)	> 1	PET	75.64	45.84	16.11
54 (gray)	> 1	PET	75.54	46.45	15.93
57 (black)	< 1	HDPE	32.95	4.91	0.93
61 (light blue, mixed)	> 1	PET	75	41.6	16.41
65 (light blue)	> 1	PET	77.56	39.79	16.46

Table. Selection of tested samples of recyclate and N*i*r* measurements. Source: Sensor Instruments

Outlook

It is intended that the insights gained from the use of this technology will be applied directly in production in the future to make corrections to the recipe. Sensor Instruments is currently working with a machine manufacturer on a metering unit for metering both recyclate and virgin material. In line with the composition of the recyclate, more or less virgin material will then be added to ensure that the quality of the end product meets specifications. ■

Info

Text
Walter Braumandl is the Managing Director of Sensor Instruments.

Service
More information:
www.sensorinstruments.de

© Carl Hanser Verlag, Munich. Reproductions, even in extracts, are non permitted without licensing by the publisher.