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Complete Control
Polymer and Sheet Production. Applying the Close-Loop concept, a raw material producer’s off-line laboratory is enabled to perform continuous online metering. This continuous control makes it possible for the manufacturer to optimize the process, while making immediate amendments. At the same time, the raw material’s quality is determined. Even producers of high-end films monitor 100 % of the extrusion process, thus detecting problems in raw material or process quickly. This way, in case there are any changes in the process, they can take measures without delay (title picture).

The Approaches of Online Quality Control

Generally speaking, online quality control comprises two areas: measurement of the granules and measurement of the extruded cast or blown films.

Measuring the granules provides information on LAB color value, melt index (rheometer), pellet size distribution (pellet size and shape distribution systems) as well as dust/abrasion and contamination (pellet scan systems).

Yet, measuring the extruded film on-line makes statements on bittiness (gel count), additive content and physical properties (IR spectroscopy), brilliance (glossmeter) and/or the value of turbidity (hazemeter).

Online Pellet Analysis

Conducting pellet analysis online, a sampler withdraws the granules from the flow of production. The system then automatically takes them to the measuring system, examines and sorts them out. Those granules that exceed the specified demands, are returned to the process. For the purpose of measuring the color, the pellets are transported into a cuvette, where LAB values, yellowness index and several other color values are determined.

The Online Pellet Scan System, on a vibrating table or a swivel plate, passes the transparent or opaque granules below a color matrix camera. The pellets are examined as to color soiling or foreign particles, and rejected, if necessary.

The Pellet Size and Shape Distribution Analysis examines the granules during free fall. It uses a line scan camera to check granule size distribution, sphericity, angel hair, dust/wear, doubles and triples.

All of the systems mentioned can be connected right in series and be controlled by an integrated software solution. Via an...
interface such as Modbus, they are linked to the Production Data Acquisition (PDA) system. In case of deviation, the operator is alerted fully automatically.

“At-Line” Rheology

The rheometer of the newly patented OCS technology (manufacturer: OCS Optical Control Systems, Witten, Germany) is a hybrid between measurement of granules and extruded films. Highly precise off-line laboratory measurement following ASTM 1283 and ISO 1133 is carried out continuously as well as right “at line” next to the production facility, thus giving the operator at hand parameters crucial for reactor control (Fig. 1). This is done by continuously taking specimens out of the granule flow, heating them up and submitting them to high pressure to compress them carefully. This process causes only relatively slight changes in molecule structures, reaching reproducible accuracies of 0.5 % which is much better than off-line laboratory equipment. At the same time, metering without screw shear does not change the polymer structure and maintains better correlation with the ASTM/ISO methods.

Measuring Extruded Sheets Online

The analysis methods mentioned above, however, fail to provide any information on the granules’ speck content and their actual quality. To enable this measurement, a narrow film is extruded, in parallel, while regular extrusion takes place, and its speck content determined continuously. It is of major significance here, to seize the utmost number of small specimens, in order to safeguard continuous process control. A gel shower, for instance, may last 5 to 10 minutes, and then disappear. Therefore, it is recommended that cycles should comprise at least 50 specimens per hour.

Following cast or blown film extrusion, the sheet passes below a line scan camera and is wound without a tube on a mechanical mandrel (Fig. 2). The winding unit is suspended at one side (godet structure) and comprises several servo drives. These provide for the film guidance to be absolutely stable and they avoid fluttering. Sheet guidance is just as essential as a clean environment (up to a cleanroom), since granules for applications such as high-voltage cables have resolutions of down to 5 µm, which must be inspected, too. For downmarket raw materials such as polyethylene (PE), standard resolutions are 50 µm to 25 µm.

The process has been optimized for raw material control and it works almost autonomously. Other measurements, e.g. of haze according to ASTM 1003, of additive density and composition (infrared spectroscopy), of brilliance or thickness can easily be integrated into the winding unit and software. The Web Browser supports remote control and maintenance of the plant. The systems are inter-linked internally via an OPC server, and connected externally to the customer’s PDA system.

Quality Concept for a Polymer Plant

A world-scale raw material supplier has integrated his polymer plant a standardized online Close Loop concept. In order to minimize problems resulting from granule transport, such as generation of dust or abrasion, a container was placed right next to the extruders, suited to perform cleanroom measurements (Fig. 3). Analytical software is integrated into the PDA system via a Modbus, Profibus, Ethernet OPC interface etc., thus enabling the operator to control the plant from the control room. From here, the raw material specimens can be automatically allocated to the individual measuring systems.

Pellet analysis systems sort out contaminated granules, camera systems evaluate speck content, IR spectroscopy determines additive content and composition. In case there should be a problem, the plant operator is alerted immediately and the contaminated material is diverted into a different silo. Simultaneously, the system significantly reduces changeover times, anticipates maintenance and optimizes maintenance intervals.

Inspection of Extruded Films during Production

Producers of high-quality sheets today use sheet inspection systems, thus monitoring 100 % of outputs. These systems detect flaws such as specks, brands, fish eyes, streaks, flow lines or insects, mark them and alert the operator immediately. In doing so, they monitor the process itself and the raw material, as well as the final product.

The system raises an alarm in case it detects e.g. a critical individual flaw (a fly for instance), flaw trends (such as more than 10 gels of 200 to 300 mm diameter per square meter), or if there is a roll or use error, that is not specified. The data is stored in the system and can be accessed at any time (e.g. for complaints). Production tendencies can be presented online for a relatively long period of time, for instance the past 12 hours. In an offline mode, moreover, entire campaigns can be compared to each other and evaluated, thus enabling the engineer, for ex-
ample, to evaluate the bittiness of a raw material charge applied on a certain extruder. What is more, the system provides protocols of roll pressures, tailored to the individual manufacturer’s needs.

**Inspection Technology**

Today’s inspection systems reach pixel frequencies up to 160 MHz per camera, being processed by an Embedded PC right beside the camera. A single camera can buffer up to 1,800 photos of flaws a second. All measured data is transmitted, via Ethernet, to a server, visualized and stored. Analysis is conducted in real time, alerting the operators, in case of irregularities.

Subject to the individual application, CCD line cameras can be used with either 2,048, 4,096, 6,144 or 8,192 pixels. The scan rates achieved range from 72,000 per second with 2,048 pixels, up to 18,000 per second with 8,192 pixels. This way, solutions are high in web direction, even with very high web speeds. While using special objectives and thanks to technological development in CCD sensors, the image quality of long CCD lines (e.g. 8,192 pixels) today is reproduced just as sensitively as with short CCD lines (e.g. 2,048 pixels). For the sheet manufacturer, this means that findings from inspections remain good while investment costs are significantly lower, since the price of a CCD camera for long lines is only slightly higher.

With standard sheet processing, control is performed on speeds achieving up to 600 or even 800 m/min (roll slitting machine, coating) and widths reaching up to 10 m (biaxial stretching unit) (Fig. 4). Solution is 50 µm, in optical films, while ranging between 200 and 300 µm in thermoformed high-barrier films. In laminated sheets, the value is between 100 and 200 µm, while ranging from 300 to 400 µm in diaper films. Generally speaking, solution is determined by the end customer’s specifications as well as the production process.

**Examples of Practical Application**

While producing surface-protecting films, the causes of specks were examined. Having evaluated the situations of alert, engineers found out the following: 40 % of all specks are caused by dust and abrasion during raw material transport. This comprises silos and silo tankers, as well as pellet conveying systems in the factory to transport the material from the silo to the extruder. Specks caused by the raw material itself, e.g. by inter-linkage or insufficient shearing, make up 25 %. The extrusion plant causes 20 % of the specks, due to e.g. dissatisfaction screw geometry or dead zones, while 15 % are attributed to the production process, for instance screen changes or wrong temperature parameters.

An enterprise producing sanitary film also compounds the blends it requires. In the compounding sector, each charge is submitted to continuous examination on a laboratory extruder that includes units designed for winding, as well as gel count. Via an interface, the data is transmitted to the PDA system. The information serves as a basis for producing the film according to the customer’s quality specifications. On the cast film extruder, 100 % film inspection is carried out, while the film is 2,000 mm wide and speed is 100 m/min. The data obtained from the two inspection systems is evaluated by the same off-line analysis software, which also relates them to each other.

**Conclusion**

Close Loop today is a standard concept applied in raw material production. Not only does it monitor qualities; it moreover controls and optimizes the production process. It thus reduces ROI to far less than one year. Even to produce sophisticated sheets, most producers control 100 % of extrusion and refinement, thus detecting raw material faults immediately.

At present, each of the two optical camera systems has different inspection parameters, for instance solution and type of flaw. These two areas will have to and will converge. Yet, there are some integrated applications, already.

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