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Film Inspection and Process Control

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Manufacturers of high-quality film nowadays control their entire production using film inspection systems, which flag any errors detected and immediately alert the operator. The process, the raw material and the end product are all monitored.

Film inspection systems are increasingly becoming essential components of production lines. On one hand the market demands quality control (pharmaceutical, medical, food-wrapping film, etc.) and on the other film manufacturers want to cut waste and to optimize production. Even though their production lines are very capital intensive, manufacturers have no objective knowledge about the quality of their film or processes.

Dual line cameras support shuttering when used in conjunction with high-quality LED lighting. This consists in recording the same defect with a single camera under two different types of illumination, e.g. bright and dark fields in transmission mode, and leads to improved detection and classification.

The inspection systems have interfaces for integrating external sensors, e.g. for measuring shrinkage or color. These document the Lab color-space values and also alert the operator to deviations.

Modern systems detect surface defects such as specks/gels, black specks, fish eyes, coating tears, streaks, flow lines, and insects. The operator can program the types of defect into the system which will then automatically define the criteria for classifying them.

Definition of Gels and their Causes

Gels are small film inhomogeneities that are characterized by their area (size in transmitted light) and their elevation above the film surface (Fig. 1).

Gel Count Standards at Raw Materials Producers

Raw materials producers have been using gel counts for decades to perform standardized in-house quality control.

The once widely used boast that “my film has no gels” is now outdated. Gels occur in all films and are an unavoidable outcome of the production process and the properties of the polymer. Gels, as it were, are only a matter of resolution.

Film manufacturers know from experience that the reasons for such defects can be broken down as follows:

- Extrusion line (non-optimal screw geometry, deposits, etc.): 20%
- Raw material (contamination, cross-links, etc.): 25%
- Production process (wrong temperature parameters, poor purging, etc.): 15%
- Pellet transport, external and internal (contamination of silo trucks, PE abrasion, etc.): 40%

Technology for Holistic Integration

As a result of technological advances, the cameras on ultra-modern inspection systems can now realistically process data at a rate of up to 400 MHz. An application may feature 2,048-, 4,096- or 8,192-pixel CMOS line-scan cameras with dual line sensors or, where low-contrast color error needs to be detected, color line scan cameras with CMOS sensors. These can scan at rates of up to 144 kHz. Consequently, even at very high line speeds, high resolution can be achieved in the machine direction.

Fig. 1. Cross-section through a speck
(figures: Mondi Gronau)

Fig. 2. On-line quality control (extruder with gel count) at a raw materials producer

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These entail automatically extracting 50 random samples every hour and transferring them to a cleanroom for analysis on an extruder fitted with a gel counter. The data are transmitted directly to the process control system and the process is controlled in this way (Fig. 2).

Resolutions for online inspection are in the range of 50 µm for standard applications, such as PE and PP production. Special applications, e.g. polymers for high-voltage cables, operate with resolutions down to 5 µm.

**Cataloguing Defects**

Defects may be classified as gels, black specks, fish eyes, holes, insects, and streaks. They each have their causes and they also give rise to various problems in downstream processing.

However, defects are not classified in any ISO or DIN standard and nor are there any clear rules on what constitutes scrap, etc. Descriptions of them can therefore vary substantially with the viewpoint of the person talking about them.

That is why it is important to address this issue openly and to involve both suppliers and customers into the topic of defect classification and resolution or size detection. This is increasingly becoming a matter of company competitiveness.

Typical errors in the extrusion process (Fig. 3):

- Gel (unmelted material or crosslinks – like a water drop in a transparent film),
- Black specks (cracked or burnt material – brown or black),
- Fish eyes (unmelted material or crosslinks – often in opaque film with subsequent thin spot; but this defect is often equated with a speck),
- Other errors that can be detected by modern systems, such as holes, streaks, flow lines, insects etc.

**Integration into Production**

Mondi Gronau GmbH (formerly Nordenia Gronau GmbH), Gronau, Germany, is a pioneer in this area and operates a comprehensive process analysis and integration system.

The raw material is monitored partly in line, while the quality of the compound produced is inspected in parallel “at line” with the aid of laboratory extruders and camera systems. The films are checked in extrusion by film-inspection systems, and alert thresholds have been set up for the machine operator.

Also integrated are external measuring systems, such as colorimetry. Checks are conducted in downstream lamination (film strips between nonwovens), where the incorporated strips themselves are measured and inspected. Critical individual defects are cut out in post-processing (Fig. 4).

**PDA Interface**

The systems are integrated into the company’s internal data acquisition system (PDA). Every time a roll is changed, the readings are automatically saved on an internal server under the roll number and production date linked to that roll. This ensures immediate traceability of all roll data details in the event of later complaints. It also allows the customer to block certain rolls if it proves necessary to avoid potential problems.

The readings on the inspection server are automatically deleted every six months. This period is long enough to allow historical comparisons to be made with results from the same production if gel problems arise in extrusion. Troubleshooting can proceed faster as a result.

The machine operators use the systems for running-in and setting the extruders. A warning light automatically alerts the operators in the event of critical single defects, too many gels or a poor film rating, so that they can intervene directly in the process.

**The Data Manager**

These quality assurance measures are rounded out with a data-manager program that enables the readings to be sorted and processed under certain criteria. For example, a single mouse-click will call up an intuitive display of all grades of film that have been produced in a given period of time – on any installation. Batch, roll and wear records can be generated and statistical analyses performed (Fig. 5).

A separate centralized analytical software program reads in material, raw material and process parameters from the PDA or via an open platform communications (OPC) interface (which nowadays is the standard software interface for...
manufacturer-independent communication in automation technology). The resultant data obtained are then mapped to the respective quality/film rating for the purpose of long-term statistical process control (SPC).

**Benefits for Production**

The roots of problems with quality in production need to be identified and selected in real time from around 500 properties of a highly complex manufacturing machine. These must be processed so as to provide suggestions for improvements for the machine operator in order that deviations in quality may be counteracted in good time.

The extended networking of complex data sets yielded by OCS inspection systems (supplier: Optical Control Systems GmbH – standard for inspection and/or quality control at raw materials producers, film producers and converters) and PDA by means of smart data preprocessing supports the acquisition of knowledge from established database structures.

Sophisticated statistical tools for processing, analyzing, modeling and reporting data from commercial and research are used to identify and visualize the causes mentioned and to generate suggestions for improvement.

On-line monitoring of trend curves and statistical parameters helps to reduce scrap, post-processing and machine downtimes. In the wake of the insights discussed above, monitoring and alerting tools from OCS are increasingly being used to extend the functionality of other machines and to enhance process monitoring and control (Fig. 6).