Abstract

Today in modern Polymer plants an online quality control is done automatically and alarming the operators immediately so that the operators can react and avoid more damage to the final product. This “close loop”-concept also allows a grading of the pellet lot.

The Film producers, the customers of the Polymer plants, also use web inspection systems to control their final product quality, the quality of the raw materials and also their process parameters.

Between both control concepts exist some interrelationships and also problems, because the environment parameters are different. This relative correlation and the impact for the Polymer and film producers will be discussed with practical examples.

In today’s rough economic environment value added film extrusion needs more and more a 100% online production control. Modern web inspection systems alarm the operators immediately so that they can react and avoid more damage to the final product. Furthermore, the quality of the raw materials and also the process parameters are fully controlled.

Today’s state-of-the-art web inspection systems consist of fast standard CCD sensors, sophisticated lighting technology and a self-learning software to control and optimise the production process. Critical defects will be marked and reworked on a roll doctor.

The web inspection systems are in some cases directly integrated into the IPC of the extrusion line, e.g. BOPP, cast or blown film lines. Also, this integration enables a roll data handling in combination with all the other production parameters.

Application examples for customised web inspection systems will be discussed with regards to the integration costs to achieve the benefits and return from such an investment.

Introduction

The “close loop”-concept brings the offline Laboratory in Polymer Plants to an online measurement. This permanent control helps the producer to improve and monitor his process and react immediately. Also it allows a grading of the pellet quality that is often required by the customer.

High quality film producers also guarantee a 100% inspection of their production and will realise process or raw material problems. They can react immediately to any kind of problem.
The online “Close Loop”-Concept

The idea behind the online “Close Loop”-Concept is to bring the offline laboratory directly to the pellet production process, to grade the raw material and thus to shorten the reaction time if problems occur. In former times it took up to ten hours until the producer received results from the laboratory and knew the production quality. This is crucial if contaminations occur. Furthermore, the fully integrated automation, encapsulation and nearly clean room environments eliminate any external influence to the measurement like the contact with a higher humidity outside the production process.

In the “Close Loop”-Concept there are taken permanently small samples out of the pellet stream and automatically transported to the measurement devices for immediate analysis. This online quality assurance is linked to a process computer, which determines the process parameters and gives a direct feedback to control the process. This concept generates a return on investment within less than one year.

Principal of Online Quality Control

In principal the online quality control can be divided into two parts: the measurement on pellets and the measurement of extruded films in a cast or blown film process.

The online measurement on pellets gives information on the LAB colour values, the Yellowness Index (Colour Measurement), dust and impurities (Pellet Scan Systems) and the form and roundness (Pellet Size and Shape Distribution Systems).

The online measurement of the extruded film in a cast or blown process delivers online data about the contamination of gels, black specs or fish eyes (Gel Count), the additive content and physical properties (IR-Spectroscopy), the gloss (Glossmeter) or haze value (Hazemeter).

Benefits of Online Polymer Control

The benefits of the online Polymer control can be realised in two parts: the process control and improvements and the quality of the raw material itself.

The direct feedback on the process detects and cuts out shower of contaminants, which can occur within a couple of minutes and than vanish, by changing the silo. The level of gel contamination monitors the impact of different plant operations. Furthermore, cleaning procedures can be anticipated and plant shutdowns better planned. Also, the start up time during transition can be optimised and waste reduced.

The online measurement with frequent sampling gives the possibility of grading the raw material and eliminating out of specification material. This leads to better material, less claims, more competitive products and last but not least to a better relationship with the customer.

Online Pellet Analysis

For the online colour measurement the pellets will be automatically transported into a cuvette and the LAB colour values and the Yellowness Index are determined. After measurement the pellets are transported back into the process. The calibration of these systems is fully automated.

The online pellet scan systems inspect the transparent or opaque granules on a vibrating channel or moving belt and detect contamination, discolouration and foreign particles. After inspection these defects can be sorted out into a separate container. The good material can be fed back into the process. These systems reach throughputs up to 250 kg/h.
The pellet size and shape distribution analyser separates the granules on a vibrating surface and controls them with a sophisticated camera system in the free fall. The system detects twins, triples, dog bones, tails and measures their features like size, shape, elongation, roundness, roughness and convexity. The out of specification granules will be sorted out automatically.

All systems measure permanently the throughput and the measurement data will be available directly and can be linked via interfaces to the production data acquisition system.

**Online Measurement of Extruded Films**

The frequently taken pellet samples will be transported automatically to a gravimetric dosing unit and than extruded to a small film in a cast or blown film process.

After extrusion a special winding unit with several servo drives guarantee an absolute stable film path without any up and down movements. This is important for the achievement of very precise measurement results that are identical to the statically measured offline laboratory results. The winding unit is optimised for the raw material control by using a galette design for fast start up and a pneumatic expansion central winder to work without any cores.

The winding unit is equipped with a camera system to measure and store the gel and contamination level of the extruded film including the defect photos and –if necessary- alarm the operators. Further measurements like haze according to ASTM 1003, gloss, thickness, the density and composition of the Polymer can be measured online.

All these measured data will be processed in real time, linked to each other and available in one control software via OPC server concept. So, for example the extruder process parameters are available in the gel count statistics. The data can be connected to the polymer plant’s overall Production Data Acquisition (PDA) system and so a direct “close loop” feedback is available to control the production process. A web browser enables the plant staff to control all parameters from the complete line from everywhere in the plant and also enable the manufacturer to do online troubleshooting –if necessary- from everywhere in the world via Internet.

**Web Inspection in Film Extrusion**

Today value adding film producers control their production inline 100% by using highly sophisticated optical camera inspection systems. These intelligent self-learning systems recognise the exact position of every defect, take a photo of the defect and alarm the operator in real time. This helps to control the extrusion process better and to avoid the production of waste.

**Benefits of Web Inspection in Film Extrusion**

The benefits of web inspection are achieved in three parts of film extrusion: the process itself, the raw material or the final product.

In terms of process control a web inspection system contributes to optimise the production by eliminating waste production directly because of warnings. Realising gel and black spec contamination the machine downtimes for die cleaning will be reduced and its capacity enhanced.

In the extrusion process a web inspection system can optimise the raw material choice and helps to find the best material combination. A sophisticated offline analysis software adds all produced rolls of a whole raw material lot to one roll and determines for example the total gel level. Thus, the 100% web inspection is a valuable tool for control of the raw material itself.
Defect Types/Origin of Defects

The typical “classical” defects in film extrusion are gels, black specs and fish eyes. These defect types are similar to those of the online extrusion process in a Polymer plant. The film producer is facing additional defects from the different process or environment like holes, foreign particles/insects, die/flow lines, oil stains, laminating defects, cracked coatings, air bubbles/inclusions, streaks, wrinkles, lack of adhesive or craters. The different defects are referring to the type of production process. An online web inspection system should be flexible to learn in new defects that show up. The identification and classification of the exact defect type is more and more important for the operator to find out the cause and to react.

The origin of the defect can vary. A screen change or a change in the extruder temperatures itself will result in gel/black spec shower. The reason can be for example a sub optimal geometry of the extrusion line, where some material is lasting too long in some dead areas and causing this defects time by time. Or the raw material can be contaminated caused by the cracking process or by the transport of the pellets.

Technology

State-of-the-art web inspection systems use high speed digital CCD (Charged Couple Devices) line scan camera technology in combination with high performance PCs. These Embedded PCs are located next to the camera in a one box and achieve very high calculation capabilities in real time (buffering up to 1.800 defect photos per second). They inspect the web, evaluate the measured data in real time and send the results via Ethernet to a server. The server (Operating System Windows XP) visualises the defects (photo), documents them in a data base and gives alarms (horn, lamp or marker).

This concept allows the use of line scan cameras from several suppliers with data rates of 80 and 160 MHz can be combined with sensors of 2048, 4096, 6144 or 8192 pixel. For slow web speeds (e.g. 100 m/min.) long CCDs with 8192 pixel are suitable to work with only a few cameras. For high speed applications at a speed of 600 m/min. with a desired resolution of 280 µm 160 MHz CCD line scan cameras with 4096 pixel and a scan rate of 36.000 scans/sec. are needed.

High end inspection software enables the operator to teach in defects and thus to create –if desired- its own defect classes. Using Fuzzy Logic the system classifies different defect classes like gels, black specs, streaks, insects, holes etc. automatically.

Quality Reports/Alarms

The systems alarms the operator directly and can also control a labeller to mark the defects. Later the defects will be removed in the slitter department using also a print quality report.

Alarms and also printouts can be configured for critical single defects like insects, trend defects (e.g. not more than 20 gels of a special diameter per m²), repeaters, gel showers, defects per slit and the whole reel.

Interrelationship and Correlation

Example

A high tech extrusion company is producing breathable diaper films and to have a competitive advantage against other competitors its own compounds. With the compounds the company is extruding different quality grades of films for different customer specifications in a cast film line.

In the compounding department they are taking permanently samples from every produced bag, controlling the compounding process and grading the final lot. The measurement data are linked to a data base in the overall PDA system. With this information they can decide what quality grade of film for what customer they are able to produce.
This decision making tool has been achieved with the integration of an inline web inspection system into the cast film line. The line is running up to 100 m/min. at a width of 2000 mm.

Online Concept for Plant Control
Example

The customer has a fully integrated online “Close Loop”-concept implemented into its various polymer plants. The whole process was accompanied by an overall integration process concept.

To avoid long distance pellet transport including the problems of wear debris of pellets, clean room measurement containers have been installed directly next to the extruders. An analyser control software including a bus integration into the customer’s production planning system controls the whole concept from one operator’s panel in the plant’s control room.

A sample taker is permanently getting small samples out of the pellet stream and the pellet transport system brings them to the measurement devices. Before entering an analysing device a de-dusting system removes the dust coming from the transport. After that step a pellet distribution system controlled by the PDA software transports the pellets to the different measurement devices.

Pellet analysers are sorting out contaminated granules, evaluating the roundness and detecting angle hair etc. Extrusion cast film lines with camera systems determine the gel level and contamination. Online IR-Spectroscopy systems analyse the density and additive content.

The measurement data and also the alarms created by the system are given to the production staff in the control room in real time. In case of an gel shower that last less than ten minutes the operators can decide to put the contaminated material into another silo or to downgrade the whole lot. The system tells the operator when to start preventive extruder cleaning and when to shut down the plant. Also, transition process will be optimised significantly. The whole investment generated a return of investment much less than one year.

Summary

The online “closed loop” control concept is nowadays standard in modern polymer plants. It controls the production process, improves the quality significantly and makes the plant much more profitable.

Nearly all high tech film producers inspect their films 100% and realise any polymer problem immediately within the extrusion process.

Both are using optical inspection systems, but the inspection parameters like defect types, resolution

Nowadays web inspection systems with CCD line scan cameras are becoming more and more affordable and much easier to handle. Intelligent systems can be taught just by learning in the defect image (photo of the defect). The system helps to optimise the production process, the material recipes and the extrusion line.

The integration costs of such a system can be reduced by making an integration concept, but they depend on the depth of integration into the production process.

In the future, web inspection systems will be essential for the film extrusion and extrusion coating like the automatic profile control in blown film lines.
References

Online Inspection of Polymers, Films and Coatings/Laminates

- technology, benefits and costs

Oliver Hissmann
Sales Manager
OCS Optical Control Systems GmbH
Contents

- Introduction
- Online Quality Control in Polymer Plants
  Technology, Benefits, Online Lab, Close Loop Concept
- Web Inspection in Film Extrusion
  Technology, Benefits, Integration
- Interrelationships and Correlation
- Practical Examples
- Summary
Online „Closed Loop Control“-Concept

Additives

Raw material

Process

Production

Sampling

On-line Quality Assurance

Data (opt. measuring technique)

Determination of the process parameters

Process computer

Feedback
Benefits of Online Control

- **Process Control**
  (Optimisation, capacity, cleaning, waste)

- **Product**
  (better quality, customer satisfaction/relation, less claims, more competitive products)
Pellet Scan System

- Hopper
- CCD-Camera
- Lighting unit
- Pellet stream
Pellet Scan System

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<tr>
<th>Defect</th>
<th>Reject</th>
<th>Black</th>
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<td>200</td>
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**Start** [F1]
**Stop** [F2]
**Pause** [F3]
**Load** [F4]
**Print** [F5]
**Settings** [F6]
Pellet Size & Shape Distribution

- Hopper
- Pellet stream
- CCD-Camera
- Lighting unit
Pellet Size & Shape Distribution

<table>
<thead>
<tr>
<th>Size (µm)</th>
<th>Total</th>
<th>SF-1,0</th>
<th>SF-3,5</th>
<th>SF-5,0</th>
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<td>432,15</td>
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<td>Mean</td>
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<td>Stdev</td>
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Histogram and distribution graph showing size and shape distribution of pellets.
Size Distribution: Pellets with Dust

[Graph showing size distribution with cumulative and dust markers]
Pellet Colour Measurement

visible light

visible light

color measuring device

<table>
<thead>
<tr>
<th>Color Values</th>
<th>Average</th>
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<td>b*10°D65</td>
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Online Quality Control
Online Integrated Measurement Solution
Online Integrated Measurement Solution
Online Gel Count
Defect Types

- Gels
- Black Specs
- Contaminations
Web Inspection System
Embedded Multiple Camera Solution
Web Inspection in Film Extrusion

100 % Optical Control of the Web

- Photo of every defect
- Position of every defect
- Database Interface
- Reports
- Alarms
Defect Types

- Gels
- Black Specs
- Contaminations
- Die Lines
- Insects
- Calander Defects
- Oil Stains
- Air Bubbles
- etc.
Advantages of Web Inspection

- **Process Control**
  (cleaning, waste, reduction of downtime)

- **Raw Material**
  (control material + recipe)

- **Product**
  (better quality, less claims, more competitive products)

Considerable Cost Savings!!
Origin of Defects

- Extrusion Line 20%
  (screw geometry / dead zones)
- Resin 25%
  (contamination, recipe)
- Production Process 15%
  (extruder temperatures, screen change)
- Pellet Transport 40%
  (external/INTERNAL)
General Specifications (Resolution)

- Food Films: ∅ 300 µm
- Technical Films: ∅ 80 - 200 µm
- Surface Protection Films: ∅ 60-160 µm
- Optical sheets + films: ∅ 50 - 100 µm
- Optical Coatings: ∅ 25-50 µm
- Extrusion Coating: ∅ 350 µm
- Diaper Films: ∅ 300 µm
- Pharma Films: ∅ 200 µm
System Design

Transmission

Reflection – specular 120°

Transmission / Reflection Combination 45°
3-D Defect Analysis
Data Reduction Software Tool RMC
Quality Reports / Alarming

- Single Defect
- Trend Defects (20 gels per m²)
- Slit Defects
- Repeating Defect
- Gel Shower / Cluster
- Roll Defects
Teach-In Mode

Step 1: Choose Defect
Teach-In Mode

Step 2: Define Defect by Name
Teach-In Mode – Coating Void
Teach-In Function - Fly
Teach-In Function – Oil Stain
Teach-In Function - Gel
Blown Film Example

- **Product:** Lamination Film (transparent + opaque/white)
- **Width:** W = 2600 mm, **Velocity:** V = 80 m/min.
- **Defects:**
  - gels, black specs, fish eyes, die lines, insects
- **Web Inspection solution:**
  - 2 x 80 MHz 8192 pixel CCD line scan cameras
  - Transmission with high frequent fluorescence lamps
  - With PMMA focussing lens
  - Resolution: **MD 160 µm**  **CD 160 µm**
Closed Frame Blown Film
Time History (Gel Level)
Rolling Map / Die Defect
Cast Film Example

- **Product:** Surface Protection Film
  (transparent + opaque/white)

- **W = 3000 mm, V = 150 m/min.**

- **Defects:**
  - gels, black specs, fish eyes, die lines, insects

- **Web Inspection solution:**
  - 3 x 160 MHz 6144 pixel CCD line scan cameras transmission with high frequent fluorescence lamps with PMMA focussing lens
  - resolution: MD 110 μm  CD 160 μm
Lane Distribution
Defect Results

Fish-eye in a 3-layer Coex Film
Defect Results

Black Fish-eye with hole in a film laminated to aluminum
Defect Results

Fish-eye marked in aluminium sheet
Defect Results

Aluminium/Film Laminate with Contamination
PET Film/Sheet Example

- **Product:** PET Film (opaque/white + transparent)
  Roll Stack/both sides polished

- **V = 150 m/min., W = 2000 mm**

- **Defects:**
  gels, black specs, die lines, calander defects, oil stains

- **Web Inspection solution:**
  2 x 80 MHz 4096 pixel CCD line scan cameras
  reflection / transmission combination with high
  frequent fluorescence lamps with PMMA focussing lens
  resolution: MD 140 µm  CD 250 µm
Die Defect
Closed Frame Optical Films 50 µm res.
Coated BOPP Film Example

- **Product:** Coated BOPP Film
- **Slitter,** $W = 3200$ mm, $V = 600$ m/min.
- **Defects:**
  - gels, black specs, fish eyes, laminating defects, insects
- **Web Inspection solution:**
  - 3 x 160 MHz 4096 pixel CCD line scan cameras
  - transmission fiber optics / reflection LEDs
  - resolution: MD 280 $\mu$m   CD 270 $\mu$m
Inspection System Slitter 3200 mm 600 m/min.
Inspection Systems
Inspection Systems
Product: Laminated PET Film

Slitter, W = 1500 mm, V = 600 m/min.

Defects:
- gels, black specs, fish eyes, laminating defects, insects

Web Inspection solution:
- 3 x 80 MHz 2048 pixel CCD line scan cameras
- transmission + reflection (top side) combination
- resolution: MD 280 µm  CD 250 µm
Open Frame on Slitter 1500 mm 600 m/min. Reflection/Transmission - Kombination
Alarms / Repeating Defect
Extrusion Coating Example

- Product: PE coated aluminium foil or white board
- W = 2800 mm, V = 500 m/min.
- Defects:
  - PE spots, black spots, coating spots,
  - aluminium splices, missing coating,
  - aluminium peel-off, paper board creases
- Web Inspection solution:
  - 2 x 160 MHz 4096 pixel CCD line scan cameras
  - specular reflection and diffuse reflection (both sides)
  - resolution: MD 250 µm  CD 350 µm
High Power LED 3.000 mm
Extrusion Coating Alu
Contamination
Insect
Metal Splice
Oil Drop
Burst Bubble
Wrinkle
Interrelationship and Correlation
Example

- Online Compound Control (Gel Analysis)
- Oracle Database Integration
- Decision for Film Extrusion Quality (Grading)
- 100 % Web Inspection in Cast Line (Diaper Breathable Film)
Online Container for Plant Control (Example)
Gel Shower
Online Anticipation of Plant Shut Down
Online Transition Control

Start extruder cleaning

Stop injection cleaning agent

Stop extruder rinsing
Online Control of Extruder Start Up

Extruder startup after plant restart, start extruder cleaning

Stop injection cleaning agent

Stop extruder rinsing
Summary

➢ Close Loop Online Control (Process + Grading) is today’s Standard in Polymer Plants

➢ 100 % Web Inspection in Film Extrusion + Converting

➢ Different Defect Types, but close Interrelation

➢ Working Together avoids Problems and improves Web Quality
Thank You

Oliver Hissmann
Sales Manager
OCS Optical Control Systems GmbH
hissmann@ocsgmbh.com

Please remember to turn in your evaluation sheet…