Web Inspection in Film Extrusion and Coating- a Benefit for the Producer

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Abstract

In the history of web inspection high speed line scan camera systems are becoming more and more popular because of enhanced performance and good price/performance ratio.

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.

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

Today’s state-of-the-art film inspection systems guarantee a 100% optical control of webs like paper, films, aluminium, coatings, laminates etc. These intelligent self-learning systems recognise the position in machine and cross direction of every defect and take a picture of the defect. The defect data are stored in a network environment (Windows XP client-server architecture). The system delivers quality print protocols and sets alarms to activate a horn, a lamp or a marker in real-time.

Benefits of Web Inspection

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

Referring to the control of the process a web inspection system helps to optimise the production by eliminating waste production directly because of warnings. By anticipating rinsing intervals the machine downtimes for die cleaning will be reduced and its capacity enhanced.

A web inspection system in extrusion helps to optimise the raw material and to find the best material recipe. The offline software can add the produced rolls of a whole raw material lot to one roll and analyse e.g. the total gel level. Thus, the 100% inspection gives a good control of the raw material itself.
Defect Types/Origin of Defects

Typical “classical” defects in film extrusion and extrusion coating are gels, black specs, fish eyes, holes and foreign particles/insects. Other important defects are die/flow lines, oil stains, laminating defects, cracked coatings, air bubbles/inclusions, streaks, wrinkles, lack of adhesive or craters. The defects depend on the type of production process and a system should be open to teach in new defects that will occur in the future. It is getting more and more crucial for the producer to identify and classify the defect type immediately to have an idea about the origin of the defect to avoid further waste and improve the production process.

The origin of the defect can be based on the extrusion line, the raw material or the production process itself. An example for the process is a screen change or a change in the extruder temperatures with the result of gel/black spec showers. Regarding the extrusion line the screw geometry can be sub optimal and produce some cracked material time by time because of some dead zones. Also the raw material can be contaminated caused by the cracking process or by the transport of the pellets. The web inspection system will detect the defects and it helps the operator to find out and eliminate the reason for the fault.

Embedded Solution/Technology

The “Embedded Solution Concept” combines the advantages of smart cameras with those of classical client/server systems. An Embedded PC with a high speed frame grabber and disc on chip technology achieves data rates up to 160 MHz. Long distances of more than 100 m between the inspection system and the server can be bridged via an Ethernet 100 MB connection while maintaining very high calculation capability in real time (buffering up to 1.000 defect photos per second). The server (Operating System Windows XP) visualises the defects (photo), documents them in a data base and gives alarms (horn, lamp or marker).

Because of this concept digital CCD (Charged Coupled Devices) 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 80 MHz CCD line scan cameras with 2048 pixel and a scan rate of 36.000 scans/sec. are needed.

Lighting Technology

The application of the right light and system design is prerequisite to precise surface inspection. The CCD sensor is very sensitive in the infrared and visible red spectrum, whereas the human eye is sensitive within the visible green/blue spectrum.

Besides IR lighting most popular referring to price/performance ratio are high frequent fluorescence lighting tubes with a focussing lens. These lights are affordable in costs, easy to maintain and have a life time of 6.000 –7.000 hours. The focussing lens brings 50% more brightness so that these lamps can inspect still double lay flat blown film with an opacity of 60% at a speed of 80 m/min. in transmission.

Other light sources like fibre optics with metal halide lamps are used for high speed applications or opaque films, but are expensive in the initial purchasing and maintenance costs. Red LEDs are maintenance free for 10 years, but the initial investment is quite high and they have some technical and optical disadvantages in detecting defects in transmission.
System Design

Crucial for surface inspection is the system’s design of cameras and lamps, because only the detected or seen defects can be classified.

In general, there is a possibility to work in transmission (for transparent and translucent films) and reflection (for opaque films). In reflection mode various inspection angles are possible. For the detection of physical distortions of the surface (e.g. scratches, craters or lack of adhesive) a very flat opening angle (e.g. 120° - specular lighting) between camera and lamp will be used. But no pigment/coloured spot on the plane surface will be detected. For the detection of this defect a diffuse reflection lighting is needed. In some cases a combination of reflection and transmission lighting is suitable, e.g. for thermoforming barrier films.

In general, it is important to do a feasibility study with all materials and a defect sample catalogue when designing a web inspection system. For some applications some standard designs can be used.

Software/Intelligent Classification

Sophisticated web inspection systems offer an intelligent classification: the operator singles out surface defects with the help of the photos and classifies them according to defect types. The classifier automatically determines the inspection parameters within a vector for the defect type. Since, these systems operate with Fuzzy Logic, they are able to distinguish between defects such as gels, fish eyes or flies and mark the.

Quality Reports/Alarms

Today’s state-of-the-art web inspection systems deliver quality print reports and alarms (to activate a horn, lamp or marker) for the following situations:

Critical single defects like insects are important for the food or pharmaceutical packaging industry and should be eliminated 100%. In other applications trend defects (e.g. not more than 20 gels of a special diameter per m²), repeating defects, gel showers and defects per lane or slit are the control parameters for the operator. As for the whole roll the system should also deliver print reports and alarms for the defect density.

Integration Concept/Costs

The integration of a web inspection system into a production line contains the following costs:

Two weeks before start up there should be a two days pre-training for the system’s administrators with original customer’s film on a re-winder. This pre-schooling should take place outside the daily business so that there are no disturbances during the training.

During the installation and start up the administrator will assist the service engineers and afterwards the administrator will train his operators (in total 3-5 working days).

After four to ten weeks after installation there follows up a re-training and fine tuning by a technician. This session can answers minor questions that arise during daily work with the new web inspection software.
The costs of integration depend also of the system’s integration into the production process and/or PDA network interfaces. A basic configuration can be achieved with the above mentioned working days.

**Example: Blown Film**

The first example deals with the extrusion of double lay flat blown film with an opacity up to 60% and a haul off speed of 80 m/min. Two cameras work in transmission with fluorescence lighting units over the whole width of 2.600 mm and achieve a resolution of 160 µm in machine (MD) and cross direction (CD). The film is used for laminating purposes and so gels, black specs and fish eyes are critical. Also, the system helps to optimise the rinsing and die cleaning by anticipating the intervals.

**Example: Extrusion Coating**

In the extrusion coating for the liquid packaging market it is crucial that the juice etc. does not have any contact with the aluminium foil/board. So every violation of the PE coating has to be detected and cut off in a later process. At a processing speed of 420 m/min. and a max. width of 2.800 mm two inspection beams equipped with two 80 MHz 4096 pixel cameras each are working in specular and diffuse lighting to achieve a resolution of 350 µm in MD and CD.

**Example: Cast Film**

A 3.000 mm wide cast extrusion line produces surface protection film at a max. speed of 150 m/min. Every defect within the opaque/white film with a physical distortion of the surface like a gel, die line, black specs, fish eyes etc. causes a damage of the protected web (aluminium, steel coils etc.). The damage mostly will be realised at the final product (e.g. a laptop). Three high speed CCD line scan cameras with 6144 pixel are scanning 100% of the web with a resolution of 160 µm in MD and CD in transmission lighting.

**Example: 9-layer Flat Film**

A 9-layer co extrusion barrier film line for the food industry is controlled by a combination of transmission (for the transparent films) and reflection light (for the opaque films) using one camera beam for each side. The web inspection system detects gels, black specs, calander defects, oil stains and insects and immediately warns the operator. Besides insects gels with a diameter bigger than 500 µm are important, because these defects generate web breaks within the thermoforming process.

**Example: Lamination Film / Slitter**

A customer is processing laminated PET film for food packaging in a slittery winder at a width of 1.500 mm and a max. speed of 600 m/min. The customer is processing transparent and opaque films. Therefore he is using a transmission/reflection lighting combination. With three 80 MHz 2048 pixel CCD line scan cameras he achieves a resolution of 280 µm even at full speed. The system warns the operator of critical defects like gels, contaminations, lamination defects etc. and so the customer can guarantee his end user the quality of his films.
Summary

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


Introduction

Benefits of Web Inspection

Web Inspection Technology
- CCD Cameras, Lighting, System Design, Software/Classificator

Application Examples
- Cast/Blown Film, Extrusion Coating, Lamination, Optical Sheets/Films

Integration Concept and Costs

Summary

Web Inspection

100 % Optical Control of the Web
- Photo of every defect
- Position of every defect
- Database
- Reports
- Alarms
Benefits of Web Inspection

- **Process Control**
  (Optimisation, capacity, cleaning, waste)
- **Raw Material**
  (Optimisation material + recipe, control material)
- **Product**
  (better quality, customer satisfaction/relation, less claims, more competitive products)

Origin of Defects

- **Extrusion Line**
  (screw geometry / dead zones)
- **Resin**
  (contamination, recipe)
- **Production Process**
  (extruder temperatures, screen change)

Defect Types

- Gels
- Black Specs
- Contaminations
- Die Lines
- Insects
- Lamination Defects
- Oil Stains
- Fish Eyes
- etc.
Common Customer Specifications

- Food / Thermoforming: \( \varnothing 300 \mu m \)
- Laminating Film: \( \varnothing 200 \mu m \)
- Surface Protection Films: \( \varnothing 160 \mu m \)
- Optical PC/PMMA films: \( \varnothing 50 \mu m \)
- Extrusion Coating: \( \varnothing 350 \mu m \)

Web Inspection System

Embedded Multiple Camera Solution

- High Speed CCD Line Scan Cameras
  80 – 160 MHz, 512 – 8192 Pixel
- Embedded PC with High Speed Framegrabber
- Windows XP Server (network)
- Exact information on defects within the web
  (mosaics, position, alarms, protocols, storage)
Lighting Technology

- High Frequent Fluorescence with Focussing Lens (low cost, long life, easy maintenance)
- Red LED's (maintenance free, high intensity)
- Fiber Optics / Metal Halide Lamps (PLC, automatic diffusor, closed frame)

System Design

Transmission

Reflection – specular 120°

Transmission / Reflection Combination 90°

Defect Detection / Classifier

- Detection by Grey Values
- Automatic Classification with Fuzzy Logic
- Defect Teach-In Mode
Teach-In Mode

Step 1: Choose Defect

Teach-In Mode

Step 2: Define Defect by Name
Quality Reports / Alarms

- Single Defect
- Trend Defects (20 gels per m²)
- Lane Defects
- Repeating Defect
- Gel Shower / Cluster
- Roll Defects

Integration Concept

- Kick Off Meeting
- Pre-Training at Winder (Administrator 2 days)
- Start Up (Administrator + Operator 3 days)
- Re-Training after 4-10 weeks (1 day)

Blown Film Example

- Product: Lamination Film (transparent + opaque/white)
- W = 2600 mm, V = 90 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
Extrusion Coating Example

- Product: PE coated aluminium foil or white board
- W = 2800 mm, V = 400 m/min.
- Defects: PE spots, black spots, coating spots, aluminium splices, missing coating, aluminium peel-off, paper board creases
- Web Inspection solution: 2 x 80 MHz 4096 pixel CCD line scan cameras specular reflection and diffuse reflection (both sides) resolution: MD 350 µm CD 350 µm
Coatings / Reflection

Cast Film Example
- Product: 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 120 MHz 6144 pixel CCD line scan cameras
  - Transmission with high frequency fluorescence lamps
  - With PMMA focusing lens
  - Resolution: MD 140 µm  CD 160 µm

Lane Distribution
3-D Defect Analysis

Fisheye

Flat Film Example
- Product: 9-layer Film (opaque/white+ transparent) Calander/both sides polished
- V = 30 m/min., W = 900 mm
- Defects: gels, black specs, die lines, calander defects, oil stains
- Web Inspection solution: 1 x 60 MHz 4096 pixel CCD line scan cameras reflection / transmission combination with high frequent fluorescence lamps with PMMA focussing lens resolution: MD 50 µm CD 220 µm
Die Defect

Calander Defect

Lamination Film Slitter Example

- 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
Closed Frame / Slittery Winder

Alarms / Lamination

Summary

- 100% Web Inspection (photo + defect position)
- Embedded Concept
  (160 MHz CCD line scan cameras 2048 – 8192 pixel)
- Standard Components
- Client-Server Architecture
  (OS Windows XP)
- Automatic Classifier
Thank You
very much
for Your Attention!