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Film Inspection: The Gel Count Standard
What resolution and defect detection can be realised and makes sense - with practical examples

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Abstract

Nowadays web inspection systems are more and more an integrated part of extrusion and converting/laminating lines. On the one hand the customer demands a 100% quality control (pharma, medical, food, technical films etc.), on the other hand the film producers and converters need to avoid scrap and optimise their production process.

But no ISO or DIN standard for the definition of defects like gels and no rules for the definition of scrap exists. Every plastic film consists of contaminations, which come from the production process or are a part of the nature of Polymers. Thus gels are only a question of resolution.

In Polymer plants an online quality control and lot grading via gel count is done as a standard within each raw material producer for many years.

The definition of defects in extrusion and converting lines distinguish types like gels, black specs, fish eyes, holes, oil stains, insects, scratches, coating voids, air bubbles etc. These defect types have different causes of origin and impact on the further processing.

A close interrelationship and discussion between the raw material suppliers, the extrusion/converting companies and the end customer is becoming more and more crucial to succeed within the market and to achieve a competitive advantage.

Application examples for web inspection systems for the following markets will be discussed:

- Optical Films
- Pharma Films
- Technical Films
- Diaper Films
- Food Films (PET)
- Surface Protection Films

Introduction

Today value adding film producers and converting companies 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 warn the operator in time. This helps to control the extrusion and converting process better and to avoid the production of waste.

The benefits of web inspection are achieved in three parts of film extrusion and converting: 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 and converting 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.

Definition of Gel

Gels or also so called fish-eyes are small film homogeneities characterised by their area (size in transmitted light) and protrusion above the film surface. The gel count is, to some extent, an inherent film property.

In higher-molecular-weight constituents from the polymerisation process, or foreign polymeric materials, do not completely melt, form gels. Contaminants such as dust from bulk containers, abraded particles in material transfer lines and foreign materials, e.g. from poorly cleaned silos, can also cause fish-eyes.

During the transfer of PE pellets in pipelines, some of the PE pellets melt and smear on the walls of the pipelines due to abrasion and form ribbon-like streamers (angle hair) that gradually flake off into the pellet stream. While the streamers are still adhering to the pipeline walls, their large surface area comes into prolonged contact with atmospheric oxygen. This gives rise to reactive molecular groups, which form fish-eyes. Deposits on the inside wall of the extruder or excessively long thermal exposure during a stoppage can lead to fish-eyes with characteristic brownish occlusions. Poorly homogenised additives such as pigments, antiblocking agents, etc. act as nuclei around which polymer accumulates to form fish-eyes.

No ISO or DIN standard for the definition of gels or fish-eyes and also for its measurement exists. Film manufacturers and converting companies try to measure the gel level with film inspection systems. They want to minimise the gel count and gel size to a level where the fish-eyes pose no problem for the particular film converting process and intended application.

The Inspection Standard of the Polymer Industry

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 shorten the reaction time if problems occur. In earlier days 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 almost 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 small samples are taken permanently 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 a year.

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 Control

The benefits of the online control can be realised in three parts: the process itself, the raw material or the final product.

The direct feedback on the process detects and cuts out shower of contaminants, which can occur within a couple of minutes and then 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 the elimination of out of spec material. This leads to better material, less claims, more competitive products and last but not least to a better relationship with the customer.

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

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 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 and to have an idea about the origin of the defect thus avoiding further waste and improving the production process.

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 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.

Origin of Defects

The origin of the defect can be based on the extrusion line (20% root cause), the raw material (25%), the production process itself (15%) or the pellet transport (40% external and internal transport).

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 from time to 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.

Practical Examples

Optical Films & Sheets & Coatings

In the field of optical films, sheets and coating resolutions from 25 - 100 µm are mainly used depending on the guaranteed defect detection to the customer. The defects vary from normal defects like gels or black specs to special defects like optical distortions, lenses, flow lines or scratches. Resolutions below 100 µm require a clean room environment because otherwise too many pseudo defects such as dust, etc. are detected.

Pharmaceutical Films & PVDC Coatings

PVC calendering or PVDC coating line inspection systems and pharmaceutical films require web inspection system resolutions of around 200 µm. Defects such as holes, insects, black specks, coating voids or structures of 0.1 mm^2 must be reliably detected and marked. These, in the production process highlighted defects, can then be removed during assembly.

Technical Films

Technical films are very often extruded on blown film lines. Since these installations are not often produced in clean rooms, 100 µm resolution is problematic to use and not practical. It is now standard practice to classify specks by their diameter: < 250 µm, 250 –400 µm and > 400 µm. The film is for example 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.

Diaper Films

In the market for hygiene diaper films (e.g. breathable back sheets) holes and black specks larger than 1 mm must be reliably detected. Also, insects and metal contamination are not acceptable. This requires a system with a minimum resolution of 500 µm and frequent validation of the inspection systems.

PET Food Films

In the market for food barrier films no visible defects such as insects and black specks are tolerated. Besides the visible contaminations for the consumer also the barrier can be damaged. Resolutions of around 200 µm are the current standard on the market. Besides insects black specks with a diameter bigger than 500 µm are important, because these defects generate web breaks within the thermoforming process.

Surface Protection Films

Protruding specks are very critical, especially for surface protection films. However, since these are hard to determine, the diameter of the speck is multiplied by a factor, such as 1.1–1.5 times the film thickness. Resolutions are thus in the 100 µm range and above. Every protruding defect within the film causes a damage of the protected web (aluminium, steel coils etc.). The damage mostly will be realised in the final product (e.g. a laptop or refrigerator).

Extrusion Coating on Aluminium Boards

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 barrier has to be detected and cut off in a later process on the roll doctor.

Conclusion

As a conclusion online inspection and control is coming more and more crucial in the extrusion and converting market. The widely used and established general resolution requirements vary widely.

Optical films & sheets are mainly inspected in a resolution range from 25 – 100 µm. Pharmaceutical films with 200 µm, technical films range from 100 – 200 µm, diaper films with 500 µm, PET food films in the range 200 – 500 mm, surface protection films from 60 - 160 µm and extrusion coated aluminium boards with 350 µm.

In the future, web inspection systems will become more and more essential for the film extrusion and extrusion coating like the automatic profile control systems.

The resolution requirements will be much higher and a closer cooperation and discussion between the raw material suppliers, the extrusion/converting companies and the end customer is becoming more and more crucial to succeed within the market and to achieve a competitive advantage.

References

1. Hissmann, O.: “Big Brother for Films”. Kunststoffe plast Europe (2003) 10, pp. 63-65

2. Hissmann, O.: “Film Inspection – A Question of Location”. Kunststoffe Plast Europe (2004) 6, pp. 76-78

3. Hissmann, O.: “The Embedded Solution as a Symbiosis of Intelligent Hardware and Software”. Kunststoffe Plast Europe (2004) 10, pp. 246-248

4. Finn, G./Hissmann, O.: “Uncompromising Eyes”. Kunststoffe International (2007) 5, pp. 2-4

5. Schnabel, A. /Hissmann, O.: “High Quality Pharmaceutical Films”. Kunststoffe International (2007) 7, pp. 54-60

6. Hissmann, O.: “Complete Control”. Kunststoffe International (2007) 10, pp. 168-170

7. Stehen, H. /Hissmann, O.: „Standard Search for Specks“. Kunststoffe International (2010) 10 pp. 138-140