Filmex cast film line for production of high-quality film (photo: W&H)

Melt Filtration. Film for protecting sensitive surfaces is used in a variety of applications. Whether glass, ceramic, plastic, steel or painted – all surfaces must be protected against external influences between production and use. Moreover, the requirements that must be satisfied by the film are as varied as the products themselves. Absence of blemishes and impurities in such applications is especially important.

Protection for Sensitive Surfaces

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As a rule, film intended to protect a surface is applied to the product to be protected either during or immediately after production. Most applications involve flat surfaces, but sometimes quite complex surfaces need to be protected – for instance, painted parts and automotive field. The film must adhere well to the particular surface and be removed with no residue left behind. Good thickness tolerances and flatness, and sometimes minimal shrinkage are additional requirements. Depending on the application, the adhesive layer can be coextruded during production of the film or applied as a coating immediately after extrusion. Suitable methods of production include extrusion of blown or cast film, but the requirements for the end product are ultimately the determining factor. Cast film exhibits, among other features, better transparency, thickness tolerances and less shrinkage. Polyolefins frequently serve as the substrate material, while the adhesive layer often is determined specifically on the basis of the particular application.

Maximum Purity Required

The primary attribute of high quality film used for surface protection is absence of blemishes. Black spots or impurities, for example, can adversely affect the appearance of the product being protected or, in the worst case, even damage the product. The requirements for film used during production of LCD screens are especially stringent. Sometimes, the requirements call for impurities no larger than 50 µm in size per 1 m² of film. In addition to suitable resins, producers must focus on the cleanliness of the production environment and high-quality inspection systems and, in this context, on melt filtration especially. Filter medium selection, the filter fineness, the filtration area and the design of the filter all play an important role.

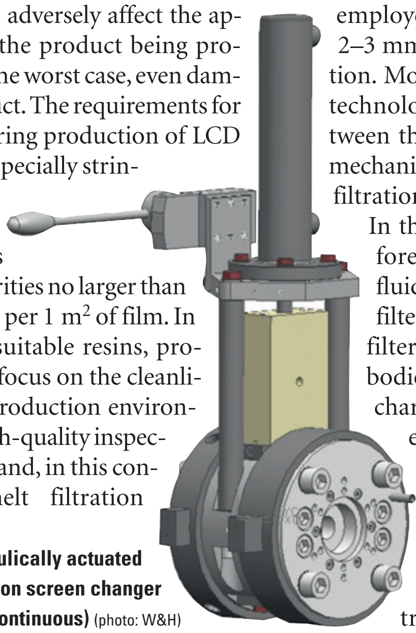

Fig. 1. Hydraulically actuated piston screen changer (discontinuous) (photo: W&H)

The general objective of melt filtration is to separate solid and viscoelastic contaminants from the polymer melt by means of a suitable filter medium. In actual practice, wire mesh woven in a variety of ways, nonwoven filter media, packed sand or sintered filter elements are employed; with pore sizes of 5 µm to 2–3 mm defining the quality of filtration. Moreover, in the field of filtration technology, a distinction is drawn between the two fundamental separation mechanisms: surface filtration and depth filtration.

In the case of surface filtration, the foreign bodies removed from the fluid remain at the interface with the filter media. As a porous phase, the filter cake formed by these foreign bodies can also exhibit certain filter characteristics. Surface filtration is especially well-suited to filter out solid particles.

In contrast, in the case of depth filtration, the impurities are not retained at the surface of the filter, but rather are trapped inside the filter media.

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Fig. 2. Hydraulically actuated D-SWE piston screen changer (discontinuous) (photo: Kreyenborg)

stant to ensure that the results could be compared exactly.

In an initial experiment, wire mesh screens woven in different ways and exhibiting different degrees of filter fineness were used **(Fig. 3)**. It was found that use of optimized screens produced a drastic reduction in the number of gels per square meter of film. It was also noted, however, that in spite of the fine degree of filtration employed, surface blemishes with a

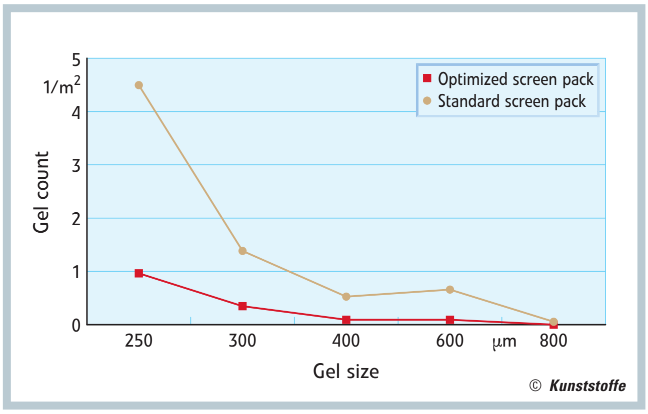

Fig. 3. Comparison of different wire mesh screen packs

Depth filtration is particularly well-suited to remove impurities with viscoelastic characteristics; these are often called gels. Gels are distinguished from the melt by their high viscosity.

Simple filtration systems are usually found in conventional cast film systems for processing virgin resin with few impurities. These are often discontinuously operating slide plate or piston screen changers with one filtering position **(Figs. 1 and 2)**. To replace the filter elements, it is necessary in this case to stop the film line and restart it after changing the filter. To keep lost production time as short as possible, the screen is changed during the required cleaning of the die lip and chill roll that that takes place at regular intervals anyway.

Depending on the amount of impurities in the resin to be processed or when processing recycled materials, it may also be practical to employ continuous filtration systems. In this case, the screen is changed while the equipment continues to operate – without disrupting production.

The filter packs in conventional film lines frequently consist of several circular wire screens in contact with one another and held in position by a breaker plate to prevent deformation. In addition to providing mechanical support, the ideal geometry of this breaker plate fulfills the function of ensuring uniform melt distribution over the entire surface area of the filter, thereby preventing core-flow effects. In a filter pack constructed in this way, the separation limit is defined by the size of the opening in the wire mesh and thus represents a type of surface filtration.

Comparison of Filters

Against the backdrop of the demanding quality requirements that must be satisfied by film used to protect sensitive surfaces, different filter media were tested and compared as part of a series of experiments conducted on a cast film system from Windmöller & Hölscher KG (W&H), Lengerich **(Title photo)**. The evaluation employed an optical inspection system from OCS GmbH, Witten, Germany. For the experiments, the system was fitted with a piston screen changer from Kreyenborg GmbH, Münster, Germany, and partially equipped with filter elements from Seebach GmbH, Vellmar, Germany. All of the experiments were conducted with a polypropylene from Borealis AG and taken from a single batch. The process parameters were held con-

Fig. 4. Screen plate with filter candles (photo: Kreyenborg)

size of 200 to 300 µm still occurred. This experiment thus demonstrated the pronounced elastic behavior of gel particles: in the filter, they undergo deformation as a consequence of shear deformation, then pass through the wire mesh and subsequently resume their initial form.

Based on these less than surprising results, a follow-up experiment was planned where the filtering area of the screen changer would be increased while retaining the same filter fineness and same mesh. This involved inserting a screen plate with screwed-in filter candle elements into the cavity of the filter **(Fig. 4)**. In this way, it was possible to increase the filter area by a factor of 7. At the same time, this increase in surface area was supposed to achieve two beneficial effects. First of all, a larger active filter area means a lower flow rate through the filter element and thus a reduced shear rate. At the same time, this measure was intended to reduce the pressure loss across the filter and thus the inlet pressure. Both changes should lead theoretically to better filtration of the gels, since they are subjected to less shear deformation. Contrary to expectations, however, the experiment did not yield better filtration results **(Fig. 5)**.

In the following analysis, the reason for these results is explained as follows. The screen pack consists of a multi-layer structure of individual wire mesh screens that, in addition to mechanical support of the superfine filtration stage, also pro- →

vides a drainage effect or lateral flow of the melt within the filter pack. This makes it possible to use the entire circular surface of the screen pack for filtration, and a correspondingly lower pressure drop across the filter pack results. In contrast, when manufacturing the filter candle, a compacted, symmetrical filter laminate is rolled into small-diameter tubes and welded, with the superfine filtration stage ending up in the center. These filter tubes were then inserted into a threaded base, covered and welded all around at these two locations to prevent any leakage flows. This design did not provide the mechanical support found in the screen pack. Rather, compacting the laminate provided the mechanical strength needed for use. This compacting had a corresponding adverse effect on the porosity and free surface area through which the melt could flow. Moreover, in spite of the sevenfold increase in filter area, a larger pressure drop across the filter candle plate and a larger number of gels than with the screen pack resulted.

From the comparisons of conventional screen packs with filter candles, it is also possible to draw the conclusion that flow around the edge of the screen pack did not occur, since the fully sealed de-

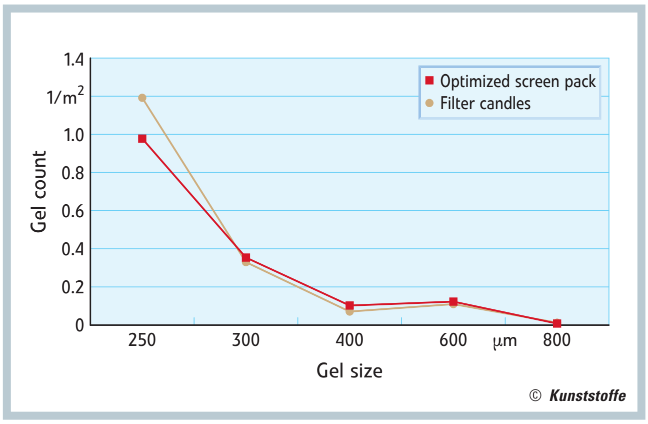

Fig. 5. Comparison of screen pack and filter candles

Fig. 6. Screen packs with special nonwoven material and seal around the outer edge (photo: Seebach)

sign of the filter candles provides a direct comparison with the interference fit of the screen pack. The screen pack is thus able to ensure effective sealing.

Taking the knowledge gained from the above-mentioned experiments into account, a filter medium with depth filtration characteristics that has been used for a long time in polymer and fiber production as well as in production of biaxially oriented PP film was selected for a follow-up experiment. For the screen packs used, a special nonwoven material in the core was protected on both sides by wire mesh and sealed tightly (leak-free) around the outside diameter by a stainless steel ring **(Fig. 6)**. Viscoelastic impurities are trapped in the pores of the nonwoven material and not at the surface, as is the case with wire mesh screens.

A further series of experiments was intended to permit comparison of the filtering effect of different nonwoven materials. The optimized screen pack from the initial experiments was also taken as the reference in this series of experiments **(Fig. 7)**. While the results obtained with nonwoven materials A and B were comparable to or worse than those from the reference, nonwoven material C produced significantly better filtration results. The experiments also showed, however, that a significantly larger pressure drop resulted with nonwoven material C than with the reference. In addition, the pressure increase during production was more pronounced due to the retention of gel particles in the nonwoven material.

Based on the knowledge gained from these experiments, it is obvious that nonwoven material is ideally suited for production of film with extremely few gels, but that increasing the amount of filter area is absolutely essential. For this reason, so-called long-life filters are used in Asian countries in particular **(Fig. 8)** to produce high-quality cast film for protecting surfaces on IT products **(Fig. 9)**. For these filters, numerous filter disks are slid onto a perforated mandrel and enclosed in a housing. The melt enters the housing, flows through the filter disks from the outside to the inside and then through the holes in the mandrel, finally leaving the filter. The benefit of this design is that it is possible to achieve an almost unlimited surface area ranging from 1 to about 25 m^2. The large surface area means a lower pressure drop and less shear on the melt, so that nonwoven filter material with a filter fineness between 5 and 40 µm produces exceptional filtration results. Depending on the size, impurity content of the melt and filter fineness, the filter lifetime can last from a few weeks to several months. The filter is changed by replacing the entire long-life filter with a second filter that has been cleaned and preheated. The filter disks can be cleaned 10 to 20 times in special solvent baths or pyrolysis ovens and then reused.

However, when using a long-life filter, certain peculiarities that can have an adverse effect on product flexibility must be kept in mind. Because of size and geometry, the amount of melt in the filter is significantly greater than in conventional screen changers, and the design is char-

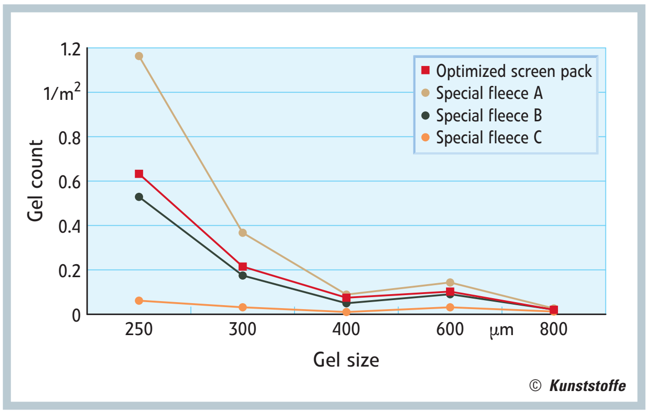

Fig. 7. Comparison of different nonwoven filter materials

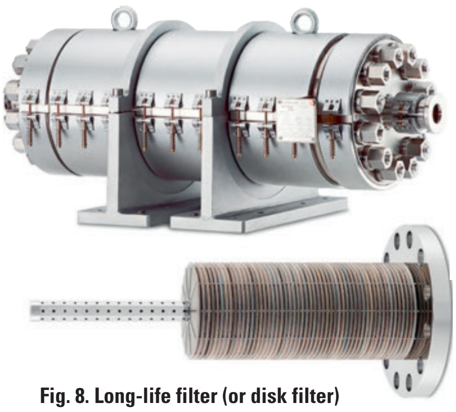

Fig. 8. Long-life filter (or disk filter) with a number of filter disks (photo: Seebach)

Fig. 9. Filmex cast film line in a cleanroom for production of film used to protect sensitive surfaces (photo: W&H)

acterized by a wider residence time distribution. This places certain limitations on product, color or resin changes. In addition, the quality of filtration and regular changing of the filter disks translate into higher production costs. As a rule, use of such a long-life filter is practical only if it is needed for a high percentage of the product range.

Another way to increase the amount of filtration surface is to use optimized piston screen changers fitted with several filter disks. While this does not increase the filter surface area to the same extent achieved in a long-life filter, there is some benefit in relying on a system that is well-established in the extrusion industry and permits fast and easy filter element changes. Product, color and resin changes are quick and easily performed without the need for disassembly. Furthermore, the lower melt volume in piston screen changers means a narrower melt residence time distribution with the resultant benefits. The concept of several filter disks in a piston screen changer makes it possible to achieve a considerably better filtration result without having to accept restrictions on flexibility. Existing screen changers in film applications can be converted to permit use of several filter disks in order to optimize the product quality produced by the equipment

Conclusions

Experiments have shown that a significant increase in filtration quality can be achieved by optimizing wire mesh screen packs. Use of filter candles to increase the surface area available for filtration did not yield any additional improvement. Use of nonwoven filter materials presents an opportunity to further improve the filtration results considerably. This, however, also requires an increase in the amount of surface area available for filtration. With highly specialized lines, use of long-life filters is recommended, since the exceptional filtration results outweigh the loss in flexibility and higher costs. For flexible systems used to produce a wide range of products and subject to frequent changeovers, use of several filter disks in conventional piston screen changers is also a possible solution. If necessary, both systems can be tested under production conditions on the equipment in the W&H technical center. ■

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