Extruding Plasticised PVC Film

Cost-efficient Production. Using a specially-assembled co-extrusion system, it has proved possible, for the first time, to produce film that could previously only be produced by the calendering process. This permits more cost-efficient production with a high quality at the same time.

Producing Film on Calenders

So far, the film needed to manufacture the products referred to above has been produced virtually exclusively on calenders. On these systems, the powdered raw material is plasticised on either Buss co-kneaders or planetary gear extruders. Both systems prepare the material gently and ensure good homogenisation and dispersion. At the same time, the melt temperature generally remains very low. The large surface of the planetary gear extruder, in particular, allows the melt temperature to be extensively influenced via the machine parameters.

The drawbacks, however, are the extremely high investment costs and the fact that the systems are unable to build up pressure. In other words, it is not possible to feed the melt to the first roll gap via a slot die. Instead, the small pieces of melt emerging from the extruder are conveyed to the first roll gap on the calender by conveyor belts. In order to prevent too large a melt bank from developing at certain points, the conveyor belts move to and fro across the entire width of the rolls. The material drawn in is formed into a raw film, without an adequate surface finish as yet. From the first calender gap, the melt web then runs over the second calender roll into the next gap. A bank forms at this point, since the plastic melt accumulates upstream of the narrower roll gap. Under the pressure of the outer layer and the rolls, the material that has been pushed back moves into the bank vortex. Banks of this type are to be found at all the roll gaps on the calender. They ultimately determine the quality of the film. Given their importance, they are permanently measured on state-of-the-art systems with modern camera units, and their size is controlled by varying the corresponding process parameters.

At least three roll gaps and hence four rolls are necessary to guarantee an adequate film quality. Before the film is drawn off from the final calender roll, the so-called hot trimming is performed. Once the melt has spread out towards both sides, the edges of the melt web are cut off by a round blade running along with the web and fed back into the first roll gap. The film produced in this way is removed by means of a take-off unit and then runs over the tempering and cooling unit. After this, the film thickness is measured. The next step is the so-called cold trim, where the edges of the film that have been damaged by the guide units and through film transport are removed prior to the film being definitively wound up [1].

Extrusion Process Easier to Master

If a general comparison is drawn between the calendering and the extrusion process (Fig. 1), then the advantages of the calendering process are to be found in the area of raw material costs and material consumption. The low temperatures that prevail during the entire plasticisation and forming process mean that only a very small amount of stabiliser has to be added. The compounds can thus be made up in a correspondingly cost-efficient manner.

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In addition, the thickness tolerances achieved with this process are extremely low, in other words, the extra allowance required to ensure that the specified minimum film thicknesses are achieved can be kept to a minimum – something which is directly reflected in the amount of material consumed. The attainable throughputs are also very high. The film width and thickness can similarly be varied without having to exchange individual system components.

One drawback of the calendaring process is the very high investment costs involved and also its low flexibility compared with other materials. In addition to this, it is a highly complex process that is difficult to master and requires the individual components to be precisely set.

The extrusion technique offers a number of advantages compared with this. The investment sum for a flat-film extrusion unit is some 30 to 40 % lower, for a correspondingly lower performance. Minor modifications to the machine (a change of screw) make it possible to process different raw materials with dissimilar melt behaviour. The lower investment sum and the more readily controllable extrusion process have led to a situation where considerably more flat-film units than calendaring units are employed for the broad mass of thermoplastics that are relatively easy to extrude. Critical products, such as film in plasticised PVC, are still processed on calendared systems, however, since, as already mentioned above, the quality requirements in terms of surface finish, optics and thickness distribution are very high and cannot be achieved with other technologies.

Films for Medical Applications

To enable the above advantages to be exploited for this demanding field all the same, an extrusion system was constructed and successfully brought into operation for the first time a few months ago which can be used to produce plasticised PVC film for the medical sector. This was made possible through consistent further development of the individual system components and precise coordination of the units. Figure 2 shows the layout of the system.

As shown in Fig. 2, this system uses three single-screw extruders with a screw diameter of 125 mm for plasticising the material. The extruders are equipped with screws specially tailored to this product. The stringent requirements on melt homogeneity, in particular, constituted a major challenge. This could only be met by using mixing heads of a completely new design and by incorporating static mixers in the melt lines. The temperature of the melt, established with the aid of a measuring cross, displays a maximum inhomogeneity of +/−1.5 °C.

The slot die downstream of the extruders is a standard automatic die that is equipped with a corresponding coex adapter. The three melt flows are placed uniformly one on top of the other here and formed into a melt web. What is important is that the melt should be allowed sufficient time to relax after having spread out widthways. Any stresses that may prevail will be smoothed out and distortion of the film avoided.

The use of three extruders in conjunction with a coex adapter offers considerable advantages, which justify the higher investment costs. Mention should be made on this point of:

- a central layer in regenerate, outer layers in high-grade, skin-compatible compounds;
- the possibility of colouring the individual layers differently;
- avoidance of defects going right through the film.

Figure 3 shows two thin sections aimed at giving an impression of the different possibilities open to the system operator through the use of three extruders.

Downstream Units Further Developed

The requirements on the film in terms of flatness, straight running and shrinkage values also necessitated further development of the chill-roll downstream unit. This was equipped with additional cooling rolls and a film relaxation station (Fig. 4). In addition to this, a defined surface structure can be embossed on the film with the aid of the combined cooling/embossing roller configuration.

Once the film has cooled, its thickness is measured. Films of this type can only be produced rationally and in a verifiable quality at system speeds in excess of 100 m/min by using automatic dies linked into a control network with a highly advanced, rapid film thickness measurement system. The actual values established are fed to the control unit where they are compared with the setpoint values. If excessively high deviations result, then the nip area of the nozzle will be selectively adjusted by the control system. The film tolerances achieved in this way are approximately +/−5 % for film thicknesses of around 100 µm.

At the end of the line comes the wind-up unit. The high line speeds mean that only fully-automatic systems are suitable here. These make it possible to precisely control the web tension on the one hand and permit reliable, problem-free reel changes at maximum line speeds, on the other.

The control unit constitutes a decisive component of the system (Fig. 5). This is of key importance for the system’s efficiency. It must be possible for all the system components to be controlled from here, so that the operator can gain a rapid overview of the running processes and intervene if necessary. Trend graphs, which depict long-term changes, are a key aid in this respect. The user interface should have a clear structure. Serious input errors should be avoided through the appropriate algorithms and safety prompts.

It is also essential for all the key process parameters to be recorded all the time, since the system operator is generally required to provide proof of the quality for the production process as a whole.
Conclusion

To sum up, it can be said that, for the very first time, this system has made it possible to produce films which could previously only be produced by the calendering process. This new technology is now opening up a wide range of advantages. Mention should be made of the considerably lower investment costs (some 40 to 50 % of those of a calender unit), the production costs that are lower in overall terms (both operating and personnel costs) and the greater degree of flexibility in the materials being processed. In addition to this, the follow-up production costs were clearly lower. It was possible to weld the films produced on this system more rapidly while still achieving an up to 40 % higher weld strength.

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Fig. 3. Thin sections through a three-layer PVC film

Fig. 4. Chill-roll unit including relaxation rolls

Kühl-/Relaxationsrollen = Cooling/relaxation rolls; Gummierte Andrückwalze = Rubberised pressure role; Prägewalze = Embossing roll

Fig. 5. Integration of the unit in the control system taking the example of the C4