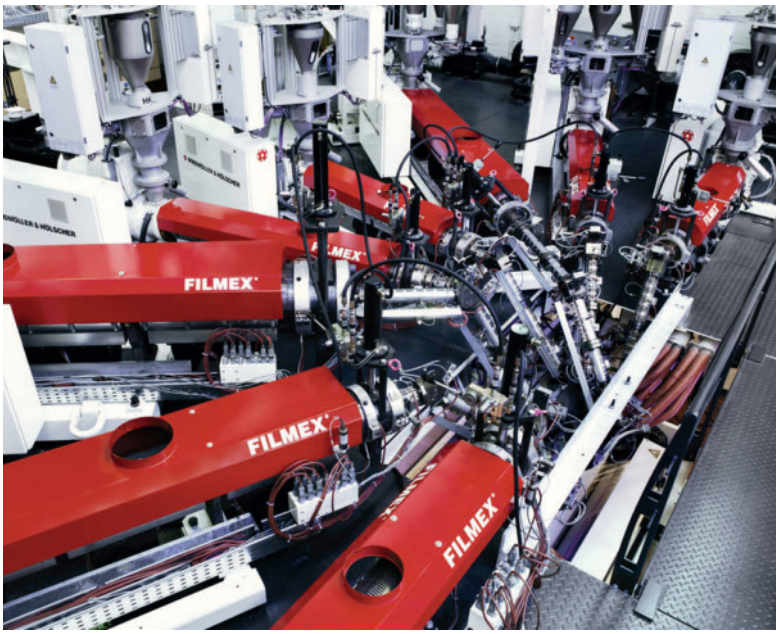

Extruder platform of a cast film line (photo: Windmöller & Hölscher)

Boosting Throughput – Increasing Flexibility

Film Extrusion. Falling batch sizes and frequent changes of material and product mean that film manufacturers are increasingly demanding greater flexibility of their production plant, which also still has to be cost efficient at the same time.

When paying a visit to the supermarket, consumers are delighted to see the ever-longer „best-by" dates and increasingly attractive packaging designs. In purchasing a film-wrapped product, the consumer does not spare a thought for the many different requirements that the films are subject to in order to make them into high-tech semi-finished products. Both film manufacturers and machine builders are confronted with the challenge of producing these films economically in the face of constantly rising raw material prices and increasingly stringent requirements. Added to this comes the fact that energy costs have also risen constantly over the past few years, which has led to machine builders making more use of energy-efficient drive concepts and heat recovery systems.

Despite the onset of the economic crisis in the last quarter of 2008, the packaging industry was able to record a 6 % increase in sales in 2008 compared with the previous year according to the German plastics processing industry association (Gesamtverband Kunststoffverarbeitende Industrie e.V. – GKV), and thus come out top of all the sub-sectors observed. Even the quantity of polymer processed grew by 3 % in 2008 compared with the previous year, to stand at 4.1 million t. The following article sets out a number of selected innovations in flat film, blown film and downstream units.

Flat Film

It is not just since the start of the economic crisis that a large portion of the film sector has been confronted with differing and, in part, contradictory requirements: with constantly falling batch sizes, on the one hand, and an increased melt throughput, on the other hand, aimed at ensuring the most efficient use of resources and the highest quality for the lowest possible cost. These conflicting objectives have prompted a range of further developments in the production systems employed which are still ongoing.

Extruder technology. Higher throughputs with smaller machines, shorter residence times in the extruder and a reduced outlay on maintenance – alongside lower investment costs, these are the key reasons behind the increasing spread of so-called fast-runners, i.e. machines which can also be equipped with direct drives and operate without gears. Systems of this type have already been under development for a number of years now, and the problems due to an excessively high melt temperature seem to have been overcome through suitably adapted screw designs. Fast-runners are now an integral part of almost every machine manufacturer's range and are being used to an ever-increasing extent.

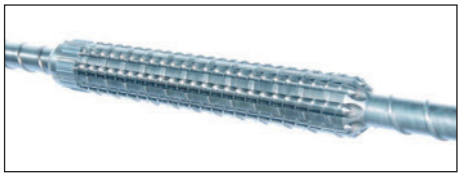

Fig. 1. MRS system for PET degassing (illustration: Gneuss)

PET processing. One particular trend has been emerging in PET processing for a number of years in that the high pressure of competition between raw materials manufacturers, coupled with the now established recycling system, has led to a disproportionately low price increase in the material. The pre-drying →

Translated from Kunststoffe 10/2009, pp. 154–159
Article as PDF-File at www.kunststoffe-international.com; Document Number: PE110212

required on account of PET's susceptibility to hydrolysis takes up a large amount of time and energy. For this reason, energy efficiency is being constantly enhanced through innovative process control, including, for instance, selective dew-point control or alternative drying techniques (such as infrared). The so-called melt degassing technique is becoming increasingly widespread. This involves water being removed directly from the melt, thus permitting a reduction in the amount of pre-drying required or the elimination of pre-drying altogether. Alongside the degassing apparatus that has now become established on the market, such as single-screw and co-rotating twin-screw extruders and the Vacurema technology developed by Erema GmbH, Ansfelden, Austria, interesting new developments were presented at K'07 in Düsseldorf, Germany, already (multi-rotation system – MRS). On the MRS extruder manufactured by Gneuss Kunststofftechnik GmbH, Bad Oeynhausen, Germany, the non-dried PET is melted in a single-screw section and conveyed into a degassing zone made up of a single-screw drum which has conveying screws set in it **(Fig. 1)**. The big degassing surface and high level of surface renewal ought to make it possible to process 100 % post-consumer PET bottle flakes without pre-drying. The alternative planetary roller system from Battenfeld Extrusionstechnik GmbH, Bad Oeynhausen, Germany, has a planetary roller section with involute teeth directly downstream of the single-screw extruder, which additionally ensures that the screw flights are self-cleaning and similarly makes for efficient degassing.

Fig. 2. Edge encapsulation in a slot die
(photo: Verbruggen)

Die technology. Developments in die technology are being conditioned by the need for increased line speeds with lower film thicknesses. In order to ensure maximum system flexibility still, especially with small batch sizes, the die width that is actually used (which at Verbruggen N.V., Temse, Belgium, for example, has now attained 8.1 m) can be infinitely varied with the aid of an internal deckling system on virtually all makes of die. The trend towards an ever-increasing number of layers in plastic films that has prevailed for many years is continuing unabated. While simple asymmetric barrier films can already be produced with three layers, the possibilities for enhancing cost efficiency with an increasing number of layers are virtually unlimited. The distribution of PA layers to improve thermoformability and reduce the tendency to curl up, the skilful combination of PA and EVOH to improve visual appearance, the use of stiffer materials to permit downgauging, and the use of ever-thinner functional outer layers are just a few examples of the many possibilities that exist. While seven or nine-layer systems were still the benchmark at K'07, Windmöller und Hölscher KG (W&H), Lengerich, Germany, successfully brought two eleven-layer cast film units into operation at the start of 2009 **(Title photo)**. But it is not only the increasing number of layers that contributes to the cost-efficiency of barrier units but also the film width that is attained and the output. One of these two units achieves an output of 2.3 t/h with a film width of 3.9 m (both net values). According to W&H, with the big working width and an optimum edge encapsulation setting **(Fig. 2)**, it is possible to reduce the mixed edge trim to 2 %.

A further increase in the number of layers can be achieved by employing microlayer feedblock technology **(Fig. 3)**. While this topic was initially discussed first and foremost for barrier applications, microlayer technology has now made its way into the production of cast stretch film. On this, W&H claims that the key to success does not, however, lie in simply multiplying the conventional layers employed but in the interaction between the microlayer and the correspondingly adapted film formulation.

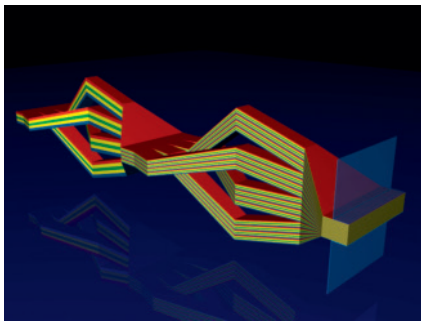

Fig. 3. Microlayer technology
(illustration: EDI)

Extrusion Dies Industries (EDI) LLC, Chippewa Falls, USA, promises an increase in impact strength, elongation and barrier properties. It has been possible to increase the oxygen barrier three to five-fold through microlayer technology. A comparable system is offered by Cloeren Inc., Orange, USA, with its so-called nanolayer feedblock.

Calender and winding technology. The considerable increase in melt throughput in flat film units over the past few years, coupled with the trend towards ever-thinner films, has now led to a situation where homogeneous cooling, low thickness fluctuations over the film width, and high-quality winding have become the limiting factors on throughput. In order to shift the boundary of what is technically feasible while still ensuring a high cost efficiency, system builders are thus supplying selectively optimized systems for individual applications, such as stretch films. The new stretch film system from SML Maschinengesellschaft mbH, Lenzing, Austria, which has had its width reduced from 4 to 2 m and is thus considerably more flexible, permits a line speed of up to 1,000 m/min and ensures the highest possible winding quality, even with thin films of less than 10 µm. At the NPE 2009, Gloucester Engineering Co., Gloucester, USA, presented a newly developed stretch film winder for cores with a reduced wall thickness, and also for core-free winding, with a line speed of up to 3,200 feet/min (approx. 975 m/min).

High-tech films. Apart from the traditional volume markets, an ever-increasing amount of film is being processed for high-tech applications in medicine and the pharmaceutical and optical sectors. The encapsulation film used for solar modules is made of the sticky material of ethylene vinyl acetate (EVA) and, alongside the particularly stringent optical requirements, must, ideally, be absolutely shrink-free. This requirement poses problems with calendered films and can so far only be achieved through particularly low line speeds of less than 5 m/min, resulting in a low productivity. A new film unit with an optimized cooling and calibration unit, designed especially to meet the special requirements of EVA films for solar modules and other applications, is now being supplied by Breyer GmbH, Singen, Germany, and promises to increase the line rate up to 15 to 20 m/min and hence to ensure improved cost efficiency of the extrusion process.

Maintaining particularly clean production conditions is essential for the production of high-tech films. Achieving full cleanroom conditions in the production shop involves a very high outlay and is not necessary at all points for a large number of applications. In many cases, it is sufficient to ensure defined cleanroom classes in individual areas of the film unit in the form of room-in-room solutions, such as in the die orifice region. There is no patent remedy here, since the requirements will depend on the product in question. It is essential to adopt a holistic approach in order to ultimately achieve cost-efficient production, and support can be obtained here from specialist consultants such as Dittel Cleanroom Engineering, Kochel, Germany. The JOA Microclimate technology developed by JOA Technology Beheer B.V., Delft, Netherlands, guarantees a virtual cleanroom through its special airflow control and preparation system, providing cleanroom class ISO 7 for a comparatively low investment outlay **(Fig. 4)**. Employing this technology in an application-specific configuration will also significantly reduce reject production in the production of standard films and thus reduce overall production costs, since, according to JOA, the level of the cleanroom class correlates directly with the number of surface defects.

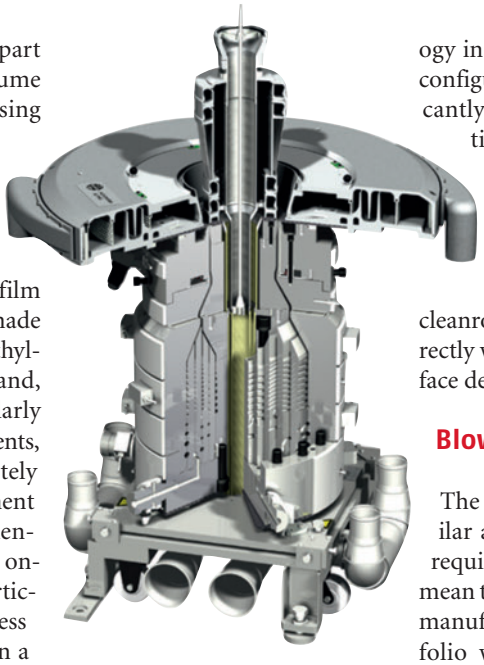

Fig. 5. Blowing head for the production of film without portlines in the X version
(illustration: Hosokawa Alpine)

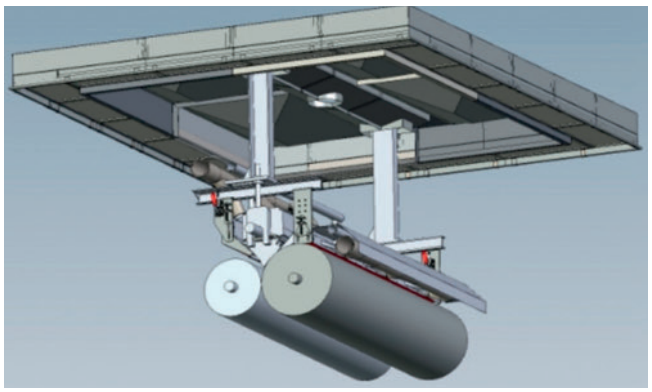

Fig. 4. Microclimate technology (photo: JOA)

Blown Film

The at times highly dissimilar and, above all, versatile requirements placed on films mean that the production unit manufacturers require a portfolio with a high degree of flexibility. Hence, the individual manufacturers offer modular systems which allow specially tailored units to be put together for different customers.

On the part of the film manufacturers, efforts are in evidence to achieve shorter product changeover times, better film qualities and higher outputs. In addition to this, converters are attempting to keep abreast of the current state of the art by fitting individual upgrade modules to existing machines, without having to make the investment that would be necessary for the purchase of new systems.

Product changeovers. Precisely at the current point in time, with the trend towards falling batch sizes, the film producers wish to keep product and material changeover times as short as possible. The plant manufacturers offer different systems that can be integrated in the individual plant control units and reduce the changeover times fully automatically. Examples include the "Easy-Change" system from Windmöller und Hölscher "Perfect-Change" from Kiefel Extrusions GmbH, Worms, Germany, "Smart Change" from Kuhne GmbH, St. Augustin, Germany, and "Rapid Purge" from Reifenhäuser Extrusion GmbH, Troisdorf, Germany. These systems are all geared towards performing material and format changes in the shortest possible time. Most of the control tools mentioned here can be retrofitted to the control systems supplied by the individual production plant manufacturers.

In a research project being conducted jointly by the Institute of Plastics Processing (IKV), Aachen, Germany, and the Institute of Product Engineering (IPE), Duisburg, Germany, state-of-the-art open and closed loop control systems are being worked out in a bid to improve material changeover procedures.

Die technology. In the field of die technology too, the flow channels are being optimized to permit reduced purging times. The trend here is towards a shortening of the flow paths, thus reducing the residence time of the melt in the die.

Fig. 6. ECP interior cooling system
(photo: Kiefel)

In order to improve film quality, Hosokawa Alpine AG, Augsburg, Germany, has developed its new X blowing head, which suppresses the so-called →

Fig. 7. Retrofitting a double cooling ring (photo: Plast-Control)

portlines through an ingenious melt flow configuration **(Fig. 5)**.

Further criteria for a good film quality are a low pressure loss in the die as well as a particularly flexible flow channel arrangement, allowing a broad range of raw materials to be processed. The system builders are constantly optimizing their systems with this in mind.

Output/increasing throughput. Different concepts are being pursued for increasing the output. On the one hand, low-temperature screws are being used, which are able to make homogenized melt available despite the lower melt temperatures. This has the advantage of considerably reducing the amount of heat that has to be eliminated after the shaping phase. Kiefel has developed its "High Efficiency Mixer (HEM)" which permits energy savings of up to 20 % in combination with a new screw geometry. Once the melt has left the die, double cooling rings have now become state-of-the-art for almost all manufacturers.

Another approach is that adopted by Kuhne GmbH and Octagon Process Technology GmbH, Würzburg, Germany, in the form of the maximizer cooling ring. This does not cool the film bubble directly at the die opening but in a slightly higher position, where the melt offers a bigger surface for cooling due to the inflation of the tube. Kuhne has extended this cooling ring with a special Iris aperture, which makes it possible to achieve inflation ratios of less than one and up to six.

Kiefel differs here on account of its interior cooling system, known as the ECP (Enhanced Cooling Package) and Perfect Cool **(Fig. 6)**. This has a water-cooled steel component inside the bubble which constantly cools the air passing by.

Retrofitting blown film plants. On account of the current economic situation, film manufacturers are making every effort to improve the productivity of their operations through low-level investments. For this reason, there is an increasing tendency to equip existing plants with upgrade elements from familiar companies specialized in the retrofitting of extrusion systems. Kdesign GmbH, Königswinter, Germany, Octagon Process Technology and Plast-Control GmbH, Remscheid, Germany, offer different solutions here. The standard is segmented cooling rings which improve the thickness profile over the circumference of a blown film **(Fig. 7)**. The customer can decide whether they would like to supplement their existing cooling ring with a segmented cooling unit, or exchange the entire cooling ring for a new one offering an improved cooling performance. This company similarly supplies metering systems and, depending on the make in question, upgrading tools, such as film thickness measurement systems that can be retrofitted.

Learning from Mistakes

Quality control systems have two essential objectives: first of all, they are intended to pick up errors at an early stage so as to avoid waste and complaints and, secondly, they ought to generate knowledge on product quality that can be used to improve the production process. This second aspect is gaining increasing importance at a time when batch sizes are falling. Each change of product involves a certain start-up time during which rejects are produced that cannot be sold. If the quality of the manufactured product is monitored without any gaps, it is possible to keep this start-up time down to a minimum. If any deviations or errors occur, then immediate intervention is possible. To ensure a targeted response, however, it is necessary to have knowledge of the process. In many cases, this is only available in the form of the plant operator's empirical knowledge, and a large number of companies do not generate and keep this knowledge on a systematic basis. Many of the manufacturers of inspection systems have recognized this problem and are offering solutions that make it easier for users to learn from mistakes.

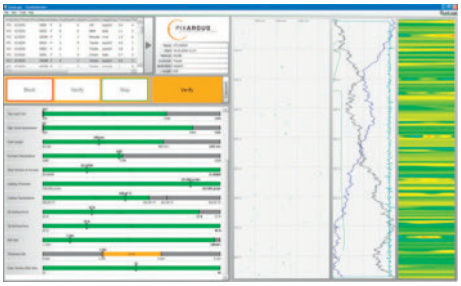

Fig. 8. Screenshot of the Pixargus "Quality Decision Server": all the production data are allocated to the running length and presented directly at the production line (illustration: Pixargus)

Film inspection. Isra Vision AG, Darmstadt, Germany markets a tool under the name of "Enterprise Data Mining" which compresses the data recorded by inspection systems and presents it in an enhanced manner. This permits the selective optimization of production. Intelligent links can then be used to pinpoint correlations that are not evident at first sight. The user can conduct and present analyses from a wide range of viewpoints. It is not necessary to observe just a single location here – analyses for globally linked locations are possible too. Individual rolls of plastic film can be allocated a globally unique production pass.

The "RAM_PAT" system from R.A.M. Realtime Application Measurement GmbH, Flörsheim, Germany, also offers an enhanced reporting capability. A large number of presentations, such as tables, trend graphs or a definable film grading, i. e. a weighted error distribution, can be generated for a rapid overview of quality. During the inspection, the operator can compile comments (e.g. "die cleaned") and add these to the roll report to the nearest running meter. The messages included here can be taken into account during the evaluation.

The "Quality Decision Server" presented by Pixargus GmbH, Aachen, Germany, links quality data and measurement data from different sources, such as inspection systems or temperature sensors, and combines these to give an overall view over the length of the film **(Fig. 8)**. Users can now define release rules on a customer, material, order or line-specific basis, which the system employs to decide on either "release" or "block". When the rules are applied, allowance is made for the data combinations of the different sensors. The user can modify the rules simply and rapidly. In this way, the criteria for film release can be adapted to different customer situations within a very short time.

Frequent product changes are making it increasingly important for film inspection systems to be easy to set up for new products. Since different errors can occur as a function of the product and process, all the manufacturers have now integrated learning processes in their systems. Users are able to define error classes themselves, allocating the corresponding class to a specific error configuration, and the system learns to distinguish this class from other errors.

The manufacturers of inspection systems are also taking into account the trend towards higher take-off speeds. This is made possible by the progress achieved in camera technology, electronics and lighting technology.

The temperature plays a key role in plastics processing. Excessively high temperature differentials can have a negative impact on the physical and optical properties of the film in flat film and cast film production. betacontrol GmbH & Co. KG, Freudenberg, Germany, has thus developed the "InfraTherm" system on the basis of infrared camera technology. By contrast to conventional systems, this focuses more precisely on the material being checked and thus eliminates external heat influences, of the type that can result from the die or the cooling roller. By employing an area scan camera, the system is able to ensure 100 % coverage of the film. Defects such as insufficient flatness, flow lines, inhomogeneities or hot spots can thus be detected at an early stage. **Figure 9** shows a schematic diagram of the way the system is structured.

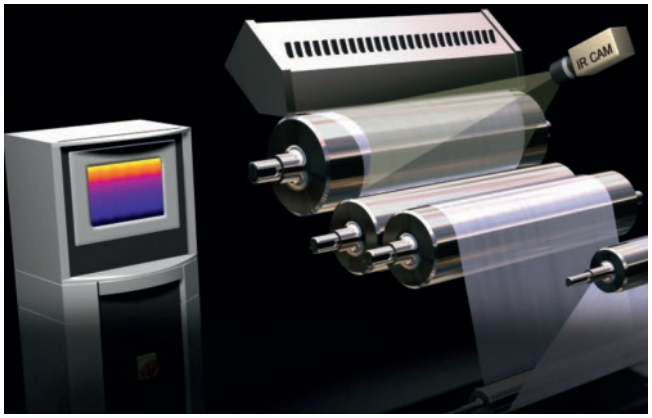

Fig. 9. Schematic diagram of the "IndiTherm" system (illustration: betacontrol)

Thickness measurement and automation. A film's thickness is a key quality parameter. Capacitor-based sensors can determine the overall thickness of a film in a robust, reliable and highly accurate manner. Plast-Control has its "C-Scan" system that can also determine the thickness of films with barrier layers, such as ones made of EVOH. This was not previously possible on a capacitive basis, since the capacitive properties of the barrier materials display a high, nonlinear dependence on the temperature. To keep these influences to a minimum, the system is installed downstream of the take-off and records its measurements by traversing the double film that has been folded over and laid flat **(Fig. 10)**. The two measuring heads positioned opposite each other both glide on an air cushion allowing the film to be guided contact-free through both measuring sensors. The sensor resolution is 0.1 µm, and the measuring area extends from 18 µm to 400 µm.

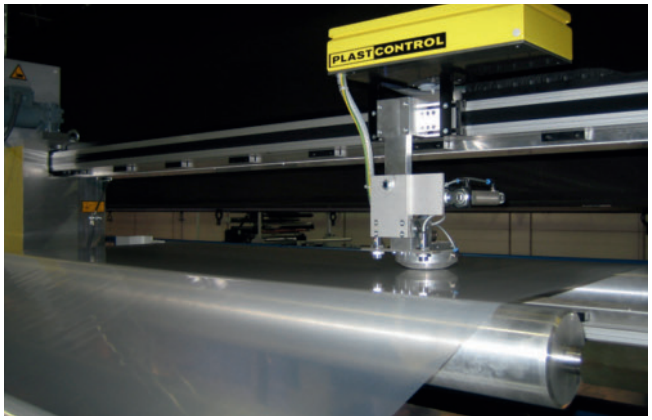

Fig. 10. Capacitive thickness measurement with the "C-Scan" system on the blown film laid out flat (photo: Plast-Control)

Employing optical technologies, it is now possible to determine the thickness of the individual layers of a multilayer film. The process can thus be run closer to the tolerances and save costs, particularly in the case of expensive barrier materials. Isis Sentronics GmbH, Mannheim, Germany, uses so-called SCI (Spectral Coherence Interferometric) technology to this end. The new "StraDex 80" sensor can measure individual layer thicknesses down to 4 µm, and the scanning rate is now higher than on the systems to date. The sensor can be employed for take-off rates of up to 1,000 m/min.

Another spectrometric measuring method – near infrared (NIR) spectroscopy – is used by Polytec GmbH, Waldbronn, Germany, for "PSS" series systems. These systems are made up of a spectrometer and an optical waveguide, which traverses the film as a measuring head. The NIR technology has a very broad spectrum of use and can be employed not only for measuring the thickness of individual layers with an accuracy extending down to the submicrometer range but also for detecting different types of plastic.

It goes without saying that the trend in film units is towards increasingly extensive automation of the systems. While it was previously the plant operator who had a "feel" for the time required for a product changeover, nearly all plant manufacturers now have computer-based solutions on offer aimed at simplifying the switchover to new products or materials. On this point, the subject of "residual quantity management" is particularly topical at present. When filling the hopper, the material conveying system makes allowance for the quantity of granules required to complete the order, so that when the order is finished only a small amount of material remains in the hopper. This is particularly attractive in cases where expensive additives are used. Reifenhäuser Extrusion is one company with an attractive new system in its portfolio, although other system builders are also active in this field now.

Conclusion

The large number of new developments in the field of film extrusion mean it is scarcely possible to pinpoint a common trend. In general terms, film manufacturers are expected to provide greater flexibility in view of falling batch sizes and more frequent material and product changes. Even if the pressure of competition from Eastern Europe and the Far East is increasing, there are sufficient grounds for the film sector in Germany to look positively towards the future even in times of economic crisis. ■

Janina Overbeck, Henning Seidel, Klaus Berdel, Lennart Ederleh