Innovations in Extrusion

Further Developments in Die Technology and in Measuring Systems

Heinz Groß, Rossdorf/Germany

It is difficult for new process technologies to become established in extrusion technology. A number of the reasons for this are the high line costs, the low number of new lines being installed, the risk of a new technology not giving the desired results after all and the high costs of the tests required on production line. Despite this, new ideas and solutions are repeatedly emerging which are aimed at both reducing the production costs of extruded products and improving product quality.

Despite the increasingly accurate calculation methods that are available for simulating complex melt flows, establishing the correct flow channel geometry still constitutes one of the trickiest tasks in the design of extrusion dies. On the other hand, however, solutions are being sought for extrusion blow moulding dies which will allow the geometry of the flow channel to be modified as the parison leaves the die, so as to give the parison a wall thickness profile in the radial direction too. This then gives rise to the question as to whether it would be possible to simply incorporate an area of wall at critical or selected points of an extrusion die which could undergo a limited amount of adjustment from the outside on a purely linear-elastic basis. This consideration was prompted by the development of the membrane technique in close cooperation with the IKV in Aachen/Germany; this involves the restrictor bars in a sheet tool being replaced by a thin, flexible membrane [1, 2].

Membrane Feed block

While, in the past, 1.5 mm spring steel sheet was still welded into the body of the die [3], it has now proved possible to integrate a large number of extremely thin walls in a die (right down to a thickness of 0.2 mm) at any desired point of the flow channel, without requiring any welding and without giving rise to any disturbances due to a parting plane. The new technology, which has already proved successful in a number of pipe dies [4], makes it possible to place as many individual walls as desired on top of each other, giving an absolutely tight connection, so that these walls will mutually support each other. In this way, the flexibility and compressive strength of the wall required to counter the melt pressure on the inside can be precisely adapted to the requirements of the application in question.

Very simple coextrusion feed blocks can be built, which make it possible to modify from the outside the flow channel geometry of the coextrusion channel at the point where the individual melt flows meet up, through the use of adjusting screws. Figure 1 shows a cross-sectional drawing of a three-channel feed block (layer structure A-B-A) for a large-scale production line used to coextrude sheet in an overall thickness of between 3 and 5 mm, with a surface layer of 50 µm on both outer sides. The feed block shown will be on display at the stand of the Institut für Kunststoffverarbeitung (IKV), Aachen, at K 2001.

The membrane feed block system constitutes the world's first commercial feed block solution that opens up the possibility of modifying the feed block geometry to the dissimilar viscosity-conditioned behaviour of the different materials as the line is actually running. At K 2001, a membrane feed block specially designed for this purpose will be on display at the stand of Extrusion Dies Inc., Chippewa Falls/USA. This feed block was designed for a laboratory line on which a wide range of different material combinations are to be tried out without the entire feed block, or even just individual parts of the feed block, having to be exchanged.

Membrane feed blocks thus essentially open up the possibility of controlling the thickness of the individual layers for the first time. This naturally calls for a measuring process that can establish the thickness of the individual layer when the line is running.

No test results are available as yet on the operating behaviour of the feed blocks. Compromises still had to be made in the layout of both feed blocks, since the customers stipulated that the connection dimensions had to be identical to those of the conventional feed blocks available on the line. In both cases, this meant that the feed blocks were considerably bigger than would have been necessary had they been designed from scratch.

Flexring Technology

As has been briefly mentioned, the newly-developed Flexring Technology for pipe dies and blown film dies has already proved successful on a large number of production lines. Figure 2 shows a pipe die for a thick-walled pipe with an integrated Flexring bushing. On this die, the die gap can be varied to a limited extent on a local basis as the machine is running, by using the 52 adjusting screws arranged around the die circumference. The screws serve to locally deform the Flexring bushing, with its multiple walls in some areas, which is integrated in the outer ring of the die. This makes it possible to further reduce the asymmetric thickness fluctuations over the pipe circumference that are generally still encountered after the outer ring has been centred.

The use of Flexring bushings for blow moulding dies, by contrast, is still at the development stage. These need to be adjusted over the die circumference as the parison is leaving the die. Flexring bushings can generally also be retrofitted to existing dies without any problems. They do not always have to be located at the die orifice, however, but can also be integrated inside the die. It is then possible to optimise the thickness distribution of individual layers in coextrusion dies during the running process and similarly to control the thickness of individual layers. Figure 3 illustrates a coextrusion die of this type with an integrated Flexring bushing. The Flexring bushing that goes

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with this die is shown in Fig. 4. This die will be on display at K 2001, at the stand of cpm GmbH, Georgsmarienhütte/Germany. A Flexring die to be exhibited by Galvanoform GmbH, Lahr/Germany, will illustrate that it is also possible for Flexring bushings to be adjusted automatically with the aid of very small geared motors. Galvanoform is currently the sole company worldwide with the know-how for producing Flexring bushings and the right to use the patented process. BFA-Plastik GmbH, Rossdorf, will be demonstrating a Flexring die at the K trade fair on a running blown film line.

Bank Measuring System

Dies with flexibly adjustable flow channel walls can generally also be adjusted by a motor, which means that they can be suitably integrated in a control process. This, in turn, makes it possible to control the local flow of melt emerging over the width of a slit die during sheet production. Since it is difficult to draw conclusions on the melt flow that is emerging from a specific point of the die from the thickness measurement values – which are generally measured online on sheet lines – these thickness values are not particularly suitable as control parameters for a closed-loop control system.

This was one of the reasons why a measuring system was developed which measures the bank distribution of the melt that forms in the feed gap of the first pair of rolls, over the width of a polishing stack [5]. Working on the assumption that the roll gap is absolutely parallel, the bank size will be directly proportional to the local melt stream that emerges from the sheet die at this point. In the case of products that run through a polishing stack, the bank measurement is thus a much better control parameter for die control than the thickness measurement [6]. Since the majority of key application properties of film or sheet, which is polished on both sides, are conditioned to a large extent by the situation prevailing in the roll gap, these parameters of importance for the final user are also controlled via the bank control system. The measuring system, which is already in use in lines in Germany, Switzerland, France and the USA, is currently still being used as an independent information system to accelerate the start-up process, improve product quality and optimise the line. Figure 5 shows the bank distribution recorded on a production line before (a) and after (b) optimisation with the aid of the information that the bank measuring system has supplied.

At the start of this year it even proved possible to modify the measuring system during its installation in a large-scale American production line in such a way that it can be used during the production of sheet with a structured surface. A new measuring strategy was developed that was correctly tailored to this application, and the corresponding new measuring software was developed. Tests are still being conducted prior to K 2001 in order to establish whether the bank measuring system is suitable for processes in which the sheet is laminated in the first roll gap. The prime aim here is to obtain reliable information on the profile of the laminating forces that act in the gap. The bank measuring system itself is not being exhibited at the trade fair. By making an appointment, however, interested parties can see the system operating on a running line independently of the trade fair.

Measuring Wall Thicknesses in Hollow-Chamber Sheet

In the past, manufacturers of hollow-chamber sheet have searched in vain for someone to supply them with a system for measuring the thickness of the outside walls on the sheet. The advantage of a wall thickness measuring system of this type, which can be integrated in the production line, is clear to see [7]. Lines for the production of twin-wall sheet (the name frequently used for hollow-chamber sheet) are particularly long, and the extrusion speed is not very high. In extreme cases it can take half an hour from the point at which the melt leaves the die and solidifies in the calibrator to the point at which this section of sheet reaches the saw at the end of the line. Adjusting the die then requires an extreme amount of patience. After each adjustment operation, the operator has to wait until the relevant section of sheet reaches the saw. Only then can the thickness distribution that has resulted from the adjustment be measured on the section of sheet sawn off. Measuring the wall thickness distribution over the width of the sheet additionally takes up a great deal of time and is generally still done by hand. Some sheet geometries have more than 400 individual chambers, with each chamber naturally having an upper and a lower wall thickness, which would all need to be measured individually by hand.

The newly developed measuring system that operates with ultrasound can be readily retrofitted to existing lines. It is integrated in the production line directly behind the calibrator. Figure 6 shows the measuring system on a big production line. The upper and lower wall thickness are measured simultaneously; the distance between the individual measuring points can be pre-selected at will via the program. Just a few minutes after adjusting the die, the line operator thus has precise information on the new thickness distribution. The measured data can, of course, be immediately used for quality assurance as well. The measuring system can essentially also be employed for building up a wall thickness control system. At present, this is not possible because the dies that are used cannot be adjusted automatically. It is just a matter of time, however, until the first twin-wall sheet die is equipped with flexlips, as has been state-of-the-art on film dies for a long time. There would then be nothing to prevent a wall thickness control for hollow-chamber sheet either.

The new wall-thickness measuring system will be presented at the stand of Omipa S.p.A., Morazzone/Italy. This measures the wall thickness distribution of a stationary sheet sample.

The Author of this Article

Dr. Ing. Heinz Gross, born in 1950, has been engaged on the development of new production technologies since 1992, working in the framework of an engineering consultants' office. In 1997, he additionally founded Gross Messtechnik, which has specialised in the development of new measuring systems.
Contact: heinz-gross@t-online.de

Fig. 1. Three-channel membrane feed block with a multi-wall flow channel wall, which can be very finely adjusted with the aid of adjusting screws while the line is running at the point at which the melts flow together
Membran = Membrane

Fig. 2. Flexring die flanged to a pipe extruder just prior to line start-up

Fig. 3. Coextrusion feed block for a pipe extruder with an integrated Flexring bushing that can be adjusted on a purely linear-elastic basis over a locally restricted area at the point at where the melts flow together

Fig. 4. Flexring bushes integrated in the coextrusion feed block (Fig. 3), made up of 7 individual walls with a wall thickness of 0.2 mm in each case between the two solid flange sections

Fig. 5. Bank distribution during a test run for the production of a critical film before (a) and after (b) optimisation with the aid of information delivered by the bank measuring system
Wulstgröße = Bank size; Folienbreite = Film width; Messzeitpunkt = Measuring time

Fig. 6. Quasi contact-free wall thickness measurement of a hollow-chamber sheet with ultrasonic sensors coupled to the sheet surface via a small drop of water. The drops of water traverse with the sensor so that no water remains on the sheet surface at all