Adjustable Flow-channel Geometries – the Future in Extrusion Die Making?

Wall Thickness Control. The wall thickness of extruded products can be controlled by influencing the local flow resistances in the die flow channel. Advances in extrusion die making now permit thickness control of pipes, sheets and even coextruded layers.

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Extrusion dies with flexible flow-channel walls permit fine tuning of the melt-flow distribution within a tool while production is running. A completely newly developed manufacturing process has now made it possible, with widely different extrusion dies, to make flow-channel gaps whose widths can be finely adjusted locally. The long-term goal is to provide processors with dies for all extrusion processes that allow the thickness to be controlled during production. The advantages of thickness-controlled production have been extensively utilised for over 25 years in film extrusion with slit dies. By automatic local adjustment of the outlet gap with the aid of the flexlip at the die outlet, a uniform film quality with extremely narrow tolerances is assured at all times. Thickness control in slit-die film production is so far the only continuous extrusion process in which the flow resistance in the die can be varied locally to reduce thickness tolerances. For many products, no dies have so far been available in which the flow-channel geometry could be locally adjusted externally while the production was running.

Circular Flexring Dies

The basic principle of the flexlip slit dies has now been successfully transferred to circular dies [1]. Flexring dies, in which the outlet gap at the die mouth can be locally adjusted by means of a large number of adjusting screws arranged around the circumference have a proven track record in pipe manufacture, in the manufacture of foamed sheets or films and in the production of blown films by the double-bubble process. With the exception of extrusion blow moulding dies, the tools still have to be manually adjusted by the operating personnel. The retrofitting or retooling of an existing die is relatively inexpensive, but the thickness distribution of the generated product inevitably depends on the skill of the operating personnel.

Particularly in the case of blown films, the outlet gap at the die mouth must be corrected in the micrometre range in order to reduce existing thickness differences. This not only requires a great deal of experience and intuitive feeling, but also additional labour costs. Now, several projects are being carried out on the automatic adjustment of flexring dies. For example, as part of a research project at the Süddeutsches Kunststoffzentrum (SKZ), Würzburg/Germany, a pipe extrusion technology is being developed to minimise the thickness tolerances around the circumference of the pipe by means of a control system. In principle, it is intended to allow a thickness control system to be retrofitted to flexring dies that are already integrated into production.

Partially Flexible Inserts

In profile dies, it has also been possible to demonstrate that, by integrating a special, partially multi-walled flexible insert into the existing die, in many cases, wall-thickness changes at specific points in the pro-

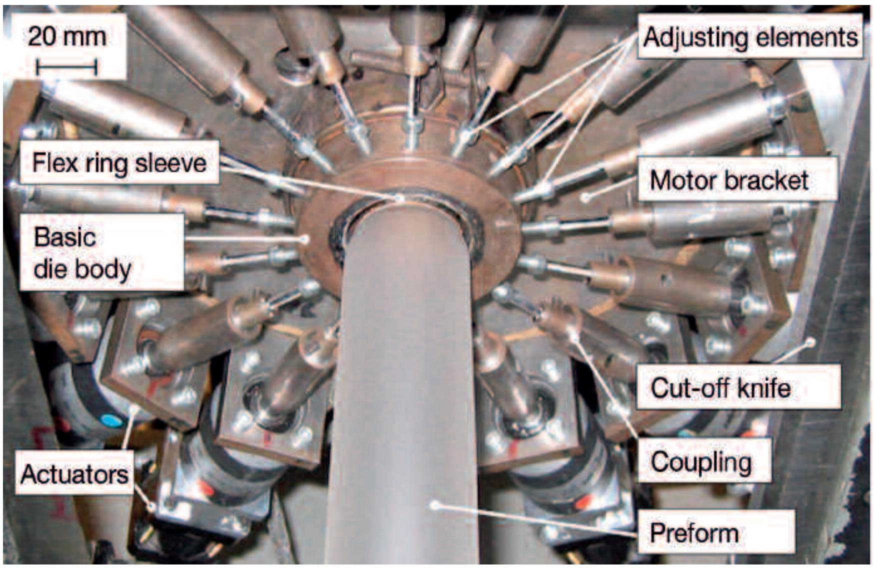

Fig. 1. Flexring die installed in a blow moulding line, with a diameter of 35 mm, which can be dynamically adjusted with 16 actuators (photo: IKV)

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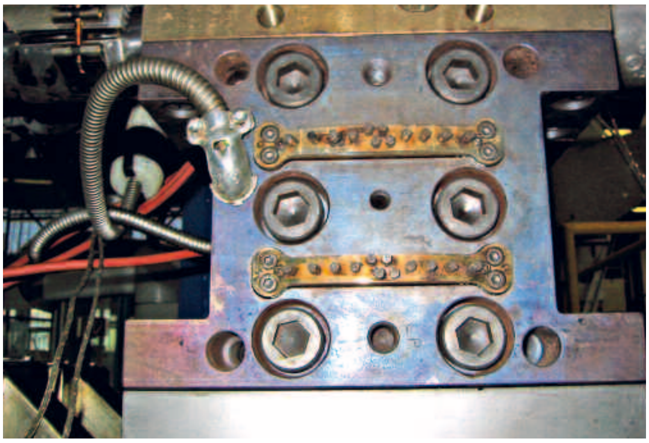

Fig. 2. Three-channel membrane adapter installed in a pilot plant, with which the geometry of the 50 mm-wide flow channel can be finely optimised at the melt merge point with 12 adjusting screws in each case

(all figures except Fig. 1: Groß Kunststoff-Verfahrenstechnik)

Fig. 4. Coextrusion sheet die made in one piece, with integrated, partially multiwalled flow-channel wall and radially disposed adjusting screws for fine adjustment of the local flow-channel gap in the region where the middle and inner layer flow together

file can be implemented while production is running. In principle, this operates well if the profile has either large radii or flat regions. In these cases, existing dies can be retrofitted with adjustable flow-channel inserts in a relatively simple manner. It is only necessary to exchange or modify the end plate of the die. Exchanging it has the advantage that the original design can be restored at any time if unexpected difficulties occur.

Radial Wall Thickness Control

During extrusion blow moulding, the process technology makes it necessary to automatically adjust the outlet gap of the die during extrusion of the parison. In a research project at the Institute of Plastics Processing (IKV) of the RWTH Aachen University, it has been proved that this can be ideally performed by means of a flexring die. To produce a bottle designed exclusively for research purposes, a flexring die was equipped with 16 actuators (Fig. 1). This allowed, during parison extrusion, the radial wall-thickness distribution in the parison to be adjusted according to the geometry varying over the height of the bottle [2]. Several industrial projects are now underway to equip existing dies in production lines with a flexring sleeve and with electrical actuators. Depending on the product, the improved thickness distribution in the blow-moulded parts is expected to produce raw materials savings of 5 to 10 %.

Adjustable Flexring and Membrane Adapters

The new production method also allows coextrusion adapters to be constructed with flow channel geometries that can be optimised while production is running. This makes unnecessary the time consuming and expensive conventional adaptation of the flow channel geometry by machining on start-up of the coextrusion adapter. Furthermore, the flow-channel geometry can be adapted to changed production conditions at any time without interrupting production. Thus, e. g., on exchange of the raw materials supplier, the layer thickness can be kept constant. Even if the increase of line speed causes a line to drift ever further from the operating point for which the adapter has been optimised with increasing operating time, the flow channel geometry can still be adjusted to the new operating point at any time without production waste. In future, it will even be possible with a single adjustable flexring or membrane adapter to process materials with different flow behaviours. Flexring or membrane adapters are the first adapter solutions in the world that allow layer thickness control.

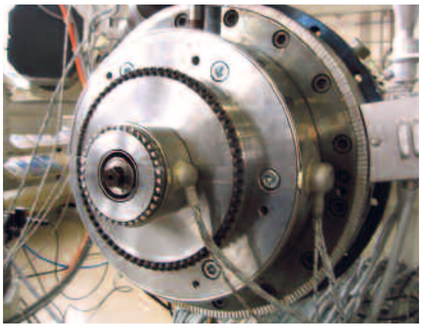

Fig. 3. Two-channel die with an integrated flexring sleeve for fine adjustment of the layer thickness of the outer layer (rear adjusting screws) and the overall thickness (adjusting screws at the die mouth)

Now, there exist a flexring adapter for pipe coextrusion, a membrane adapter for a pilot line for film and sheeting (Fig. 2) and a membrane adapter for a sheet production line. From the experience gained with these adapters, a standardised membrane adapter is under development for applying a layer onto a main stream. It is planned to make the adapter modular in design, so that an additional adapter module can be mounted at any time to apply a further layer. The individual module will only consist of three compact parts: a standardised two-part housing and a membrane insert whose geometry is individually dimensioned corresponding to the flow behaviour of the material.

Layer Thickness Optimisation in Multichannel Dies

By integrating flexibly adjustable flow channel walls into multichannel dies, it will be possible for the first time to optimise the layer-thickness distribution across the width of a coextruded film or sheet, or around the circumference of a multilayer pipe, while production is running. At the SKZ it has been possible to convert a simple pipe die into a two-channel die. This was performed by integrating a flexring sleeve with two separate flexibly adjustable wall regions into the die. With the converted die (Fig. 3), the thickness distribution around the pipe circumference can each be separately optimised for the cover layer and for the overall wall thickness without the need to interrupt the extrusion process. This is the first pipe die in the world that offers the prerequisites for controlling an individual layer thickness. For building up a

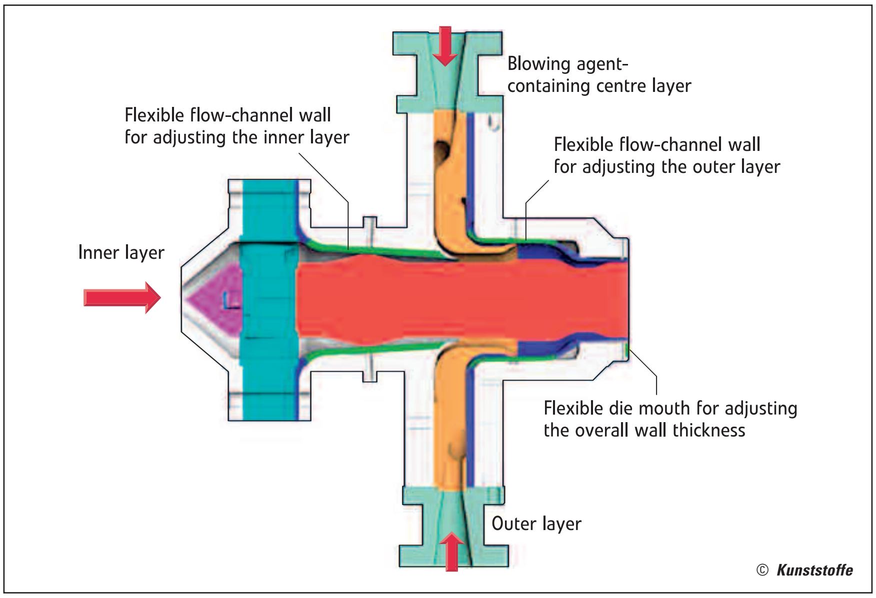

Fig. 5. The three-channel pipe die shown in cross-sectional view, with three flexible wall regions, is very compact in construction and consists of only eight individual parts

close loop control, it is of course necessary to have a selective online layer thickness measuring system in the line.

At the IKV in Aachen/Germany, a two-year research project produced a die with radial spiral mandrel distributor for the manufacture of three-layer blown film [3]. This die, too, includes a finely adjustable flow-channel wall in the centre plate (Fig. 4). It is now planned in a follow-on project to construct an automatic control for the centre layer thickness in order to reduce the layer thickness tolerances further and at the same time monitor the observation of the tolerances. For this purpose, a layer-thickness measurement system must be integrated into the blown film line, which is also capable of selectively measuring the thickness of the centre layer.

Three-Channel Die with Flexring Technology

Based on experiences with this test die, a completely novel three-channel die was conceived for manufacturing PVC foam-core pipes. The die consists of three separate flexibly deformable flow-channel regions. Besides the overall thickness, this also allows the outer-layer and inner-layer thicknesses to be optimised separately (Fig. 5). To regulate the inner layer, the multi-wall flexible flow-channel region was integrated directly into the housing (Fig. 6). This reduces the risk of leaks and also increases the ease of maintenance of the die by reducing the number of individual components. The unfoamed outer layers are fed into the production system via an extruder and into the die via a branch in the melt line. The geometry of these melt lines must be exactly dimensioned so that the inner and outer layer can also be produced with precisely the required wall thicknesses. To solve this problem, a dead point-free throttle was integrated into one of the two melt lines. This allows the flow resistance to be varied relative to the second melt line. Fig. 7 shows the throttle, whose wall, in the entire central, flat region, consists of 20 thin, mutually supporting individual walls. The free flow cross-section can be varied by means of a special adjustment device. Fig. 8 shows a three-dimensional view of the entire die, including the integrated throttle.

What Will the Future Be Like?

When, 30 years ago, the first companies made available film lines with wall-thickness control, there were heated debates among experts. Thickness control is now regarded as absolutely essential for a good film line. Now, for the first time, extrusion dies with flexibly adjustable flow-channel regions offer the prerequisites for designing a thickness control for other extruded products, such as pipes, unfoamed or foamed sheeting and even individual coextruded layers, by automatically regulating the local flow resistance in the flow channel of the die. Closed-loop controlled extrusion lines for these products will also gradually come onto the market. The pioneers here will probably be pipe systems, since online wall-thickness measurement is already integrated into many pipe extrusion lines operating today. In these cases, the pipe manufacturer does not need to purchase an expensive thick-

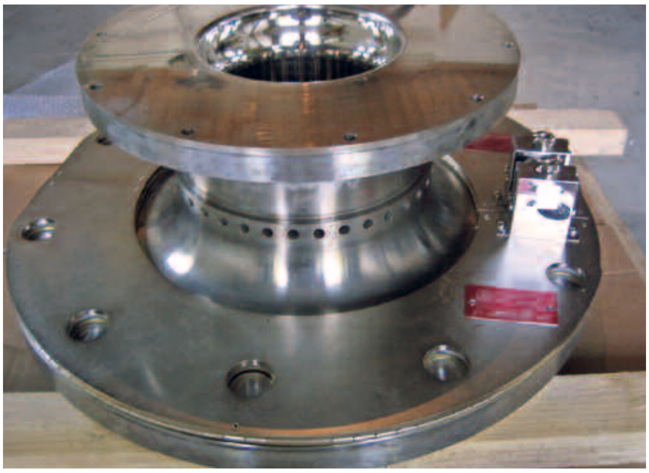

Fig. 6. Housing part made in one piece, with flexible flow-channel wall and threaded bores around the circumference for the adjusting screws

Fig. 7. Throttle body with the continuous transitions from the central flat flow-channel geometry to the respective circular inlet and outlet geometries

ness measurement system, in addition to the control system, to regulate his pipe wall thickness. The first thickness control systems for pipe systems could possibly be available at the next K Show in Dusseldorf/Germany.

It is still difficult to find a thickness measurement system that can be used online and operates reliably. It is particularly problematic, for example, with many coextruded products to measure individual layer thicknesses selectively. Measurement system manufacturers in this area have, understandably, not made particularly great efforts in this area, since the advantages of an online system, which is generally very expensive, compared with an offline system that is orders of magnitude less expensive are only marginal, as long as there is no possibility of responding directly to the measured thickness distribution. In economic terms, however, layer thickness control is particularly attractive for coextrusion since very expensive raw materials are often used for individual layers.

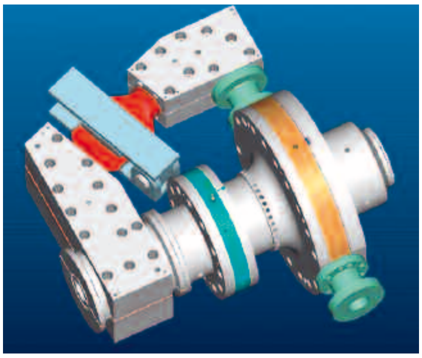

Fig. 8. Three-dimensional view of the complete three-channel pipe die with the throttle (red) integrated in the flow channel for the outer layer

In general, it is to be expected that measurement system manufacturers will redouble their efforts to further increase the resolution and accuracy of the measurement systems. It has be found in the commissioning of flexring dies that in many cases the adjustment of the die reaches limits, since the low thickness fluctuations that can now be achieved with the new flexibly adjustable dies can often only be unsatisfactorily resolved by existing measurement systems. ■

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