

## Adjustable Flow-Channel Geometries – the Future in Extrusion Die Design

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Extrusion dies with flexible flow-channel walls permit fine tuning of the melt-flow within the die while production is running. A completely newly developed manufacturing process has now made it possible, with widely different extrusion dies, to fabricate flow-channel gaps whose dimensions 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 advances of thickness-controlled production have intensively been utilised for over 25 years in film extrusion with slit dies having a flexible lip. 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 process was running.

### Circular Flexring Dies

The basic principle of flexlip slit dies has now been successfully transferred to circular dies [1]. Flexring dies in which the outlet gap at the 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 (Fig 1), in the manufacture of foamed sheets or films (Fig. 2) and in the production of blown films by the double-bubble process (Fig. 3). With the exception of

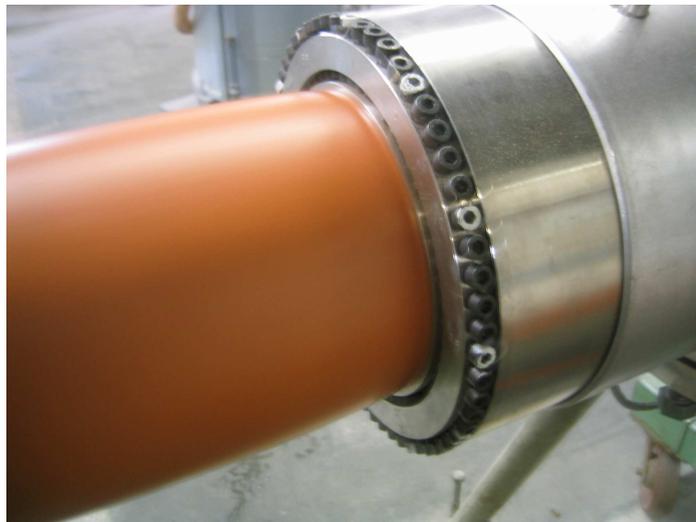


Fig. 1 The flow-channel gap at the mouth of the Flexring pipe die can be adjusted by 72 adjusting screws positioned around the circumference of the die to further reduce thickness tolerances in the produced 160 mm core foamed PVC-pipes

extrusion blow moulding dies, most flow channels have still to be manually adjusted by the

operating personnel. Flexring dies for extrusion blow moulding are adjusted by precise stepper drives which do not need any maintenance and are not too costly. The retrofitting of



Fig. 2 Flexring die during the production of a foamed sheet

an existing annular die is relatively inexpensive, but the thickness distribution of the generated product still depends in a great deal on the skill of the operating personnel.

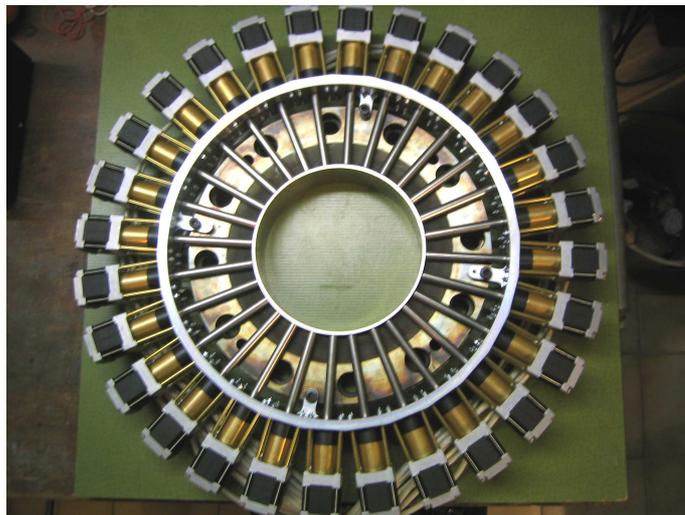


Fig. 3 Flexring sleeve equipped with 28 adjusting drives having a min. adjusting path of 300 nm to retrofit an existing double bubble blown film die

Particularly in the case of blown films, the outlet gap at the mouth must be corrected in the micrometer range in order to reduce existing thickness differences (Fig. 3). This not only requires a lot of experience and intuitive feeling, but also additional labour cost. Now, several projects are being carried out on the automatic adjustment of Flexring dies. For example, as part of a research project of 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 been also possible to demonstrate that, by integrating a special, partially multi-walled flexible insert into an existing die, in many cases, wall thickness changes at specific points in the profile can be implemented while production is running. In principle this operates will 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 to 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 should occur.

### Radial Wall Thickness Control

During extrusion blow moulding, the process technology make 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 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 exclusively designed for research purposes, a Flexring die was equipped with 16 actuators (Fig. 4). This

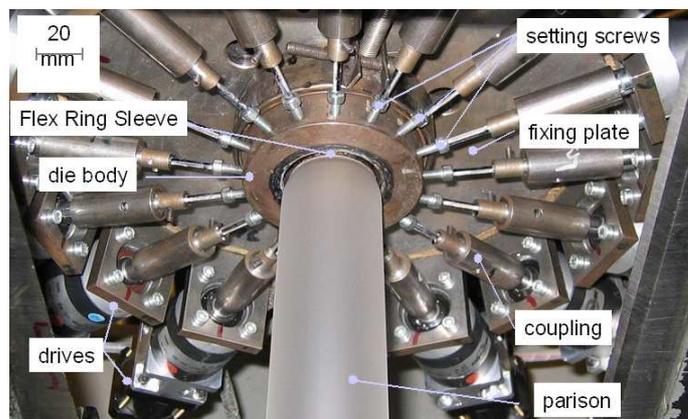


Fig. 4 Flexring die installed in a blow moulding line, with a diameter of 35 mm, which can be dynamically adjusted with 16 actuators (photo IKV)

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 machines with a Flexring sleeve and with electrical or hydraulic actuators. Fig 5 shows a 550 mm Flexring die with four actuators which was built to produce rectangular industrial bulk containers (IBC). Fig. 6 shows the Flexring arrangement the conventional die with which the Bobby-Car has been produced formerly, was retrofitted. The reached homogenisation of the thickness distribution in the bottom region is demonstrated in Fig 6. In October 2007 just in front of the K'07 in Düsseldorf RICUTEK/Germany signed a licence agreement to be able to build and to

offer world- wide Flexring dies for a dynamic radial wall thickness control of the parison in the extrusion blow moulding process.

### **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 for example, on exchange of the raw material supplier, the layer thickness can be kept constant. Even if the increase of line speed causes the melt distribution 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 possible with a single adjustable Flexring or Membrane adapter to process materials with different flow behaviours. Flexring or Membrane adapters are the first adapter solution in the world that allow for a layer thickness control.



Fig. 5 Flexring die with a diameter of 550 mm having 20 single walls in the flexible conical area, which are dynamically deformed by four stepper drives while the parison is extracted

Now there exists a Flexring adapter for pipe extrusion, a Membrane adapter for a pilot line for film and sheeting (Fig. 8), and a Membrane adapter for a sheet production line (Fig. 9). From experiences 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 to be processed.

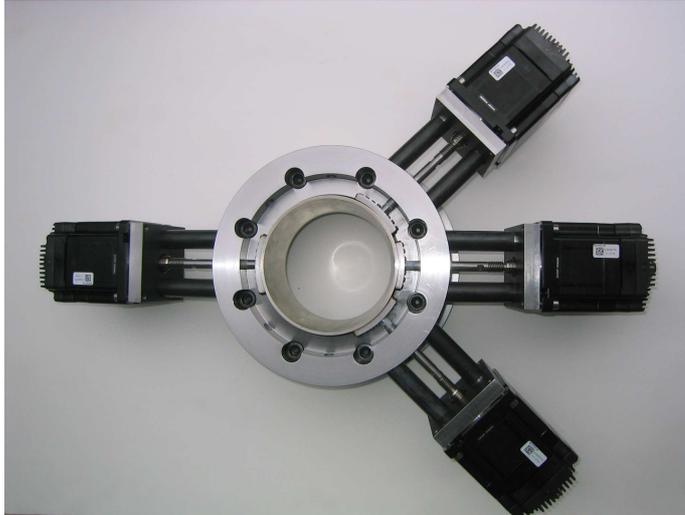


Fig. 6 Non-symmetric arrangement of the stepper drives to optimise the thickness distribution of the Bobby-Car

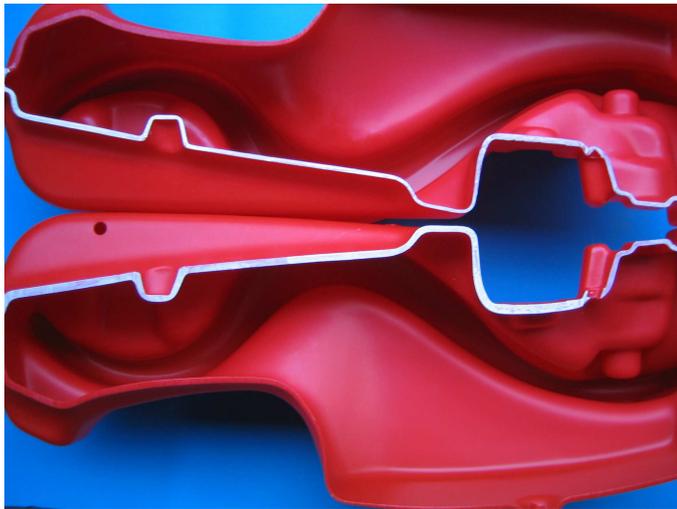


Fig. 7 Comparison of the thickness distribution achieved before (bottom) and after (top) the conventional die has been retrofitted with the Flexring arrangement shown in Fig. 5

### **Layer Thickness Optimisation in Multichannel Dies**

By integrating flexible 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 one-channel pipe die into a two-channel die. This was performed by integrating a Flexring sleeve with two separate flexibly adjustable

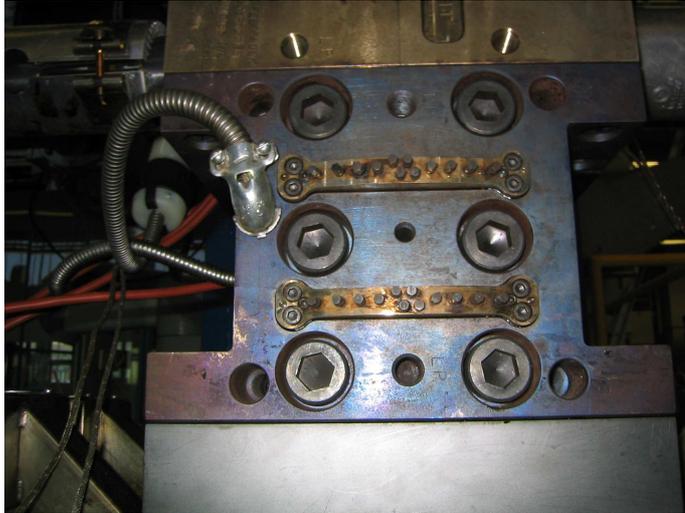


Fig. 8 Three-channel Membrane adapter (type ABC) installed in a pilot plant, with which the geometry of the 50 mm-wide flow channel can be fine tuned at the melt merge point with 12 adjusting screws in each case

wall regions into the die. With the retrofitted die (Fig. 9), 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 was the first pipe die in the world that offers the prerequisites for controlling an individual layer thickness. For building up a close loop control it is of course necessary to have a selective online layer thickness measuring system in the line.

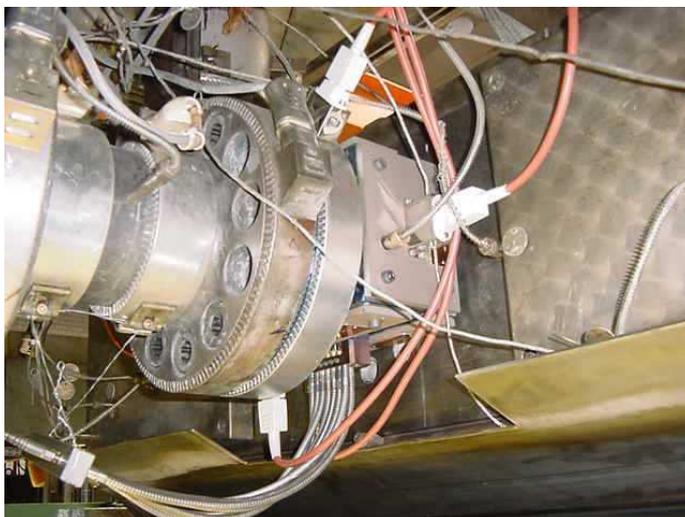


Fig. 9 Three-channel Membrane adapter (type ABA) mounted on a production line to cover a PC-sheet on both sides with a thin UV-protecting layer

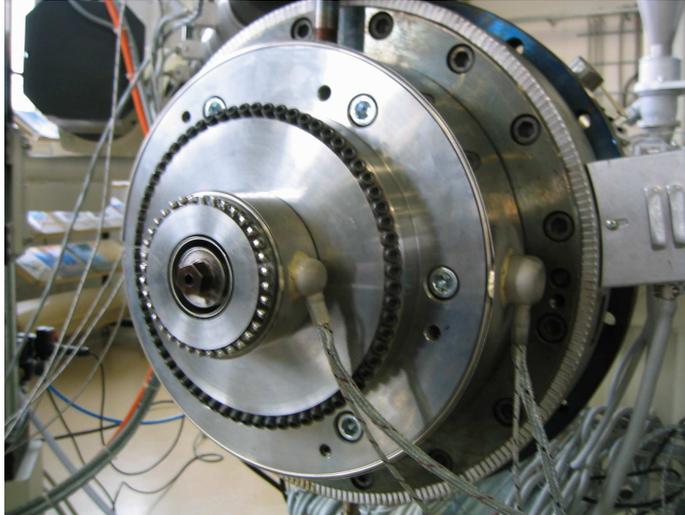


Fig. 10 Two-channel die with an integrated Flexring sleeve for fine adjustment of the layer thickness of the outer layer (rear adjusting screws) and the overall thickness (adjusting screws on the die mouth)

At the IKV in Aachen/Germany, a two-year research project produced a die with a 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. 11). It is now planned in a follow-on project to establish an automatic control for the centre layer thickness in order to reduce the layer thickness tolerances further and at the same time to 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 centre layer.

### **Three-Channel Pipe 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 thickness to be optimised separately (Fig. 12). To regulate the inner layer, the multi-wall flexible flow-channel region was integrated directly into the housing. 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 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 thickness. 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 to the second melt line. Fig. 13 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. 14 shows the complete die mounted on the line during start-up tests.



Fig.11 Middle plate of a three layer stack die with integrated, partially multiwalled flow-channel and radially disposed adjusting screws for fine adjustment of the local flow channel gap in the region the middle and inner layer flow together

### 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 control extrusion lines for these products will also gradually come onto the market. The pioneers here will probably be pipe systems, since online wall-thickness

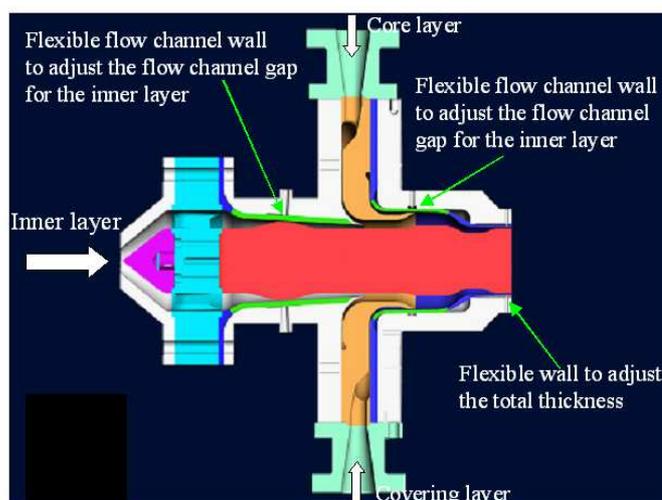


Fig.12 The three-channel pipe die shown in cross-sectional view, with three flexible wall regions, is very compact in construction and consists only of eight individual parts

measurement is already integrated into many pipe extrusion lines operating today. In these cases, the pipe manufacturer does not need to purchase an expensive thickness measurement system, in addition to the control system, to regulate his pipe wall thickness.



Fig. 13 Throttle body with the continuous transition from the central flat flow channel geometry to the respective circular inlet and outlet geometry

It is still difficult to find a thickness measurement system that can be used on-line and operates reliably. It is particular problematic, for example, with many coextruded products to measure individual layer thickness 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 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. 14 Three-channel die to produce core-foamed PVC pipes having a diameter of 110 mm during the first test run

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

## References

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