Flexible Die Walls

Die Optimisation. Flexible die walls that can be adjusted to requirements are already to be found in some applications. Flow-channel walls that can be adjusted particularly during production can lead to potential savings and offer new process-engineering possibilities.

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There must be few plastics processors who have not wished at least once that they could change the geometry of a flow channel during running production in order to quickly and cost effectively correct undesirable melt distribution in a die. The development of flexible, deformable metal walls may still be in its infancy, but they have already proved their mettle in a number of production lines. This technology offers plenty of new scope for process engineering, especially in plastics technology.

Some applications have already shown that metal walls can be designed to withstand high pressure on the one hand and still be able to undergo considerable deformation on the other. This deformation is completely reversible and so the original state prior to deformation can be regained at any time. This new technology lends itself to a wide range of applications, but it is still largely unknown.

Making Multi-Wall Flow Channels Flexible

Currently, deformable metal walls are mostly used for flow channels. They must therefore withstand the pressure acting from the processed melt, and they must also have a minimum thickness. Walls of at least such minimum thickness are used in conventional dies precisely because they are rigid and immovable. And, if they should deform even slightly under pressure forces, the effect is generally considered to be merely troublesome. This situation is in direct contrast to the new demand for linearly elastic deformation.

This new demand has been satisfied with metal flow channels that partly consist of several walls. Each individual wall has a very low thickness and is thus extremely flexible. The maximum elongation undergone by the wall remains very low because the surfaces are only a small distance from the "neutral" fibres. The mechanical strength necessary to withstand the internal pressure is now achieved by stacking several extremely thin single walls on top of each other, just like in a leaf spring assembly. Each wall provides mechanical support for the next.

Such assemblies of many individual walls can be dimensioned to exactly withstand the internal pressure. Yet, despite the fact that large wall thicknesses can be built up in this manner, this "leaf spring assembly" remains flexibly adjustable. The reason is that each individual wall has its own neutral bending line. All the operator has to do is dimension the wall to exactly meet the requirements for flexibility and pressure resistance.

Important Process Parameters Controllable for the First Time

Polymer processing, in particular, offers a great deal of scope for deforming sections of walls within certain limits. For example, such walls are advantageous wherever local flow resistance needs fine adjustment or precise melt flow distribution is needed. In many processes, they offer the possibility of controlling important parameters for the first time. The technology is particularly useful for coextrusion. For the first time ever, individual layer thicknesses can be controlled during running production – provided, of course, that the individual layer thicknesses can be measured directly in the process. But even the possibility of being able to finely adjust local flow resistance during running production by hand will help in the future to substantially lower attainable layer-thickness tolerances in coextrusion.

Several dies of this kind are already engaged in daily production. Comprehensive tests have been performed on Flexring sleeves in annular dies used in extrusion [1–3]. A Flexring sleeve is compact and made in one piece. It consists of corrosion-resistant special alloy, and one end is designed as a conventional, solid flange. At the other end, it consists of several individual walls. Figure 1 shows the outer ring of a pipe die that was retro-fitted with a Flexring sleeve. It is divided by grooves into segments because it was originally heated in segments to influence the pipe wall thickness. The cut-away drawing of the complete die (Fig. 2) reveals the rigid single-wall section of the Flexring sleeve in the lower flange area and the flexible multi-wall section in the upper mouth area. The mouth area can be deformed within limits by means of the adjusting screws located around the circumference.

Local Deformation of Annular Dies through Flexring Sleeves

Flexring sleeves of this type can be made with high precision in almost any geometry. It is generally possible to retro-fit them into existing annular dies. All that is necessary is to somewhat widen the inside of the existing outer ring of the die to allow the sleeve to be inserted. The original flow-channel geometry remains exactly as it was because the sleeve has exactly the original inside contour. It basically extends from the flange area, where centring occurs, to the die mouth. Integrating the Flexring sleeve therefore adds no new or additional parting lines. Figure 2 shows that a Flexring sleeve of this construction can be locally deformed to a considerable extent without the formation of dead zones. Flexring dies therefore may be used without restriction for materials that are very sensitive to heat.

Figure 3 shows the pipe die (110 mm foam sleeve pipe) in production. It is fitted with 60 adjusting screws. This means that thick areas in the pipe that remain after the die has been ideally centred can be further reduced in a simple manner.

Translated from Kunststoffe 8/2003, pp. 28–33

With the aid of this die, material savings of 250 g per metre of produced pipe were made on the first day of operation. Figure 4 uses another example to show how Flexring dies can be used to obtain a whole new level in thickness consistency. As a result, a pipe manufacturer was able to halve his thickness tolerance by retro-fitting a Flexring sleeve. He was additionally able to cut his start-up time by 40 % despite the large number of adjusting screws. To correct the thickness distribution, it is normally only necessary to adjust those screws where it makes sense to correct the gap. All other screws remain open. Figure 5 illustrates this for the production of a polyamide pipe of 30 mm diameter.

Another possibility is to incorporate multiple walls into the central region of a flow channel inside a die. This is necessary, for example, in coextrusion. Figure 6 shows a simple solution for retro-fitting an existing pipe die of 43 mm diameter to perform coextrusion. Only the nozzle ring has to be redesigned. All other components of the existing die remain unchanged. Not only was an existing mono-die thus converted extremely cost-effectively into a coextrusion die, but the thickness of the coextrusion layer was smoothed out while production was running. This was done by changing the first multi-wall section of the Flexring sleeve in the conical flow-channel section, i. e., precisely where the two melts flow together. Additionally, the overall thickness distribution of the pipe can be improved by changing the second multi-wall section at the die outlet. No other technology in the world even comes close to offering such technical possibilities.

Apart from simple pipe extrusion, Flexring sleeves are being tried out in dies for blown film, sausage skins and in annular dies for foamed slabs. For example, the Institute of Plastics Processing (IKV) in Aachen/Germany is testing ways of using deformable flow-channel walls to minimise thickness fluctuations in the central layer of a three-layer coextrusion bubble in a project sponsored by the AiF. A second project is aimed at selectively changing the wall thickness of the preform about its circumference during extrusion blow moulding. Naturally, the Flexring sleeve has to be automatically deformed when the preform is discharged [4]. Manually operated Flexring dies featuring automatic adjustment can be simply retro-fitted with stepper motors with flanged-on drives. Because very small forces are necessary for adjusting the Flexring sleeve, very small drives are adequate (Fig. 7).

In the applications described so far, parts with flexible wall sections were made separately and integrated into the die. In the meanwhile, it is possible to integrate multi-wall flow-channel sections seamlessly into the dies direct, without the need to heat the work piece to a critically higher temperature. Figure 8, for example, is a 3D view of the top half of a feed block for the manufacture of coextruded panels that can be optimised while the line is running. The green flow-channel section consists of 10 individual walls in succession that can be deformed within pre-defined limits while the line is running. This enables the layer distribution in the coextrusion layer to be rendered uniform during operation. The advantage of this solution over the conventional coextrusion feed blocks otherwise used is that the flow-channel geometry can be changed any time to suit altered production conditions. New production parameters can quickly arise in production when another raw material is used or when the throughput is increased after the machine speed has been optimised. A feed block that has a flexibly adjustable flow-channel wall can be used to provide an immediate response to a change in layer distribution. ■

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Complete die in cross-section

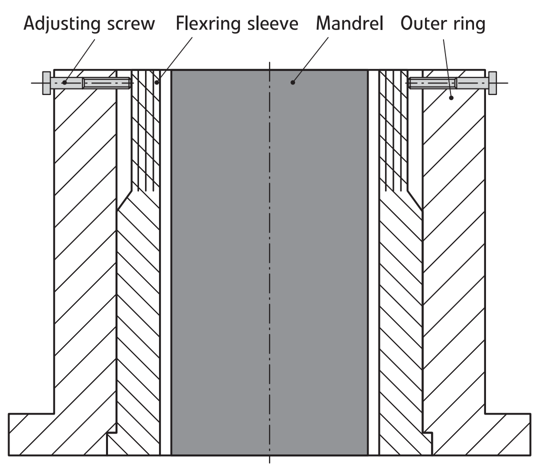

Fig. 2. The multi-wall mouth section is flexible

Title photo. Pipe manufacture on a pipe die that was originally centred thermally: The use of 60 adjusting screws to optimise the flow-channel gap led to savings of 250 g material per metre of pipe

Fig. 1. The outer ring of a pipe die with a Flexring sleeve can be deformed by means of adjusting screws

Fig. 3. Demonstration of the enormous deformation capability of a Flexring sleeve for a die 43 mm in diameter

Fig. 4. Running-in trial on a Flexring die: A much-improved thickness distribution was obtained when the retro-fitted Flexring die was run in
Rohrgeometrie = Pipe geometry; Anfahrsituation = Start-up situation; optimiert = optimised

Fig. 5. The optimisation of the flow-channel gap for producing a polyamide pipe only involved tightening a few screws

Fig. 6. Drawing for converting an existing single channel die into a Flexring coextrusion die. Both the single layer thickness and the overall wall thickness of the pipe can be optimised while the line is running, thanks to a multi-wall, and thus flexible, flow-channel wall section

Fig. 7. Tiny drives like this can automate adjustment of the adjusting screws of Flexring dies

Fig. 8. In this coextrusion feed block (top half), the green flow-channel section consists of 10 individual layers that are deformable while the plant is running