Improved Wall-thickness Distribution of the Preform during Blow Moulding

Flex-ring Dies. The possibility of varying the flow-channel gap at any position around the circumference of a die opens up completely new horizons for extrusion blow moulding. It not only makes it possible to manufacture even more complex parts, but flex-ring technology also extends the range of applications of dynamic wall-thickness control to all required die geometries.

HEINZ GROSS

The geometries of blow-moulded containers are becoming ever more complex. This is mostly the result of purely technical requirements. However, it is often designers who determine the part geometry independently of technical concerns. For the parts manufacturer, it is largely immaterial what reasons are used to justify the geometry of the part he is required to manufacture. His function is to produce the part with the most optimum wall thickness distribution using the technical tools of the trade available to them.

To generate the desired wall-thickness differences in the parison, the nozzle and mandrel can be provided with a profile around the circumference, and the wall thickness in the axial direction can be influenced by the use of a displaceable conical mandrel. However, this often leads to undesirable coupling between the axial and radial wall-thickness control, so that a compromise must always be made regarding the optimum wall-thickness distribution in the two directions. If the part to be produced has a very complex geometry, an optimum wall thickness distribution can only be achieved by a dynamic change in the thickness of the preform in the axial and radial direction. In addition to the programmable wall-thickness control (PWDS), which has been in use for years, parts manufacturers now have an interesting alternative for radial wall-thickness control in the form of flex-ring technology. It permits much more accurate and better targeted wall-thickness adjustment in the parison.

Translated from Kunststoffe 3/2005, pp. 61–65

Starting Situation

With a circular preform geometry, the blow-moulded parts to be produced often have strongly varying stretching conditions around their outer surface. The greater the local differences in stretching ratio in a particular part, the more interesting it becomes to vary the wall-thickness distribution of the parison around its circumference to achieve the desired wall thickness at any point on the blow moulded part.

Programmable wall-thickness control system (PWDS) was developed several years ago especially to remedy this problem [1, 2]. However, it can only be used properly with a die diameter of 60 mm or greater.

However, the process-engineering potential of this system is restricted as regards the geometry that can be implemented and the wall-thickness differences in the preform that can be achieved with it. It is also a very technically sophisticated solution that is very expensive.

Technical Requirements

The aim in developing flex-ring technology was to provide a solution that is simpler but can be used for all the die diameters that normally occur in blow moulding and that permit a more sensitive control of the wall-thickness distribution of the preform. Beyond this basic requirement

- a wide freedom in the design of the flow-channel geometry should be retained,
- the die should of course be able to withstand the pressure normally occurring in the process,
- the integration of the new technology into the die should not require a new parting line,
- if possible, the system should not create new areas where leakage can occur,

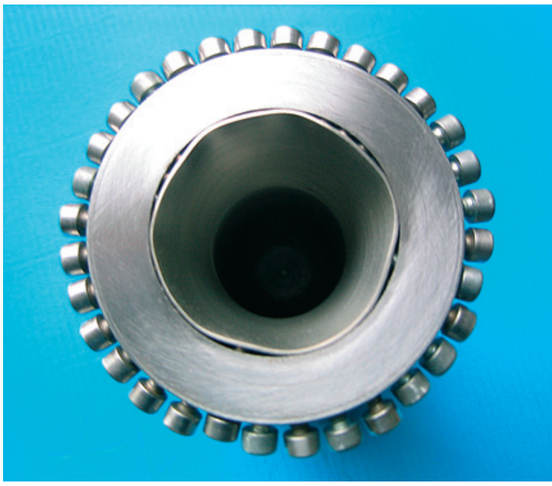

Fig. 1. Test die with 32 setting screws in which the flex-ring sleeve is subject to extreme purely linear elastic deformation for demonstration purposes

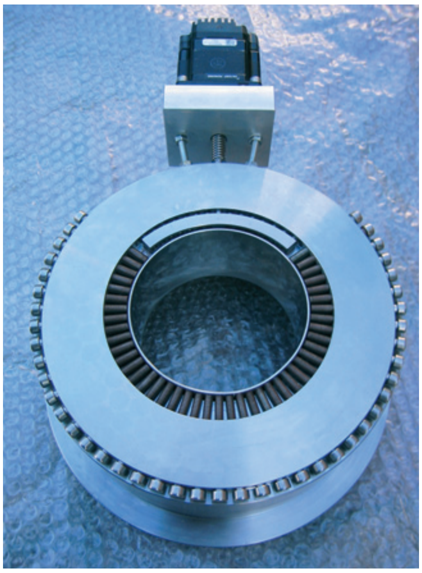

Fig. 2. Test die conceived for static setting, in which setting screws have been retroactively replaced with motorised setting jaw

- no dead zones should occur in the flow channel if possible when its geometry is adjusted,
- the entire system should be corrosion resistant and therefore usable for all conceivable dies,
- the positioning system must be simple to actuate, and
- a high positioning speed must be possible.

Technical Solution

A completely new manufacturing technology was developed to allow inserts (flex-ring sleeves) for blow-moulding dies to be produced, which are partially designed with multiple walls [3]. These flex-ring sleeves can be easily retrofitted to conventional dies, or integrated in them.

They are massively thick walled at one end, where they have a conventional flange collar, by which they are held in the modified outer ring. The underside of the flange forms the sealing face, which is required in any case in the centring parting line. In this die region there are thus no principal modifications required with respect to a conventional die.

The upper end of a flex-ring sleeve, which forms the die orifice, on the other hand, is designed with multiple walls to allow limited local variation of the flow-channel gap there. This is particularly advantageous since changes of the flow-channel resistance directly at the end of the die are considerably more effective than those that are made in the interior of the die. The flow-channel wall in this region is then assembled from a large number of extremely thin, nested individual walls to enable it to withstand the interior pressure of the melt while at the same time allowing it to be flexibly deformable.

The natural flexing line of such a "leaf spring"-like flex-ring sleeve is very short. It thus offers the possible of very sensitive, purely linear elastic deformation at almost any point around the circumference. With the example of a flex-ring die having a diameter of only 43 mm, Fig. 1 shows to what extremes such a multi-walled flex-ring can be deformed without plastic deformation taking place. Since the flow resistance in a slit flow changes with the cube of the size of the flow-channel gap, very large local wall-thickness changes can be generated in the parison in this manner. Despite this, when a flex-ring die is used there are also no sudden changes in the flow channel that can lead to dead spots, since the geometry of the flex-ring sleeve in the deformed region always changes gradually.

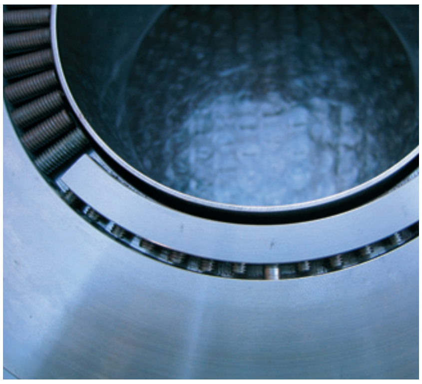

Fig. 3. Adjustment jaw with integrated grub screws for fine setting of the active setting jaw contour

Fig. 4. Blow-moulded bottle with extreme thin area which has been generated for the purposes of demonstration by short-term local closure of the flow-channel gap on the die by means of the setting jaw

The 32 setting screws allow the parison to be provided with a much better targeted control of wall thickness distribution, which is better tailored to the final product than with the only four setting position that are available in the established programmable wall-thickness control system (PWDS). In addition, with the conventional solution there is the additional restriction that two setting positions must always be located precisely diametrically opposite one another.

It is naturally not appropriate to carry out dynamic adjustment at 32 setting positions in a production plant. Both the die shown in Fig. 1 and that shown in Fig. 2 are pilot tools. They permit the optimum flow-channel contour for a new product to be determined rapidly and inexpensively during die design. By purely static adjustment, the appropriate profiling of the flow channel gap around the circumference of the die can be determined for each position along the length of the parison. The geometry can thus be optimised after each shot to obtain the desired result.

Early Test Results on Production Lines

However, such a die, which was originally designed for a purely static adjustment can, as shown in Fig. 2, also be easily converted into a dynamically controlled production die. In a partial region, the setting screws were removed and are replaced by an actuating motor whose axis executes a linear advance movement. This axis is securely connected to an adjustment jaw, with which the flex-ring sleeve can be locally deformed over a relatively large circumferential area. The adjustment jaw has, distributed across the width, 14 small grub screws (Fig. 3), with whose help the geometry of the jaw can be easily adapted to the requirements of the product.

Because of the low mass that has to be accelerated with this system, positioning movements can be executed very rapidly. To demonstrate what is possible with the flex-ring technology, in a test run, the flow-channel gap was closed at one point by means of the actuating motor for 0.3 s during extrusion of the parison. A position was chosen at which the container produced by a conventional die always had an undesirable thick point. The result of the test carried out on an accumulator-head die is shown in Fig. 4. A

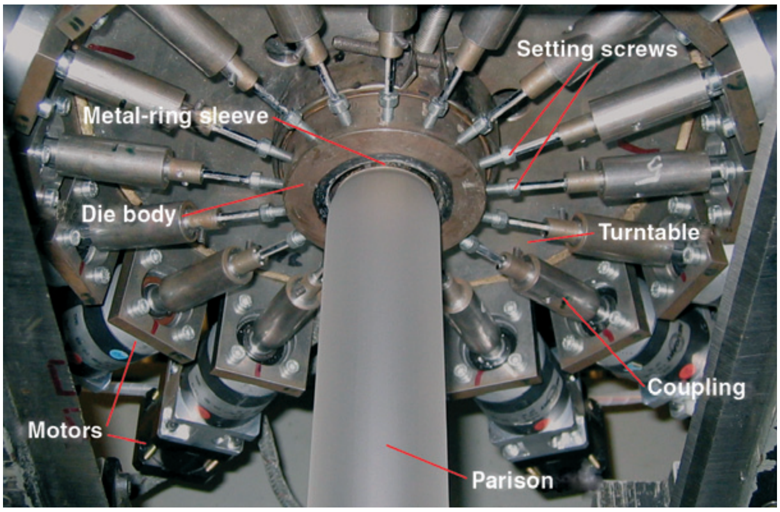

Fig. 5. Flex-ring die of the IKV with a diameter of 35 mm, which is equipped with 16 actuating motors [3]

purely visual comparison of the generated thin area with the wall thickness at the corresponding opposite position makes clear what severe wall-thickness changes are possible with a flex-ring die.

The short transition region at the edge of the generated thin area cannot be achieved in this way with any other system.

At the Institute of Plastics Processing (IKV) in Aachen/Germany, a flex-ring die was intensively studied and tested within a two-year research project. A die with a diameter of only 35 mm with 16 actuating motors was designed (Fig. 5), and an algorithm for computing the optimum setting screw position for a desired geometry of the flex-ring sleeve was worked out. Finally, a test bottle was designed with three different zones for research purposes. The geometry changed over the length of the bottle from a rectangular base region via an oval lower bottle zone to a circular geometry (Fig. 6) in the upper region of the bottle [4]. In static tests a very good thickness distribution could be obtained for every zone of the bottle (Fig. 7). In dynamic experiments, there was a synchronisation problem with the data transfer, which prevented simultaneous actuation of the 16 channels.

It must be stated here that these studies showed what is possible in principle. In a production application, the conceived symmetrical bottle would also suffice with the conventional four adjustment positions. In such a case, the time problem for data processing would certainly be overcome.

The flex-ring technique can also be advantageously used for inexpensive optimisation of the mandrel contour. Post-machining of the contour is not only very time consuming, but also very tricky. Besides the labour and material requirements, it always consumed valuable machine capacity, too. A linear, elastically adjustable flex-ring mandrel (Fig. 8) considerably simplifies this procedure, since the contour can be purposefully optimised during start-up of the die. The mandrel contour can be adjusted quasi from shot to shot. There is thus no risk of removing too much material at a particular point, and in the worst case of having to start from scratch again. With a flex-ring mandrel, every change that has not brought about the desired positive result can be very easily reversed in the next step by unscrewing the corresponding screws.

Test results

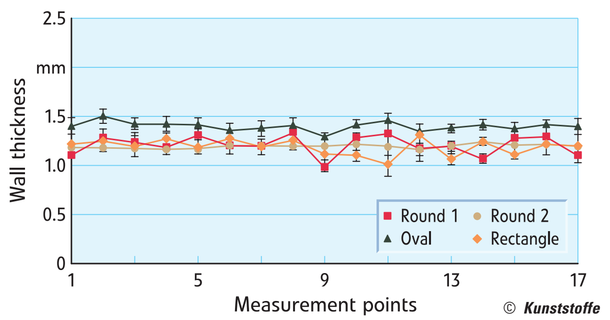

Fig. 7. Wall-thickness distribution in the sectional planes with optimum static sleeve deformation

(source: IKV)

Future Perspectives

The possibility of varying the flow-channel gap at any position around the circumference of a die opens up completely new horizons for extrusion blow moulding. It not only makes it possible to manufacture even more complex parts, but flex-ring technology also extends the applications of dynamic wall-thickness control to all required die geometries, so that in future there will no longer be limitations in the use of a radial wall-thickness control because the die diameter is too small.

Flex-ring technology offers the opportunity to considerably reduce manufacturing costs. This is carried out not only by reducing the material consumption through improved wall-thickness distribution in the blow moulded part, but principally also by reducing the cycle time, which takes place automatically

Fig. 6. Bottle manufactured with the test die with varying cross-sectional geometries

(photo: IKV)

when unnecessary thick points in the blow moulded part are eliminated. It can be assumed that the difference between the desired wall-thickness distribution in the part, and that actually achieved becomes smaller. In addition, a die is used that is simpler than the programmable wall-thickness control (PWDS) dies used until now, and therefore also less prone to possible disturbances.

At a time when calls for innovations from many sides are not only coming ever more frequently, but also ever louder and more stridently, it is therefore a little surprising how tenaciously the industry is sticking to a technically inferior, but long tried-and-tested technology. The innovations required by all sides will do nothing unless they are also accompanied by the courage to use them appropriately, even though there is of course no available long-term experience with using them in large numbers of production systems. Only those who successfully implement the innovations in their own areas will in-

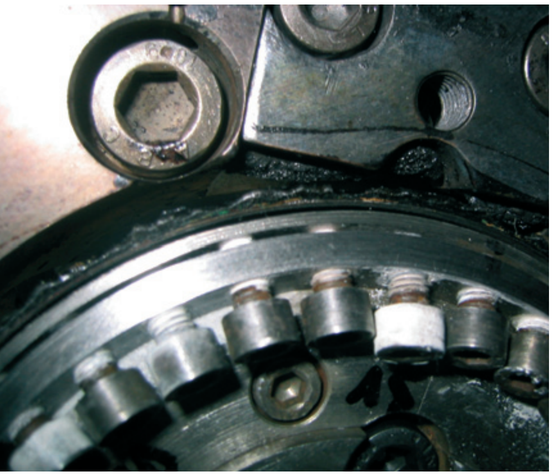

Fig. 8. Cutaway view of a flex-ring mandrel that has been retrofitted to a programmable wall-thickness control (PWDS) die for rapid optimisation of the mandrel contour

crease or at least maintain their competitiveness. In the case of the flex-ring, the costs should not prove the obstacle, since the purely mechanical part of a flex-ring die can be manufactured more inexpensively than a conventional programmable wall-thickness control system (PWDS), and the necessary electrical adjustment system also has, along with technological superiority, cost advantages compared with the established hydraulic adjustment system. ■

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