Pipe Extrusion. In addition to wall thickness control in the take-off direction, which has been become common practice and a standard feature of a good pipe extrusion system, all technical prerequisites are now in place in the field of pipe extrusion to also implement closed-loop control for the pipe wall thickness around the circumference.

Controlling Pipe Wall Thickness around the Circumference

Fig. 1. Exhibition model for demonstrating the benefits of tiling die technology. The four flange bolts are used not only for clamping purposes, but also to tilt the die (photos without fig. 4: Gross)

Fig. 2. Complete retrofit kit (mounted on a base plate) for an existing blown film die. With the aid of two stepping motors, the required position of the die with respect to the mandrel can be adjusted with maximum precision

HEINZ GROSS

In a world of global competition, it is simply no longer enough to offer better product quality than the competitors. Over the long term, the companies that survive will be primarily those who can offer their high-quality products at the lowest possible manufacturing cost versus the competition. Upon comparing the different processes used to manufacture sheet, film, pipe or profiles from plastics, it becomes clear that the field of pipe extrusion offers the greatest potential for additional reductions in manufacturing costs. Considering that material costs represent considerably more than 50 % of the overall manufacturing costs in the case of extrusion, it is obvious that the greatest savings can be achieved by reducing the amount of material used during production.

In film production, it is now commonplace to achieve thickness tolerances of less than 5 %. For pipe, the European standards usually allow wall thickness tolerances in the range of 10 %. For instance, according to EN 1401-1 the permissible wall thickness for foam-core PVC pipe with a diameter of 110 mm lies between 3.2 and 3.8 mm. Of course, all pipe manufacturers strive for tighter tolerances. Frequently, however, they still exceed 5 %. The tighter tolerances found in film production are achieved by using closed-loop control for the wall thickness around the circumference or, in the case of cast film, over the width during production, which for some time has now been the state-of-the-art worldwide. Pipe extrusion is a long way from here. When optimizing the thickness around the pipe circumference, operators are still limited to manual centering of the die with respect to the mandrel because of a lack of technical solutions. What makes it even more difficult is that it is not possible to center the die with respect to the mandrel optimally by means of the centering screws placed

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around the circumference of conventional pipe heads [1, 2].

If the objective is to reduce the amount of material used for production of pipe by implementing closed-loop control for the wall thickness around the circumference of the pipe, it will be necessary to have pipe heads with controllable actuators. To achieve an optimal result, it should first be possible to center the pipe head automatically. Once the eccentric thickness differences have been minimized, the control must reduce any remaining asymmetric thick or thin spots around the pipe's circumference. Only in this way is there any chance to achieve long-term thickness tolerances in pipe production similar to those that have long been common in film production. That this is in principle possible is demonstrated by the experimental results that have been obtained with a Flexring die.

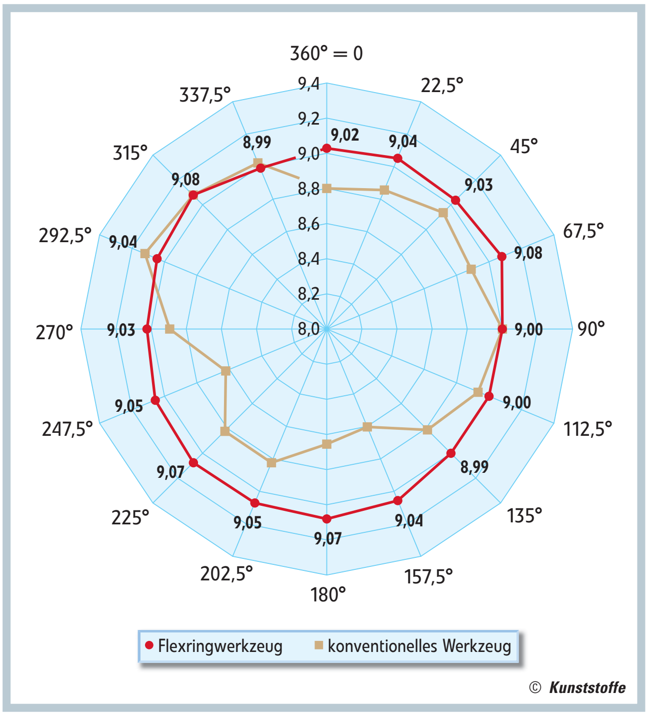

Fig. 3. Wall thickness distribution over the circumference of the die achieved with a Flexring die through local optimization of the flow channel gap (pipe geometry: 110 x 9 mm)

Automated Centering by Means of Tilting Dies

A simple solution for automatically centering a pipe head was found with development of tilting die technology [3]. To optimize the relative position of the die with respect to the mandrel, the die is tilted instead of being shifted, the usual approach. The seal between the head and die when using this new solution is achieved with the aid of a flexible seal. The seal is based on an elastomer optimized specifically for this application. Even when using conventional, manually adjustable positioning screws, this solution provides much more precise centering than what is achievable with the conventional, radially arranged centering screws. With regard to achieving the automatic adjustment that would be needed for control, tilting die technology has the significant advantage that just two low-cost stepping motors suffice to tilt or center the die automatically with much greater precision than is possible manually.

The new tilting die technology incorporating an elastic tilting element was presented for the first time last October at the plastics exhibition in Düsseldorf, Germany **(Fig. 1)**. The technology, however, has already been tested successfully in different systems with a variety of the materials and a wide range of pipe diameters. The readiness to test tilting die technology with little hesitation is made all the easier, since any existing pipe head can be retrofitted with an elastic tilting element quickly and at moderate cost. A special die for production of PLA capillaries for medical applications represents the lower end of the "pipe geometry" that has already been tested. The fact that capillaries with an outside diameter of only 0.2 mm can be produced with this die, which was initially designed as a tilting die tool, illustrates that very accurate and sensitive centering is possible with tilting die technology.

The largest die that has been retrofitted with an elastic tilting element to date has a diameter of 220 mm in the region that must be sealed between the head and die. The die is for use with a head that discharges parisons for extrusion blow molding. Since the new tilting solution allows the die to be fitted on the head only centrically because of a tight fit, setup times are shortened. What is more interesting, especially for extrusion blow molding, is that because of motorized adjustment **(Fig. 2)** the blow molding machine no longer must be stopped to optimize discharge of the parison. In the meantime, the first manufacturer of blown film has decided to take advantage of the benefits of tilting die technology and retrofit his existing blown film die with an elastic tilting element.

In terms of materials, tilting dies have already been tested successfully with polyolefins, PVC, PA and PLA. In terms of economics, tilting die technology has the additional benefit that the manufacturing costs for such a die head are lower than those for manufacturing a die head with conventional centering technology.

The upshot: for the first time, die technology is now available to equalize eccentric wall thickness differences on pipe extrusion lines. Asymmetric thick or thin sections of the pipe wall thickness can now be reduced through use of Flexring dies. Flexring dies have been available for more than ten years [4, 5]. To reduce the thickness tolerance around the circumference of pipes, they use the same basic principle that has been employed successfully for decades for cast film. The flow channel at the exit from the die is adjusted within a limited region to change the flow resistance in relation to neighboring regions. In this way, extremely tight thickness tolerances can now actually be achieved when manufacturing pipe **(Fig. 3)**.

Closed-loop Controlled Flexring Die as Solution

In spite of the favorable results, it was not possible for Flexring dies to become established in production. The primary reason for this is that, compared to a conventional pipe head, considerable additional labor is required to precisely adjust the numerous positioning screws arranged around the circumference of the die. What aggravates the problem even further is that linear fluctuations are noticed much more quickly and thus frequently when tighter thickness tolerances are achieved. The challenge: to offset this drawback with a closed-loop controlled Flexring die. For a long time, it was not →

possible to find interested parties who were willing to develop a control strategy and write the required software.

It took the economic crisis and the second stimulus package from the German government to create the conditions that made it possible to develop a technology to control the wall thickness around a pipe's circumference. The Central Innovation Program for Medium-sized Companies administered by the German Ministry of Economics is currently funding two separate projects that have the objective to develop closed-loop control for the wall thickness around the circumference of foam-core PVC pipe to as constant a value as possible. In the first of these projects, Ingenieurbüro Walz in Obertshausen, Germany, is developing a new, relatively simple and low-cost measurement system. A unique capability is that it can measure not only the wall thickness of solid, but also of foam-core pipe. **Figure 4** shows the pilot system integrated into a pipe extrusion line at Pipelife Deutschland GmbH & Co. KG in Bad Zwischenahn, Germany, on which foam-core PVC sewer pipe with a diameter of 110 mm is produced.

In a second step, an existing die head at Pipelife is being retrofitted with a Flexring sleeve and stepping motors to provide motorized adjustment of the die gap.

In the second project funded by the Ministry of Economics, aiXtrusion GmbH, Arnsberg, Germany, will design a control strategy and write the corresponding software to calculate the controller outputs on the basis of the actual values of the wall thickness around the pipes circumference as measured by the new measurement system. Using these controller outputs, the flow channel gap in the pipe head will then be corrected locally in order to reduce the thickness tolerances. All experiments will be conducted directly on the production equipment at Pipelife, which is used to produce foam-core PVC pipe with diameters of 110, 125 and 160 mm. The stated objective, naturally, is to save material through considerably reduced thickness tolerances, while at the same time improving the quality of the pipe. Ultimately, of course, it is hoped further that the personnel necessary for production and quality control can be reduced as well.

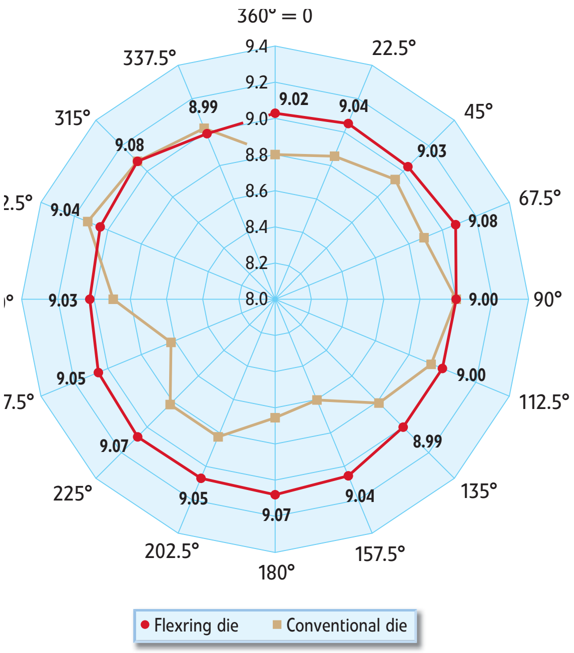

Fig. 4. New measurement system for online sensing of the wall thicknesses of solid or foam-core pipe, integrated into the pipe extrusion line downstream of the first vacuum tank (photo: Ingenieurbüro Walz)

Summary and Outlook

All technical prerequisites are now essentially available in the field of pipe extrusion to implement control of wall thickness around the circumference in addition to the thickness control in the take-off direction that has long been common practice and a standard feature of a good pipe extrusion line. While pipe production always lagged behind blown film extrusion in the past in terms of the level of automation, there is now an opportunity to even overtake it. On blown film lines, unacceptably large eccentric thickness differences must still be reduced manually by means of conventional centering screws. The objective in the current development of wall thickness control for pipe is to also correct eccentric thickness differences. This is to be achieved for the first time through the use of tilting dies with elastic tilting joints. Ultimately, it is a question of the necessary investment and amortization time as to whether retrofitting is worthwhile on an individual basis. The existence of a suitable thickness measurement system on the extrusion line would naturally facilitate such a decision. If this is not the case, the wall thickness measurement system currently being developed could present an interesting alternative, since it is likely to be less expensive than a conventional ultrasonic measurement system. At present, however, only the pilot system shown in **Figure 4** is in the testing phase. The algorithm necessary for control must still be written. As a consequence, it is difficult to predict at the moment when the first equipment manufacturers will be able to offer new lines on which pipe wall thickness can be controlled in both the take-off and circumferential directions. ■

REFERENCES

1 Gross, H.: Manuelles Zentrieren wird überflüssig. Extrusion International Magazine 16 (2010) 6, pp. 22–25
2 Gross, H.: Manual centring becomes superfluous. Extrusion International Magazine 16 (2010) 7, pp. 52–55
3 Gorczyca, P.: Sustainability – Highlighting a New Image. Kunststoffe international 100 (2010) 12, pp. 36–39, PE110659
4 Gross, H.: Neuheiten in der Extrusion. Kunststoffe 91 (2001) 12, pp. 82–85
5 Gross. H.: Flexible Die Walls. Kunststoffe plast europe 93 (2003) 8, pp. 8–9

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