Emerging new Technologies will improve Pipe Quality and reduce Production Costs

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Nowadays it is no longer sufficient to offer superior product quality compared to the competitors. Due to the globalized market only those companies that are able to produce high quality products at minimized costs will be successful in the future. This is valid for processors of extruded products in general and particularly those using annular dies. Predominantly in pipe extrusion the thickness tolerances are larger compared to all other extruded products. It is well known that in extrusion the percentage of the cost which relates to the material is normally much higher than 50 percent. So it is clear that the potential savings are great if the material consumption is reduced.

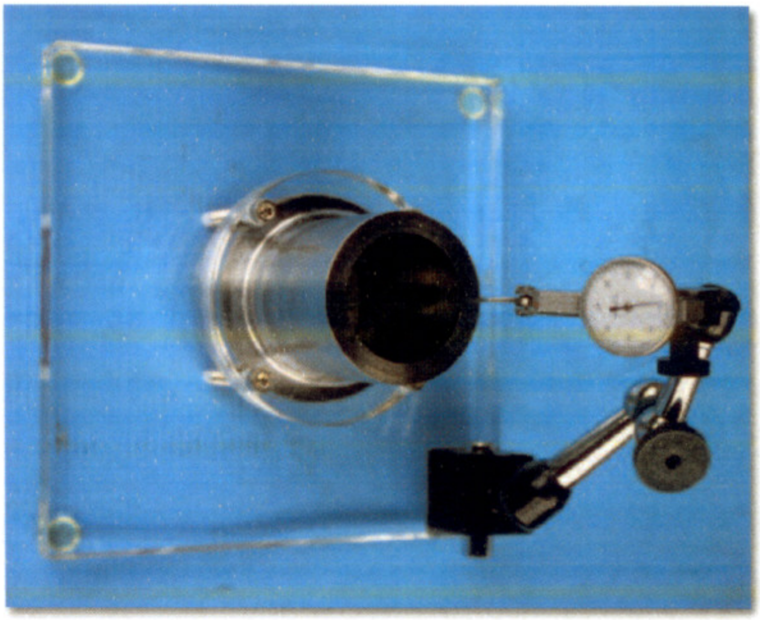
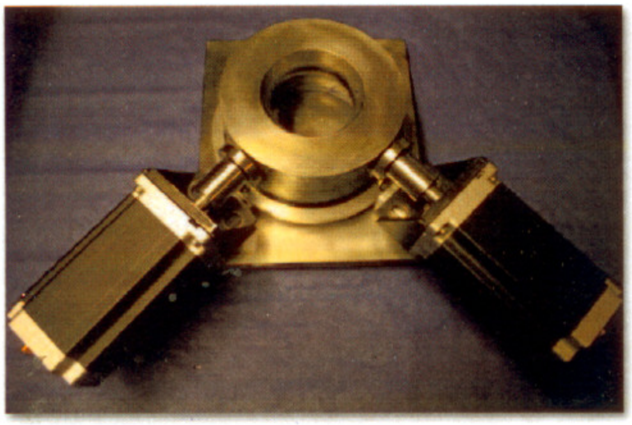


Fig. 1: Demonstration model that has been used during the K-show testifies that it is extremely easy to integrate a tilting joint into a pipe die

Since the early days of pipe extrusion virtually nothing has changed in regard to the method to mount the die to the head and to centre it before the process is started, so it is not surprising that the actual technical solution which is still used worldwide seems to be a little bit old fashioned. Centring screws are positioned around the circumference of the die.



Special shifting systems are often used for dies in blow moulding when complete access to the head is not possible, but these systems still have to be manually operated using adjusting screws. This is not at all a convincing solution to meet the existing technical requirements.

List of requirements for the centring operation

The requirements for an ideal solution are easy to formulate. The head has to be designed in a way that the die or the outer ring can only be mounted to the head in a centred position. In this case the head can immediately be heated up and the production can start without any delay. Skilled operating people might reply that it is still necessary to move the die slightly out of the centre in order to achieve the best possible thickness distribution in the final product. This is the case as generally the thickness distribution around the circumference is not good

Fig. 2: Tilt die retrofit kit (entrance diameter 7.8 inch) equipped with two stepper drives mounted on a flat ground plate in order to test the achievable tilting angle

when the die is positioned exactly in the centre of the head. Consequently it is nevertheless necessary to adjust the position manually. This is indeed the case but at least additional machine capacity is generated when no special centring operation is necessary any longer. Consequently it has to be added that in spite of the compulsory centred mounting it must still be possible to sensitively correct the flow channel gap at the exit of the head in order to achieve the optimum result.

This is due to the fact that each machine has some small deficiencies which disturb the homogeneous local velocity over the circumference of the head. The special solution should take into account that the necessary changes are rather small in practical operation. It would be an advantage if the gap could be changed in the range of 0.00004 inches especially with heads for the production of blown films which possess small flow channel gaps at the exit. Additionally it would be ideal if it were possible to reproduce any gap situation which has been reached at an earlier time. Naturally it is also an important point that the solution can be fabricated with little cost.

Fig. 3: Pipe head that has been retrofitted with a tilting joint during tests at Krauss Maffei

Actual solution

It must be realised that at this time the above stated requirements are not at all fulfilled while rating the actual solution. The use of centring screws or shifting systems within a head does not allow for a close fit between the head and the die. As a consequence the die has either to be centred before the machine is put into operation or this has to be done while the line is running. The result is that machine downtime is created or additional scrap is processed. In either case qualified operators are almost always necessary.

The technical tools are not at all convincing as well which are actually available for the operators. High forces are necessary to seal the shifting area of the head which is why the clamping screws are usually very large. But threads of big screws have by nature coarse pitches. This makes fine adjustment somewhere between difficult and impossible. The problem is increased because some tension has to be generated to overcome friction before the die starts to move when trying to centre the die. This is the reason that the exact path the die moves in is impossible to predict accurately. As a consequence it is also impossible to reproduce exactly the position which has existed before the adjustment when using the conventional solution. It is well known that operators will almost always stop their efforts before the possible optimum setting has been reached. Furthermore especially for thermal sensitive polymers it is also a problem that dead zones are created in the flow channel of the head when the die is shifted out of the centre.

New solution to optimise the flow channel gap situation of annular dies

There have been many attempts in the past to find a better technical solution. A construction can be found in the patent literature [1] where the die is not shifted but where a tilt joint is used. But the tilt joint construction proposed needs very precise manufacturing. Therefore it is not only rather expensive but requires very sensitive handling by the operators during production and maintenance. That is the reason why that solution can hardly be found on the market. The new solution also uses a tilting joint.

It is now possible to use a very low cost elastic tilting joint instead of the mechanical joint which is costly to manufacture. The technology has been presented to the public at the K-2010 show for the first time. **Fig 1** shows the model which was used to demonstrate the advantages of the new tilting solution. As already mentioned a close fit can be used while using an elastic tilting joint because the die has no longer to be shifted relative to the head. Due to that solution the die is by itself centred immediately after it has been mounted to the head. A further advantage is that every existing annular head can be easily retrofitted with a tilt joint.

Even an automatic adjustment becomes possible when using the new tilt solution. **Fig 2** shows a tilting arrangement where the position of the die can be fine tuned with the help of two stepper drives. These are mounted to the head in a 90 degree arrangement. The drives can make adjustments as small as 0.00004 inches with an extreme precision due to the small steps and the additional transmission ratio of an eccentric transmission. Now it is possible to reproduce any situation or position which has existed before an adjustment has been completed.

Advantages of the tilting solution

During pipe extrusion it is no longer necessary to pre-centre the die after it has been dismantled for cleaning and attached to the line again. The optimisation of the thickness distribution around the circumference of the pipe can be done much more accurately. In the past operators have resigned themselves to use elongated tools to adjust the big conventional adjusting screws. The danger of injuries which exists with those manual adjustments is also eliminated with the new tilting technology. No great forces are necessary when using an elastic tilt joint.

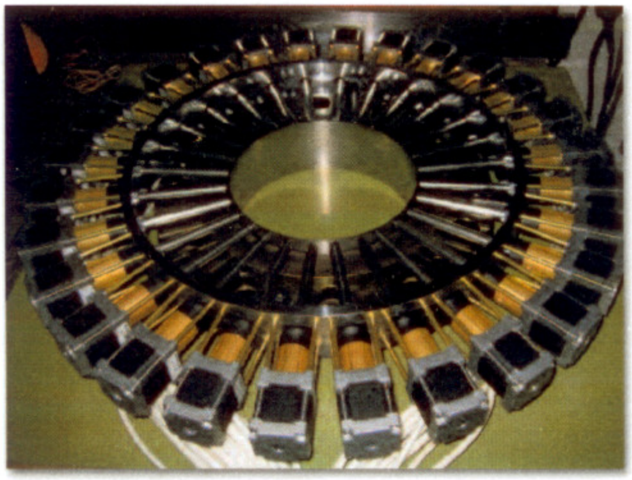


Fig. 4: Flex Ring die equipped with 28 stepper drives to locally adjust the flow channel gap between the die and the mandrel (not shown in the photo)

That is why normally. four clamping screws are sufficient to fix the die to the head. They mainly have to carry the weight of the, die apart from those dies where the flow channel diameter reduces from the entrance to the exit of the die. In this case naturally the additional forces generated by the pressure in the die have to be taken into account. Fewer clamping screws promote a quicker assembling and disassembling of the die.
In consequence not only cost for the line and the operators but also additional resin cost can be saved during the start-up of the line. Even much more material can be saved due to the fact that a better adjustment of the die immediately leads to a reduction of the thickness tolerances. At the same time the quality of the extruded products are improved. Tilt joints can be easily retrofitted to any existing pipe head. **Fig. 3** shows a pipe head that has been retrofitted with a tilt joint. The relation between cost to modify the head and gain is excellent. In the case when a new head is directly designed with a tilt joint the manufacturing cost for the head will be even reduced compared to those that are necessary to fabricate a head that is equipped with conventional centring screws.

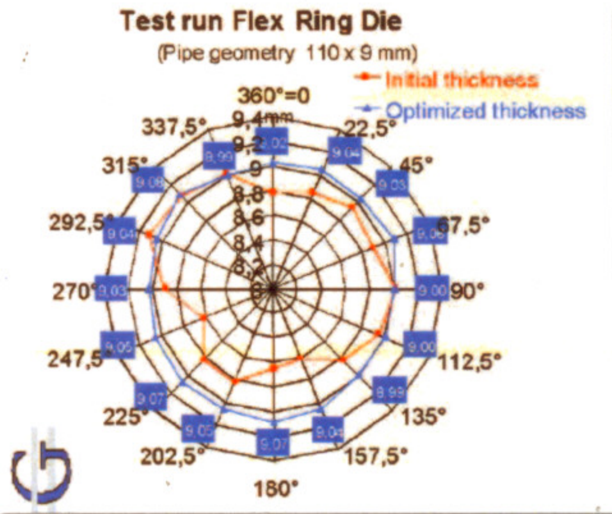
Closed-loop thickness control during pipe production

The optimal material savings in pipe extrusion is achievable when a closed-loop control for the thickness is used in extrusion direction and around the circumference of the pipe. To make this possible a die is required which possesses not only a tilt joint but also a Flex Ring sleeve. Firstly the eccentric thickness tolerances have to be reduced. Thereafter it is necessary to minimize asymmetric thickness variations of the pipe. Both the tilt joint and the Flex Ring sleeve have to be operated by actuators in order to change the flow channel situation dynamically. **Fig. 4** shows a Flex Ring die equipped with stepper drives for an automatic adjustment of the local flow channel gap at the exit of the die. Older static tests which have been performed with a Flex Ring die have testified that there exists a remarkable potential to reduce the thickness tolerances in pipes (**Fig. 5**). What is still missing is the software and the control algorithm to calculate the adjusting paths for the actuators according to the measured difference between the wanted and the actual thickness values.
Presently the conventional ultrasonic on-line thickness measuring systems are unable to measure foamed core PVC pipes. Research is underway by the Ingenieurbüro Walz, Obertshausen, Germany who are testing a new online measuring system which can also measure the total thickness of core foamed pipes. Fig. 6 shows the pilot measuring system integrated into a production line for 110 mm core foamed PVC pipes at the German Pipelife production site in Bad Zwischenahn. Parallel to these activities the aiXtrusion GmbH, Arnsberg is working to develop the necessary control algorithm and to establish the software for the controller. Both activities are funded by the German government.

The use of tilting dies in blown film extrusion and in extrusion blow moulding

The advantages described for the extrusion of pipes are more or less also valid for the production of blown films. Additionally the last hindrance is eliminated which prevents an automatic start-up of blown film lines after the head has been dismantled for cleaning. In the future the blown film head can be operated with a closed-loop control which reduces not only the thickness differences over the circumference of the bubble but also the eccentric thickness distribution within the bubble. As a result the quality of the produced films is totally independent from the special skill of the line operator who is available.
During pipe and blown film extrusion the head can be centred while the line is running. The same can be done while producing small hollow parts using the extrusion blow moulding process. But this is no longer possible when the parts and consequently the heads become bigger. In this case the process has to be stopped. The guard door has to be opened and the ope-

Fig. 5: Comparison between the thickness distribution achieved with the "ideal" round flow channel (red) and after optimizing the flow channel situation with the help of a flex ring sleeve (blue)



rator has to climb into the space between the open mold to be able to adjust the die at all. The Chief of Production will not only profit from improved security at his machine but also from an increased line capacity. This is due to the fact that when using the new tilt solution the process has no longer to be stopped. In this case additional time will lapse until afterwards the machine has reached the steady state production situation again. During this time the machine produces scrap and precious production time gets lost. While using a head with a tilting joint which is actuated by stepper drives (see **Fig. 7**) this problem is immediately eliminated totally.

The biggest progress in extrusion blow moulding is achieved when using a tilting die for the production of blow moulded tubes which possess a bend. The tilting die first solves the wear problem which exists in the shifting area when using conventional x-y dies. Secondly the tilting die is much cheaper in production compared to the conventional solution. This is due to the fact that no high forces have to be overcome in the shifting area because small forces are sufficient to tilt the die. Those forces can be realised with stepper drives which work with high precision, which are totally maintenance free and which never the less are rather cost efficient. Expensive servo valves and heavy hydraulic pistons with their hydraulic hoses become superfluous. No hydraulic unit is necessary. For all the above reasons the tilting die is the perfect solution for "All-Electric" blow moulding machines which are generally acknowledged as the logical progression by all leading machine builders

Future prospects

Probably every existing annular head can be retrofitted with an elastic tilt joint. The relevant costs vary naturally according to the size and the detailed construction of the special head. For head diameters equal or smaller than 12 inches less than a five figured dollar amount will be sufficient. The economic advantage will naturally vary with the special application. In pipe extrusion the biggest profit will be achievable when it will be possible to use a closed-loop control to reduce the thickness tolerances over the circumference of the pipe. But it will still take some time until such a technology will be offered on the market.

Fig. 7: Head mounted to a blow moulding machine equipped with a tilting joint which is actuated by two stepper drives positioned in a 90 degree arrangement

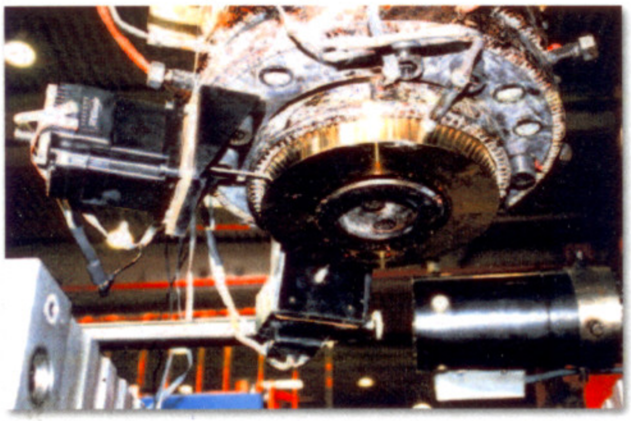


Fig. 6: Pilot system to measure the thickness during tests in a production line for 110 mm of core foamed PVC-pipes

In extrusion blow moulding the implementation of the tilting technology into existing production machines processes has already started. In this application the tilt joint can be used to centre the die statically and then to tilt the die dynamically to profile the parison according to the needs of the part which has to be produced. In regard of economics it is also of importance that it can be expected that tilt dies will need less maintenance and will not have to struggle with any wear problems. The time for the return on investment naturally depends from several individual internal factors of the relevant producer. In the end a precise calculation of the economic value is consequently only possible when an existing conventional die is retrofitted with a tilting joint and when the achieved savings are determined in detail and then compared to the former situation.

References

[1] Offenlegungsschrift DE 10 2005 026 726 A1; Extrusionsblaskopf, day of submission 09.06.2005

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