挤出模头的新技术：成本降低，产品质量提升

New die technology cuts costs and improves part quality in extrusion

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图2：单流道柔性环模头 / Fig. 2 One channel Flex Ring die

当今所采用的技术，或者是通过计算确定模头流道的几何形状，或者继续依据长期的依赖于特定种类模头的经验来设计模头。平缝式模头的流道形状大多数依据计算来确定，其模头轮廓的加工仍然常常依靠经验。无论哪种方式，最终它的几何形状都被确定地用坚实的钢铁块加工出来，然后这些部件被装配成模头。无论流道的几何形状是依据经验设计的或是计算出来的，其形状都必须要准确地符合特定的实际用途。实际上，这些计算是基于简单化的假设，在生产中的重要参数 — 例如产量 — 与用来计算的数据相比，通常会有至少是轻微的差异。机器的操作人员在生产线的优化方面越是成功，这意味着加工速度越快，这种差异就会越大。在共挤的情况下，这一差异显得更为突出，因为在产量增加时，不同层次的融体分布会有明显的改变。由于流道的几何形状不会随着生产线速度的增加而变化，导致各共挤层的厚度公差会变得越来越大。

It is state of the art to either calculate the flow channel geometry of a die or still to design it according to long lasting experience depending on the special type of die. The shapes of the flow channel in slit dies are mostly calculated those of profile dies are often machined empirically still. Whatever way is used at the end a fixed specific geometry is milled or cut into solid steel blocks or parts which finally are assembled to establish in the die. Neither the flow channel geometry which has been empirically designed nor the calculated one hits exactly the shape which is necessary for the special practical application. This is true not only because calculations are based on simplifying assumptions, but also because during production the important parameters as for instance the throughput rate normally differ at least slightly from those which are used for the calculation. The more the machine operator is successful in optimising his line, that means in speeding up his process, the more the difference increase. This is especially critical in the field of co-extrusion as the melt distribution of individual layers can significantly change with increasing throughput rates. As a consequence

图1：柔性环模头的照片（左图）和剖面图（右图）/ Fig. 1 Photo (left) and cross sectional drawing (right) of a Flex Ring die

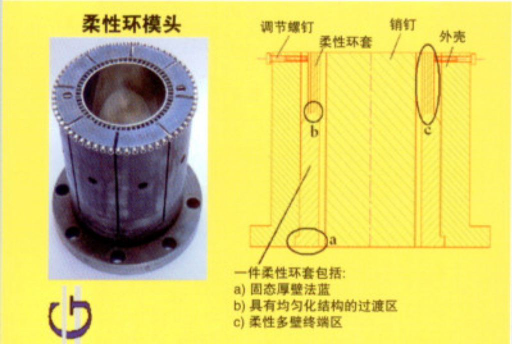


图3：双流道柔性环模头
Fig. 3 Two channel Flex Ring die

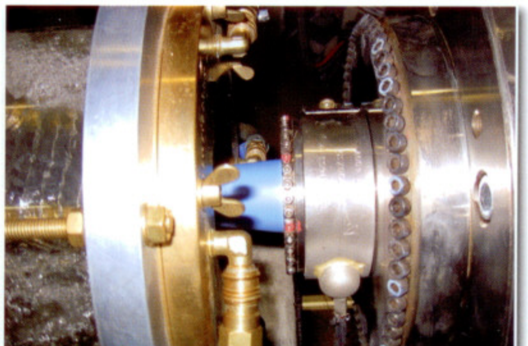


图4：三流道柔性环模头示意图
Fig. 4 Drawing of a three channel Flex Ring die

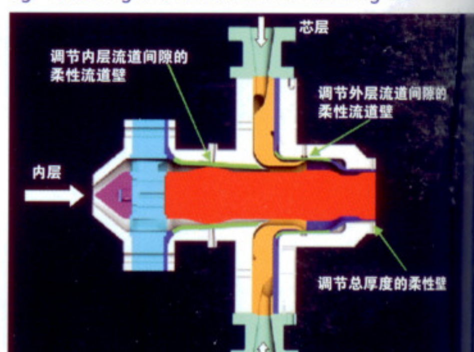


图5：生产线上的三流道柔性环模头
Fig. 5 Three channel Flex Ring die in operation

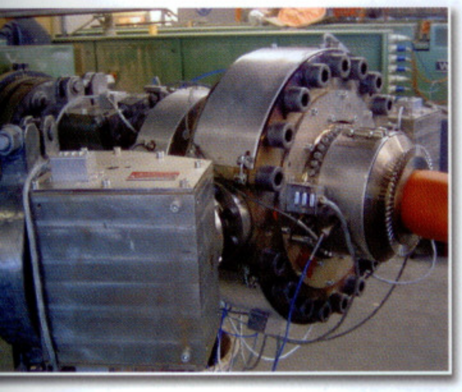
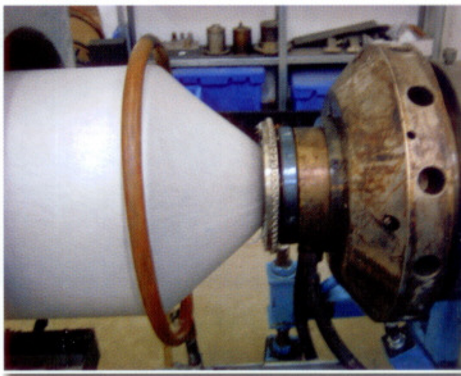


图6：采用圆形柔性环模头生产发泡片材的生产线 / Fig. 6 Line which produces foamed sheets using a circular Flex Ring die

图7：柔性环模头，口唇部位有68个调节螺栓，用于精细调节流道间隙。
Fig. 7 Flex Ring die having 68 adjusting screws at the mouth of the die to fine tune the flow channel gap



这就是为什么以往许多加工者梦想有那种“橡胶状态的模头”的原因。在生产过程中，他们希望这种模头流道的几何形状可以调节。这种梦想与现实之间的差距现在被缩小了，现在出现了一种全新的技术：制造流道壁断面呈现多层状态的挤出模头。由于这种外壁采用弹性叶片结构，所以在生产过程中，这种流道壁可以按照纯线性的弹性方式有限地局部变形。25 年来，在平缝模头的出口处采用柔性模唇这一当代技术，实现了极小的薄膜厚度公差。采用闭环控制，在模头的整个宽度连续优化。这样保证了在整个生产过程中薄膜质量的一致性，以及非常小的厚度公差。目前，在管材挤出领域，这种可能性尚不存在，这就是为什么管材的厚度公差远大于薄膜厚度公差的原因。将灵活可调的流道壁集成到管模头上去，也就是将已得到验证的技术拓展到所有挤出领域中去。下面要介绍的就是对不同加工工艺的创新方案。

管材挤出

柔性模唇平缝模头的基本原理成功地应用到了环形模头。[1].管材挤出柔性环模头在其出口缝隙处的圆周上同样有柔性模唇（柔性环）。通过大量分布在圆周上的调节螺栓，可以局部调整流道的间隙。图1显示的是柔性环模头的剖面图（右图）和照片。管材生产者采用照片所示部件更新了现有模头，由于柔性环模头缩小了厚度公差，因此原料节省了3%。图2显示了装在生产线上的柔性环模头。由于采用了多壁流道，甚至可以优化单共挤层的厚度分布。图3显示双流道模头，第一排调节螺栓优化外层厚度分布，模头口唇处的第二排调节螺栓优化双层管总的壁厚的厚度分布。全新的三层柔性环模头生产芯层发泡管，目的是在生产线运行中能够优化独立内层的厚度以及独立外层的厚度。为实现这一点，内层由后方进入到模头（图4），内层在整个圆周上的融体分布可以通过流道的第一柔性区来优化，在这里调节螺栓沿着圆周分布。外层也是一样，在它与主流道融合前进行优化。模头的末端还有调节螺栓，进一步缩小管材总厚度的变化。图5显示安装在生产线上的模头。采用可调节的流道壁让生产者只须简单地按照改变后的新原料的粘度改变流道的几何形状，就可以自由地采用同一个模头加工不同的原料。

the thickness tolerances of individual co-extruded layers become steadily greater and greater while increasing the line speed as the flow channel geometry does not follow these changes. That's the reason why in the past many processors dreamed of some “rubber like” dies where the geometry of the flow channel can be adjusted while the process is running.
The gap between the reality and such dreams have become smaller now. A totally new technology has been developed to build extrusion dies having flow channel wall sections which are multi-walled. Due to these leaf-spring wall constructions such flow channel walls can be deformed locally limited in a purely linear elastic way while the process is running.
Since over 25 years it is state of the art to reach extreme small thickness tolerances by using slit dies having a flexlip at the die outlet. The flow channel gap over the width of the die is continuously optimised using a close-loop control. Thus are uniform film quality with extremely narrow thickness tolerances is assured over the complete production run. In pipe extrusion such possibilities did not exist so far. That is the reason why thickness tolerances in pipes are much greater compared to films. Integrating flexible adjustable flow channel walls into pipe dies allow to transfer that proved technology to all extrusion processes. Following the developed solutions for the different processes are described.

Pipe extrusion

The basic principle of the flexlip slit die has now been successfully transferred to circular dies [1]. Flex Ring dies for pipe extrusion also have a flexible die lip (a flex ring) around the circumference at the outlet gap of the die. By means of a large number of adjusting screws arranged around the circumference the flow channel gap can be locally adjusted. Fig. 1 shows a cross-sectional drawing (right) and a photo of a Flex Ring die. The pipe producer who retrofitted his existing die with the parts shown in the photo saved 3 % of resin due to smaller thickness tolerances which he achieved with the Flex Ring die. Fig. 2 shows the Flex Ring die mounted to the production line. By using multi-walled flow channel walls it is even possible to optimise the thickness distribution of single co-extruded layers. Fig. 3 shows a two channel die with a first row of adjusting screws to optimise the thickness distribution of the outer layer and a second row of adjusting screws at the mouth of the die to optimise the thickness distribution of the total wall thickness of the

采用圆形模头生产发泡薄膜和片材

通常，采用与管材柔性环模头同样的方式可以将发泡薄膜的厚度公差进一步减小，前提条件是采用圆形模头，并且薄膜或片材是在冷却后再切开，如图6所示。与柔性环套相结合，流道间隙可以调节，从而在整个圆周上消除厚度偏差（图7）。甚至只须增大模头口唇部位的流道间隙，通常由于支撑芯棒的模芯支架所产生的薄弱部位也可以被消除。

吹膜挤出

在吹膜的情况下，模头口唇部位的出口间隙必须在微米范围内校正，以减小存在的厚度偏差。如果用手工来调节，这不仅需要大量的经验和直觉，而且需要额外的劳动成本。与闭环厚度控制的现代吹膜技术相比，这实在是相差甚远。双泡工艺生产出来的薄膜具有更好的机械特性，但是如果将现有的控制系统应用到双泡工艺，它将不能工作，因为膜泡离开模头后不吹涨。第一次尝试开始建立双泡吹膜工艺闭环厚度控制是采用柔性环模头。这一策略是可以与用于平膜挤出相比。模头口唇的流道间隙可以通过沿模头圆周排列的步进电机调整。

位于德国亚琛工业大学的塑料加工协会（IKV）正致力于在采用传统吹膜工艺的三层吹膜生产线上对内层建立闭环控制。这只有在柔性环模头出现后才有可能实现。图9显示的剖面图和照片，就是具有一体化柔性壁的特殊模芯。内层的流道间隙同样是采用步进电机调节。

挤出模塑

柔性环套与模头结合在一起生产模塑部件，拓展了挤出模塑的加工能力。即使对于小瓶子也可以进行沿型坯圆周的动态壁厚控制功能。哪怕小到直径只有4毫米的模头，也可以配备动态壁厚控制系统。这样，即使小椭圆瓶子也可以采用在连接瓶盖的部位具有均匀厚度的型坯来生产。不均匀的厚度分布按照理想的方式在瓶子的椭圆体部位的局部拉伸比相关联来实现。图 10 显示这一结构，生产小椭圆瓶的现有的传统模头改造成为可以实现动态壁厚控制功能的模

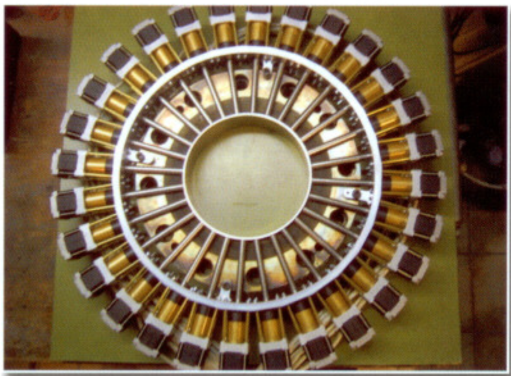


图8：改装套件，建立双泡工艺闭环控制，由柔性环套和28个步进电机组成，调节局部流道间隙。
Fig. 8 Retrofitting kit to establish a close-loop control for a double bubble process consisting of a Flex Ring sleeve and 28 stepper drives to adjust the local flow channel gap

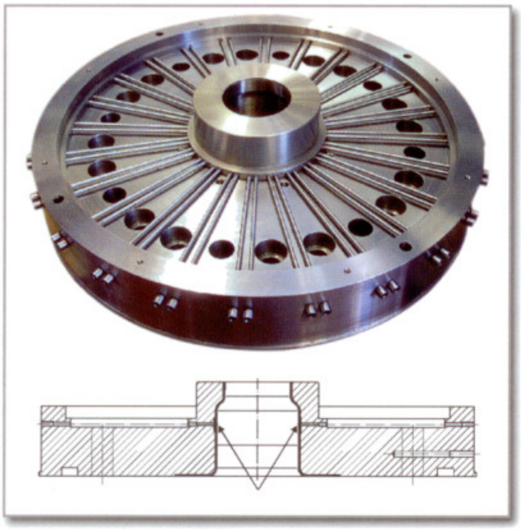


图9：具有柔性流道区域的螺旋芯棒模头口模芯，中间层的流道在生产线运行中可以灵敏地调节。
Fig. 9 Disc of a radial spiral mandrel die having a flexible flow channel section in the flow channel of the middle layer which can be sensitively adjusted while the process is running (photo IKV)

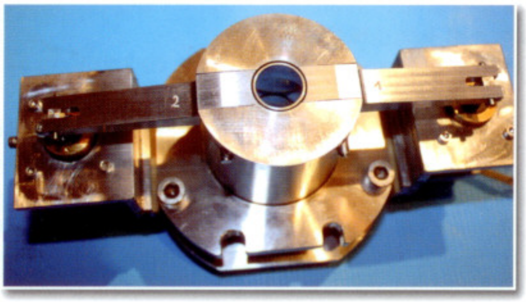


图10：改造后的吹制模塑模具，包括两台步进电机，对直径18mm的柔性环套实现动态变形 / Fig. 10 Retrofitting kit for a blow moulding head containing two stepper drives to dynamically deform the Flex Ring sleeve (diameter 18 mm)

two layered pipe. Fig. 4 shows a totally new three layer Flex Ring die to produce core foamed pipes. The goal was to be able to optimise as well the thickness of the individual inner layer as also the thickness of the individual outer layer while the line is running. To achieve this the inner layer is fed from the backside into the die. The melt distribution over the circumference of this inner layer can be optimised by passing a first flexible region of the flow channel where adjusting screws are positioned around the circumference. The same can be done with the outer layer before it joins the main flow channel. At the end of the die there are again adjusting screws to minimise the variations of the total pipe thickness. Fig. 5 shows the die mounted on the line. Using adjustable flow channel walls gives the producer the freedom to process different materials on one die by simply changing the flow channel geometry according to the changed viscosity of the new material.

Production of foamed films and sheets while using circular dies

The thickness tolerances of foamed films can be further reduced naturally in the same way as it is done with pipes. Precondition is that a circular die is used and that the film or sheet is cut after it has been cooled down as shown in Fig. 6. Incorporating a Flex Ring sleeve the flow channel gap can be adjusted to get rid of thickness differences over the circumference (Fig. 7). Even the thin region which is normally created by the spider which supports the mandrel can be eliminated by opening the flow channel gap at the mouth of the die.

Blown film extrusion

In the case of blown films the outlet gap at the die mouth must be corrected in the micrometre range in order to reduce existing thickness differences. This not only requires a great deal of experience and intuitive feeling if it is done by hand but also additional labour cost. Additionally it would be a step backwards as it is state of the art to run blown films with a close-loop thickness control. But if you switch over to a double bubble process which creates enhanced mechanical film properties the existing control systems do not work as the bubble is not inflated after it has left the die. First attempt have been star-

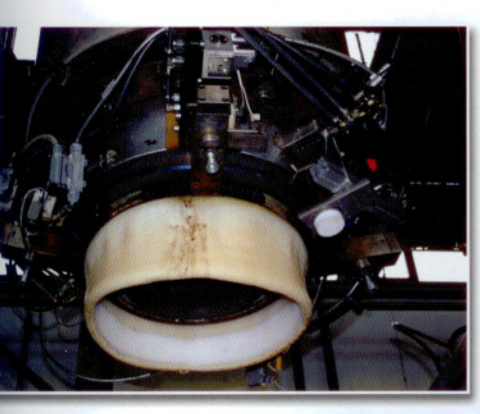


图11：直径550mm的动态调节柔性环模头正在开始运行。/ Fig. 11 Dynamically adjustable Flex Ring head having a diameter of 550 mm during the start-up

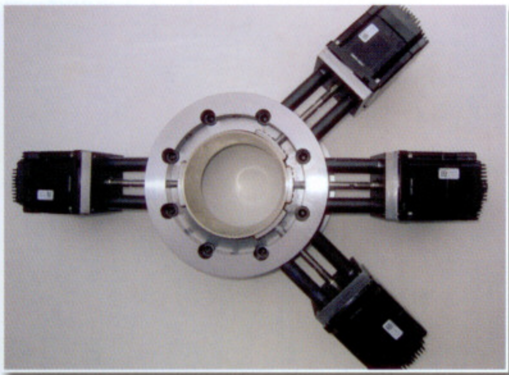


图12：经过改造的模头，用于 Bobby-Car®。模头由柔性环套（直径130mm）与外壳以及四台调节电机组成。 / Fig. 12 Retrofitting kit for the Bobby-Car® head consisting of Flex Ring sleeve (diam. 130 mm) incorporated into an outer housing and four adjusting drives

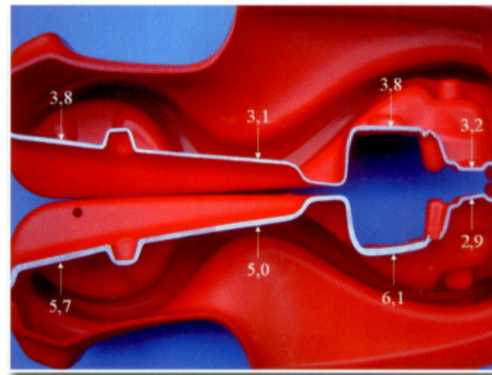


图13：厚度分布状况：采用动态型坯外廓（上）与采用传统静态外廓（下）
Fig. 13 Thickness distribution reached with the dynamic parison profiling (top) and with the conventional statically profiled head (bottom)

头。图 11 显示柔性环模头，同样装备了动态径向壁厚控制功能，用于生产工业大容器（IBC）。在工业大容器通过了所有技术测试的前提下，实现了减轻重量超过 10% 的目标。图 12 显示经过改造的模头结构，用于生产儿童玩具（Bobby-Car®）。在这一结构中，调节电机按照部件的非对称形状排列。

在图 13 中，用传统静态成型模头和改造后的动态径向壁厚 [2] 生产 Bobby-Car® 部件的厚度进行了比较，每个零件节省原料达 50 克，生产节拍减少了 6 秒钟。

（下期待续...）

膜片和柔性环技术系德国 Rossdorf 的 Heinz Gross 博士私人所拥有 (Heinz-gross@t-online.de)。该技术已在全世界许多国家包括中国取得了专利。Gross 博士是一位真诚的研究者，致力于改进挤出工艺。他正在寻找那些有兴趣得到这类专利并从该技术的优势中获取利益的公司。在中国国际橡塑展期间，如欲获得更多信息，敬请光临位于 5.1 号展厅 B21 号的 ENTEX 展台

Membrane and Flex Ring Technology are privately owned by Dr.-Ing. Heinz Gross, Rossdorf, Germany (heinz-gross@t-online.de). The technology is patented in many countries over the world including China. Dr. Gross is a pure researcher who works on improving extrusion processes. He is looking for in to companies who are interested in taking a licences in order to profit from his advantageous technologies. During Chinaplas more information are available at the ENTEX booth No. B 21 in Hall 5.1.

ted to establish a close loop thickness control for the double bubble process using a Flex Ring die. The strategy is comparable to that used in flat film extrusion. The flow channel gap at the mouth of the die is adjusted by means of stepper drives which are arranged around the circumference of the die (Fig. 8).
The Institut für Kunststoffverarbeitung (IKV) at the RWTH Aachen in Germany is working intensively on establishing a close-loop control for the inner layer of a three layer film produced with the conventional blown film process. This again can only be realised since Flex Ring dies are available. Fig. 9 shows a cross sectional drawing and a photo of the special disc which has incorporated a flexible wall section. The gap within the flow channel of the inner layer is adjusted again by means of stepper drives.

Extrusion Blow moulding

Flex Ring sleeves incorporated in heads used to produce blow moulded parts broaden the processing capabilities in extrusion blow moulding. A dynamic wall thickness programming of the thickness around the circumference of the parison is now even possible for small bottles. Heads down to a diameter of only 4 mm can be equipped with a dynamic wall thickness control system. So for the first time even small oval bottles can for instance be produced with a parison which has an even thickness in the region which builds the cap of the bottle. An uneven thickness distribution is achieved taking in account the local draw ration existing in the oval body of the bottle in an ideal way. Fig 10 shows the construction which was retrofitted to an existing conventional head to make possible a dynamic wall thickness programming for a small oval bottle. Fig. 11 shows a Flex Ring head which also is equipped with a dynamic radial wall thickness programming in order to produce industrial bulk containers (IBC). A weight reduction of more than 10 % has been reached while the IBC still passes all technical tests.
Fig. 12 shows the construction which has been retrofitted to a head to produce a kids toy (Bobby-Car®). In this construction the arrangement of the adjusting drives follows the non symmetric shape of the part. By avoiding regions where the wall is too thick the cycle time could be reduced by 6 seconds (Fig. 13).

This article will be continued in WORLD OF PLASTICS ASIA no. 03/2009