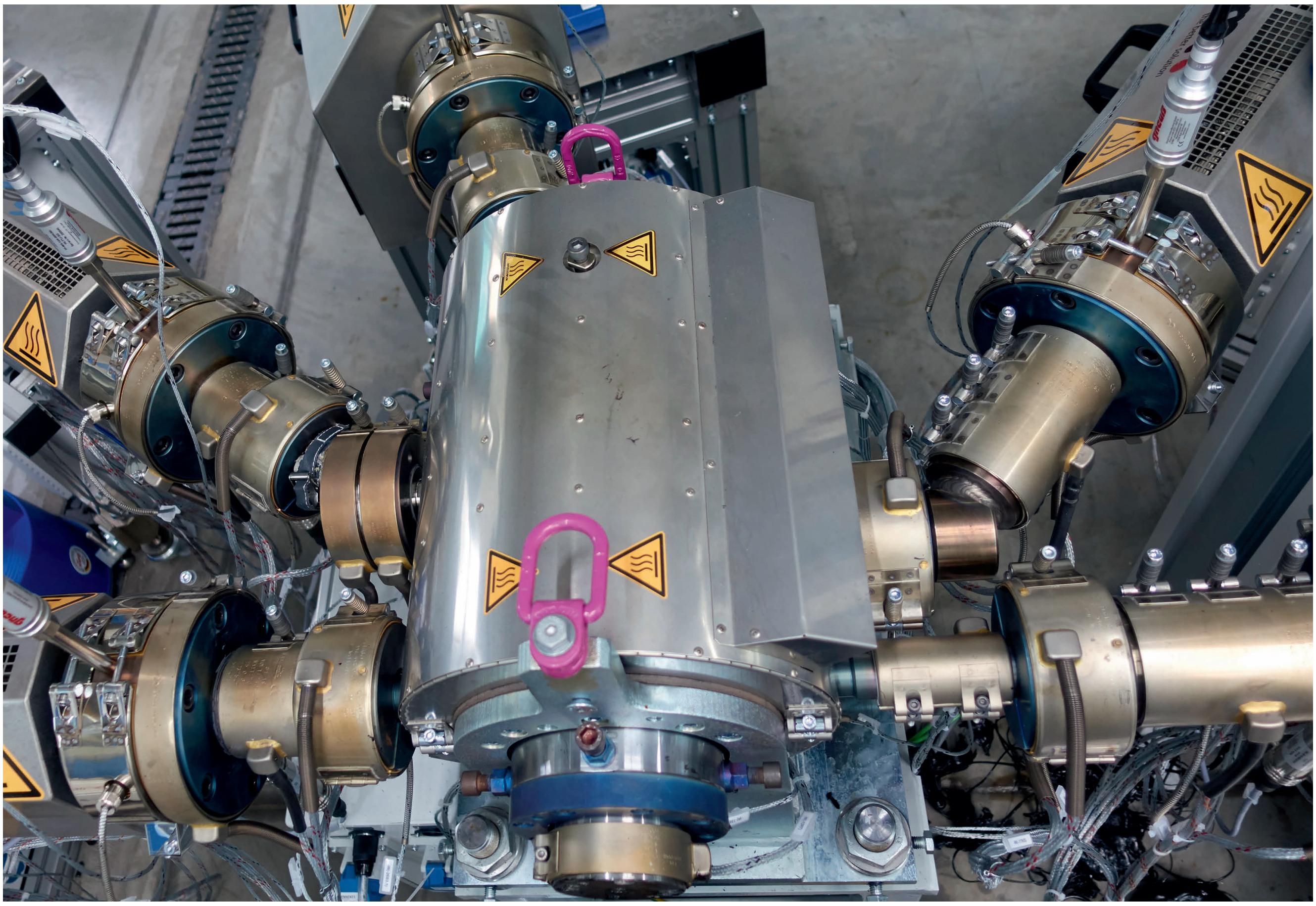
# Co-Extrusion with Thermal Control

## *Combining Polymers with Very Different Processing Temperatures*

New polymer composites for the production of multi-layer small tubes are being developed to give products specific functions. With suitable co-extrusion dies and a thermal barrier option, even complex layer composites with melt temperature differences of more than 50 °C can be processed reliably and in high quality.



CV-T 5-layer co-extrusion die in pilot plant operation: tubes with small cross-sections that fulfill a multitude of demands can be produced by co-extrusion (© ETA)

The demands on 3 to 50 mm small tubes are becoming increasingly complex. In addition to temperature and chemical resistance or electrical conductivity, new developments are concentrating especially on barrier properties. By combining suitable plastics via co-extrusion, the properties and functions of the tubes produced can be targeted to the various, often combined requirements. ETA Kunststofftechnologie GmbH supplies extrusion dies for the production of co-extruded products with up to seven layer tubular cross-sections.

### *Circular Distributor Dies Avoid Flow Lines*

More and more co-extrusion dies that produce two- to six-layer small tubes for the automotive, medical, communication, or water installation markets »

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are equipped with circular distributor systems that first pre-distribute the melt and then distribute it radially to the center (**Fig. 1**). This type of circumferential distribution avoids flow lines such as those associated, for example, with spider-type or mandrel dies. Since being launched more than ten years ago, this concept has been tried, tested, and continuously developed further. The die principles developed on the basis of modular designed circular distributors not only offer flexibility and variability in the number of layers, but also enable different thermal influencing of each layer. [1]

Co-extrusion processes make it possible to design efficient materials composites that are tailored to the particular case of application. This design freedom is limited by the need to melt the polymers and bring them together. Physical barriers can arise here due to the processing temperatures that differing strongly among the polymers used from one to another. The predetermined temperature windows in the data sheets from the polymer manufacturers have to be maintained in order to avoid damage to the product, or to individual layer materials, and thus ensure desired functions. That is why co-extrusion dies are especially intended to perform this task by bringing the various melts together under ideal thermal conditions.

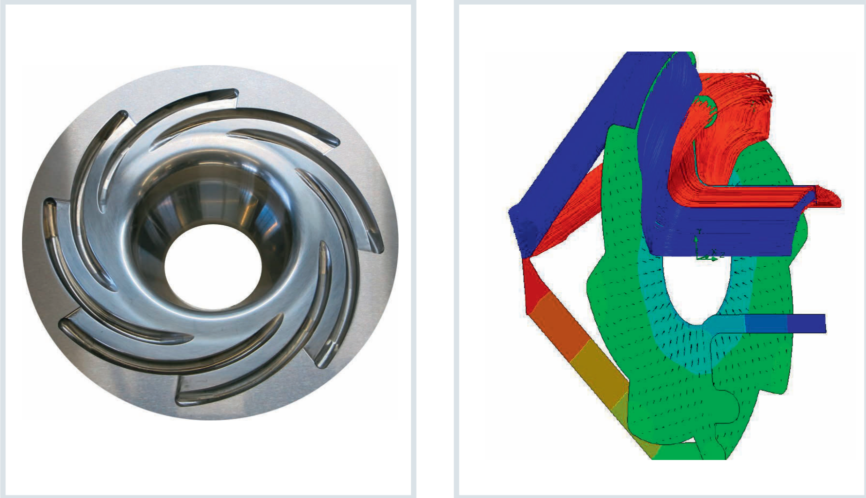


**Fig. 1.** The circular distribution principle: left: a circular distributor, right: the simulation of radial circumferential distribution after pre-distribution of the melt (© ETA)

## Demands on Co-Extrusion Dies

Today's polymer processing companies, moreover, demand from a co-extrusion die that it be well suited to produce any and all materials combinations planned. Based on this, the following requirements can be derived:

- Long service life without cleaning cycles,
- capability to process a wide range of raw materials,
- fast color and materials changes,
- production of thin function layers with narrow individual tolerances,
- high productivity and full system availability,
- suitability for different product categories (e.g. smooth and corrugated tube), and
- flexible and retrofittable to increase the number of layers

A wide range of products with various sandwich structures has been developed for the fuel line market [2].

This development has resulted in numerous patents for various sandwich structures consisting of raw materials such as PA12, PA6 and PA612, polyvinylidene fluoride (PVDF), ethylene-vinyl alcohol copolymer (EVOH), the polyphtalamides PA9T, PA10T and high-density polyethylene (HDPE), as well as of fluorpolymers, such as ETFE (ethylene-tetrafluoroethylene copolymer), THV (terpolymer from tetrafluoroethylene, hexafluoropropylene, and vinylidene fluoride), and EFEP (modified fluorinated ethylene-propylene copolymer).

Electrically conductive compounds are also finding increased use for the inner layer. Depending on the composite, polymers, some of which tend to corrode die surfaces, are being co-extruded whose processing temperatures differ by as much as 80 °C. The layer structure of a 5-layer fuel line with an 8 mm cross-section and 1 mm wall thickness is illustrated in (**Fig. 2**).

## Suitable for Complex Materials Combinations

Due to a thermal barrier created within the die, the circular distributor CV-T die series (circular distributors with thermal barrier) is especially well suited for complex products. Its "plate design" enables each distributor module, i.e., polymer layer to be tempered according to the processing temperature recommended for the raw material. The heated center mandrel keeps the melt of the interior layer flowing there at an optimum temperature. These thermal control functions

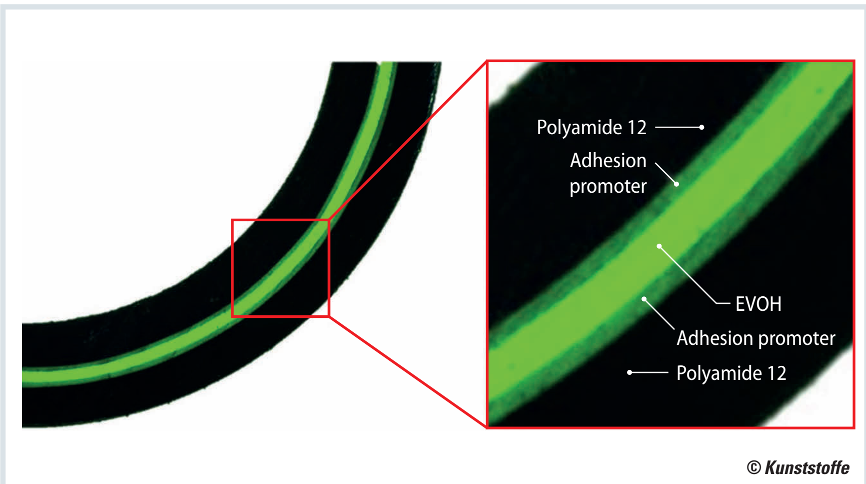



**Fig. 2.** 5-layer fuel line: left: tube cross-section, right: detailed view (source: ETA)

are the prerequisite for the best possible product quality and dimensional stability over a long service life without the formation of deposits, even with sensitive combinations of materials.

One frequent market requirement calls for the capability to manufacture products with inner layers of high-temperature, technical polymers, often in addition with electrical conductivity. Depending on the polymer composite, the co-extrusion dies used for these types have one or more inner thermal barriers. Further ideas for various structure types have led to the design of dies for products with six layers and four separate tempering zones.

In addition to the usual heating zones 4 and 5 for targeted temperature control, the 5-layer co-extrusion die shown in (**Fig. 3**) is conceived for processing fluoropolymers in both inner layers. It has three separately settable temperature levels 1, 2, and 3 with inner thermal barriers that can either be heated or cooled by forced convection. For the production of corrugated tubes, the central mandrel can be centered to enable centering operations without interrupting production.

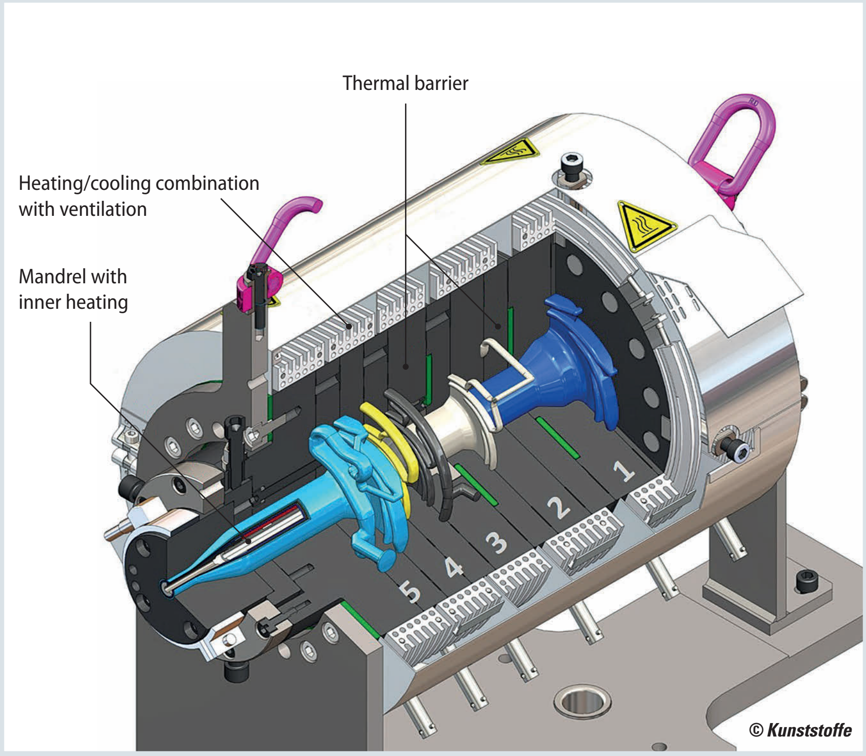



**Fig. 3.** CV-T 5-layer co-extrusion die in part-sectional view: the colored areas represent the five materials to be processed, i.e., their distribution. The numbers indicate the individual layer modules within the die (source: ETA)

## *Simulating Thermal Behavior in the Die*

To illustrate the advantages of thermal barriers, the thermal conditions in the CV-T co-extrusion die during production of a 5-layer fuel line are shown by the product example in (**Fig. 4**). Beginning with the inner layer, this layer structure consists of a PA 6, an EVOH, and three different layers of PA12. According to manufacturer's data, the melt temperatures are approx. 275 °C for the PA6, approx. 220 °C for the EVOH, and approx. 240 °C for the PA12 types. Thanks to the tempering capability of the extrusion die, these values can be precisely maintained in practice, even though the temperature difference between the EVOH module (2) and the PA6 module (1) is 55 °C. Thus with the CV-T concept, thermally sensitive materials in particular, such as EVOH, can be processed very gently and without local damage to the material due to overheating. This ensures the quality and functions of the processed materials within the composite structure.

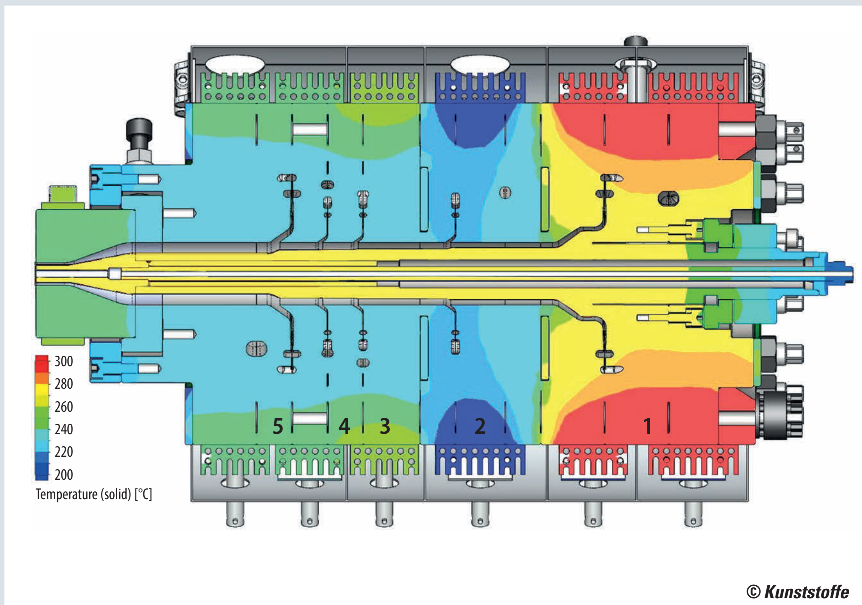
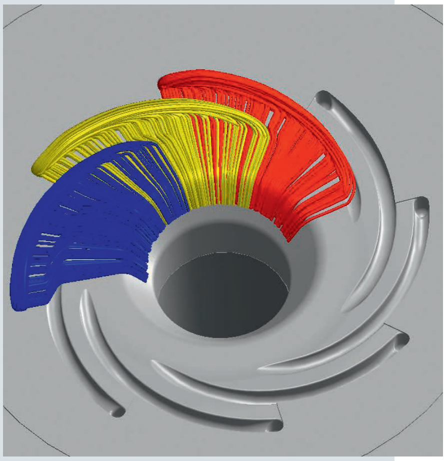



**Fig. 4.** Simulation of the thermal condition within the CV-T die during production of a 5-layer fuel line (source: ETA)

To determine the maximum temperature difference achievable between neighboring polymer layers, the target temperature settings for the three neighboring, temperable modules are selected such that a "hot – cold –hot" tempera- »

## Principle of Circular Distribution

After the feeding and suitable pre-distribution, the separate melt streams are distributed planar on both sides in the circumferential and the radial direction. The distribution principle is illustrated for three of the total of eight spiral streams. The resulting circumferential overlap of the partial flows keeps flow lines from forming.
In the center of the distributor plate, the melt reaches the so-called mandrel and is shaped into an annular stream in the direction of the extrusion axis. In a co-extrusion die, each of the raw materials used is distributed separately in this manner. The individual layers are brought together sequentially and, at the die outlet, form the desired layer composite.



The melt is distributed circumferentially (here: clockwise) and flows radially toward the mandrel (© ETA)

ture profile results. Modules 1 and 3 are continuously heated, while a cool-air current removes heat from module 2.

In consequence, temperatures develop near the melt-guiding areas that are representative of melting temperatures at which the polymers being processed can be converted stably and constantly. This die concept can thus process two neighboring polymers whose melt temperatures differ by as much as 80 °C. It is thereby possible to process a polymer with a melt temperature of 220 °C while both of its neighboring polymers in the layer structure can be processed at a melt temperature of up to 300 °C without any negative mutual influencing taking place.

### *A Die for Less Complex Materials Combinations*

In the future, more and more products will be functionalized by specifically coordinated material combinations whose demands on the processing technology they require will continue to grow. The CV-T die is already suited for such application cases. However, standard products made from less complex materials combination will continue to be represented on the market and play no less an important role.

Not every co-extruded material composite requires the use of extrusion dies with special options in consideration of the materials to be combined. The modular designed CV-e (economy) series of circular distributor extrusion dies will be used as required for such products. Dispensable equipment versions are intentionally not integrated in the CV-e in order to realize a cost-efficient die concept while maintaining the same high quality. Equipment versions, such as thermal barriers, inner centering for corrugated tubing, or long-term processing capability for flouropolymers, are not provided for.

Just as with the T-series co-extrusion dies, the e-series has also been designed using CFD (computational fluid dynamics). With low dwell times and low materials stress, both die concepts have optimally configured flow channel cross-sections with no stagnation zones [3].

For production testing and sample making, ETA operates a pilot plant together with Bellaform GmbH, Gau-Algesheim, Germany (**Title figure**). Both die series are available for testing up to five layers here. This facility is used regularly for testing new materials or layer composites, as well as for product sampling. ■

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## Service

### References & Digital Version

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