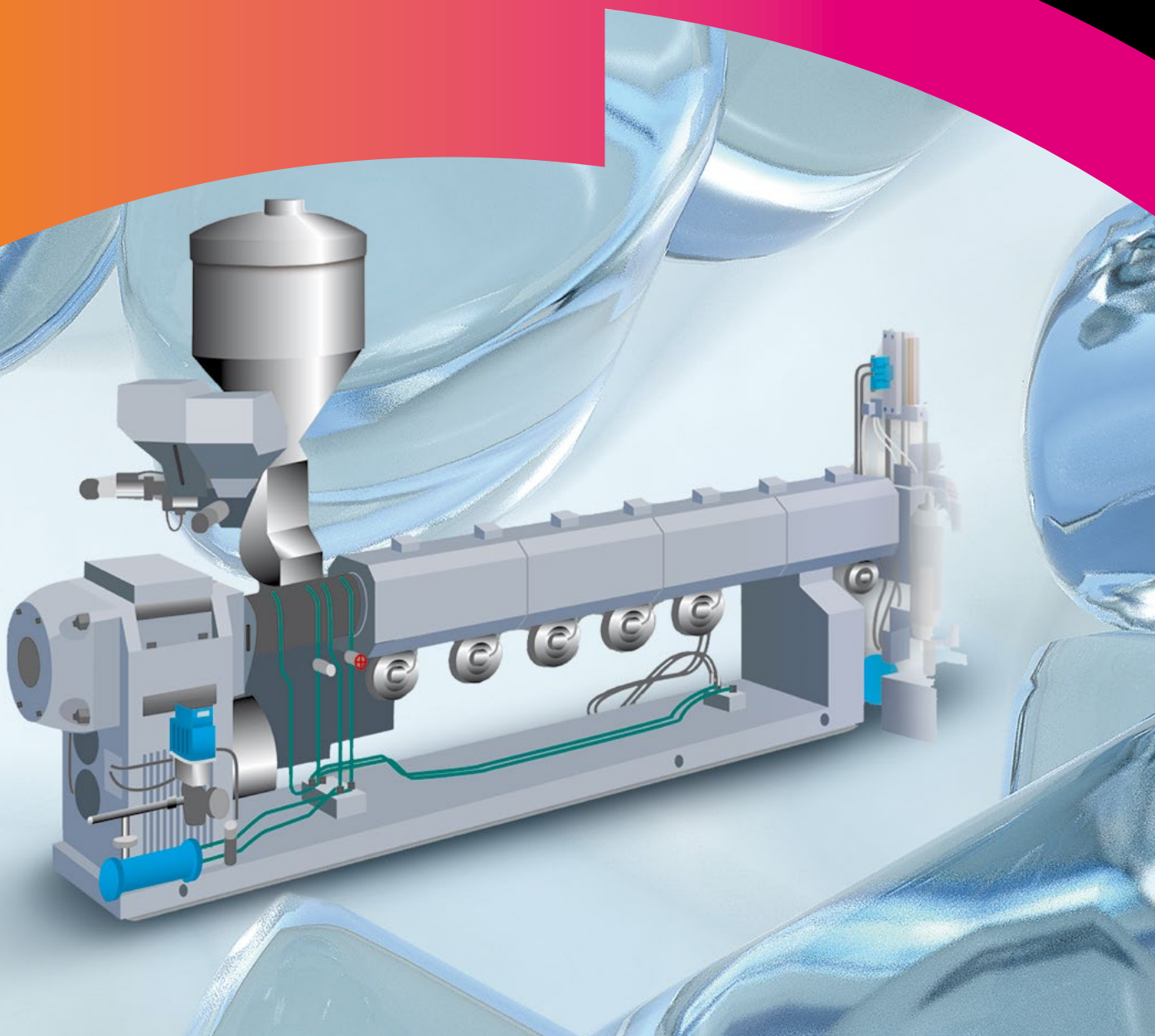




Processing of TPU by Extrusion and Special Processes





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Desmopan®



Texin®



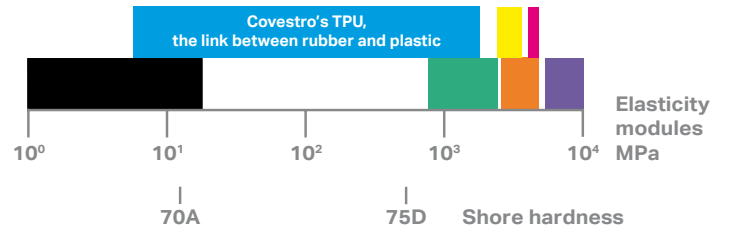
Utechllan®

1.

Product description

Covestro's TPU ...

are thermoplastic polyurethanes. Their properties qualify them as high-grade thermoplastic elastomers (TPEs) that bridge the gap between rubber and traditional thermoplastic materials.





The main advantages

- High abrasion resistance
- High elasticity over the entire hardness range
- Excellent low-temperature impact strength
- Flexibility over a wide temperature range
- Freedom from plasticizers
- Excellent resistance to oils, greases and many solvents
- Good resistance to weathering and high-energy radiation
- Pleasant tactile properties
- Weldable and bondable
- Easy coloring
- Easy recycling
- Excellent rot resistance (special grades)

2.

General remarks

Covestro's TPU can be processed on the equipment normally used for processing thermoplastics. The most important processing techniques are:

- Injection molding
- Extrusion
- Blow molding

2.1 Form supplied

Covestro's TPU are supplied as natural-colored cylindrical or lentil-shaped granules. Depending on the particular grade, the color ranges from transparent / clear and whitish opaque to white.

The product can be supplied in quantities of between 20kg and 1,000kg, depending on the grade. For sampling purposes, 20kg or 25kg sacks or plastic drums with a content of 20kg can be supplied.

2.2 Storage

Covestro's TPU should be stored in cool, dry conditions. Temperatures above 40°C should be avoided. Optimum processing is ensured within approximately 6 months after delivery.

2.3 Pretreatment of the granules

TPU absorbs moisture from the air. The extent and rate at which this happens depends on the raw material type, hardness and climate (Figs. 1 and 2).

Moisture absorption of Covestro's TPU granules (at 23°C/50% r. h.)

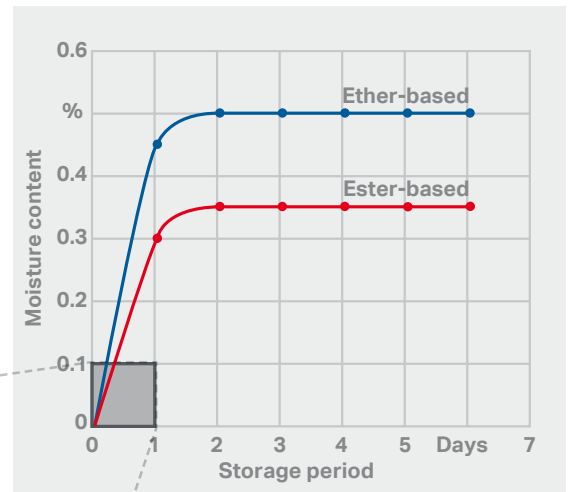


Fig. 1

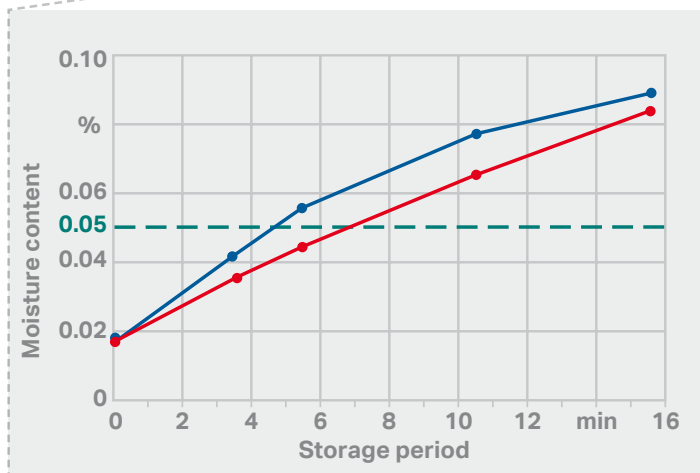


Fig. 2

- Ether-based TPU
- Ester-based TPU
- Threshold value for optimum processing

To ensure trouble-free processing and avoid any loss of quality, we recommend drying to a moisture content of $\leq 0.05\%$.

If the granules are too moist, blisters or streaks can occur on the surface of the finished components. The extrudate is no longer smooth and glossy but foamy and gassy.

A frequent cause of defects is also the use of undried functional concentrates. These batches should be separately pre-dried and have a moisture content of $\leq 0.05\%$. Such levels can be reliably reached in conventional dry-air and circulating air dryers (Fig. 3).

Depending on the hardness, the recommended drying temperatures are between 80 and 110°C, with drying times of 1 to 3 hours. Better drying can be achieved in a shorter time with dry-air dryers (Fig. 4).

Dried, hot granules should not be left to cool down in the open air. They must be stored in dry containers that can be re-sealed. The machine hopper must be kept covered.

Operation of a dry-air drier

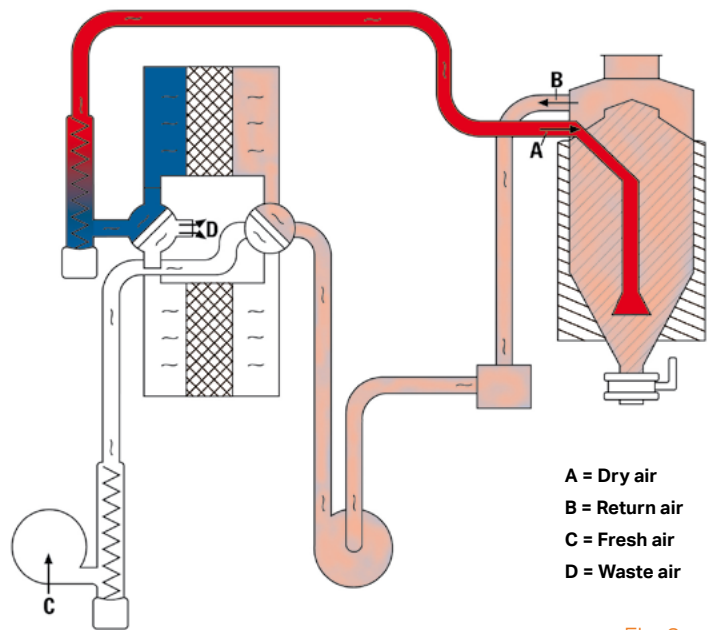


Fig. 3

Drying kinetics for Covestro's TPU granules

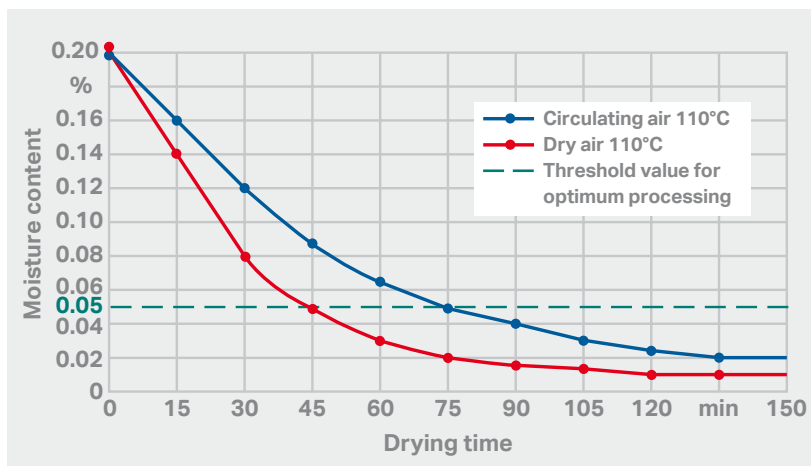


Fig. 4

General remarks

2.4 Post-treatment of the finished articles

TPU products attain their optimum physical property level only after they have spent some time at room temperature. This process can be speeded up by an annealing process in a circulating air heating oven, reducing it to 15 to 20 hours.

For articles with a hardness of ≤ 92 Shore A, we recommend annealing at 80-90°C, and for a hardness of ≥ 93 Shore A, 100-110°C. The optimum compression set can only be achieved by annealing!

The physical data given in our data sheets are always measured on annealed, conditioned test specimens.

2.5 Coloring

Covestro's TPU are supplied in their natural color and can easily be pigmented, most commonly using color granules (masterbatches), but also using coloring pastes, liquid colors or pure pigments.

Standard commercial equipment can be used to add the colorants and mix them in with the Covestro's TPU. For occasional coloring, use rolling-drum mixers, tumble mixers or similar. It is important to ensure that the colorants and other additives do not contain any moisture. A static mixer in the adapter will significantly improve color dispersion and also reduce the amount of colorant needed.

2.5.1 Color masterbatches

Color masterbatches provide the simplest, cleanest and most reliable means of coloring Covestro's TPU, particularly when Covestro's TPU are also the carrier materials. SAN-resin-based color granules are also suitable to a limited extent. Color granules based on polyolefins and PVC are not suitable. Suppliers normally recommend employing metering quantities of between 1.0 and 4.0% depending on the wall thickness of the articles and the color density of the pigments.

2.5.2 Color pastes, liquid colors and pigments

It is less common to use color pastes, liquid colors and pigments to color Covestro's TPU because of the more complicated procedure involved. However, there may be benefits in the form of fast color changes and transparent pigmentation. The standard quantities generally range from 0.2 to 1.0%.

2.6 Additives

To improve the processing characteristics or specific properties, we recommend the addition of conventional functional concentrates such as:

- antiblocking agents,
- release aids, and
- UV stabilizers,

which must also be pre-dried.

2.7 Occupational hygiene and environmental information

2.7.1 Air extraction

Covestro's TPU can be machined and processed over a wide temperature range but, as with all natural and synthetic organic materials, they decompose above a certain temperature. Smoke generation signifies that decomposition is taking place. Slow decomposition commences at approximately 240°C, depending on the grade of Covestro's TPU involved. Further information is given in our Safety Data Sheets.

For reasons of occupational hygiene, we recommend efficient air extraction, especially when extruding and welding.

2.7.2 Waste disposal

Provided that they are not contaminated with other substances, Covestro's TPU can essentially be disposed of in municipal landfill sites.

They do not constitute a hazard to water. If the materials can no longer be recycled, they should be incinerated in a waste incineration plant on account of their high calorific value.

2.7.3 Energy efficiency

Thermoplastic polyurethanes are demanding high-performance materials that can reach their full potential only by a precise and optimum processing.

All process steps in the extrusion of TPU (pre-drying, extrusion, post-treatment such as calibration, cooling, etc.) are associated with a high consumption of energy. Following the recommended processing parameters is very important. The energy efficiency of the processing equipment is of great importance for economic and environmentally friendly processing.

Therefore, we recommend paying attention to modern, precise controlling and energy-efficient machinery.

3.

Processing by extrusion

Covestro's TPU grades in the hardness range between 60 Shore A and 70 Shore D are particularly suitable for extrusion applications. The following products are extruded from them:

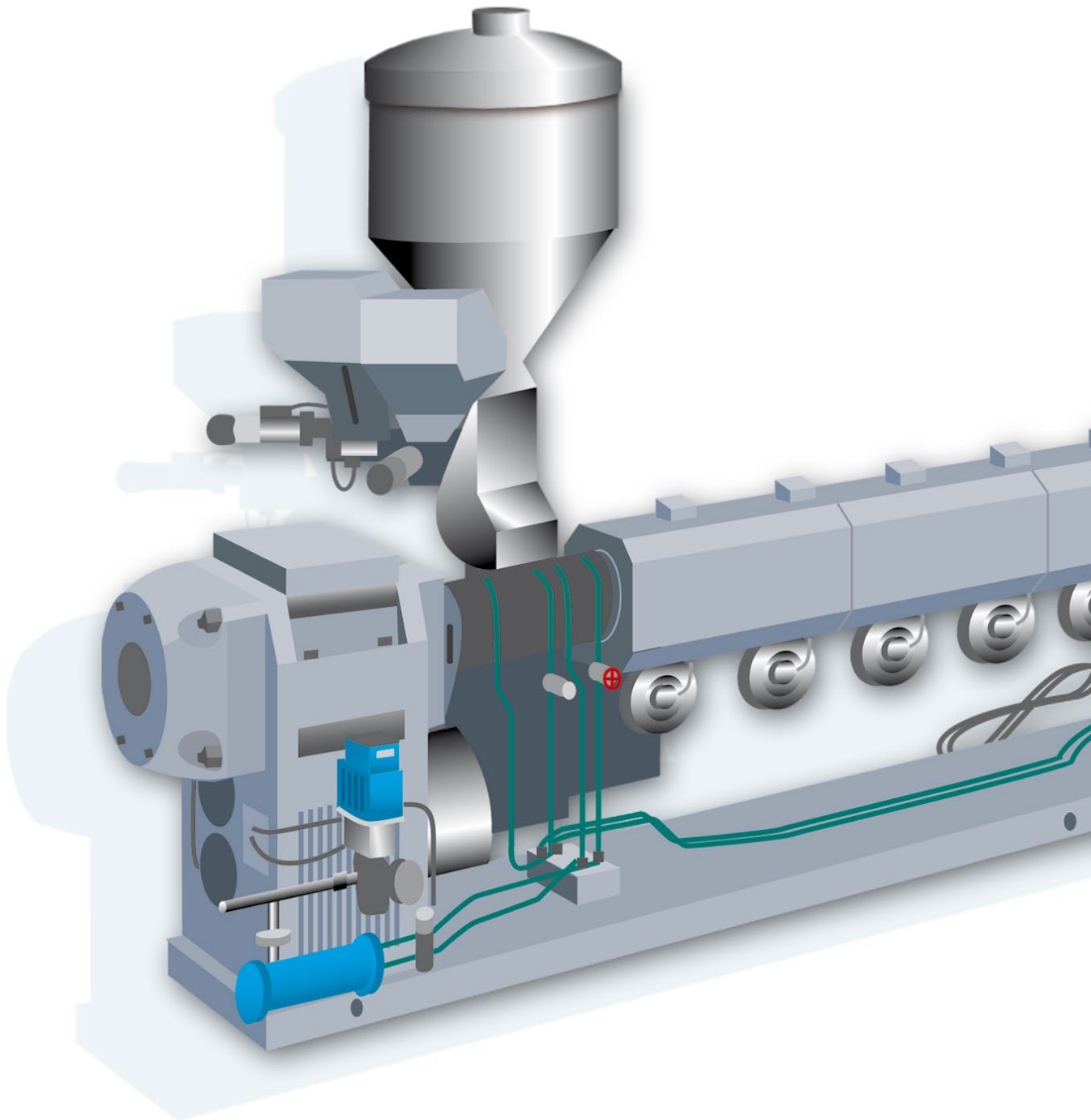
Tubing
Cables
Tubular film
Profiles

Sheathings
Flat and blown film
Blow moldings
Coatings

3.1 General

The Covestro's TPU pellets and any functional concentrates must be dried before processing to a moisture content of $\leq 0.05\%$. See Sections 2.3 and 2.5.

Conventional thermoplastic processing machines and tools can be used in Covestro's TPU extrusion. The downstream units must be optimized for the typical properties of TPU.



Blending with regrind and combining of different batches is not recommended.

Single-screw extruders are normally used for extruding Covestro's TPU. Vented barrels are less suitable. Heated, grooved feed throats (Fig. 5) ensure higher, more uniform throughput. Molten Covestro's TPU is neither corrosive nor

abrasive, which means there is no need for a special steel alloy or armor-plating of the screw. The drive ratings shown in Fig. 6 should be adhered to. Any additional torque means that processing can be carried out at lower temperatures, making for higher dimensional stability of the emerging melt.

Grooved feed throat

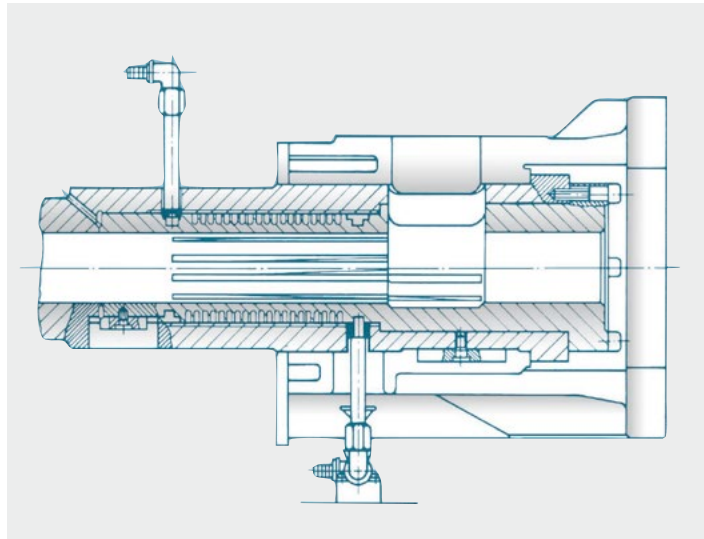


Fig. 5

Minimum drive rating as a function of screw diameter

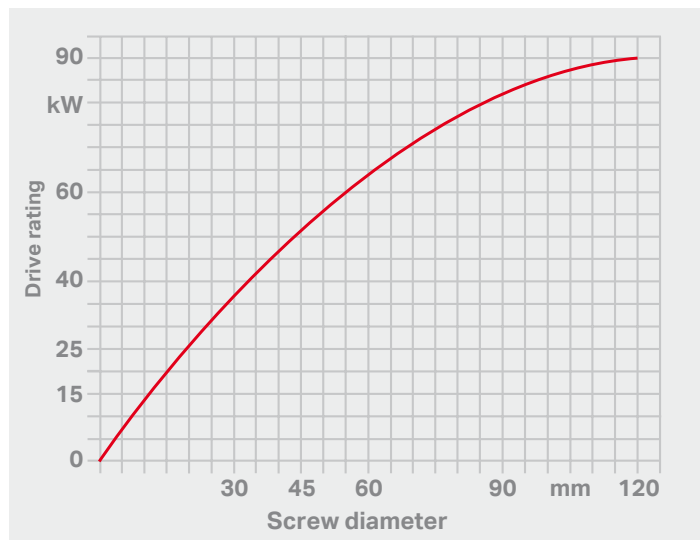
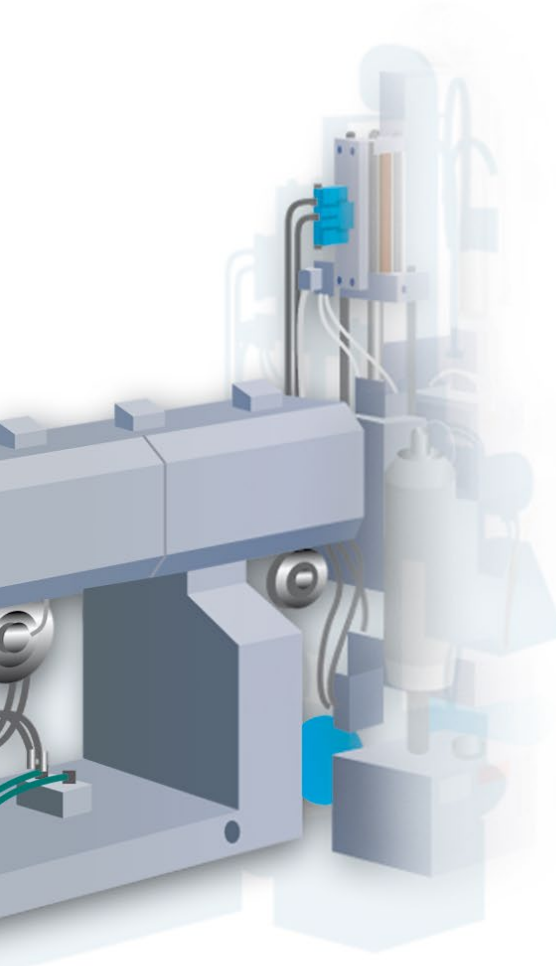


Fig. 6



3.

Processing by extrusion

3.2 Screw design

Single-thread three-zone screws with screw lengths of 24 to 35 D and a constant screw pitch have proven to be effective in extruding Covestro's TPU. Fig. 7 illustrates the structure and dimensions of this type of screw. The compression should be between 2 : 1 and 3 : 1. Constant taper screws (PVC screws) can also be used.

The advantage of using barrier screws that are specially designed for processing TPU is that they permit a lower L / D ratio. Alternatively, throughput can be increased by selecting a screw of approximately the same length as a conventional screw. Fig. 8 shows the basic structure of a barrier screw that is suitable for extruding Covestro's TPU.

Short-compression screws are not suitable for processing TPU.

Heating the screw is not necessary. Shearing and mixing sections are not needed for homogenizing Covestro's TPU, although it may be advantageous to use mixing sections if particularly high color dispersion is needed, for example with thin film or coatings. The shearing section (Fig. 9) and mixing section (Fig. 10) should be designed in such a way that the energy input is as low as possible. Dead spots must be avoided under all circumstances.

Extruder screw for processing Covestro's TPU

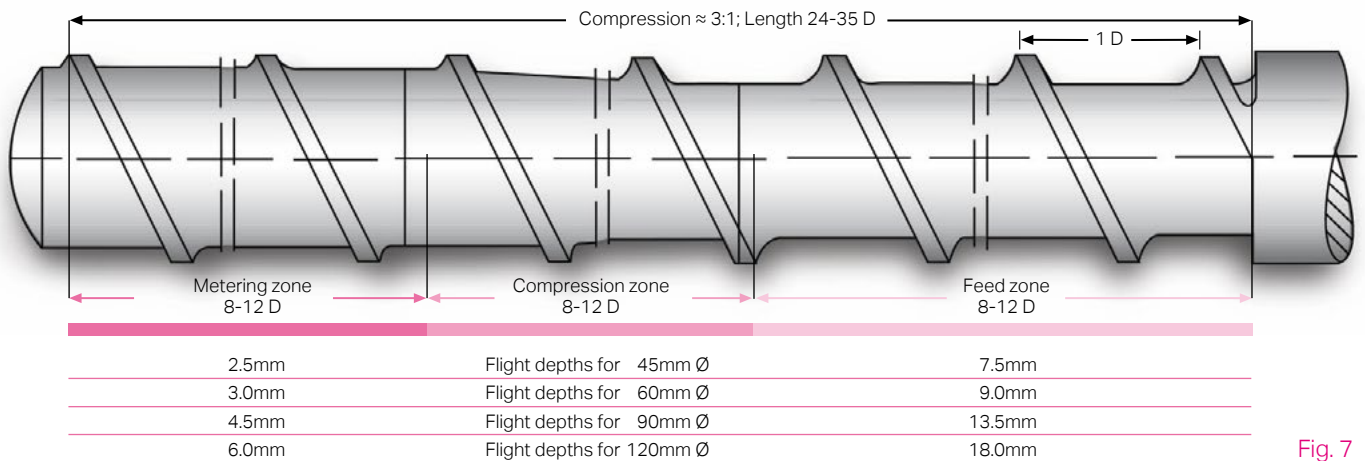
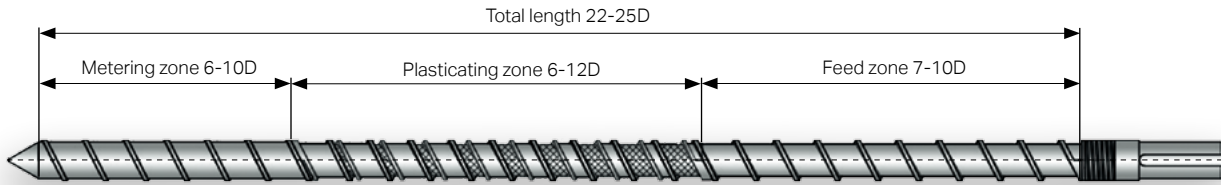


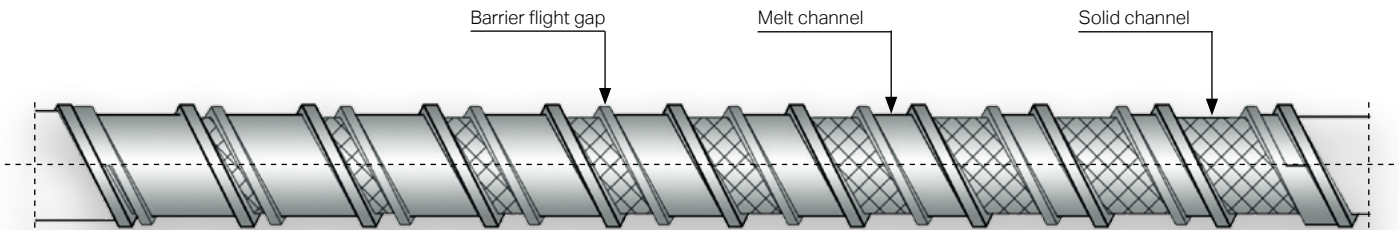
Fig. 7

Barrier screw



The compression ratio, the barrier geometry and the barrier flight gap must be adapted to suit the particular raw material.

Fig. 8



Barrier screws for extruding Covestro's TPU are available for extrusion machines of 30mm to 150mm in diameter with a throughput to 5 to 500kg/h.

MeKuma® GmbH, Bülow

Spiral shear section

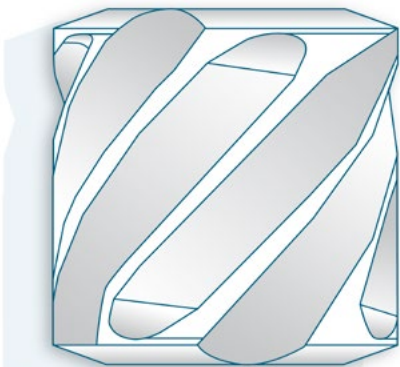


Fig. 9

Toothed disk mixing section

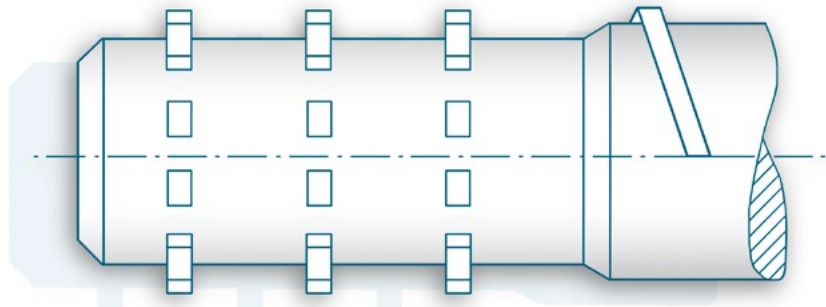


Fig. 10

3.

Processing by extrusion

3.3 Processing parameters

3.3.1 Temperature setting for the barrel and die

The melt temperatures for Covestro's TPU extrusion range from 160 to 230°C and depend on the product type, its shore hardness and its melt range. The size of the extruder and the screw diameter also affect the temperature setting. The peripheral velocity of the screw should not exceed 0.3m/s. If larger extruders are used, lower temperatures may generally be set on account of the higher shear strain. *Fig. 11* specifies guideline temperature settings for the cylinders and mold heaters.

In certain circumstances, it may be advantageous to use an "inverse temperature profile." When this is the case, the peak temperature is located in the feed zone.

By adjusting the nozzle temperatures, it is possible to control the glossiness of the article's surface. Low temperatures result in matte surfaces and high temperatures in glossy surfaces.

3.3.2 Screw speed

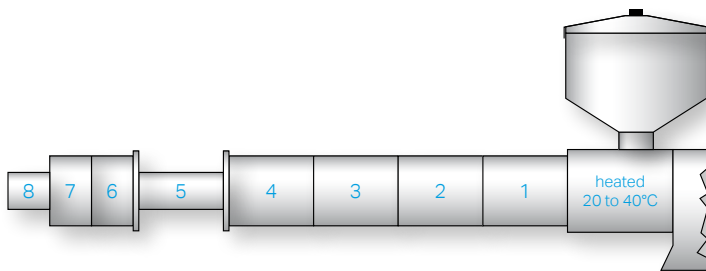
In addition to the temperature, the screw speed also exerts a major influence on the quality of the extrudate.

Low screw speeds mean that the melt has to spend a long time in the extruder, with the result that it may become damaged by heat.

Excessive screw speeds also lead to thermal decomposition due to friction.

Fig. 12 specifies guide values for the screw speed as a function of the diameter.

Temperature profile according to hardness range



8	7	6	5	4	3	2	1	Shore hardness
170 to 210	170 to 200	170 to 200	170 to 200	170 to 210	170 to 200	170 to 190	160 to 180	70 to 92 Shore A
180 to 220	180 to 210	180 to 210	180 to 210	180 to 220	180 to 210	180 to 200	180 to 200	92 to 95 Shore A 40 to 53 Shore D
200 to 230	200 to 230	200 to 230	200 to 230	200 to 220	200 to 210	200 to 210	200 to 210	53 to 80 Shore D

Fig. 11

Screw speed range as a function of diameter

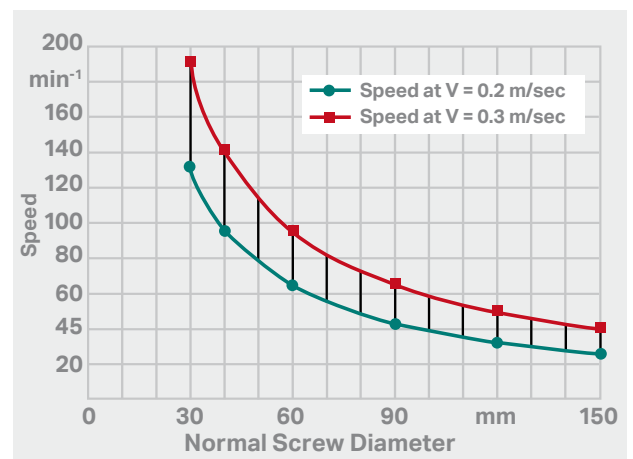


Fig. 12

3.4 Adapters and extrusion dies

3.4.1 Adapters

It is important to have adequate controlled heating of the die adapters and connecting flanges. With unheated flanges, so much heat may be dissipated that the temperature in this area drops too heavily. The flow channels must be designed so as to encourage good flow (i. e., without any dead spots), and the cross section should be geared to the mass flow rate. For the same reason, leaps in pressure must be avoided at all costs.

In long adapters, static mixers have proved useful for maintaining transverse mixing as they ensure greater uniformity of temperature and color dispersion in the melt. The use of strainer disks with and without a screen pack is of course also a possibility (*Fig. 13*).

3.4.2 Melt pump

A microprocessor-controlled gear pump for the melt raises the output and improves overall quality in the extrusion of profiles or tubes of very low dimensional tolerance. The melt pump also compensates for any extruder-related problems such as output fluctuations and incorrect pressure / temperature ratios.

The basic principle is that the melt pump breaks down the extruder output into smaller, volumetrically controlled individual flows and conveys them at a very accurate rate.

With respect to throughput, it is necessary to adjust the size and speed of the melt pump in such a way that as little friction heat enters the material as possible.

Example of a strainer disk with a screen pack

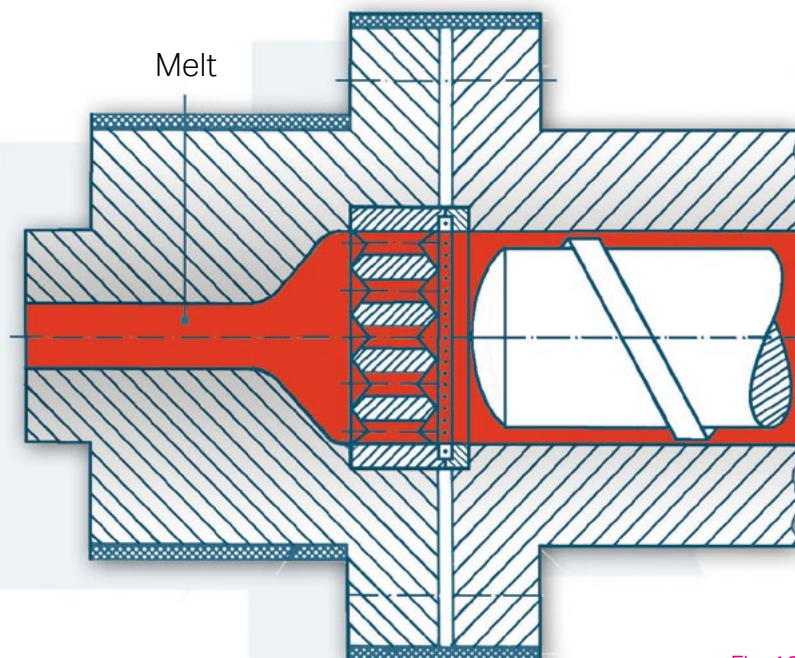


Fig. 13

3.

Processing by extrusion

3.4.3 Extrusion dies

As far as the dies are concerned, the same flow and heating guidelines apply as for adapters.

Covestro's TPU can be processed with side-fed dies (Fig. 14), spider-type dies (Fig. 15), flat

film dies (Fig. 16) and flat-film coextrusion dies (Fig. 17).

The tools must allow a uniform flow front and be equipped with an easily centered die with a parallel guide (die land).

Side-fed die (tubular film production)

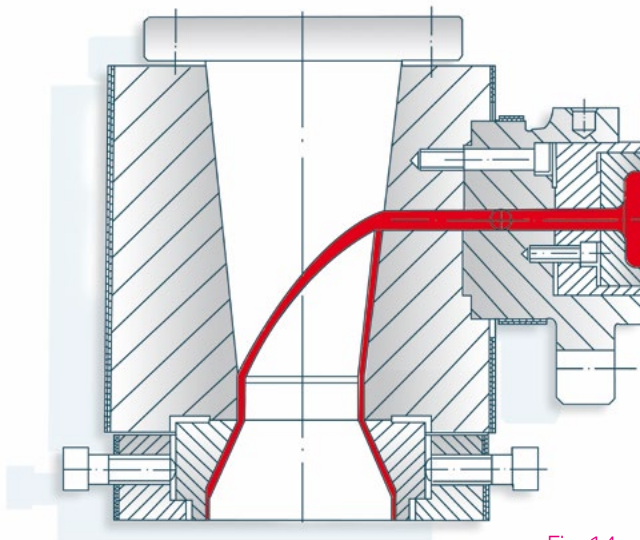


Fig. 14

Spider-type die

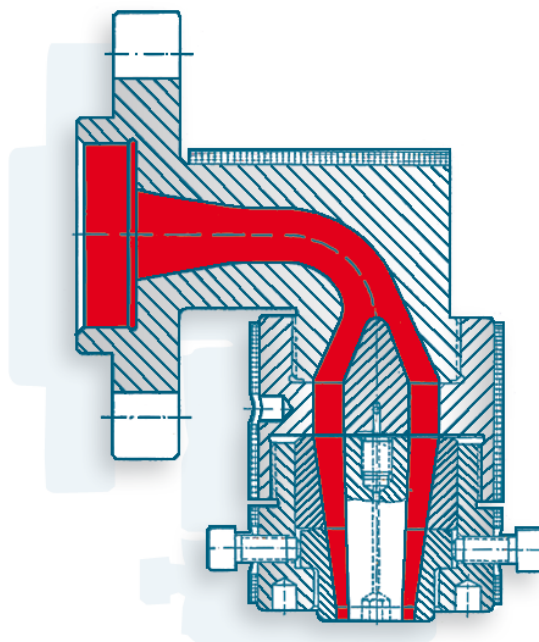


Fig. 15

Coathanger-type manifold for a flat-film die

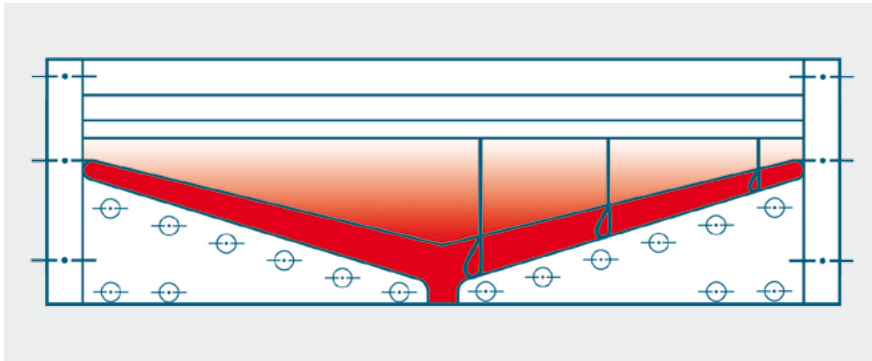


Fig. 16

Slot die for coextrusion

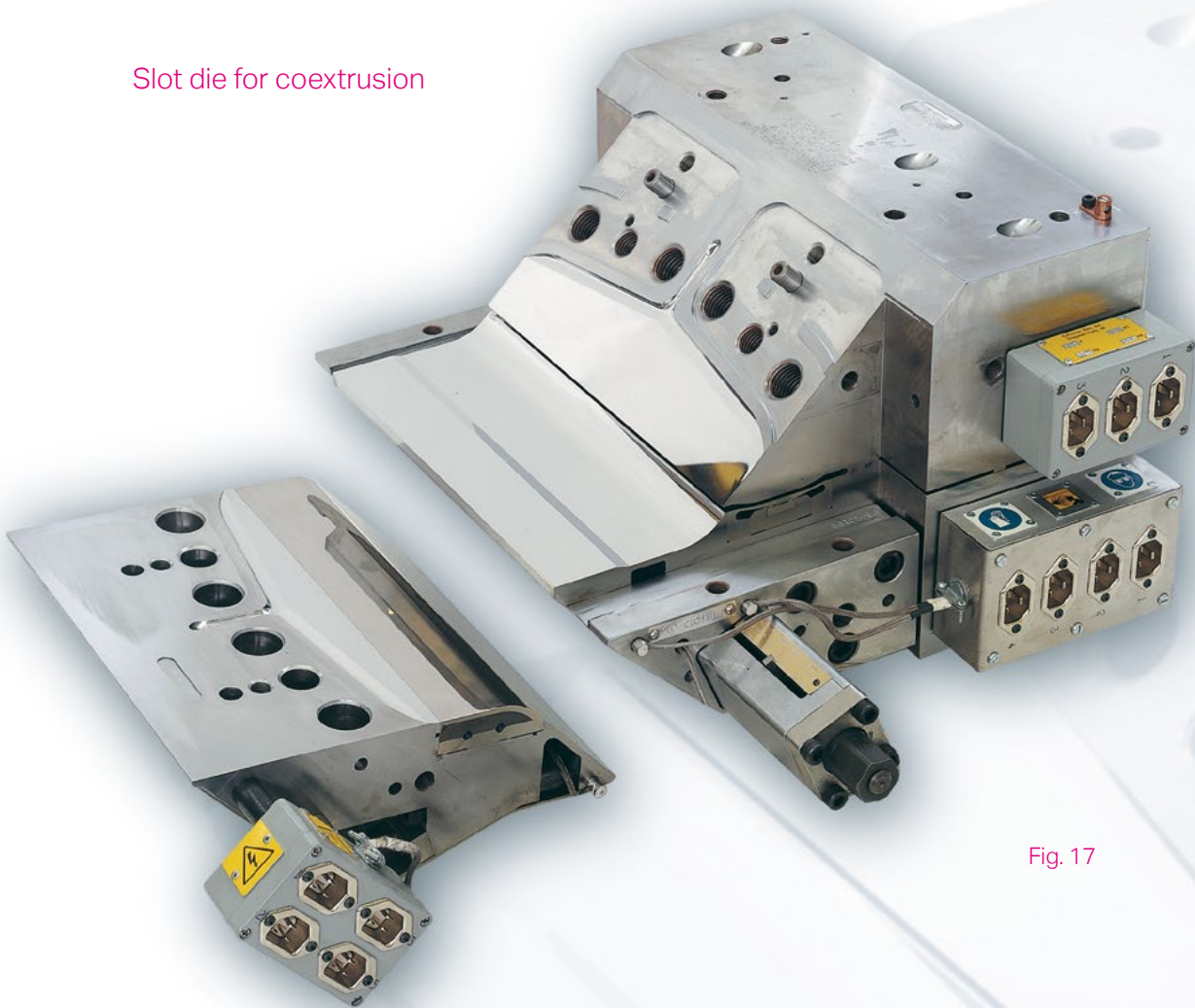


Fig. 17

3.

Processing by extrusion

3.5 Cooling and calibrating the extrudate

When the melt leaves the die, it has low dimensional stability. It should therefore be cooled as close as possible to the die without influencing the temperature control at the head of the die. Water baths, water spray jets, air showers or a combination of these systems can be used for cooling. To prevent any deformation of the extrudate while still in a plastic state, cooling should be carried out gently. The length of the cooling section will depend on the type of

article, wall thickness and take-off speed. The final temperature should be 40°C.

Calibration systems such as sizing / draw plates, floating plugs and vacuum calibration can only be used with TPU if a lubricating film builds up between the extrudate and the calibrating surface.

Fig. 18 shows a vacuum low-friction calibrator.

Low-friction calibration

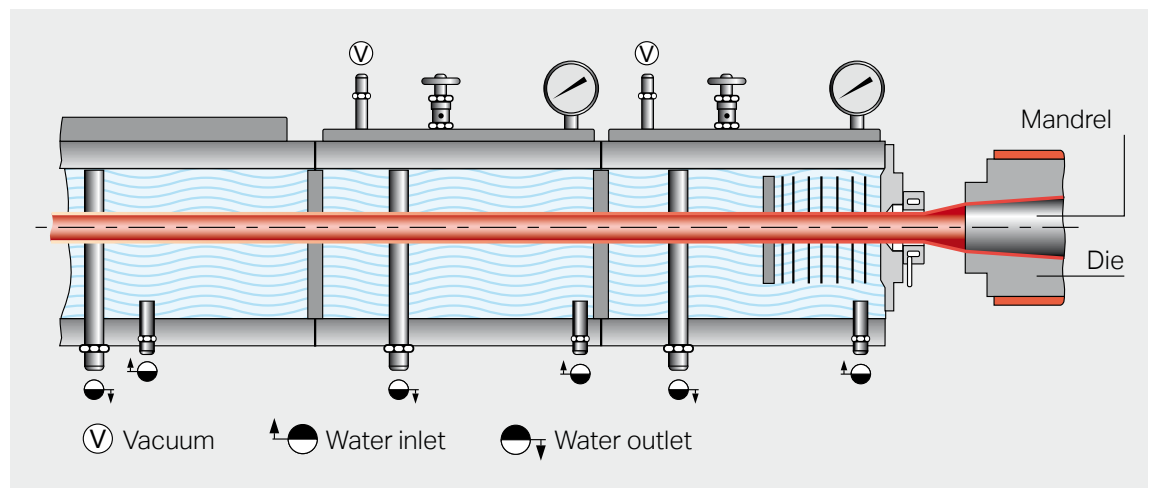
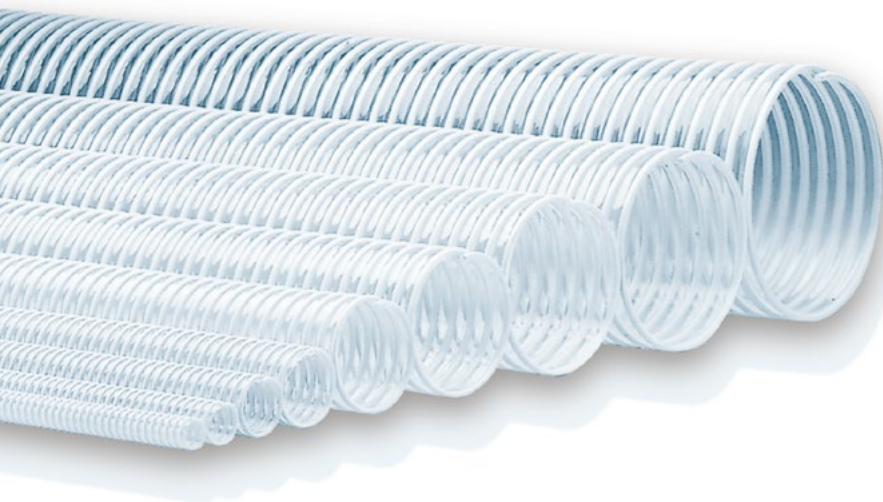


Fig. 18



3.6 Extruded articles

3.6.1 Tubing

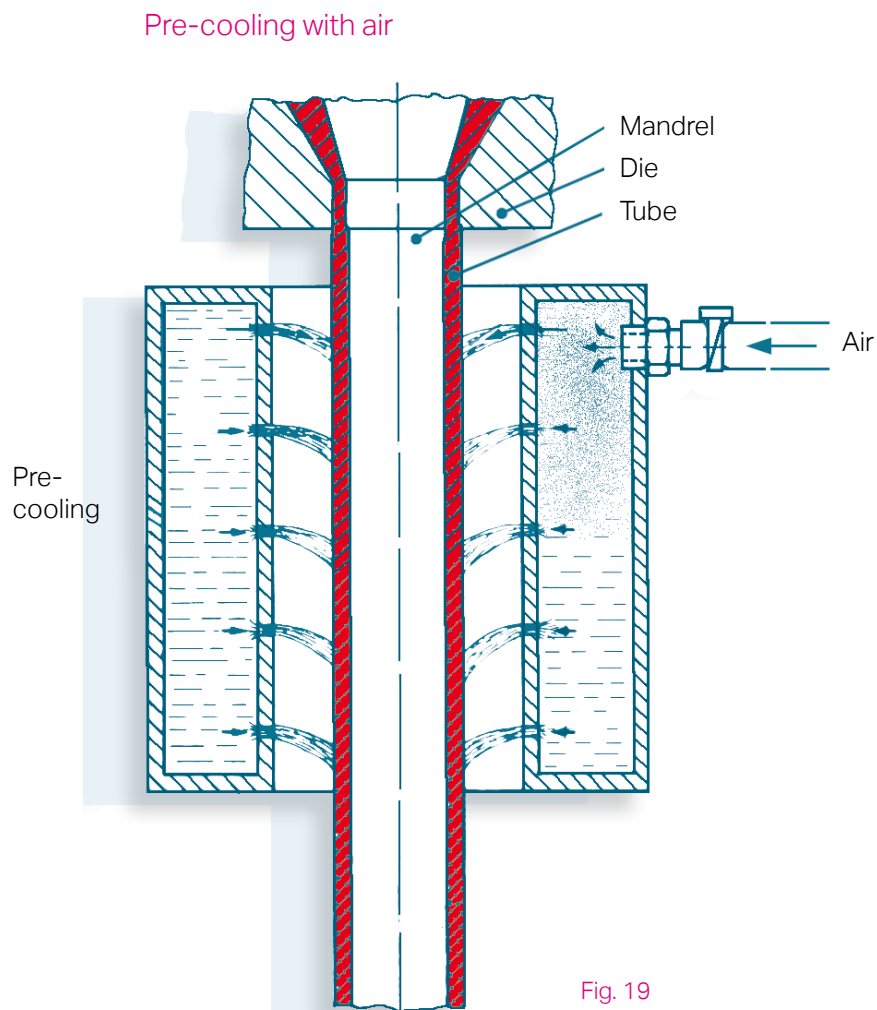
Tubes can be manufactured from Covestro's TPU either horizontally or vertically. The horizontal arrangement is usually selected where the pipes / tubes cannot be deflected around corners because of their hardness and size. Vertical manufacture is recommended for the production of thin-walled tubular film that is wound up flat.

To ensure that the bubbles do not collapse on leaving the die and that no dimensional fluctuations occur, a constant supply of calibrating

air must be passed through the die to inflate the tube and keep it in shape.

When extruding thin-walled tubing, it is advantageous to pre-cool it intensively with air. The flow of air solidifies the surface so that the subsequent water cooling cannot make any marks on the tube (*Fig. 19*).

For the take-off unit, conveyor belts or rubber-covered caterpillar take-off units give good results.



3.

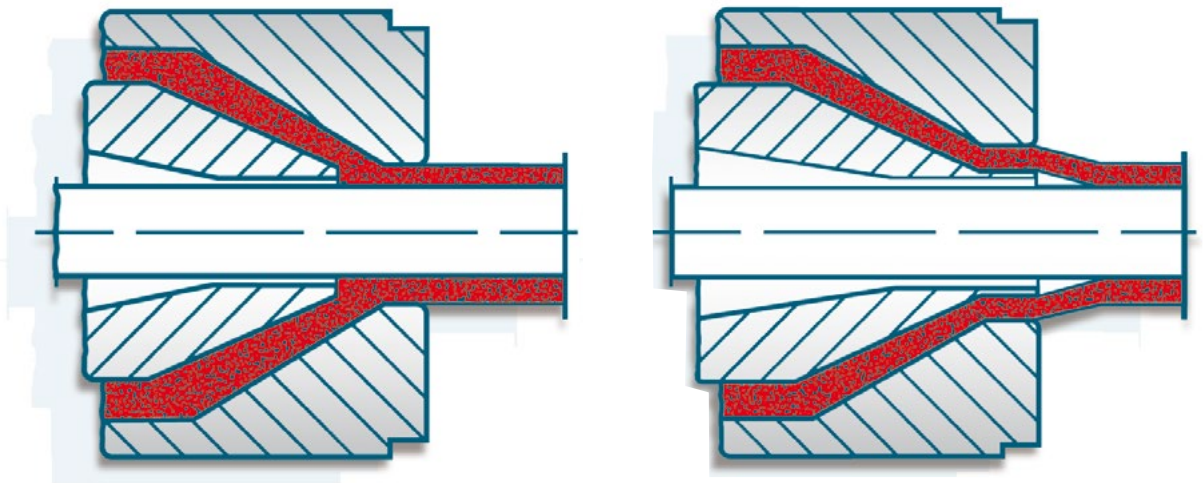
Processing by extrusion

3.6.2 Sheathing of electric cables, ropes and connecting hoses

Dies extending beyond the head should be heated. The mandrel through which the product to be sheathed is passed should be adjustable in the axial direction to allow the surface quality of the sheath to be influenced. The actual sheathing process is carried out by the pressure or tubular process (Fig. 20). With the pressure technique, a non-circular substrate can be topped up to produce a circular cross section. With the tubular process, a coating of even thickness is applied, which largely adjusts to the given cross section.

Adhesion of the Covestro's TPU extrudate to the carrier material essentially depends on which sheathing process is used. Good adhesive strength can generally be achieved by the pressure method. On the other hand, the tube / pipe extrusion method allows easy peeling off of the sheathing. By applying a vacuum to the mandrel, adhesion can be adjusted to suit requirements. It is important to have a dry, grease-free substrate; otherwise, blistering and adhesion problems may occur.

Sheathing dies



Pressure die

Tubular die

Fig. 20

3.6.3 Profiles

Covestro's TPU can be used to extrude profiles with a wide variety of different geometries. The aim should be to keep the wall thickness as uniform as possible.

With major variations in wall thickness, the cross sections of the die must be designed in such a way that a uniform melt front is formed.

3.6.4 Flat film

Flat film extrusion is generally used for film thicknesses greater than approximately 0.5mm. Both the chill-roll process and the take-off calender are suitable. In the case of the calender, the first flight land clearance must be adjusted so that the film is polished on both sides. If a matt surface is required, matted PTFE-coated rollers or rollers covered with silicone rubber should be selected. The roll temperatures should be between 5 and 30°C.

3.6.5 Blown film

With the blown film process, film can be produced with a thickness of between 0.02 and approximately 1mm. The addition of functional concentrates (e. g., anti-blocking agents) or the use of a supporting foil facilitates the entire handling process. *Fig. 21* shows a blown film line.

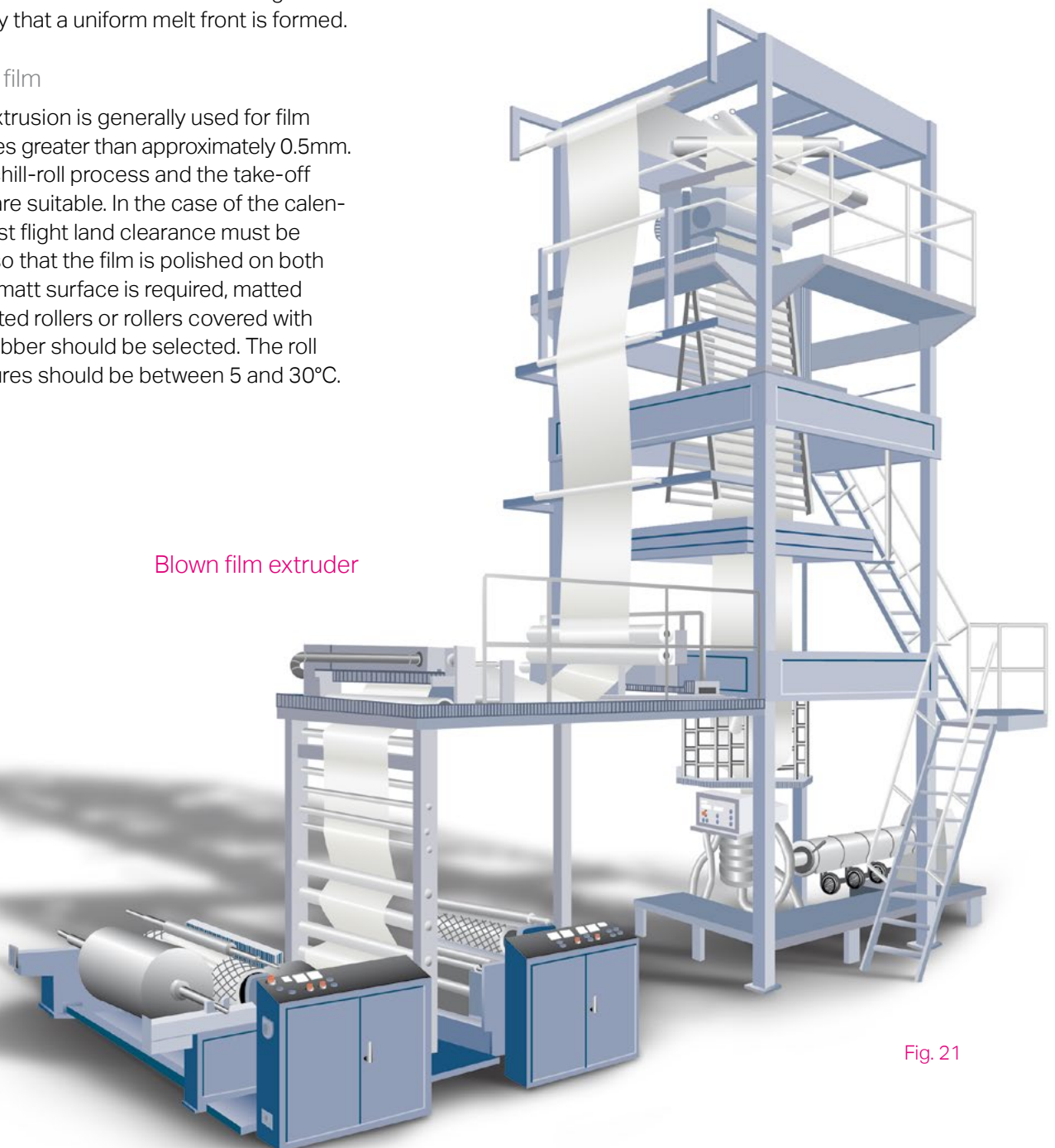


Fig. 21

Processing by extrusion

3.6.6 Extrusion coating

A range of fabrics, such as knitted fabrics, felts and non-woven materials, as well as other materials such as paper, foils and plastic sheets, can be coated with Covestro's TPU in the extrusion process. A slot die is used to apply the TPU film directly onto the substrate. A calender or impression roller is used to smooth out the melt film, which is still plastic, and bond it to the base.

The adhesion of TPU to different substrates depends on the material and / or the surface design. Pretreating the substrate can improve the compound's adhesive properties. If there is insufficient adhesion, applying the adhesion promoter Desmomelt® by coextrusion is often a cost-effective alternative. The adhesion promoter is applied to the web being coated by coextrusion.

3.6.7 Coextrusion

Coextruding Covestro's TPU onto hard thermoplastics such as PC / ABS or ABS adds to the resulting components' range of properties and applications. Covestro's TPU improve the scratch resistance of the surfaces, give them a pleasant feel and deaden noise. Aliphatic grades of Covestro's TPU do not turn yellow when exposed to UV light. They can therefore be pigmented with light colors too, which further extends the design possibilities.

TPU hot-melt adhesives such as Desmomelt® can also be applied to flat films and blown films by coextrusion. Moreover, coextrusion is suitable for manufacturing liners for fabric-reinforced hoses such as fire-fighting hoses. Coextrusion is used to apply Desmomelt® directly to the TPU that forms the main layer. This avoids the need for a lengthy bonding process and the use of solvents.

3.6.8 Extrusion blow molding

Hollow parts such as bellows (Fig. 22) can be produced on commercially available blow-molding machines from specially developed grades of Covestro's TPU using tube dies and accumulator heads. Two-layered blow-molded parts (with an outer layer of aliphatic Covestro's TPU and an inner layer of aromatic Covestro's TPU) have also been produced successfully by coextrusion blow molding. To ensure that the TPU grades used exhibit optimum melt stability, the shear strain should be minimized during melting. This is achieved with low screw speeds and / or low screw compression. The wall thickness control systems that are commonly used in blow-molding plants should also be used with Covestro's TPU to compensate for the change in wall thickness caused by stretching the preform.

Extrusion blow-molded bellows



Fig. 22

Special processes

4.1 Calendering

Calendering (*Fig. 23*) is widely used as a means of coating substrates and – depending on the machine configuration and material structure – can also be used as an alternative to extrusion coating. Calenders are typically used with medium coating thicknesses. Low-melting grades of Covestro's TPU adapted specially for the technique can be processed on virtually all standard calender configurations. An extruder should be used to feed the TPU into the roller nip in the form of a preplasticated melt.

4.2 Powder coating

Another method of coating industrial fabrics is powder coating. This process is ideally used with relatively large wall thicknesses. Low-melting, usually colored TPU powders are applied with a doctor blade onto the substrate and sintered in an oven, and the resulting surface is smoothed using rollers or embossed. Covestro's TPU are not directly supplied in powder form for this technique, but delivered in the form of granules to suitable partner companies that then produce cold-milled powder, which they sell. We would be happy to put you in touch with these partners upon request.

Calendering unit

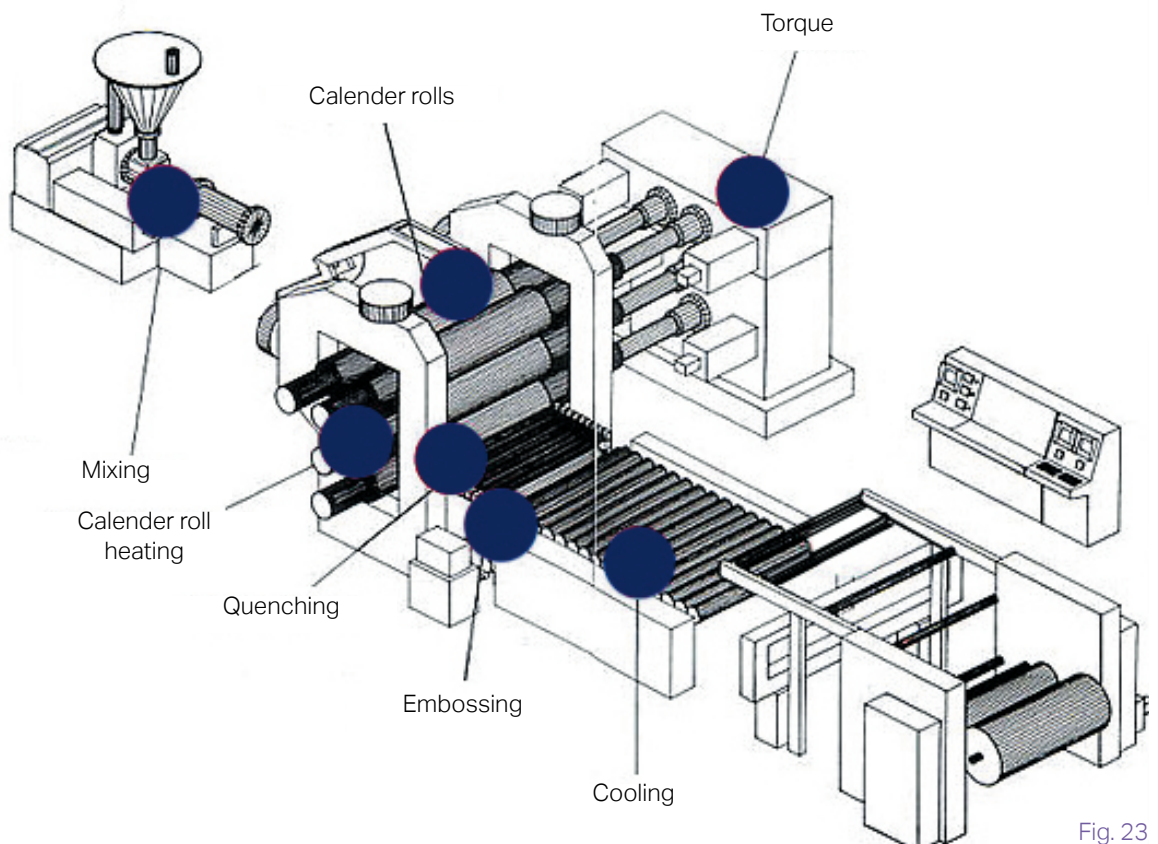


Fig. 23

4.3 Slush molding

Rotation sintering, also known as slush molding, is ideal for producing molded skins (Fig. 24). It is mainly used for applications in the automotive industry. In slush molding, a closed mold rotates around one or more axes. The powder fuses onto the hot mold surface and sinters together. After cooling, the result is a three-dimensional skin that exhibits very even wall thicknesses – regardless of the design complexity of the part. This is a particular strength of slush molding.

The range of Covestro's TPU products for slush molding includes aromatic and lightfast aliphatic slush grades already used in some models of car in Europe, Japan and the United States. Because of the automotive industry's stringent requirements for material properties, the products are supplied as colored powders for direct processing.

Schematic of the slush molding process

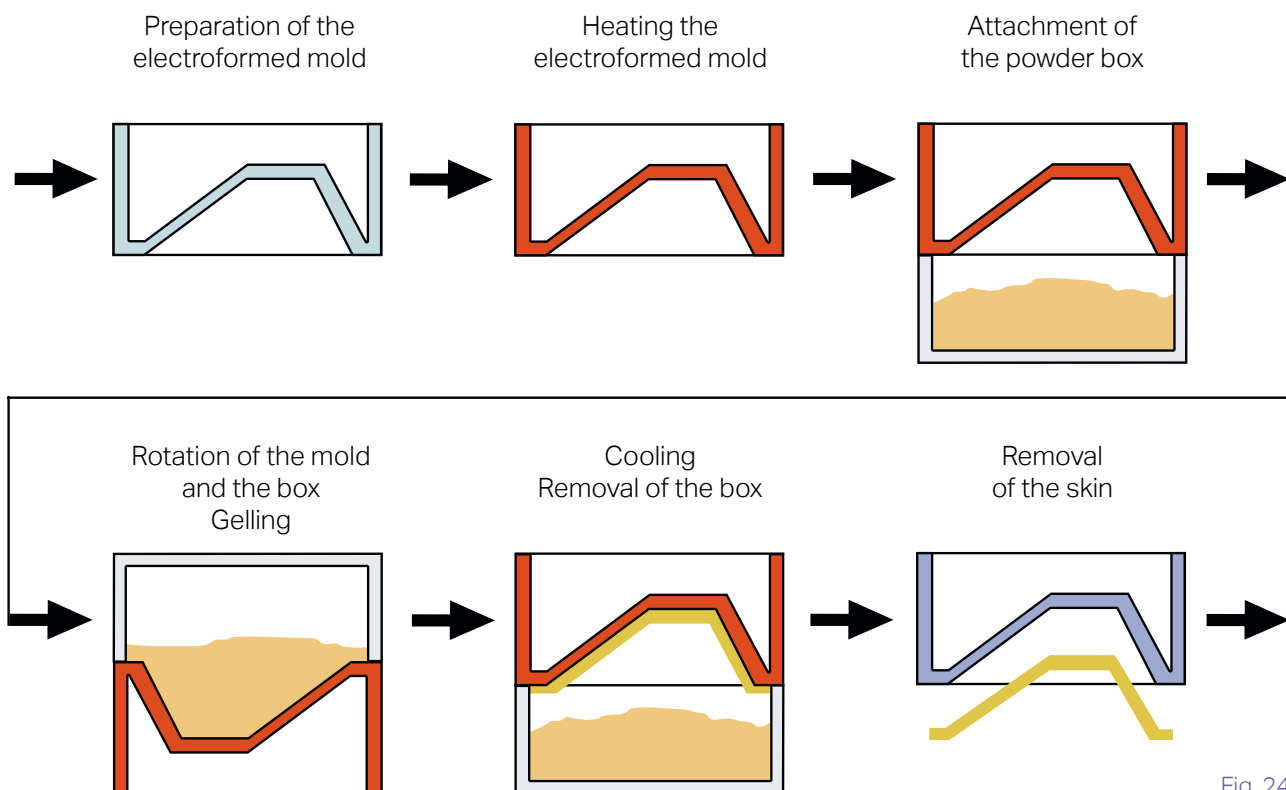


Fig. 24

Machining and fabrication

5.1 Bonding

Polyurethane- or cyanoacrylate-based systems for bonding Covestro's TPU are supplied by the adhesives industry under a variety of trade names.

Cyanoacrylate adhesives cure extremely quickly, but are brittle. The bonded joint breaks under pressure, so they are only suitable to a limited extent for elastic, flexible materials such as TPU. They should only be used for temporary bonds or bonds that are not subject to bending.

Polyurethane adhesives take longer to cure but, like Covestro's TPU, are flexible and elastic. They are therefore ideal for long-lasting bonded joints.

Only a few solvents (including NMP, DMF and MEK) dissolve Covestro's TPU to such an extent that it is possible to produce a bonded joint. These solvents are harmful to health, and it is essential that the information given in the Safety Data Sheets be observed.

5.2 Bonding to metals

Covestro's TPU can be used to produce high-strength bonds with metals. The surface of the metal must first be treated with adhesion promoters. These are normally applied as a solution by spraying, coating or immersion. The pretreated metal parts can then be insert-molded. It is essential to read the instructions for processing metal adhesion promoters carefully. Our experts can provide recommendations about the appropriate adhesion promoters to use with Covestro's TPU.

5.3 Printing

Covestro's TPU parts can be printed using any conventional technique:

- **Hot embossing**
- **Ink-jet printing**
- **Pad printing**
- **Laser printing**

5.3.1 Hot embossing / Hot stamping

In this printing technique, films or foils are embossed on a Covestro's TPU part using a hot stamp.

Hot embossing films are available from various suppliers and display excellent adhesion to the parts.

5.3.2 Ink-jet printing

Ink-jet printing is a very effective method for inscribing Covestro's TPU. We recommend that you adjust the solvent in the ink to suit TPU.

5.3.3 Pad printing

Pad printing is another very effective method for inscribing Covestro's TPU. Again, the composition of the solvent in the ink should be adjusted to TPU.

5.3.4 Laser printing

Covestro's TPU cannot be laser printed without first being modified, because their energy absorption is too low. They must first be compounded with laser additives or laser additive batches. We would be happy to provide recommendations about suitable additives on request.

5.4 Coating

Covestro's TPU are outstandingly well suited to coating and yield high-strength coatings. Because of the excellent elasticity of Covestro's TPU, two-component polyurethane coatings (DD coatings) are normally used. A primer has to be applied to the cleaned, grease-free parts before coating. It should be formulated for TPU and dissolve TPU on the surface to ensure that a strong bond is created with the topcoat.

5.5 Metallizing

New techniques have been introduced to enable the surfaces of Covestro's TPU to be metallized. The thin metal coating is so elastic that the TPU part can withstand bending up to a certain angle without cracking. We would be



happy to put you in touch with selected partner companies that specialize in this technique on request.

5.6 Welding

Covestro's TPU components can be joined together by welding. Suitable methods include:

- **Hot air and nitrogen welding**
- **Hot plate welding**
- **Heated tool and heat impulse welding**
- **High-frequency welding**
- **Friction welding**
- **Vibration welding**

In all cases, an efficient extractor must be provided for any carbonization gases.

5.6.1 Hot air and nitrogen welding

When welding with hot air or hot nitrogen, the flow of gas (measured 1 cm in front of the nozzle) should have a temperature of 290 to 330°C. To increase the weld strength, it is advisable to solidify the plastic weld with a cooled pressure roller.

4.6.2 Hot plate welding

Hot plate welding is particularly useful for the butt-welding of profiles. Both surfaces are melted on plates heated to 290 to 330°C and joined together under pressure so as to produce a bead. This bead can, if necessary, be machined off after cooling.

5.6.3 Heated tool and heat impulse welding

The heated tool and heat impulse welding methods are suitable primarily for thin-walled articles and film. Care must be taken with these processes that sufficient pressure is exerted on the two parts being joined until the weld has cooled.

5.6.4 High-frequency welding

Covestro's TPU can be joined very well indeed by high-frequency welding. A 1mm-thick film can be welded perfectly on a 2 kW unit, and a weld strength of 70 to 95% of the material's strength is achieved. Even with film of 2mm thickness, the weld strength is still 40 to 60%. The higher strength applies to soft Covestro's TPU grades and the lower one to hard grades.

5.6.5 Friction welding

Axially symmetrical parts of Covestro's TPU can be joined together by friction welding. With suitable apparatus, this process can also be used on the production line. Depending on the nature of the component and the holding device, the mean peripheral velocity of the rotating half of the component should be 300 to 500 m/min. The faces of the parts being welded should be melted so that a bead becomes visible on pressing them together. The resultant loss of length must be established in preliminary trials and taken into account when dimensioning the component.

5.

Machining and fabrication

5.6.6 Vibration welding

Vibration welding is useful in cases where friction welding is unsuitable because of the shape of the article. It enables large parts of differing geometries to be welded securely to each other. Vibration welding can be used for parts to be joined either at an angle or straight.

5.6.7 Ultrasonic welding

This welding technique is not recommended because of the high inherent damping of TPU. The strength of the welds is lower than with the other welding processes.

5.7 Machining

Sharp cutting tools are needed for Covestro's TPU. Hard grades can be machined as easily as polyamides. In the case of soft grades (<90 Shore A), the tough and elastic character of the material has to be taken into account. Covestro's TPU can be machined on normal metal and woodworking machines.

Excessive heat generation should be avoided and efficient removal of the shavings must be ensured. Tools of fast-cutting steel are suitable for machining Covestro's TPU. The tools must cut and not exert pressure. With large cutting



depths, cooling with compressed air or drilling oil emulsions may be necessary.

Recommendations for different types of machining are given on the following pages.

5.7.1 Sawing

Conventional saws can be used but, especially when sawing by hand, saw blades intended for wood usually give better results than metal ones. Only saws with crossed teeth should be used.

5.7.2 Drilling

Twist drills with relief-ground cutting edges (clearance angle = 12-16°) and a small twist angle (approximately 30°) are recommended.

Drill tip = 150°

Cutting speed $V = 40-50\text{m} / \text{min}$.

Advance $s = 0.01-0.03\text{mm} / \text{rev}$

Care must be taken to provide adequate ventilation and to remove the shavings. Cooling may be necessary for deeper holes.

5.7.3 Turning

Clearance angle = 5-15°

Effective tool side rake = 25-30°

Cutting edge angle = 40-60°

Cutting speed, hard TPU

$V = 100-150\text{m} / \text{min}$

Cutting speed, soft TPU

$V = 300-500\text{m} / \text{min}$

Advance velocity,

$s = 0.1-0.2\text{mm} / \text{rev}$.

Tip radius = approx. 0.3mm-0.5mm

5.7.4 Milling and planing

Machines used for woodworking are suitable.

Clearance angle = 5-15°

Effective tool side rake = 15°

Cutting speed $V = \text{approx. } 1,000\text{m} / \text{min}$

Advance up to 0.5mm/rev.

5.7.5 Punching

Harder TPU types can be punched more easily and accurately.

Average cutting speed

$V = 50-100\text{mm} / \text{sec}$.

5.7.6 Thread cutting

Thread cutting is possible with hard Covestro's TPU. The screw taps must be very sharp indeed and the pre-drilling hole should be approximately 0.1mm larger than is usual with steel.

5.7.7 Grinding

Soft, ceramically bonded silicon carbide discs with a fine glass paper grain have proved successful for this purpose. The resultant dust must be effectively extracted.

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