Processing
Extrusion

Machine Design

Diagrammatic view of a three-section screw

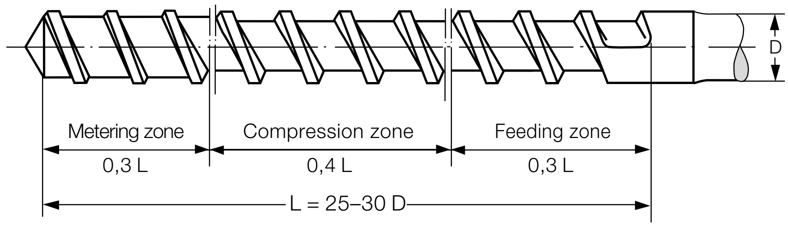

Fig. 16

Single-screw extruders with a compression ratio of 1:2 to 1:3, preferably 1:2.5, are recommended for processing of Elastollan.

Our experience shows that three section screws with a L/D ratio of 25 to 30 are most suitable.

Three-section screws should have a continuous, constant pitch of 1D.

The radial clearance between screw and barrel should be 0.1 to 0.2 mm.

For processing of Elastollan multi-zone screws, e.g. barrier screws (undercuts ≥1.2 mm) have also proven suitable. Short screws with a high compression ratio are unsuitable.

Barrels with a grooved feeding zone have proven successful in practice, and provide the following benefits:

- constant feeding characteristics
- improved pressure build-up
- increased output

If grooved feeding zones are used, cooling is necessary. It is also advisable to use a screw with a mixing section, in order to improve homogeneity of the melt. Such mixing sections should, however, be designed to avoid shear degradation.

Relation: screw diameter – flight depth (feeding zone)

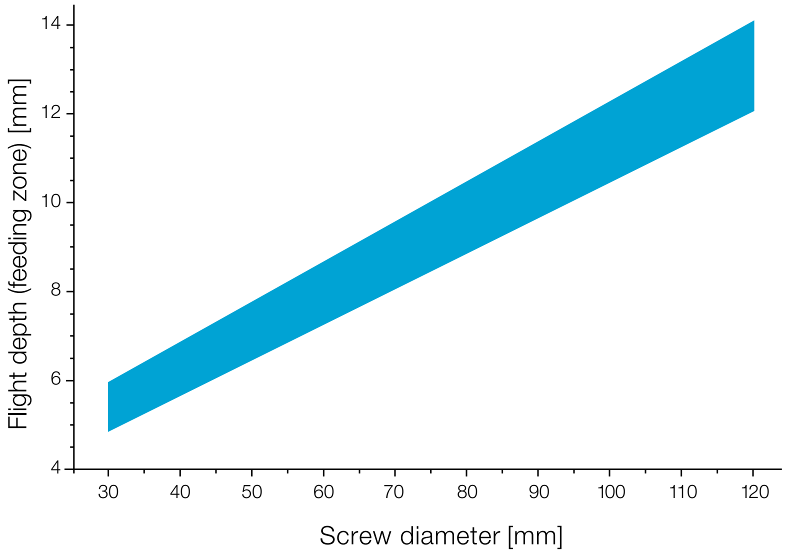

Fig. 17

Processing Extrusion

Machine Design

Use of breaker plates and screen packs is recommended. Good results have been obtained from a combination of two screens of 400 mesh/cm² as backing plates and two fine screens of 900 mesh/cm². Finer screens may be necessary for certain applications (e.g. film production).

Depending on screw diameter and type of die, breaker plates should have holes of 1.5 to 5 mm in diameter.

Extrusion of thermoplastic polyurethane requires **a more powerful motor** than for other thermoplastics. Power consumption is between 0.3 and 1 kWh per kg output, depending on screw design.

Melt pumps have proved successful for continuous melt flow.

Processing Parameters

Processing Temperature
The following temperature ranges, which are dependent on the hardness of the Elastollan grades are recommended:

Screw Speed
Since thermoplastic polyurethanes are shear-sensitive, excessively high screw speeds may lead to a reduction in product properties.

Fig. 18 shows the relation of max. screw speed to screw diameter.

Recommended temperatures for processing in °C

Shore hardness	Heating zones Cylinder	Adapter	Die head	Nozzle
60 to70 A	140–175	160–175	165–170	160–165
75 to 85 A	160–200	175–200	175–205	170–205
90 to 98 A	170–210	200–220	195–215	190–210

Table 6

Relation: max. screw speed – screw diameter

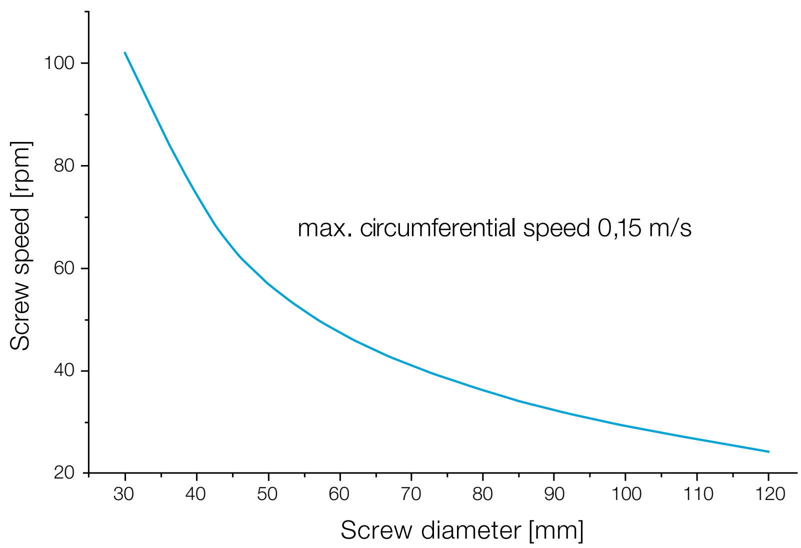

Fig. 18

Processing
Extrusion

Processing Parameters

Melt Pressure
Melt pressure is dependent on the head-design and the die gap, and on melt temperature. Normally the maximum pressure at the adapter is 300 bar, however, peaks of up to 1.000 bar can occur at start-up. Thus, for safety at start-up, a variable screw drive is recommended. If needed, starve feeding is possible.

Cleaning of the Extruder
When changing grade or after several days of continuous operation, cleaning of the extruder is recommended.

Polypropylene or HDPE, which require higher processing temperatures, are suitable for this purpose. In addition, it is sometimes necessary to use a purging compound.

Die Design

To ensure a constant melt flow, it is important to operate with narrow cross-sections and to avoid dead spots in the die. This will cause automatic self-cleaning of the die.

In all other respects, guidelines for head design are the same as for the extrusion of other thermoplastics.

Fig. 19 shows examples of typical dies:

Wire and cable sheathing dies

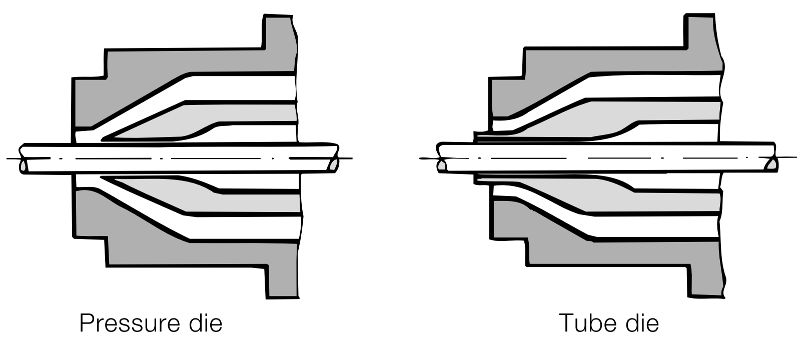

Fig. 19

Processing
Extrusion

Die Design

For extrusion of tubes and profiles, dies with a relatively long land are recommended. This reduces the shear stresses, thus permitting a constant discharge. Land length should be two to four times nozzle diameter.

Tube extrusion die

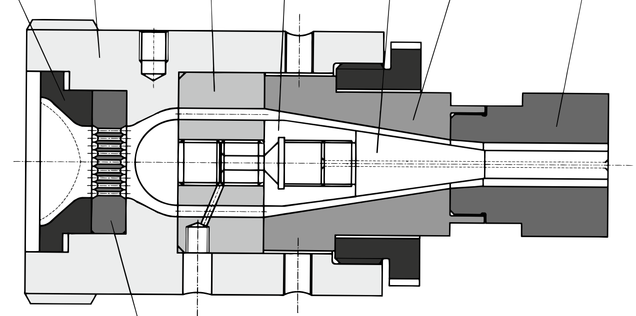

Fig. 20

Cooling and Calibration

Freshly extruded thermoplastic polyurethanes have a relatively low melt strength and are therefore prone to distortion. This necessitates effective cooling. The water bath should be close up to the extruder head. Chilled water is preferred. Instead of cooling baths a cooling line with spray nozzles is also suitable.

The length of cooling bath required for Elastollan grades generally exceeds the requirement for other thermoplastics. The length depends on the grade of material, extrudate shape and section, and haul-off speed.

Due to high coefficient of friction, compared to general thermoplastics, active calibration of thermoplastic polyurethane is not possible.

Calibration devices as shown in diagrammatic view in Fig. 21 are suitable to support the extrudate.

It is essential to provide a lubricating film of water between the surface of the extrudate and the calibrating die. This can be achieved by a water spray ring located before the entry into the cooling bath.

Fig. 22 describes the layout of a tube extrusion line for Elastollan.

Calibration die

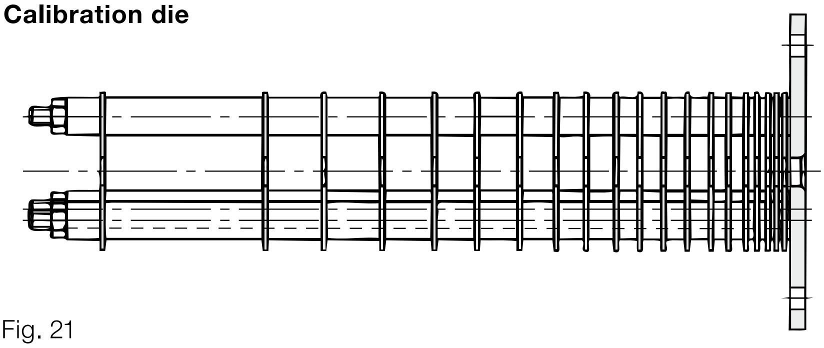

Fig. 21

Processing Extrusion

Cooling and Calibration

Cooling bath for tube extrusion

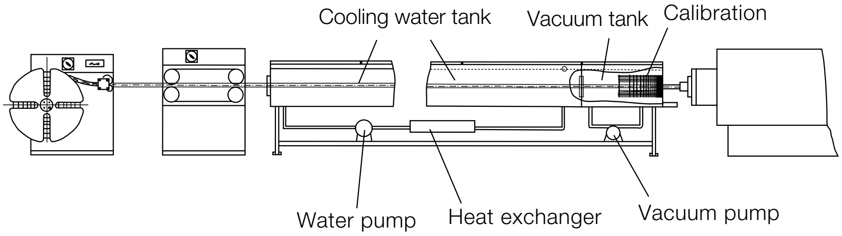

Fig. 22

Extrusion techniques

Tubes and Profiles
Tubes and profiles are mostly extruded horizontally. However, thin-walled tubes, e.g. fire-hose linings, are generally extruded vertically.

It is necessary to supply supporting air to prevent collapsing of the tubes.

To assist shape stability for hollow shapes it is recommended to use vacuum.

The guide rollers in the cooling bath should be matched to the shape of the extrudate.

Sheathing
Sheathing of cables, hoses, etc. is carried out by using a crosshead (see Fig. 23), equipped with a pressure or tube die (see Fig. 19). The inner-core which is to be sheathed must be dry and free from grease, in order to avoid blistering after extrusion and to ensure good bonding.

Diagrammatic view of a crosshead

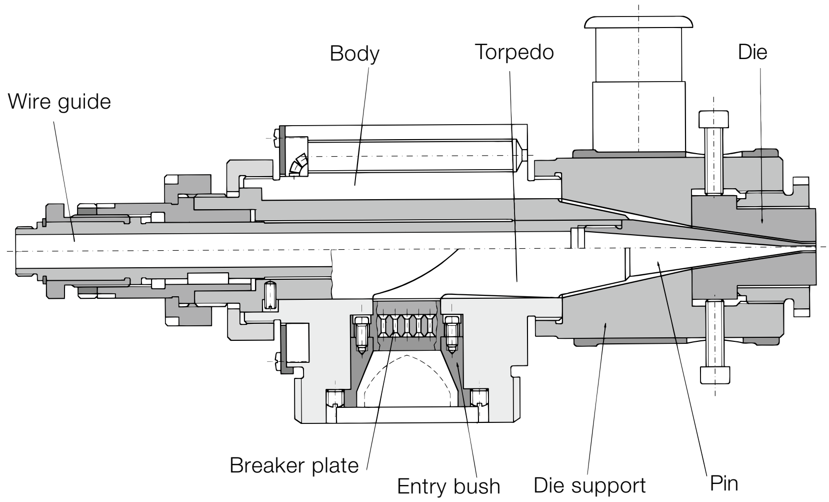

Fig. 23

Processing
Extrusion

Extrusion Techniques

Film

Special Elastollan grades are suitable for the manufacture of blown film.

Fig. 24 shows, in diagrammatic form, a film blowing head.

Diagrammatic view of a film blowing head

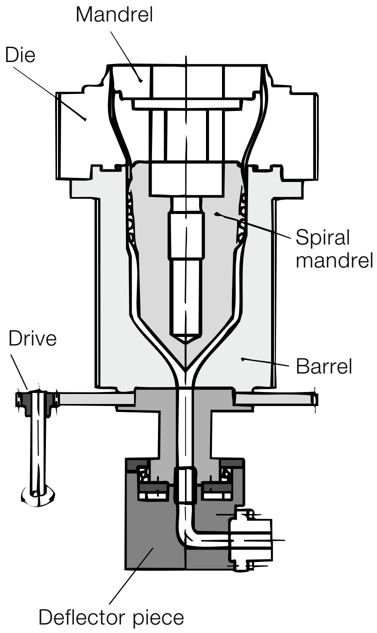

Fig. 24

Films of greater wall thickness can be produced by the flat film extrusion process using a sheet die (see Fig. 25); normal extrusion grades are suitable.

Diagrammatic view of a sheet die

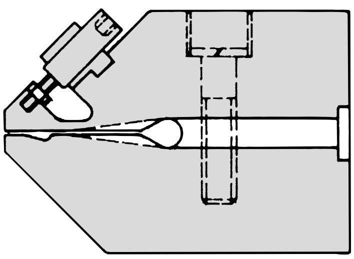

Fig. 25

Blow moulding

Blow moulded articles can be manufactured from selected Elastollan grades using conventional blow moulding machines.

To improve ease of demoulding, the use of a mould with roughened surface (approx. 35 µm) is recommended. Wall thickness control is necessary to compensate for elongation of the parison. Fig. 26 shows a torpedo head for blow moulding.

Diagrammatic view of a torpedo head

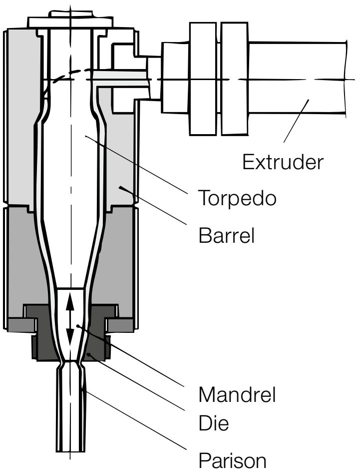

Fig. 26

Processing
Extrusion

Special Processing Methods

Following special methods are suitable for Elastollan:

Coextrusion
to achieve a combination of properties of different thermoplastics in one processing step.

For bonding reasons materials have to be compatible. Compatibility can differ between Elastollan ether and ester types.

Thermoplastic Foam Extrusion
for weight reduction and to achieve special properties.

Two methods are applicable:

- Chemical expanding
  of the melt by addition of expanding agent with conventional extruders; foam density between 0.4 and 1.0 g/cm³ is attainable.

- Physical expanding
  of melt by injection of gas into the extruder. Foam density below 0.4 g/cm³ is attainable. The structure of foam is controlled by a nucleating agent.

Trouble Shooting Guidelines

Trouble shooting guidelines

	Melt/ Cylinder temperature	Die temperature	Die pressure	Screw speed/ Output	Land length	Homogenisation	Moisture content	Material contamination	Cooling feeding zone	Lubricant
Pulsation	●		●	▼		●	▼		●	▼
Rough surface	▲	▲		●	●	▲				▲
Surface streaks	▼	▼			●	▲	▼			●
Bubbles/Blisters	▼	▼	▲	▲			▼		▼	▼
Flow lines/ Spider lines	●		●	▼		▲	▼			
Excssive blocking	▼	▼	▲	▼			▼			▲
Unmelted particles	▲	▲		▼		▲		▼		
Dimensional variations	●	●	●	●	●	●	▼		●	▼
Unsufficient dimensional stability	▼	▼	▲	▼	●		▼			
Melt fracture	▲	▲	▼	●	●	●				▲
Material degradation	▼			●		▼	▼			

▲ Increase to solve problem
▼ Reduce to solve problem
● Increase or reduce to solve problems

Table 7