## Extrusion

The main form of Ultraform® used for extrusion is the high-molecular weight grade H4320. Another grade Ultraform® H2320 004, is available for extruding small pipes and slab stock.

Up to a few years ago the most common type of screw for POM was the short-compression zone screw.

On the basis of BASF experience, Ultraform® can be processed to particular advantage using three-section screws having a total length L of 20 to 25 D and a constant pitch of about 1D. Table 1 contains suggested screw geometries for the most frequently used extruder sizes. Material stresses and degradation due to friction can be significantly reduced by means of a feed zone of appropriate length and an extended compression section having a maximum compression ratio of 3:1.

| Length of section | | | | | Flight depths | |
|---|---|---|---|---|---|---|
| Overall length | L | 20-25 | D | D mm | $h_E$ mm | $h_A$ mm |
| Feed section | $L_E$ | 8 | D | 45 | 7.7 | 2.8 |
| Compression section | $L_K$ | 3-5 | D | 60 | 9.3 | 3.3 |
| Metering section | $L_A$ | 9-12 | D | 90 | 10.8 | 3.8 |

D = screw diameter
$h_E$ = flight depth in the feed section
$h_A$ = flight depth in the metering section

Table 1: Guide values for the screw geometry (extrusion)

**Production of semi-finished parts**

Thick-walled hollow and solid profiles are usually manufactured by the cooled-die extrusion method. The dimensions for the standard sizes of such POM profiles and the quality requirements for them are standardized as follows:

- DIN 16980 and DIN 16985 Round-section rod (new: DIN EN 1549)
- DIN 16986 Sheet
- DIN 16809, 16978 and 16983 Hollow rod

The requirements of DIN 16985 can be very reliably fulfilled by Ultraform® H4320, because this grade, when correctly processed, has very little tendency to discolor or to produce voids. Compared with products, this type allows processing speeds which are significant higher.

Fuel filter housing

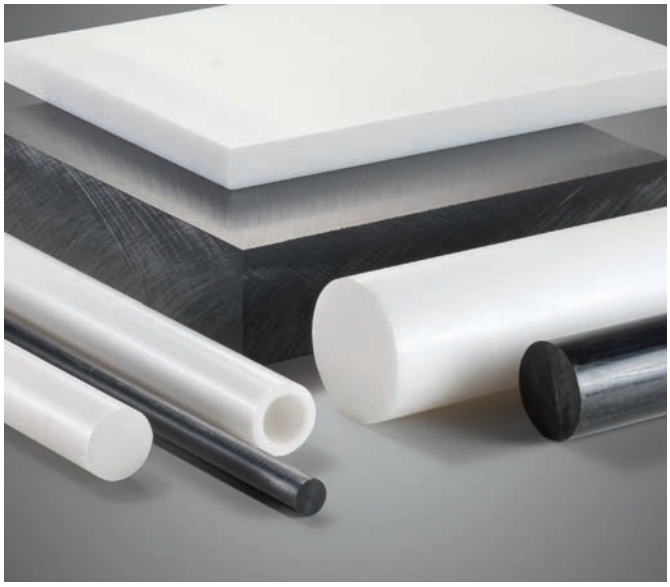
The necessarily long residence time of the melt in the extrusion of semi-finished parts requires that the melt temperature be kept as low as possible. For thicker rod, for example, the melt temperature should not exceed 175 °C to 180 °C.

Volume shrinkage can be compensated by high pressure and an output rate adapted to the wall thickness.

Stresses can arise due to the different solidification and cooling of the melt, which varies according to time and place. These can be removed by subsequent heat treatment. Tempering is essential when high demands are placed on dimensional stability. It can be carried out in air, liquid wax or oil at temperatures of 130 °C to 150 °C, mostly 140 °C to 145 °C. Lower temperatures are not effective. The duration depends on the wall thickness (10 minutes per 1mm wall thickness).

| | **Ultraform® H4320** |
|---|---|
| Rod diameter | 60 mm (4-aperture die) |
| Extruder | 45 mm Ø, 22 D |
| Screw<br>– Section length<br>– Flight depth | <br>$L_A$ = 9 D, $L_E$ = 9 D, $L_K$ = 4 D<br>$h_E/h_A$ = 7.5/2.5 mm |
| Temperature control<br>– Extruder<br>– Adapter<br>– Die heated<br>– Die cooled | <br>200/180/170 °C<br>175 °C<br>175 °C<br>20 °C |
| Screw speed | 42 $min^{-1}$ |
| Take-off rate | 20 mm/min (per rod) |
| Output | 17 kg/h |

Table 2: Processing examples for the production of round-section rods



Semi-finished parts

### Production of tubes and pipes

Smaller Ultraform® tubes are mainly used to protect and guide Bowden cables. They have an outer diameter of 3 to 10 mm and a wall thickness in the range 0.4 - 1.0 mm.

The vacuum water bath method is recommended for the production of tubes and pipes. For calibration, draw plates (set) arranged one behind the other or radially slotted or drilled calibration sleeves are suitable. In both cases the internal diameter of the calibration unit is set approximately 2.5 % greater than the desired outer diameter of the tube to be produced. Based on experience, this difference corresponds to the shrinkage in processing. In order to be in a position to utilize the off-take speeds possible with this product, the ratio of the die diameter of the pipe extrusion head to the internal diameter of the calibration tube must lie approximately in the range 2:1 to 4:1, depending on the size of the tube. The die gap of the pipe extrusion head should be 3 to 4 times the size of the desired wall thickness of the tube.

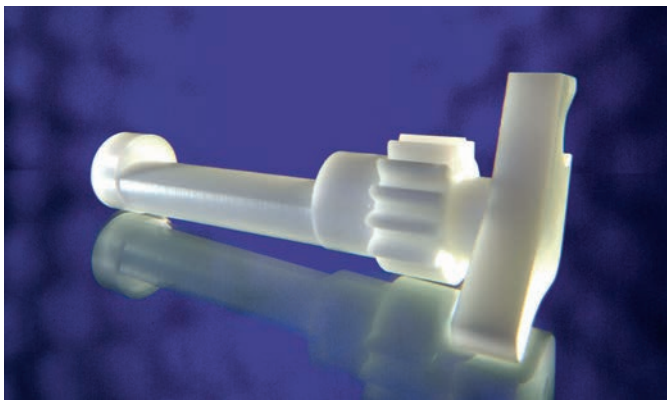
The rapid solidification requires that the distance between the pipe extrusion head and the calibration unit be kept as small as possible. If the spacing is too great the outer skin of the molten tube will have solidified so much at the inlet that the tube can no longer be reliably calibrated.

Large, thick-walled pipes are preferably produced by the vacuum water bath method.

With standard equipment and standard extrusion grades, such as Ultraform® H4320, it is possible to produce pipe with a maximum wall thickness of 8 mm. For thicknesses greater than this, the melt flows increase in the direction of gravity, causing a growing difference in thickness between the upper and lower sides of the pipe.

| | |
|---|---|
| Pipe dimensions (external diameter x wall thickness) | 3.5 · 0.9 mm |
| Extruder Ø | 45, 20 D mm |
| Screw<br>– Section lengths: $L_E$ / $L_K$ / $L_A$<br>– Flight depths: $h_E$ / $h_A$ | <br>8 D/3 D/9 D<br>7.7/2.7 mm |
| Temperature control<br>– Extruder<br>– Adapter<br>– Die body/die aperture | <br>180…180 °C<br>180 °C<br>170/170 °C |
| Pipe extrusion head<br>– Die Ø<br>– Mandrel Ø<br>– Gap | <br>12 mm<br>6 mm<br>3 mm |
| Vacuum water bath<br>– Draw plate Ø<br>– Water temperature | <br>3.6 mm<br>18 °C |
| Distance between pipe extrusion head and calibration unit | approx. 3 cm |
| Screw speed | 26 $min^{-1}$ |
| Off-take speed | 16 m/min |
| Output | approx. 10 kg/h |

Table 3: Examples of the production of pipes from Ultraform® H2320 004



Semi-finished part

### Production of sheet

Ultraform® H2320 004 is excellent for producing sheet with thicknesses between 1 and 6 mm. Standard sizes are defined in DIN 16 977 and the quality requirements in DIN 16985.

Sheet is produced on commercial installations aligned horizontally with slot dies, three-roll polishing stack followed by an off-take unit. The lips of the slot dies should extend as close as possible to the nip. The temperatures of the rolls depend on the sheet thickness and vary between 130 °C and 170 °C.

The throughput and off-take rate are matched to one another in such a way that a small, uniform bead is formed over the width of the roll ahead of the nip. In this way the tolerance and surface quality of the sheet can be adjusted in optimum manner. By using vented extruders, the surface quality can be improved still further. Otherwise pre-drying of the pellets is recommended (3 hours at 100 °C to 110 °C).

| | | | |
|---|---|---|---|
| Sheet cross-section | 770 mm · 1.6 mm | | |
| Extruder | 90 mm Ø, 30 D | | |
| Screw<br>– Section lengths<br>– Venting<br><br>– Flight depths<br><br>– Die | <br>$L_E$ = 9 D, $L_K$ = 1.5 D, $L_A$ = 6 D<br>0.5 D<br>$L_{E1}$ = 4.5 D, $L_{K1}$ = 1 D, $L_{A1}$ = 7.5 D<br>$h_E/h_A$ = 10.8/4 mm<br>$h_{E1}/h_{A1}$ = 16.8/5.6 mm<br>800 mm wide | | |
| Temperature control<br>– Barrel<br><br>– Adapter<br>– Die | <br>150/160/160/170/170/155/155/155 °C<br>(while extruder is running)<br>180 °C<br>throughout 185 °C | | |
| Three-roll stack | 300 mm roll diameter | | |
| | Temperature (set) | top<br>center<br>bottom | 170 °C<br>145 °C<br>140 °C |
| Screw speed | 25 $min^{-1}$ | | |
| Melt temperature | 200 °C | | |
| Off-take rate | 0.63 m/min | | |
| Output | 68 kg/h | | |

Table 4: Example of the production of sheet from Ultraform® H2320 004

### Manufacture of monofilaments

Ultraform® H2320 004 and H2320 006 are suitable for manufacturing stiff bristles and technical monofilaments with a diameter of up to about 0.5 mm. A quick cooling-phase and recking is important.

### Blow molding

Ultraform® E3320 makes it possible to produce elaborate hollow bodies by extrusion blow molding.

When blow molding Ultraform®, it is generally necessary to ensure good and homogeneous processing of the melt. It is recommended that a screw with an effective screw length of no less than 20 D and a low channel depth be used so that the melt can be processed homogeneously. Maddock, rhombus-shaped mixing elements, barrier webs and other suitable screw elements can further enhance the processing.

Appropriate temperature control which differs from traditional blow molding is also required. Controlling the temperature of the feeding zone to a temperature between 100 °C and 230 °C helps to melt the granules. The zones next to the feeding zone should be heated up from 180 °C to 230 °C. Constant temperature control or a temperature profile which declines slightly toward the tip of the extruder with melt temperatures of around 200 °C helps to produce a stable melt and components with good mechanical properties.

The blow molding tool should preferably have a temperature of over 90 °C. Controlling the temperature of the tool helps to mold the tool cavity well. The blow pressure to be chosen depends on the component, but in most cases it will be between 4 bar and 10 bar.