6 Design of Gates

6.1 The Sprue Gate

The sprue gate is the simplest and oldest kind of gate. It has a circular cross-section, is slightly tapered, and merges with its largest cross-section into the part.

The sprue gate should always be placed at the thickest section of the molded part. Provided proper size, the holding pressure can thus remain effective during the entire time the molded part solidifies, and the volume contraction during cooling is compensated by additional material forced into the cavity. No formation of voids or sink marks can occur. The diameter of the sprue gate depends on the location at the molded part. It has to be a little larger than the section thickness of the molded part so that the melt in the sprue solidifies last. The following holds (Figure 5.9):

$$d_F \geqq S_{max} + 1.0 \text{ (mm)}. \tag{6.1}$$

It should not be thicker, though, because it then the melt solidifies too late and extends the cooling time unnecessarily.

To demold the sprue without trouble it should taper off towards the orifice on the side of the nozzle. The taper is

$$\alpha \geqq 1\text{–}4°. \tag{6.2}$$

American standard sprue bushings have a uniform taper of 1/2 inch per foot, which is equivalent to about 2.4°.

The orifice towards the nozzle has to be wider than the corresponding orifice of the nozzle. Therefore

$$d_A \geqq d_D + 1.5 \text{ mm} \tag{6.3}$$

(Refer to Figure 5.9 for explanation of symbols)

If these requirements are not met, undercuts at the upper end are formed (Figure 5.8).

Very long sprues, that is if the mold platens are very thick, call for a check on the taper. Possibly another nozzle has to be used in the injection molding machine.

To a large degree the release properties of the sprue also depend on the surface finish of the tapered hole. Scores from grinding or finishing perpendicular to the direction of demolding have to be avoided by all means. Material would stick in such scores and prevent the demolding. As a rule the interior of sprue bushings is highly polished.

A radius r_2 (Figure 5.9) at the base of the sprue is recommended to create a sharp notch between sprue and molding and to permit the material to swell into the mold during injection.

To its disadvantage, the sprue always has to be machined off. Even with the most careful postoperation, this spot remains visible. This is annoying in some cases, and one could try to position the sprue at a location that will be covered after assembly of the article. Since this is often impractical, the sprue can be provided with a turnaround so

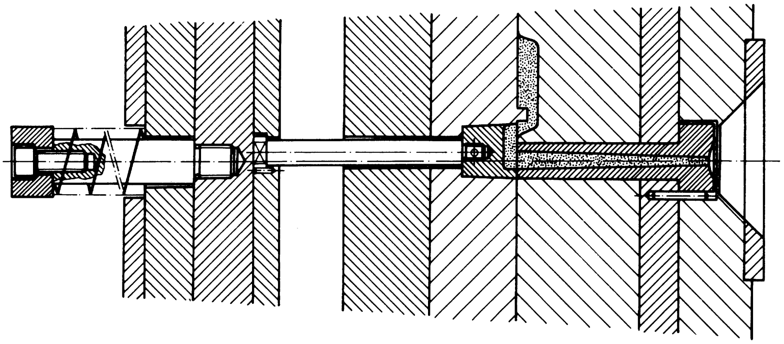

Figure 6.1 Sprue with turnaround [6.1] (also called “overlap gate”)

that it reaches the molded part from the inside or at a point not noticeable later on (Figure 6.1). The additional advantage of such redirected sprues is the prevention of jetting. The material hits the opposite wall first and begins to fill the cavity from there [6.2]. Machining as a way of sprue removal is also needed here.

Another interesting variant of a sprue gate is shown in Figure 6.2 It is a curved sprue, which permits lateral gating of the part. It is used to achieve a balanced position of the molded part in the mold, which is now loaded in the center. This is only possible, however, for certain materials, such as thermoplastic elastomers.

6.2 The Edge or Fan Gate

An edge gate is primarily used for molding parts with large surfaces and thin walls. It has the following advantages:

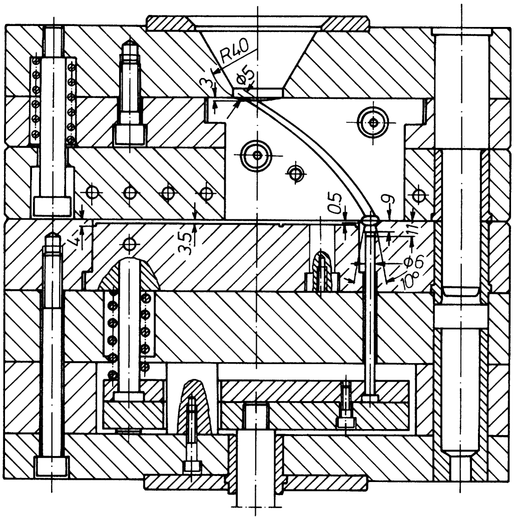

Figure 6.2 Curved sprue [6.3]

- parallel orientation across the whole width (important for optical parts),
- in each case uniform shrinkage in the direction of flow and transverse (important for crystalline materials),
- no inconvenient gate mark on the surface.

The material leaving the sprue first enters an extended distributor channel, which connects the cavity through a narrow land with the runner system (Figure 6.3). The narrow cross-section of the land acts as a throttle during mold filling. Thus, the channel is filled with melt before the material can enter the cavity through the land. Such a throttle has to be modified in its width if the viscosity changes considerably.

The distributor channel has usually a circular cross-section. The relationship of Figure 6.3 generally determines its dimensions. They are comparable with the corresponding dimensions of a ring gate, of which it may be considered a variant.

Besides the circular channel, a fishtail-shaped channel is sometimes met (Figure 6.4). This shape requires more work and consumes more material, but it results in excellent part quality due to a parallel flow of the plastic into the cavity.

Dimensioning was mostly done empirically so far. Today it can be accomplished with the help of rheological software packages such as CADMOULD, MOLDFLOW, etc. (see Chapter 14).

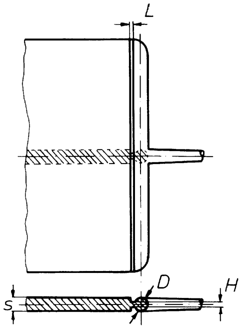

Figure 6.3 Edge gate with circular distributor channel [6.1, 6.4]
D = s to 4/3 s + k,
k = 2 mm for short flow lengths and thick sections,
k = 4 mm for long flow lengths and thin sections,
L = (0.5 to 2.0) mm,
H = (0.2 to 0.7) s.

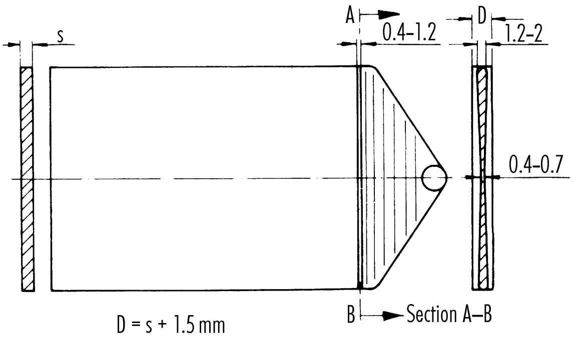

Figure 6.4 Edge gate with adjusted cross section resulting in uniform speed of flow front [6.5]

6.3 The Disk Gate

The disk gate allows the uniform filling of the whole cross-section of cylindrical, sleeve-like moldings, which need a mounting of the core at both ends. The disk can be of a plane circular shape (Figure 6.8) or a cone usually with 90° taper (“umbrella” gate) (Figure 6.5) and distributes the melt uniformly onto the larger diameter of the molded part. This has the advantage that knit lines are eliminated. They would be inevitable if the parts were gated at one or several points. Besides this, a possible distortion can be avoided. With proper dimensions there is no risk of a core shifting from one-sided loading either. As a rule of thumb, the ratio between the length of the core and its diameter should be smaller than

$$\frac{L_{\text{core}}}{D_{\text{core}}} < \frac{5}{1} \tag{6.4}$$

[6.5] (see also Chapter 11: Shifting of Cores).

If the core is longer, it has to be supported on the injection side to prevent shifting caused by a pressure differential in the entering melt. In such cases a ring gate should be employed (Section 6.4). A design like the one in Figure 6.6 is poor because it results again in knit lines with all their shortcomings.

The “umbrella” gate can be connected to the part in two different ways; either directly (Figure 6.5) or with a land (Figure 6.7). Which kind is selected depends primarily on the wall thickness of the molded part.

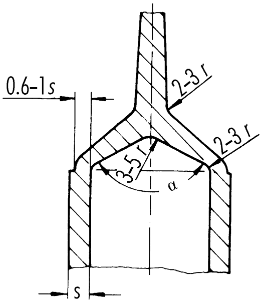

Figure 6.5 Disk gate [6.5] 90° taper

There is another type of umbrella gate known as a disk gate [6.5, 6.6]. A disk gate permits the molding of cylindrical parts with undercuts in a simple mold without slides or split cavities (Figure 6.8, left).

6.4 The Ring Gate

A ring gate is employed for cylindrical parts, which require the core to be supported at both ends because of its length.

The melt passes through the sprue first into an annular channel, which is connected with the part by a land (Figure 6.9). The land with its narrow cross-section acts as a throttle during filling. Thus, first the annular gate is filled with material, which then

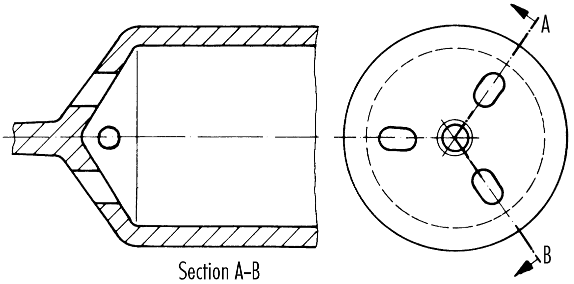

Figure 6.6 Conical disk gate with openings for core support [6.5]

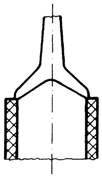

Figure 6.7 Disk gate

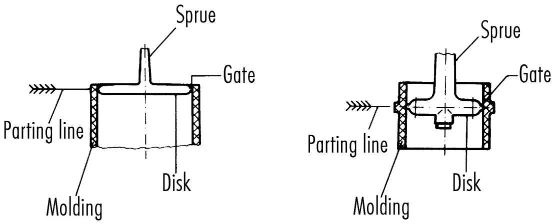

Figure 6.8 Disk gates [6.5, 6.6]

enters the cavity through the land. Although there is a weld line in the ring gate, its effect is compensated by the restriction in the land and it is not visible, or only slightly visible.

The special advantage of this gate lies in the feasibility of supporting the core at both ends. This permits the molding of relatively long cylindrical parts (length-over-diameter ratio greater than 5/1) with equal wall thickness. The ring gate is also utilized for cylindrical parts in multi-cavity molds (Figure 6.9). Although similar in design, a disk gate does not permit this or a core support at both ends.

The dimensions of a ring gate depend on the types of plastics to be molded, the weight and dimensions of the molded part, and the flow length. Figure 6.10 presents the data for channels with circular cross-section generally found in the literature.

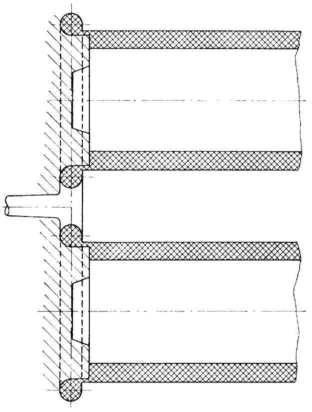

Figure 6.9 Sleeves with ring gates and interlocks for core support [6.1]

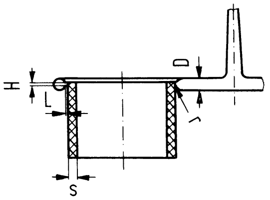

Figure 6.10 Ring gate with circular cross-section [6.4, 6.5]
$D = s + 1.5$ mm to $4/3\ s + k$,
$L = 0.5$ to 1.5 mm,
$H = 2/3\ s$ to 1 to 2 mm,
$r = 0.2\ s$,
$k = 2$ mm for short flow lengths and thick sections,
$k = 4$ mm for long flow lengths and thick sections.

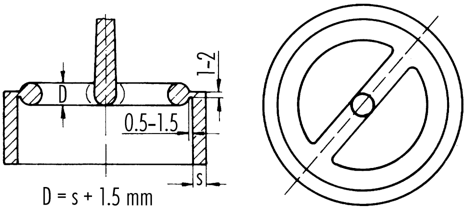

Figure 6.11 Internal ring gate [6.5]

The gates in Figures 6.9 and 6.10 are called external ring gates in the literature [6.5]. Consequently, a design according to Figure 6.11 is called internal ring gate. It exhibits the adverse feature of two weld lines, is more expensive to machine, and complicates the core support at both ends.

A design variation of the common ring gate can be found in the literature. Since it is basically the usual ring gate with only a relocated land (Figure 6.12), a separate designation for this does not seem to be justified.

6.5 The Tunnel Gate (Submarine Gate)

The tunnel gate is primarily used in multi-cavity molds for the production of small parts which can be gated laterally. It is considered the only self-separating gating system with one parting line, which can be operated automatically.

Part and runner are in the same plane through the parting line. The runners are carried to a point close to the cavities where they are angled. They end with a tapered hole, which is connected with the cavities through the land. The tunnel-like hole which is milled into the cavity wall in an oblique angle forms a sharp edge between cavity and tunnel. This edge shears off the part from the runner system [6.7].

There are two design options for the tunnel (Figures 6.13a and 6.13b). The tunnel hole can be pointed or shaped like a truncated cone. In the first case the transition to the molded part is punctate, in the second it is elliptical. The latter form freezes more slowly

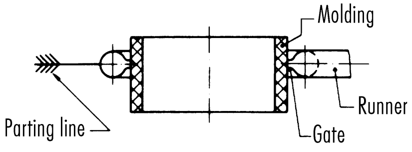

Figure 6.12 External ring gate (rim gate) [6.6]

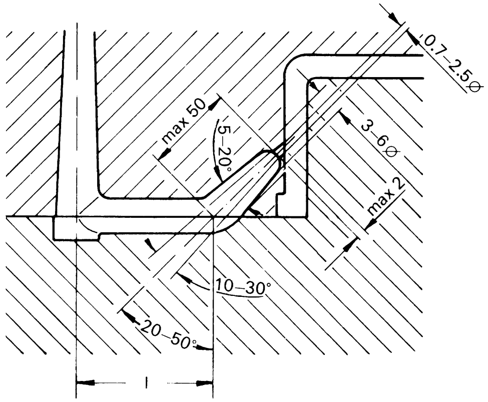

Figure 6.13a Tunnel gate with pointed tapered tunnel [6.5]

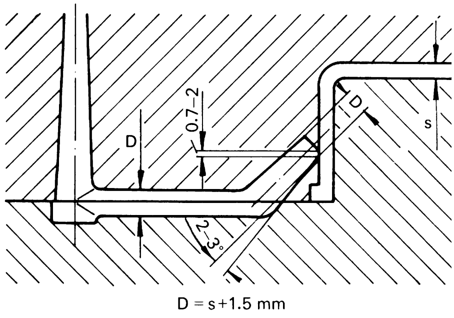

Figure 6.13b Tunnel gate with truncated tapered tunnel [6.5]

and permits longer holding pressure time. Machining is especially inexpensive because it can be done with an end-mill cutter in one pass.

For ejection, part and runner system must be kept in the movable mold half. This can be done by means of undercuts at the part and the runner system. If an undercut at the part is inconvenient, a mold temperature differential may keep the molded part on the core in the movable mold half as can be done with cup-shaped parts.

The system works troublefree if ductile materials are processed. With brittle materials there is the risk of breaking the runner since it is inevitably bent during mold opening. It is recommended therefore, to make the runner system heavier so that it remains warmer and hence softer and more elastic at the time of ejection.

In the designs presented so far, the part was gated laterally on the outside. The tunnel is machined into the stationary mold half and the molded part is separated from the runner during mold opening. With the design of Figure 6.14 the part, a cylindrical cover,

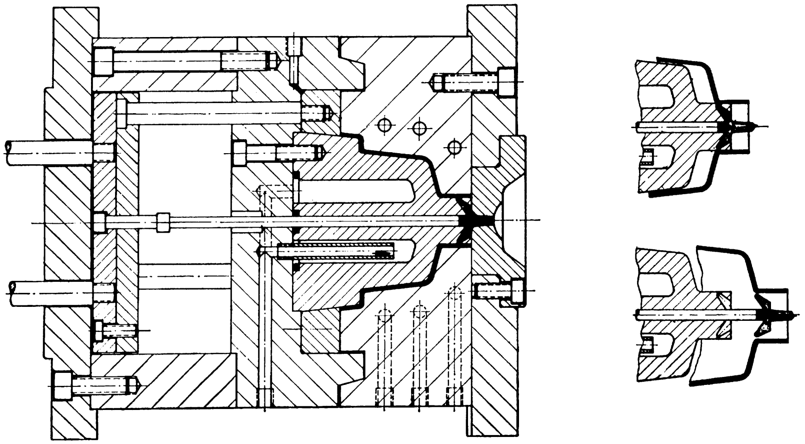

Figure 6.14 Mold with tunnel gates for molding covers [6.8]

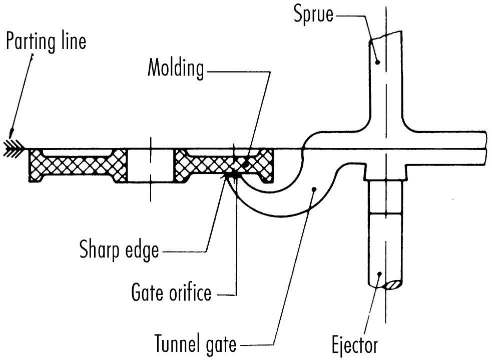

Figure 6.15 Curved tunnel gate [6.6]

is gated on the inside. The tunnel is machined into the core in the movable mold half. The separation of gate and part occurs after the mold is opened by the movement of the ejector system. The curved tunnel gate (Figure 6.15) functions according to the same system.

6.6 The Pinpoint Gate in Three-Platen Molds

In a three-platen mold, part and gate are associated with two different parting lines. The stationary and the movable mold half are separated by a floating platen, which provides for a second parting line during the opening movement of the mold (Figure 6.16). Figures 6.17 and 6.18 show the gate area in detail.

This system is primarily employed in multi-cavity molds for parts that should be gated in the center without undue marks and post-operation. This is particularly the case with cylindrical parts where a lateral gate would shift the core and cause distortion.

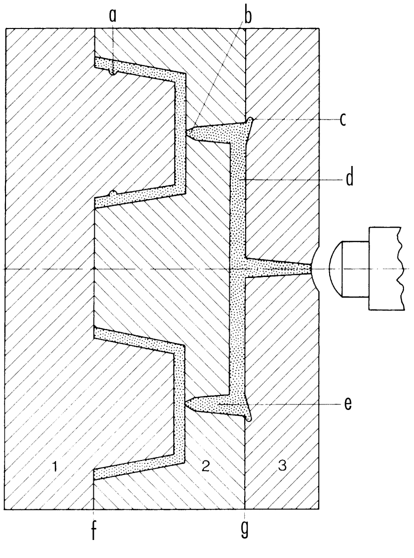

Figure 6.16 Three plate mold [6.9]
1 Movable mold half, 2 Floating plate,
3 Stationary mold half,
a Undercut in core, b Gate, c Undercut,
d Runner, e Sprue core, f Parting line 1,
g Parting line 2.

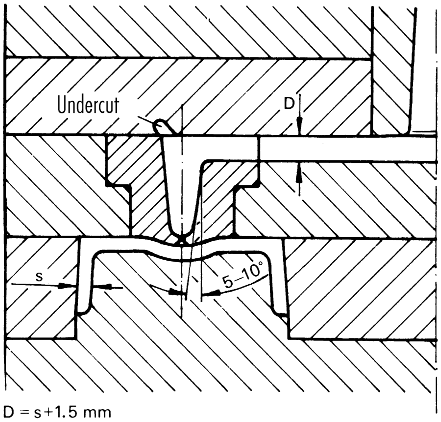

Figure 6.17 Pinpoint gate in three-plate mold [6.5]

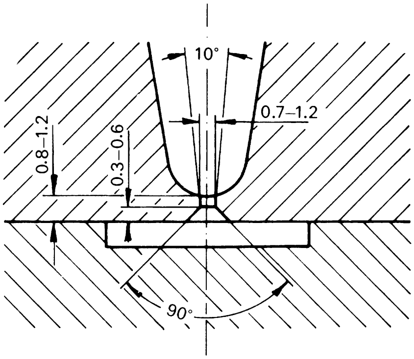

Figure 6.18 Dimensions for pin point gate [6.6]

Thin-walled parts with large surface areas are also molded in such a way in single cavity molds. Multiple gating (Figure 6.19) is feasible, too, if the flow length-over-thickness ratio should call for this solution. In this case special attention has to be paid to knit lines as well as to venting.

The opening movement of a three-platen mold and the ejection procedure separate part and runner system including the gate. Thus, this mold provides a self-separating,

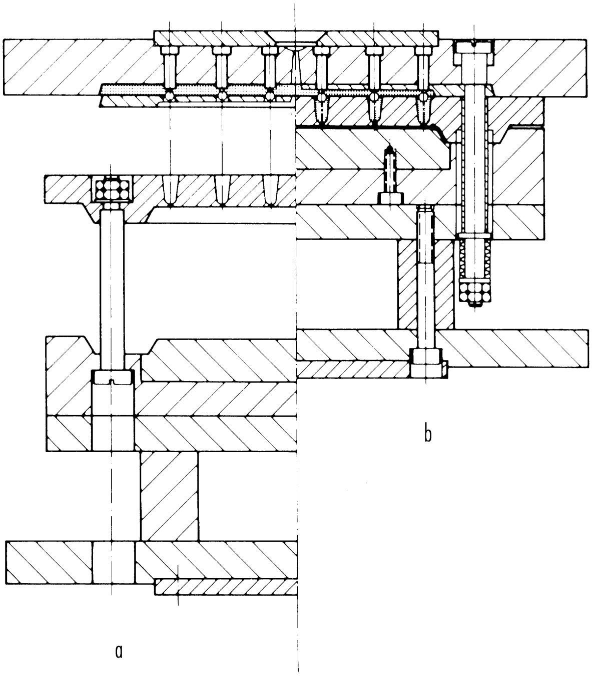

Figure 6.19 Three plate mold for multiple gating in series [6.10] a Open, b Closed.

automatic operation. The mold is opened first at one and then at the other parting line, thus separating moldings and runner system.

6.7 Reversed Sprue with Pinpoint Gate

The reversed sprue is frequently enlarged to a "pocket" machined into the stationary mold half. It is connected with the cavity by a gate channel with reversed taper.

During operation the sprue is sealed by the machine nozzle and fully filled with plastic during the first shot. With short cycle times the material in the sprue remains fluid, and the next shot can penetrate it. The nozzle, of course, cannot be retracted each time.

The principle of operation of a reversed-sprue gate is demonstrated in Figure 6.20. The hot core in the center, through which fresh material is shot, is insulated by the frozen plastic at the wall of the sprue bushing. Air gaps along the circumference of the bushing obstruct heat transfer from the hot bushing to the cooled mold. The solution shown in Figure 6.20 functions reliably if materials have a large softening range such as LDPE, and the molding sequence does not fall short of 4 to 5 shots per minute [6.11].

If these shorter cycle times are impractical, additional heat has to be supplied to the sprue bushing. This can be done rather simply by a nozzle extension made of a material with high thermal conductivity. Such materials are preferably copper and its alloys. The design is presented in Figure 6.21. The tip of the nozzle is intentionally kept smaller than the inside of the sprue bushing. With the first shot the gap is filled with plastic, which protects the tip from heat loss to the cool mold later on.

Major dimensions for a reversed-sprue design can be taken from Figure 6.22.

The gate diameter like that of all other gates depends on the section thickness of the part and the processed plastic material and is independent of the system. One can generally state that smaller cross-sections facilitate the break-off. Therefore, as high a melt temperature as possible is used in order to keep the gate as small as possible.

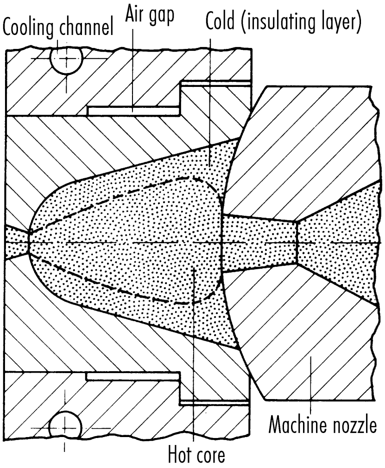

Figure 6.20 Bushing for reversed sprue [6.9]

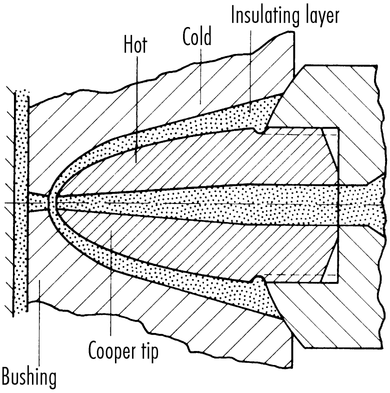

Figure 6.21 Reversed sprue heated by nozzle point [6.9]

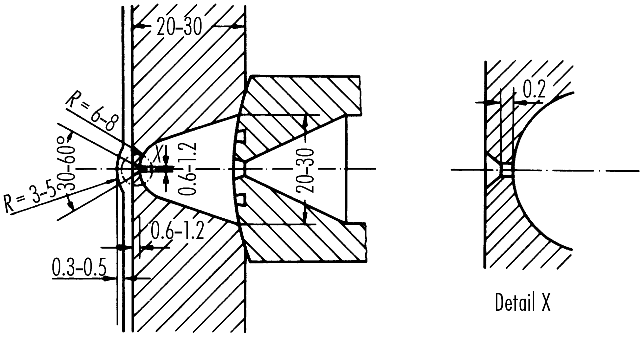

Figure 6.22 Reversed sprue with pinpoint gate and wall thickening opposite gate for better distribution of material [6.11] right: Detail X (Dimensions in mm)

A tapered end of the pinpoint gate is needed, even with its short length of 0.6 to 1.2 mm, so that the little plug of frozen plastic is easily removed during demolding and the orifice opened for the next shot.

Some plastics (polystyrene) have a tendency to form strings under those conditions. In such cases a small gate is better than a large one. Large gates promote stringing and impede demolding.

It is practical to equip the nozzle with small undercuts (Figure 6.22), which help in pulling a solidified sprue out of the bushing. The sprue can then be knocked off manually or with a special device (Figure 6.23).

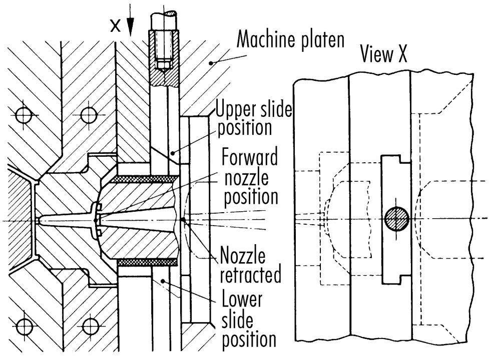

Figure 6.23 Sprue strike-off slide in a guide plate between mold and machine platen [6.12]

A more elegant way of removing the sprue from the bushing is shown in Figure 6.24. The reversed sprue is pneumatically ejected. An undercut holds the sprue until the nozzle has been retracted from the mold. Then an annular piston is moved towards the nozzle by compressed air. In this example it moves a distance of about 5 mm. After a stroke of 3 mm the air impinges on the flange of the sprue and blows it off [6.12].

6.8 Runnerless Molding

For runnerless molding the nozzle is extended forward to the molded part. The material is injected through a pinpoint gate. Figure 6.25 presents a nozzle for runnerless molding.

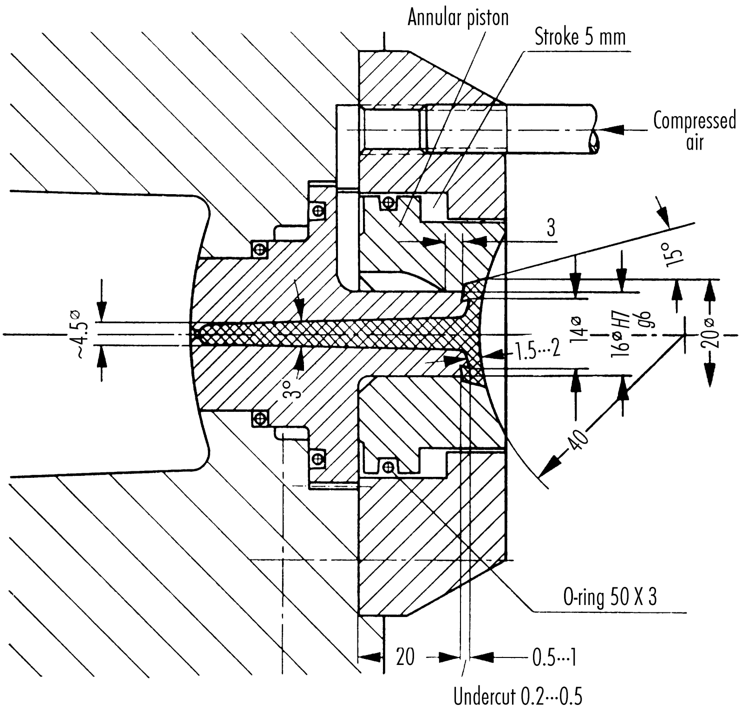

Figure 6.24 Reversed sprue with pinpoint gate and pneumatic sprue ejector [6.12] Dimensions in mm

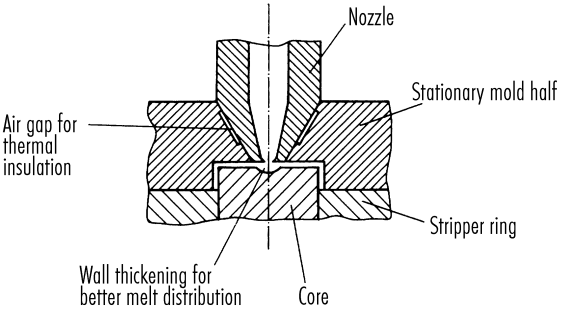

Figure 6.25 Sprueless gating

The face of the nozzle is part of the cavity surface. This causes pronounced gate marks (mat appearance and rippled surface) of course. Therefore, one has to keep the nozzle as small as possible. It is suggested that a diameter of 6 to 12 mm not be exceeded. Because the nozzle is in contact with the cooler mold during injection- and holding-pressure time, this process is applicable only for producing thin-walled parts with a rapid sequence of cycles. This sequence should not be less than 3 shots per minute to avoid a freezing of the nozzle, which is only heated by conduction. The applicability of this procedure is limited and it is used for inexpensive packaging items.