HANSER

Hot Runner Technology

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4 Heating of Hot Runner Manifold Blocks

During the transient heat-up phase the hot runner manifold block together with the solidified melt is brought up to processing temperature (melt temperature) during time t. After reaching this temperature (quasi-stationary phase), the heat only compensates energy losses due to conduction, convection, and radiation.

There are a number of different designs for heating elements. The hot runner manifold block serves as a heat source for indirectly heated hot runner nozzles or torpedoes. Optimum heating conditions are required to achieve thermal homogeneity, which means uniform temperatures in every part of the hot runner manifold block. Heat losses are the reason why this goal is hard to reach; although they can be minimized, the cannot be totally eliminated. It is essential to control the temperature of the hot runner manifold block.

Two designs of hot runner manifold blocks are available, distinguished by the type of heater:

- External heating
- Internal heating

With external heating, the heat source is placed outside of the melt channel; with internal heating it is inside the melt channel. When using internally heated systems, the flow cross section is reduced by the cross section of the heating element and in addition by insulating layer of solidified melt.

4.1 Cylindrical Cartridge Heater

Two types of high performance cartridges are available: highly compressed with surface loads up to 50 W/cm^2 and lightly compressed with approx. 6.5 W/cm^2. The metal jacket has a ground finish. The lower the surface load, the longer the service life. The design principle of a cylindrical cartridge heater is shown in Fig. 4.1.

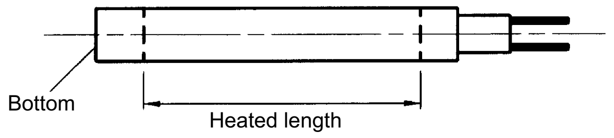

Figure 4.1: Cylindrical cartridge heater

The mounting bore for the cylindrical cartridge heater is usually finished with a H7 fit. To avoid local hot spots, which will lead to premature failure of the heater, a proper fit must be provided along the entire jacket length. The use of heat sink paste is recommended; it provides improved heat transfer and easier fitting and dismantling of the heater. It must be taken into consideration that heat sink pastes may be electrical conductive.

The mounting bore for the cartridge heater should be designed as a through hole to facilitate easy dismantling for repairs. This can be done by a tube-type drift punch, see Fig. 4.2. Upsetting of the heater bottom is to be avoided. Dismantling of cartridge heaters by pulling the connecting cables (!) is often not possible; not to mention the fact that it is technically not wise. Nonetheless, this method is still (sometimes?) used.

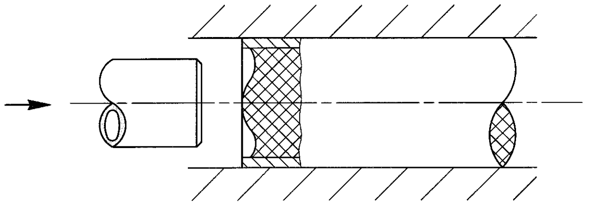

Figure 4.2: Dismantling of cartridge heater by a tube-type drift punch

Threaded cartridge heaters [1] are used for easier fitting and dismantling. Cartridge heaters should not be exposed to moisture; drying over several hours at 160 to 180 ºC is recommended.

It must be taken into consideration that the top and bottom of cartridge heaters have "cold zones". This results in a non-uniform temperature distribution in axial direction of the heater. To balance the temperature profile, cartridge heaters with a flat copper bottom are offered. In addition, the cartridge head should protrude from the hot runner manifold block by the length of the cold zone. The length of the unheated zone is specified in the suppliers' manuals.

High performance cartridge heaters have an outer diameter tolerance of $d^{-0.02}_{-0.06}$. For a diameter d = 12.7 mm and a quality of fit of H7 for the bore, this results in a maximum allowance for interference of 0.078 mm. The resulting air gap acts as an undesirable thermal insulation. Several design solutions are offered to solve this problem, see Figs. 4.5 and 4.6.

Cartridge heaters are also available with integrated thermocouples in the bottom area; however, this measures only a composite temperature between the heater and the hot runner manifold block (which may be further distorted by air insulation between both measuring points). The better alternative is to separate heat source and measuring point [2], thus providing for an "exact" measurement. Yet another alternative is offered by a heater as described in Fig. 4.3. Here, the thermocouple is positioned outside of the cartridge heater. An additional advantage of this *ceramic* cartridge heater is the fact that cold zones are avoided by a special winding technique of the heater coil [2]. The design solutions are described in Figs. 4.4 to 4.6; they are thermodynamically favourable, although difficult to machine.

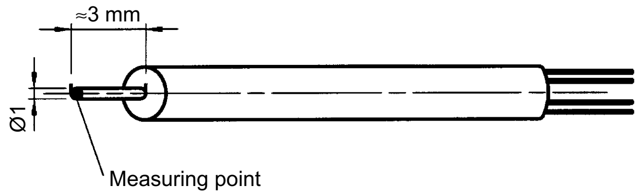

Figure 4.3: Ceramic cartridge heater with thermocouple positioned outside (Design Xintech)

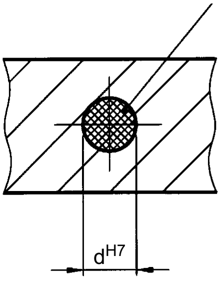

Figure 4.4: Cartridge heater mounted into solid bore; with precision workmanship efficient heat transfer is accomplished

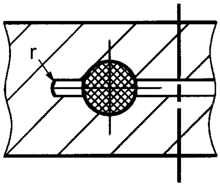

Figure 4.5: Cartridge heater mounted into split bore with locking screw; forming of contact surfaces by elastic deformation; very good heat transfer; easy dismantling of cartridge heater

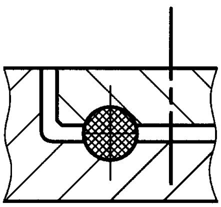

Figure 4.6: Cartridge heater mounted into split bore by a pressure bar with locking screw; very good heat transfer, easy dismantling of cartridge heater

4.2 Tapered Cartridge Heater

This type of heater has a cone ratio of 1:50, a surface load of < 20 W/cm^2, a corrosion- and acid resistant casing made of stainless steel 1.4541 (X10CrNiTi18 10), and is machined with a thread for proper mounting and easy dismantling. Tapered bores are machined with standardized taper drills and taper reamers. Appropriate finish of the tapered bore guarantees precise fitting of the cartridge heater. It also guarantees excellent heat transfer.

A special solution for cylindrical cartridge heaters are tapered thermal conducting sleeves made of brass [1]. These sleeve can be easily dismantled using a spanner.

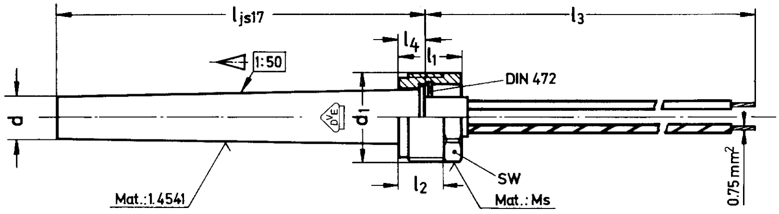

Figure 4.7: Tapered cartridge heater [3]

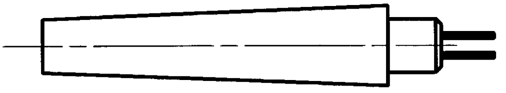

Figure 4.8: Tapered cartridge heater

4.3 Threaded Cartridge Heater

Figure 4.9 shows a threaded cartridge heater with external thread M 12 × 1 and a width across flats; the casing is made of stainless steel 1.4541, the surface load < 14 W/cm^2 [4].

The assumption that the thread will enlarge the heat transferring casing surface implies complete contact of all flanks of the screw thread. As a matter of fact, the clearance between the nut- and screw thread is going to enlarge when the connection is tightened. Only one profile of each flight is active, see Fig. 4.10. Therefore, there is no increase in heat transferring casing surface. The threaded cartridge heater has not fulfilled expectations.

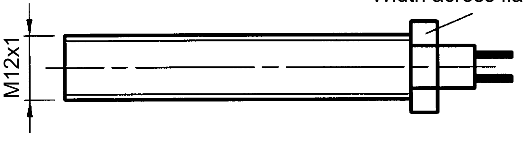

Figure 4.9: Threaded cartridge heater

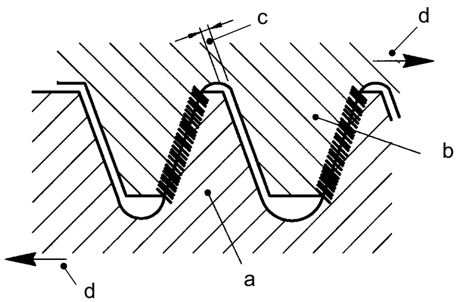

Figure 4.10: Clearance in a stressed screw connection:
The active flights (dark shaded area) are preloaded, a: Screw, b: Nut, c: Clearance, d: Power transmission

4.4 Tubular Heater

Tubular heaters have proven successful, particularly for the heating of hot runner manifold blocks, because they can be installed individually and typically have a long service life, see Fig. 4.11. They are designed to withstand surface loads between 1 and 10 W/cm^2, depending on the length of the heated zone. As long as minimum bending radii are used, tubular heaters are easily bent [1].

Tubular heaters are offered in either straight, bent, or coiled shapes. In order to optimize heat transfer, they can be cast either in aluminum, brass, copper, copper alloys, nickel, or embedded in thermal conducting cement.

Regardless of the relatively low coefficient of thermal conductivity compared to, e.g., copper, see Table 2.2, thermal conducting cement is a low priced as well as technically suitable alternative to embedding of tubular heaters. For

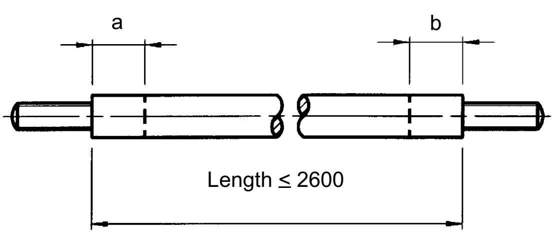

Figure 4.11: Tubular heater
a and b: Unheated zones

repairs, the thermal conducting cement and the failed tubular heater can be easily removed, which does not apply for cast heaters. It is essential to pay close attention to the processing instructions provided by the thermal conducting cement supplier. Uniform and slow drying of the thermal conducting cement is essential, because developing steam pressure will cause destruction of the thermal conducting cement, which consequently will lead to hot spots and heater breakdown. This precautionary measure applies strictly for the very first heating period.

Flexible tubular heaters allow for easy handling; manual bending is possible; no bending fixture is needed to fit the heater into the machined groove [5]. The required time is minimal.

Figure 4.12 shows two different mounting designs for tubular heaters. The milled groove should be chamfered, to minimize notch effects at the bottom, see Chapter 7. Because of its tendency to brittle, the thermal conducting cement should be covered by form-fitting reflector sheets, see Section 3.2. Thermal conducting cement is an electrical conductor.

Tubular heaters can also be calked, which creates a form-fitting/direct pressure joint. Figures 4.13, 4.14, and 4.15 show various layouts of tubular heaters. The heater layout shown in Fig. 4.14 leads to a non-uniform heat distribution in the areas 1 and 3, which may adversely effect part properties.

Statistical test evaluations for a 4-cavity hot runner mold for the production of ski bindings made of POM with a heater layout as shown in Fig. 4.14a showed significant differences in impact resistance between cavities No. 1 and 3 compared to 2 and 4. Parts produced from cavities 1 and 3 generally exhibited lower impact strength characteristics than those from cavities 2 and 4. After changing the layout of the tubular heater as shown in Fig. 4.15, impact strength values for parts from all four cavities were uniformly distributed in a very narrow range. To reach thermal homogeneity in the hot runner manifold block usually tubular heaters are mounted on both sides. If heat loss (e.g., caused by spacer disks) is minimized by appropriate design or material selection, this may not be necessary (see Sections 2.1.1 and 3.5).

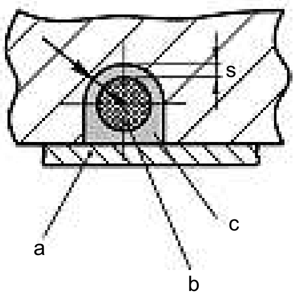

Figure 4.12: Embedded tubular heater covered by reflector sheet
a: Reflector sheet, b: Tubular heater,
c: Groove, s: Clearance

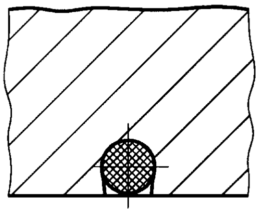

Figure 4.13: Mounting of tubular heater with tight fit, chamfered groove

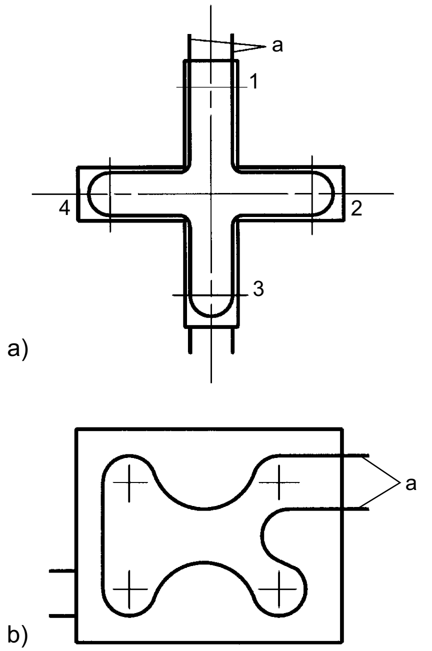

Figure 4.14: Unfavorable layout of tubular heater on top and bottom
a: Tubular heater

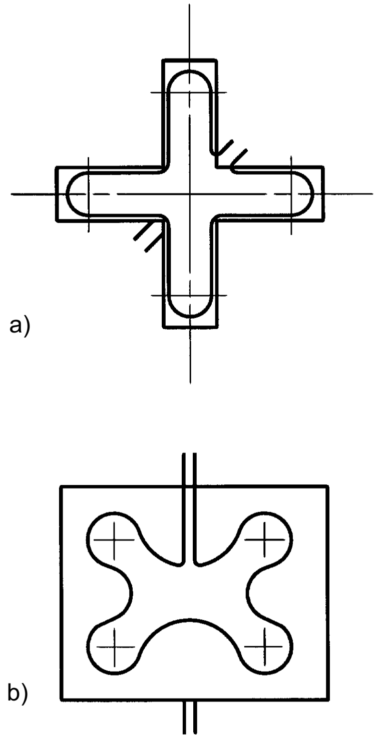

Figure 4.15: Thermodynamically favorable layout

4.5 Heater Plate

Tubular heaters are cast into a compact block – the heater plate – using copper alloy or aluminum. The heater plate is screwed on the hot runner manifold block making intimate surface contact, see Figs. 4.16 and 4.17. To minimize radiant heat losses, the surface of the heater plate should be nickel-coated (when die cast aluminum is used, surface treatment is not necessarily required).

If the hot runner manifold block is heated only in sections, the thermal homogeneity *may* be adversely effected. With identical heating capacity and symmetrical positioning of the heater plates, only one thermocouple is required (parallel connection with *one* control circuit). Heater plates must always be mounted on two opposing surfaces, see Fig. 4.18.

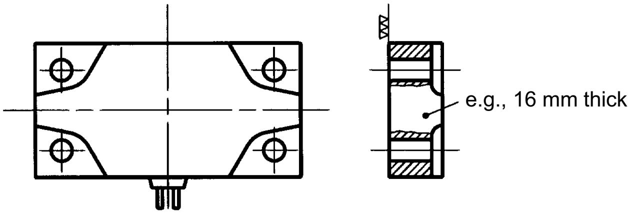

Figure 4.16: Heater plate prepared for mounting on hot runner manifold block

Figure 4.17: Heating of hot runner manifold block using heater plates (Design Mold-Masters)
a: Heater plate

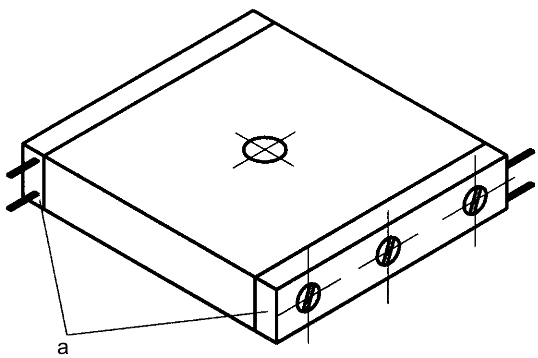

Figure 4.18: Heater plates bolted on hot runner manifold block

4.6 “Thick-Film”- Heating Element

Similar to heater plates, so-called “thick-film” heating elements [6] are screwed on to the hot runner manifold block making intimate surface contact, see Fig. 4.19, which ensures good thermal homogeneity. The geometry of the heating elements can be adapted to follow the contour of the hot runner manifold block; cut outs and holes can be relieved. The heating elements are suitable for temperatures up to max. 550 °C. Moisture absorption of the heating elements is negligible. The surface load of the heating conductors on stainless steel substrates is approx. 11.5 W/cm^2.

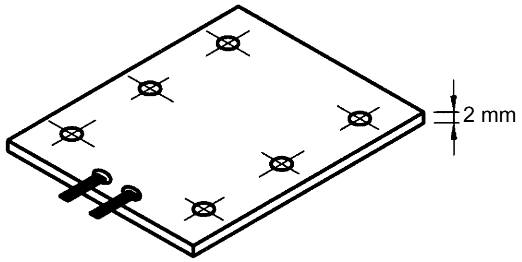

Figure 4.19: Thick-film heating element

Note: The name “thick-film” associates “large” dimensions. In fact, the thickness of the heating elements is typically only approx. 2 mm. Figure 4.20 shows a contour tracing design of a heating element suitable for a 4-cavity hot runner mold with relieves for the four hot runner nozzles and the distributor bushing. The surface of the heater element should be coated with an aluminum- or nickel layer to minimize radiant heat loss. Bolting of a (thin) aluminum sheet to the heating element is a practice-proven solution. Relieves in the area of electrical connectors must be provided.

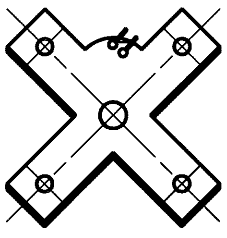

Figure 4.20: Contour tracing design of a thick-film heating element [6]