Fine Adjustment of the Melt Flows in the Hot Runner by Means of Melt Rotation

What Can You Do if Shear Effects Upset Natural Manifold Balancing?

In injection molding with multi-cavity molds, shear-induced viscosity differences in the flow channels of manifold systems can result in the various mold cavities producing molded parts with different properties – in spite of natural balancing and optimum mold quality. This situation can be remedied with a fine adjustment of the melt flows, achieved using melt rotation.

If you look at the key data for our example – the inner shell of a double-walled thermal mug made of PC (**Fig. 1**) – everything seems to have been done correctly:

- A mug-shaped, rotationally symmetrical molded part,
- central gating with melt entry via a naturally balanced valve gate hot runner system,
- a mold with four cavities, well designed and manufactured to a high level of quality.

The risk of manufacturing problems would appear to be very small. In practice, however, the picture is very different.

Although all the cavities are filled at the same time, the required concentricity cannot be achieved. Worse still, the individual mold cavities produce varied molded parts, in spite of high manufacturing accuracy, uniform temperature control and adequate mold stability. Each cavity generates a molded part with an indentation in a different place. This inaccuracy, which can only be determined by precise measurement, is particularly serious because the molded parts will subsequently be welded to the outer shell of the thermal mug. This requires the two molded parts to have the same shape and the same concentricity.

The outer shells, which are also manufactured in a 4-cavity mold, display the same fault. After various measurements, a pattern was detected and it was at least possible to safely weld similarly deformed molded parts to each other – this did, however, require a lot of extra work.

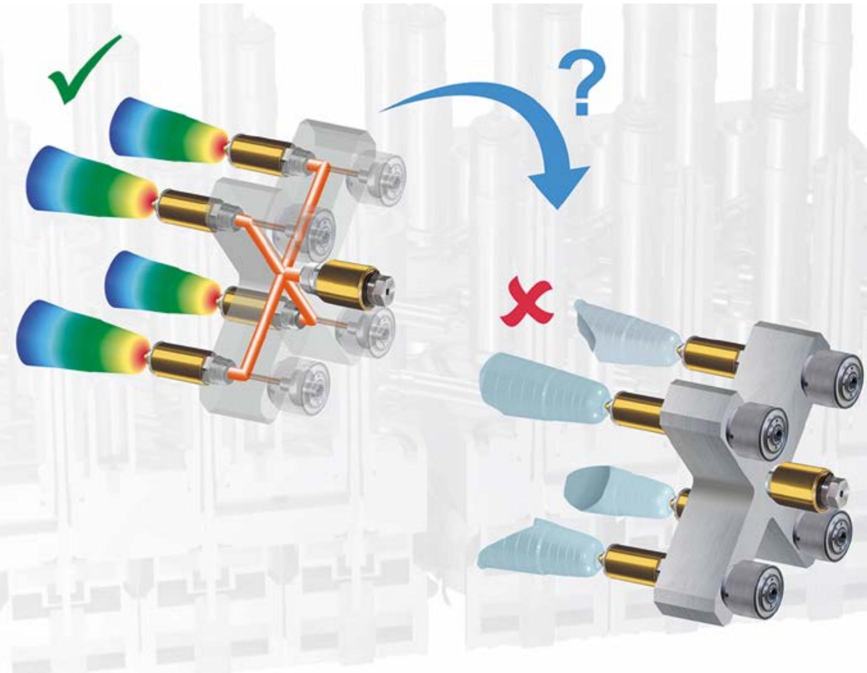

Fig. 1. Everything is correct, but it still does not work: a rotationally symmetrical molded part, a naturally balanced valve gate system, high mold quality – and yet the cavities are filled unevenly, with a serious impact on the required component quality (© Incoe)

Cause of a Failure of Uneven Filling – in spite of Natural Balancing

As a result of partial filling of cavities, the cause for varying concentricity arising out of individual cavities is becoming evident: in spite of even melt feed through the naturally balanced manifold system and in spite of the symmetrical configuration of the cavities, the melt flows faster to the side facing outwards whereas it lags behind on the side facing the center of the mold. If, as in our example, core shift, uneven temperature control or lacking production quality can be completely or extensively ruled out as a cause of the melt flowing faster sideways, then the question arises whether the effects of shear inside the melt may be the cause.

For a full understanding of this phenomenon we need to examine what is happening in the flow channel of the manifold system, or more specifically in

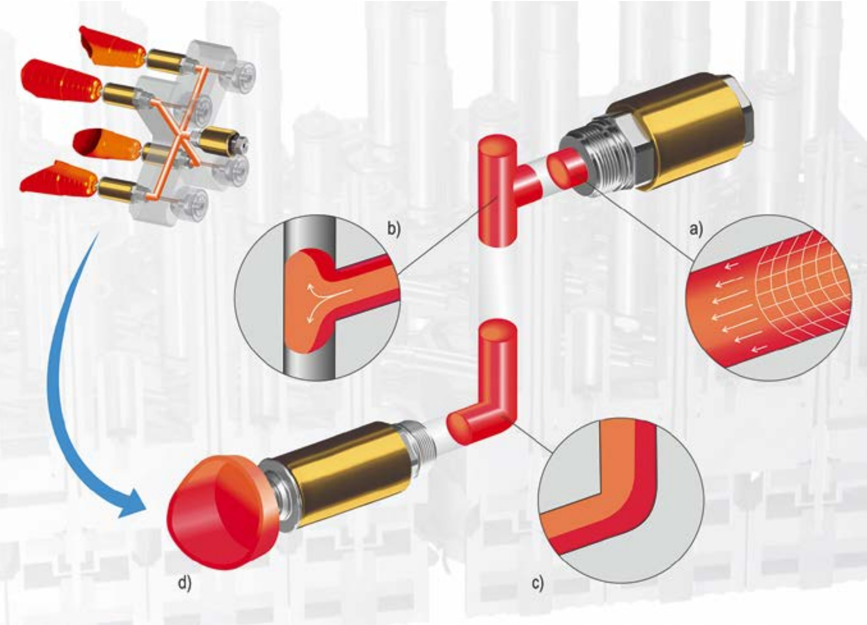

Fig. 2. Cause of shear: the shear and speed profile (a) typical for laminar flow is reduced as a result of distribution (b) and deflection (c) to one side of the flow channel. This has the effect of allowing a non-homogeneous melt flow to reach the cavity the less viscous half (d) of which flows faster; orange: lower shear, red: higher shear (© Incoe)

one of the four branches of the manifold (**Fig. 2**). This is where the laminar flow typical for thermoplastic melting occurs, i. e. the melt layers in the middle of the channel flow at the highest speed, whereas the speed of the other layers decreases approaching the channel wall (**Fig. 2a**). The melt layers, which are situated between the faster flowing melts in the middle and the slower layers at the edge, are sheared and heated as a result of this. A shear profile occurs over the cross-section of the flow channel with the corresponding effect on the characteristics of the melt: a ring with more pronounced shear, thus hotter and more viscous melt, occurs in the flow channel.

This is the typical material behavior for laminar flow of thermoplastic plastic melts and is not a problem in itself. However, a problem can arise out of this in the distribution of melt flows – something which unavoidably occurs repeatedly in manifold systems (**Fig. 2b**). The shear profile is then displaced to one side of the flow channel and a melt flow occurs one half of which is slightly less viscous than the other half (**Fig. 2c**). Thus if a non-homogeneous melt flow reaches a cavity, then as may occur in our example application, the melt can flow faster on one side thereby degrading the quality of the molded parts. Every subsequent distribution and deflection of the melt flow is able to further displace the shear profile.

As illustrated in the example of an 8-fold hot runner system in **Figure 3**, after subsequent distribution of the melt flow inside the manifold, branches are able to form with varying levels of viscosity. As a result, the various cavities are fed with melt with varying levels of viscosity, which in our example leads to the outer cavities being filled first.

How then Does Melt Rotation Help?

The principle of melt rotation can be used to counteract the uneven filling of the molded part. The melt rotation method is based on the Meltflipper technology developed by the company Beaumont Technologies Inc., Erie, PA/USA. In simple terms, this technology makes it possible to rotate asymmetrical shear profiles to a favorable position following the distribution of melt flows so that a symmetrical shear profile arises out of this upon »

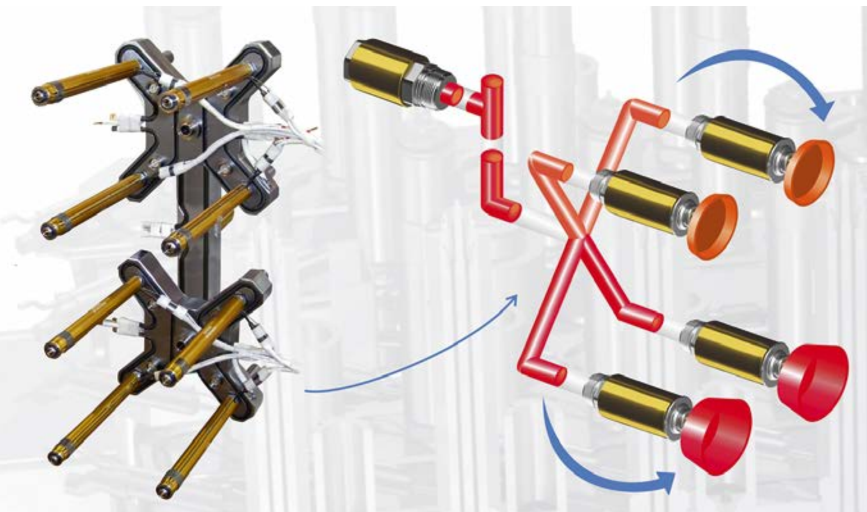

Fig. 3. Potential scenario in the 8-fold hot runner system: as a result of distributing the melt flow with an asymmetrical shear profile, branches form in the manifold with different levels of viscosity – the outer cavities are thus filled first in this instance; orange: lower shear, red: higher shear (© Incoe)

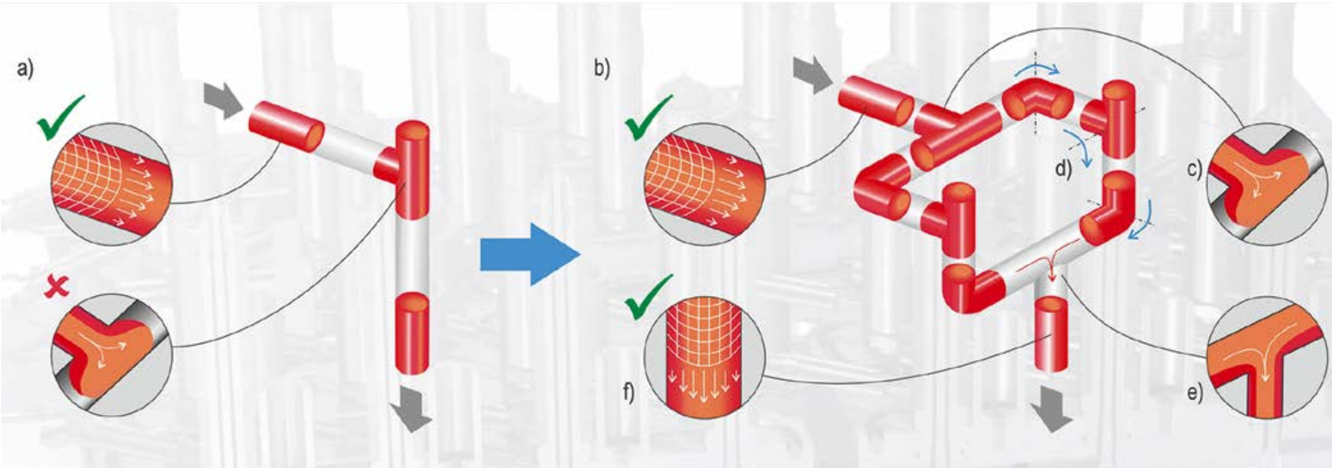

Fig. 4. The conventional runner layout (a) is significantly easier compared to the version illustrated here in the model for melt rotation (b). However, the uneven shear profile (c) caused by the distribution of the melt flow can be converted into a symmetrical profile (f) by rotating the flow cross-sections (d) and subsequently amalgamating the melt flows (e); orange: lower shear, red: higher shear (© Incoe)

amalgamation of the melt flows. For this purpose a channel geometry is introduced into manifold systems at the corresponding points that is able to fulfill this task. Thus, in the case of the conventional runner layout (**Fig. 4a**) a more complex configuration is made out of the simple T-shaped intersection of the flow channel for deflecting and homogenizing the melt flow (**Fig. 4b**).

This design concept here is illustrated based on a model built out of straight cylindrical channel sections – and thus ones that "are built" quite large – so that, wherever possible, the processes can be exhibited in the runner. In practice, a significantly more compact design is hereby implemented with, for example, curved channels.

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This is how the basic principle of melt rotation operates: the uneven shear profile (**Fig. 4c**) caused by the distribution of the melt flow is converted into a symmetrical profile (**Fig. 4f**) by rotating the flow cross-sections (**Fig. 4d**) and subsequently amalgamating the melt flows (**Fig. 4e**). Depending on the application and plastic, different runner designs can, of course, be used here, which may vary accordingly from the principle illustrated here.

Quality Assurance also in the Follow-up Process

In the case of our thermal mug, following a detailed inspection and evaluation of all possible influences everything points to the fact that the uneven filling of the cavities was caused by the shear effects in the flow channel as described above. The use of a hot runner system, which has been fitted with a melt rotation insert (type: Opti-Flo, manufacturer: Incoe International Europe, Rödermark, Germany) (**Fig. 5**), then redressed the situation accordingly.

The quality of the melt flows in the individual channels was homogenized by creating a uniform and symmetrical shear profile. This lead to all cavities being filled with the same shape simultaneously as a result of which the required concentricity could be attained. The ensuing process step of welding with the outer shell, which has in the meantime also been optimized by means of melt rotation, could then be implemented without any problems.

The "thermal mug" example application shows how the quality of the molded parts in terms of required dimensional accuracy can be optimized using melt rotation. Both inner and outer shell could then be produced in a stable process to the required concentricity. As a result, the subsequent welding ran smoothly, any overhead associated with the rejection of non-matching components could be completely disregarded. The reject rate also dropped significantly with this process optimization. In general, it was demonstrated that the balancing of manifold systems with integrated melt rotation operates more stably and with greater resistance, that is the process window is made larger, production is easier to handle and it is even feasible to achieve a reduction in the cycle time.

Melt Rotation – Balancing Solution for All Applications?

Viewed from the perspective of the picture painted above, the method of melt rotation almost seems to act like a panacea for all balancing tasks and applications – but it this actually the case? Sadly – most definitely not (always)!

It must first of all be clearly stated that the method of melt rotation should be viewed as a fine adjustment of the melt flows, which is always based on the fact that all interacting sub-sections of the injection mold have been effectively laid out and designed and combine effectively with one another. Effects due to errors such as poor manifold balancing, uneven mold temperature control, core shift due to excessively low stability, excessively high heat transfer due to inadequate thermal isolation of the hot runner system, etc. cannot be canceled out by melt rotation.

In other words, melt rotation as a means of optimizing manifold balancing always is compementary to an effectively combined overall package of measures to promote the highest quality. If, as in our example application, with an existing mold consideration is now being given to switching to a hot runner system with integrated melt rotation because the required quality of the molded parts is not being attained, then it is critical to examine beforehand how great the influence of the other assemblies and functional areas of the mold is. Only when it is evident that shear is the dominant factor in this process and other errors can be ruled out and/or rectified, is making the switch then a worthwhile consideration.

Similarly, as with every production planning exercise a cost-benefit analysis also needs to be used as the basis for implementing melt rotation. Hot runner manifolds that are conventionally balanced – and are thus less expensive – are successfully deployed in countless scenarios and make their contribution to the attainment of high quality of the molded parts – why therefore use melt rotation? The term "fine adjustment" can also be used here by way of clarification. A fine adjustment is always applied wherever a certain level has been attained with the aim of achieving a higher level and exploiting further possibilities, which were not previously possible or apparent.

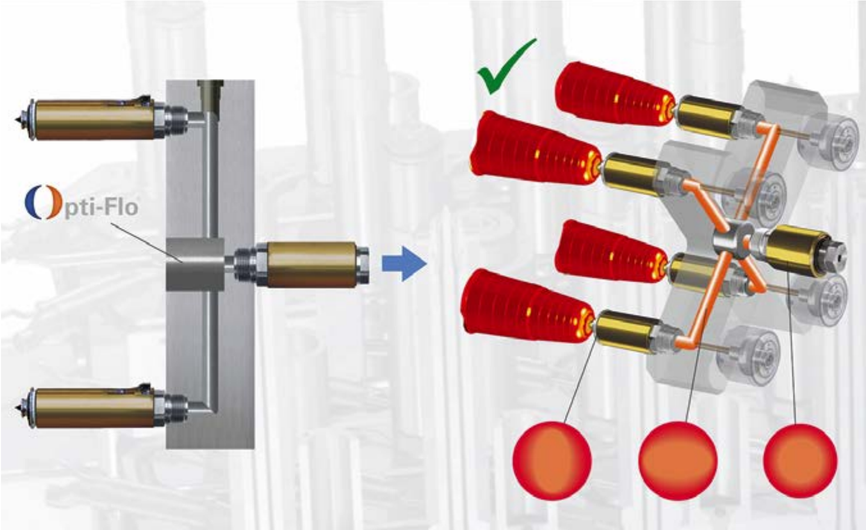

Fig. 5. The required high quality of the molded parts is achieved by evenly and simultaneously filling cavities – facilitated by a hot runner system deploying melt rotation (Opti-Flo), which is responsible for symmetrical shear profiles in all channels; orange: lower shear, red: higher shear (© Incoe)

Where High Precision in Large Quantities is Required

The areas of application for hot runner systems with integrated melt rotation, of course, fall to areas where, for example, high precision is required in very large quantities, such as in the electrical engineering example applications shown in **Figure 6**. In general terms, the method of melt rotation can be used as an investment in enhanced quality and efficiency to justify the ever-rising demands and increased cost pressure from the market using fine adjustment of melt flows in the hot runner. ■

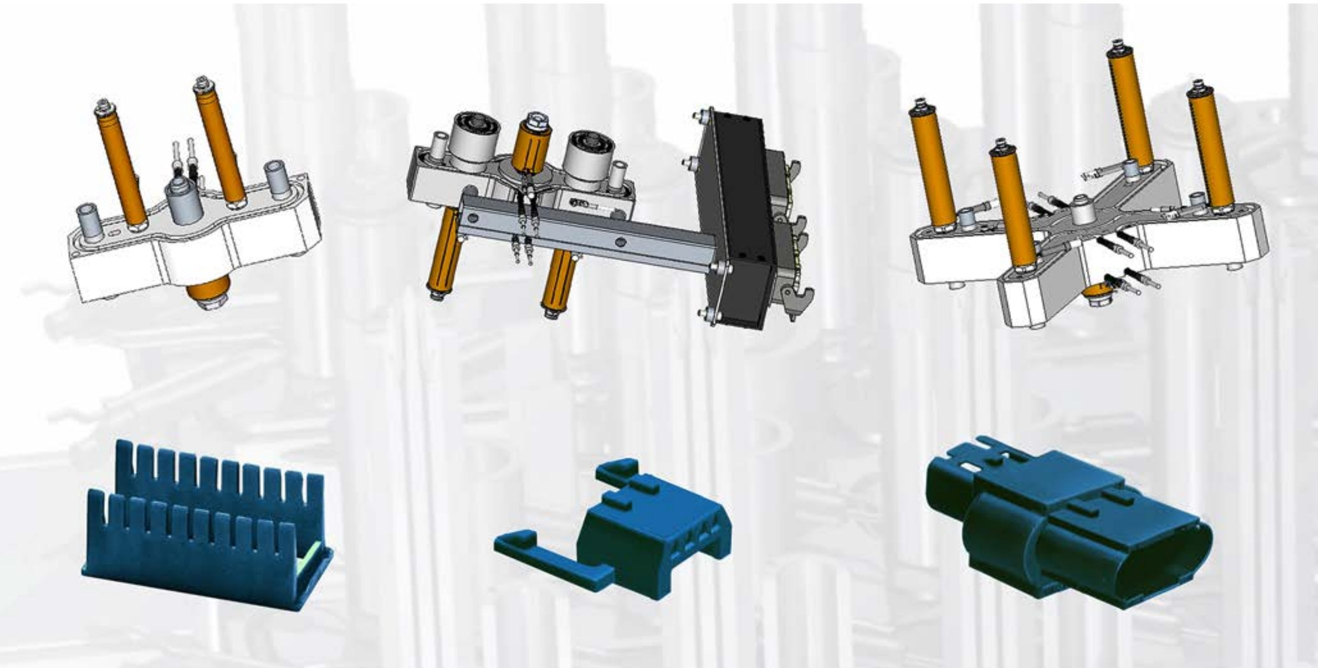

Fig. 6. Examples of electrical engineering components in the production of which hot runner systems with integrated melt rotation are used (components illustrated and not to scale) (© Incoe)