Testing the Processing Limits of Modified POM Copolymer

Looking over the Application Engineer's Shoulder

Nowhere are the demands imposed on materials higher than in the area of medical technology. That is understandable because, after all, what is ultimately at stake here is the patient's health. But any materials manufacturers seeking to use hot runner technology to process polymers in compliance with strict directives and differentiated legal regulations also need the expertise possessed by the hot runner manufacturer's application engineers.

The coronavirus pandemic has provided a vivid demonstration of the importance of plastics. Protective equipment, syringes, tubes, respirators and test swabs – all these products made with plastic are on everyone's lips at the moment. Like others, the makers of medical devices have to comply with strict legal regulations which are frequently challenging, such as the special requirements imposed on the raw materials they employ. In this regard, materials manufacturers have for the most part tended to optimize their plastics specifically for use in the healthcare sector, targeting product consistency and conformity, among other things. Before these types of polymers can be used in medical technology applications, numerous approvals have to be obtained, e.g. a listing in Drug Master File No. 11559 is needed where distribution is sought in the USA.

One testing facility in the USA for such materials is operated by the United States Pharmacopeial Convention (also known as USP). The polymers submitted there for testing have to meet various specifications and it is up to the materials manufacturers to find out the details surrounding approvals and test facilities. By contrast, the actual processing of the polymers requires materials manufacturers to share experiences with the mold makers or hot runner manufacturers. That is precisely where the expertise of Günther Heisskanaltechnik application engineers comes in.

Günther has recently installed two new injection-molding machines for customer trials in its technical center. © Günther

Getting the Processing Right

VDI 2017 guideline "Medical Grade Plastics" sets out the requirements imposed on medical grade plastics for processing. An important keyword here is consistency, more precisely of formulation, components and manufacturing process. Again, the materials manufacturer is challenged to demonstrate, for example, consistency of formulation, because plastics converters and OEMs must be able to count on long-term deliverability and predictability.

"When you have a material that has been carefully selected and tested and also meets all the complex regulations governing medical grade plastics and the requirements of the intended application, any sudden disruption to deliveries or unannounced changes in production can have devastating consequences," says Jörg Essinger, Head of Application Technology and Service at Günther Heisskanaltechnik. "As hot runner systems are the predominant choice for the production of certain high-volume medical articles, our application engineers are very often called upon to share their expertise – as is the case now regarding the material tests being conducted for Celanese, a global supplier of specialty materials," he adds.

Identifying and Implementing Optimization Potential

The application engineers at Günther Heisskanaltechnik are generally process mechanics who have received training in plastics and rubber technology, and have specialized in injection molding. "Some of our colleagues have then gone on to complete their training as industrial foremen or technicians," says Essinger, stressing the skill levels on hand. "Our applications engineers are expected »

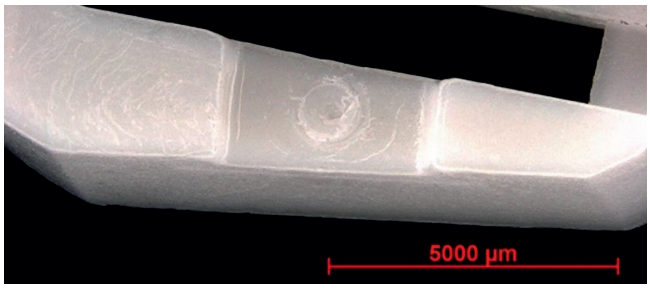

Fig. 1. Example of delamination near the gating point in the case of Hostaform POM Slidex. © Celanese

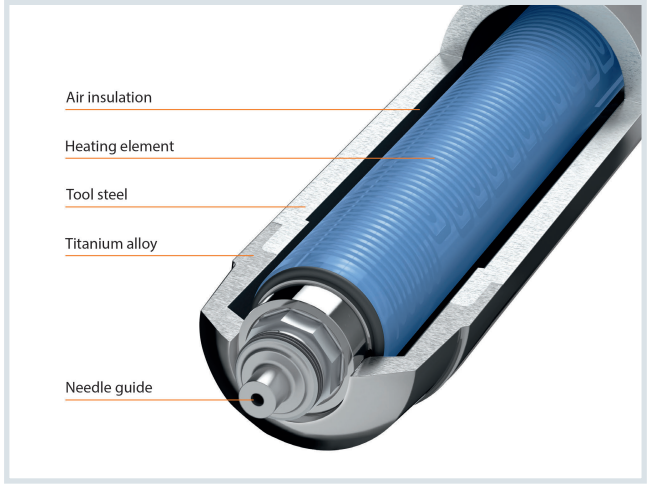

Fig. 2. Cross-sectional view of hot runner valve gate nozzle 6NHF50LA with BlueFlow thick-film heating element. © Günther

not only to know about injection molding and the processing specifics of all kinds of thermoplastics, but also to be well versed in mold technology and, of course, hot runner technology."

To the same extent that customers' application areas are diverse, molds and hot runner systems differ in their design. In addition, the applications engineer must also know how to process liquid silicone (LSR) using cold runner systems. Essinger continues, "And then there are requirements relating to the closed-loop technology for controlling the hot runner system and the open-loop technology for operating the electric valve gate systems, for example." Experience shows that, by comparison, the work of applications engineers in injection molding shops is more focused on the field of application, namely the selection of polymers, the types of applications and thus also the design of the molds and hot runner systems used by the customer.

"We are also often called in to identify and implement the optimization potential residing in materials, tools and processes," says Essinger, rounding off the activity areas of the applications engineers at Günther. "Naturally, there are customers who know all about the polymer they want processed and about the processes themselves and who have experience of optimizing their own processing methods. But there are also companies, for example, who come to us with new applications that require new types of polymer that they have little experience of or who up to now have only ever used open hot runner systems and now have to take a mold featuring valve gate technology and ready it for series production. It's no surprise that they don't have the necessary experience."

Wide Range of Hot Runner Designs

The fact that materials manufacturers often only have a limited number of proving molds featuring hot runner nozzles enables Günther to bring its technical center into play. After all, if you want to test out a wide range of different hot runner designs, it makes sense to conduct a series of trials. Just early last year, Günther maintained its position at the forefront of technology by investing in two new injection molding machines (**Title figure**): an Allrounder 370 A with a clamping force of 600 kN and an injection unit 100 (as per Euromap) for processing thermoplastics and silicone and an Allrounder 520 A with a clamping force of 1500 kN and an injection unit 400 (manufacturer in each case: Arburg).

Since the special regulations governing the medical technology sector have to be taken into account by the part designer and manufacturer in particular, but above all by the materials manufacturer, Celanese wanted to know how using different hot runner nozzles (valve gate or open nozzle with heat-conducting tip) to process a material would affect the quality of the molded part. "Hostaform POM Slidex is a tribologically modified POM copolymer that is available in an industrial and a medical grade. This is a highly shear sensitive POM. In other words, delamination can occur during processing," says Essinger, explaining the rationale for the test series (**Fig. 1**). "Celanese's experience was that both melt compounding – especially as regards temperature, screw speed and back pressure – and injection time exert a substantial influence on the delamination effect." The tribologically modified POM copolymer was being considered for a medical article to be produced in high volumes.

Agreement on how the trials would be conducted was reached in advance with the materials manufacturer. This largely concerned points that are a standard feature of material sampling, such as maximum and minimum hot runner temperature, pressure losses in the hot runners and corresponding filling studies, along with a determination of the maximum holding-pressure time for valve gate systems. The aim of the tests was to explore the limits of processing this grade of Hostaform using different hot runner nozzles. The resulting insights would subsequently form the basis of a processing recommendation. The optimal parameter settings would then be used to process the polymer for a defined period of time and so to assess its process capability.

The Goal: Robust Parameters Worthy of Discussion

Agreement having been reached on which hot runner nozzles (with valve gate or open) and test specimen to use, the test mold was mounted and set up on the injection-molding machine. In this case, it was a 2-cavity test mold with a disc-like test specimen having an injection volume of 1 cm^3 and a wall

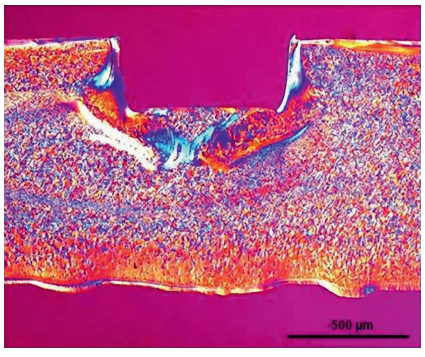

Fig. 3. The microtome section of the test specimen made of POM (Hostaform) reveals an inhomogeneous microstructure in the form of a cold plug near the gating point after closing of the needle. © Celanese

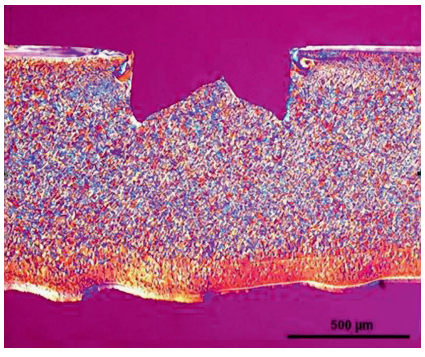

Fig. 4. The microtome section of the specimen reveals a homogeneous microstructure near the gating point after closing of the needle following optimized process control. © Celanese

thickness of 2 mm. Günther supplied 6NHF50LA hot runner valve gate nozzles (**Fig. 2**) and 5SHF80 open hot runner nozzles for the tests. "These nozzles feature a thick-film heating element which ensures a homogeneous temperature curve in the nozzle and provides adequate power concentration in the gating area. To test whether the size of the gating point in the valve gate nozzles influences the process, a needle guide with a gating point diameter of 1.0 mm was selected for one test variant and a needle guide with a diameter of 1.6 mm for the other," says Essinger, explaining the experimental setup.

To obtain robust parameters worthy of discussion in respect of the above-mentioned test goals, the tests were conducted at different melt, hot runner and mold temperatures as well as different injection times and injection points. Before each change, the parameters were reset to the default setting as doing so would enable the influence of each parameter on the quality of the component to be determined. The dwell time of the melt in the hot runner and especially in the injection molding machine unit was also determined.

The background to this is that very often the dwell time of the melt in the injection unit is too short, thereby preventing homogeneous preparation in conjunction with sufficient heat transfer to the melt. The consequence is that the melt may have different viscosity ranges, even to the extent of containing unmelted pellet particles. That, of course, has a substantial impact on process stability and part quality. "Although these are rather complex test parameters, they did provide insights into what constitutes a stable injection molding process as well as into the process capability over a specified period, usually of three hours, for Hostaform POM Slidex," says Essinger in summary.

The evaluation of the tests conducted with the valve gate nozzle reveals, for example, one case of an inhomogeneous structure in the form of a cold plug near the injection point. This occurs because the holding pressure time is too long and the mold wall temperature is too low when the needle closes (**Fig. 3**). After the process control was optimized, a homogeneous structure was seen in this area (**Fig. 4**). The holding pressure time and the mold or melt temperature exert more of an influence on this behavior than the size of the gating point.

The specialists from Günther then discussed the results with Rochus Hiekisch, who is an expert on injection molding processing and hot runner technology at Celanese. Says Essinger, "You can think of it as a mutual exchange of experience in which the polymer manufacturer contributes his knowledge of materials while the applications engineer from Günther contributes his decades of experience in hot runner systems and process technology."

Polymer Know-How and Contextual Expertise Combined

The applications engineers at Günther possess the requisite contextual expertise – i.e. the ability to find and make connections. Because only those who are able to open up contexts and make them accessible to others will find solutions. "You don't acquire such contextual expertise simply as you go along," explains Jörg Essinger. "Our applications engineers draw not only on a wealth of knowledge about machine and process technology, but also on comprehensive expertise surrounding the physical and chemical properties of polymers. And above all, they are in a position to comment on the interactions between material, design and processing. Many have been with us for decades, and some of them did their training here."

Managing Director Siegrid Sommer sums up the position of the applications engineers at Günther: "The world of polymers is not unambiguous; rather, it is diverse and ambiguous. That's why it's important for the material developer and the product developer to get together and for the downstream user or processor to meet up with the toolmaker. And, this should be done in a setting that is conducive to a genuine exchange of knowledge. Questions are not only permitted but are also heard and taken seriously. Because all progress comes from critiquing things." ■

Info

Delamination Effect

Delamination is the term used to describe the splicing or flaking of surface layers on injection-molded parts. The cause of this poor bonding between the polymer layers is a combination of excessive shearing of the relatively cold compound and mold cooling. In the case of semi-crystalline thermoplastics, this can lead to the formation of layers having different crystal structures, and in the case of amorphous thermoplastics to segregation in the melt/additive/pigment mixture.

Text

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