Challenges & Solutions for Micro Injection Molding

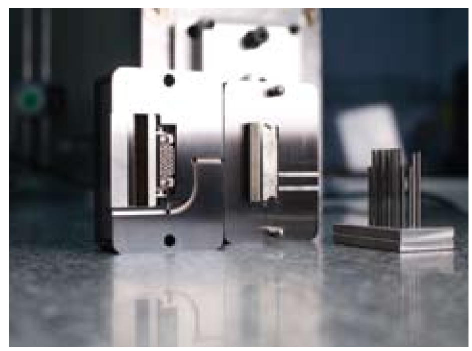
Being mindful of the challenges and obstacles that can impede success when specifying micro injection molding processes can aid designers planning to use this option. This article provides a comprehensive look at many of the areas of concern for component fabrication at this size and also offers solutions to the problems.

By Peter Szewczyk, BSME

Micro and nano products pose significant engineering and manufacturing challenges from the standpoint of tool design, production, and processing to ultimately achieve a quality part ready for end use. With molded parts designed to extremely precise tolerances, thin walled areas in the range of 0.003 in., and the need for nearly sharp corners, it requires engineering and manufacturing to approach each tool in the proper way depending on the particular customer's needs.

The critical factor for engineering of nano tooling begins with a breakdown of tooling components and the materials required. Materials used range from S-7 for its overall good shock resistance and high hardness attainability to H-13 for its high temperature strength to O6 for its excellent metal-on-metal wear resistance.

A holemaking EDM used for mold tooling production



A mold tool designed and manufactured by Dynomax Inc. for micro injection molding

Although high strength materials are used, micro- and nano-scale tooling components are still fragile. Engineers must be aware of critical components that are susceptible to damage and allow for provisions to repair the tool in case of damage during molding production runs.

Moldflow Analysis

Engineers should incorporate the use of computer aided analysis software, commonly referred to as moldflow analysis, to run flow simulations on micro and nano molded parts to verify the design and processability of the tool. At this point, data is observed to determine proper filling of the cavity, locating potential air traps, and ensuring that weld/knit lines won't form in critical areas, which can reduce the structural integrity by as much as 80%–the nominal strength of the part.

Moldflow allows analysis of values such as shear rate, shear stress, and residual stress, which are highly important factors in the processing of a quality thin-walled part. Engineers use a set of process parameters in their simulations such that residual stress is minimized. Residual stresses in molding cause deformation as the melted material gets solidified too quickly and then tries to relax to its previous size. This is usually characterized by injecting the material too fast, followed by a rapid cooling cycle.

Heat and Pressure

Nano- and micro-scale molding can be categorized as precision high-speed injection molding since injection speeds can be 10 times as fast as conventional injection molding. High shear rates, pressure, and heat must be used to counteract the restrictive flow path of thin walls, thereby allowing cavities to fill before the material solidifies.

These extreme conditions bring many processing issues, which in turn, gives a very narrow processing window where even the slightest deviation can cause a bad part.

With the increased shear rate, additional heat can be applied to the melted material without increasing mold temperature. However, care must be exercised so as to not exceed material specification for shear rate, as that can lead to material degradation during flow. As shear rates increase, so do the stresses within a material. If the shear rates reach a value above the critical shear stress point, the primary bonds in the material can be jeopardized.

For example, if too high of a shear stress rate is reached with a material like LCP that has a 30% glass filler, the molecular chains can tear.

In general, for glass-filled resins, the minimum fiber length must be assumed in order to retain the material structural properties. This means that if a resin has a glass filler with fibers 0.003 in. long and the mold part has a 0.003 in. wall thickness, serious problems could occur.

Common Challenges

With LCP molded nano parts, a commonly encountered problem is cracking or crazing. This is simply defined as a fracture in the molded part, yet it cannot be so easily remedied. As previously mentioned, shear heating is an important processing aspect of nano injection molding. By increasing the injection pressure and fill rate, internal stresses can be created that exceed the tensile strength of the material and cause the part to crack as it continues to cool after ejection.

Another factor contributing to the cracking of thin-walled components is initiated by the ejection force as it extracts the part from the tool. Elements such as undercuts, rough surface conditions, and/or no draft may cause this. In precision injection molding of nano parts, tight tolerances are of the norm–sometimes requiring features to be held within ±0.00025 of an inch, which virtually eliminates potential to draft cavity features.

Specialized Equipment

To overcome this, it is important to ensure that surface roughness is as smooth as possible. This begins with the manufacturing phase of tooling known as electrical discharge machining (EDM). By utilizing high density carbon electrodes with grain sizes of less than 1.0 µ, the best possible surface finishes and near sharp corners can be produced–essential requirements for high precision tooling. It is also very critical to polish all molded surfaces in order to reduce the coefficient of friction during part extraction and to enhance molded part appearance.

Additionally, to overcome problematic elements such as deformation and cracking common with nano molded parts, special processing equipment can be utilized on injection molding machines. In order to provide precise and better control of the material during melt and injection phases, a unique 8.0-mm injection screw unit can be employed. This ensures a uniform composition of the melted material before injection, along with minimal shot volumes and significantly shortened dwell times.


A selection of micro and nano parts produced by Dynomax Inc.

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Conclusion

By taking advantage of different cutting-edge technology resources available, manufacturers are able to produce quality precision parts exceeding customer requirements. From engineering and moldflow analysis to precision manufacturing and specialized processing techniques, they contribute to ongoing advancements in the growing world of nano components.

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