Top tips for optical moulding

Production of optical parts is a challenging task. Thomas Brettnich explains the common pitfalls and how to avoid them

Transparent plastics are used today in a wide variety of applications requiring high optical quality, such as flat, thin wall components for lamp covers, electronic device displays and headlamp lenses. Increasingly, however, plastics are now replacing glass in far more technically demanding industrial optical applications such as thick-walled optical fibres, prisms or lenses.

Industrial optical designers in fields such as sensor engineering, luminaires and automotive lighting are attracted to plastics for their light weight and the greater range of forming options, which make economical production in high volumes a reality. However, achieving the level of optical precision required for these demanding applications is a challenging task. Optical function can be compromised by inaccuracy in the contour (the shape accuracy, waviness or roughness of the moulding), while internal stresses can affect transmission, extinction and dispersion of light.

Injection moulding polymer optics requires a high degree of precision in terms of mechanical engineering, tooling and process engineering, in combination with a high level of reproducibility and cleanliness of the production environment. The injection moulder must possess the highest levels of processing know-how in order to determine the appropriate process-relevant parameters and tolerance limits, and to establish permanent quality control procedures.

For smaller to medium quantities, optical lenses are usually manufactured using conventional injection moulding technology with a maximum of eight cavities connected via a cold runner system. The cross sections of the manifold and gate are matched to the thickness of the lens so as to maintain an effective holding pressure for as long as possible. This results in cross section dimensions of up to 25mm. Holding pressure times of up to eight minutes and cycle times of up to 20 minutes may be required with thick-walled optical parts to achieve a high level of precision of the optical surfaces.

New generation lighting technologies such as LEDs are driving demand for optical quality components

From a mould filling perspective, to prevent jetting effects, flow marks and silver streaks in the often voluminous cavities, it must be possible to implement injection profiles with injection speeds of a minimum of 1 mm/s and with very smooth transitions between the individual speed levels.

Achieving the very high levels of quality required for many of the new polymer optic applications requires the use of more complex and non-standard moulding techniques. Machine controls should, therefore, provide the option to integrate processes such as compression moulding or multi-layer processing. It must also be possible to trigger external sequences, such as variotherm (heat-cool) mould temperature control, via

Large diameter feed channels are often required to produce high quality thick wall optical components

interfaces which can be programmed at freely defined stages of the moulding cycle.

Compression moulding technology, in particular, requires a certain degree of freedom in terms of programming, as selection of the point in time, pressure and speed of the embossing movement has a considerable influence on the optical quality of the component.

The multi-layer process is a new technology that manufactures thick-walled lenses in several layers. Application of a final thin surface layer enables high levels of surface precision to be attained while the dwell times of the melt and cycle times can be significantly reduced. The technique can be implemented on an injection moulding machine using just one injection unit. However, as with the tandem moulding technique, it must be possible to programme sequences in such a way that several injection and holding pressure processes take place during a cycle. (*Injection World* will look at multi-layer processes in more detail in a future edition)

Handling optical polymers

The processing of optical materials starts with the inspection of the incoming plastic granules. Once this material has been approved and released for production, it must be subjected to proper pre-drying in terms of time and temperature. In addition, the feeding and drying systems should be dustproof and should not have an abrasive effect on the material or vice versa. Dust collection systems may be included just before the material enters the filling zone of the injection moulding machine to remove any particles of dirt that may be present. Particulate contamination can lead to 'black spots' being produced in the transparent components.

Material feeding characteristics such as dosing consistency and venting can be enhanced through maintaining a uniform hopper filling level (this should be considered good practice in any precision moulding application). As a general guide, material travel distances should be short and manageable, and the pellet feeding rate should not be excessively high.

Plasticising considerations

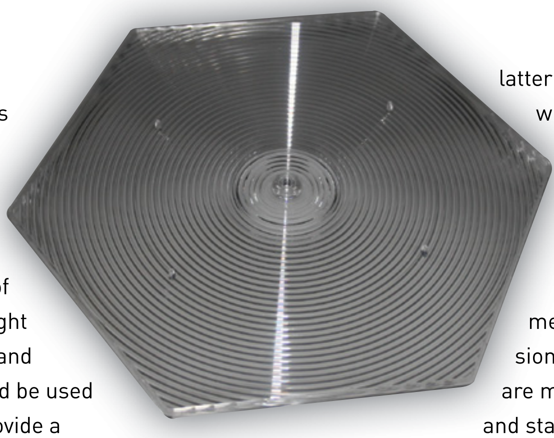
The plasticising system – which comprises the plasticising cylinder as well as the screw, the non-return valve and any protection against adhesion or abrasion - must be designed for optical processing. In particular, the energy absorption and feed characteristics of the material to be processed must be considered. In many cases, the filling, compression or metering zones will need to be optimised and custom lengths, flight depths, pitches and compression ratios adopted. Optical materials tend to display adhesion or blooming, so anti-adhesion and wear protection coating selection is also important. A variety of options are available to help permanently eliminate material residue build up and subsequent release, which can also give rise to "black spots".

The non-return valve must close rapidly and reproducibly, even when the screw decompression is very minimal or where no screw decompression is used. Some of the latest non-return valve designs guarantee complete closure after the dosing process. The closure process is independent of decompression and it is no longer necessary to retract the screw. This is particularly beneficial with open nozzles – which are widely used in optical moulding – as the danger of air being drawn in to the plasticising system is reduced. Air can cause clouding in optical parts.

When using open machine nozzles it is important that the diameter of the nozzle bore hole is adapted to the dimensions of the mould nozzle. Diameters of 15 mm can be required with moulds for thick-walled lenses running up to eight cavities and cold runner systems. In order to retain a corresponding contact surface, these have to be kept in a flat radius. Borehole surfaces are usually polished and all edges are rounded off.

Care must always be taken in the production process that a clean, concentric nozzle fitting is maintained. Damaged nozzles, which do not fit cleanly or with borehole edges which are burred can lead to smoke-like streaks appearing in the lens due to the intake of air or melt outline effects occurring during the injection moulding process.

As a basic principle, all flow channel geometries, cross-sections and approaching surfaces should be shaped as smoothly as possible. Sharp edges, deflections and dead zones must be positively avoided in the entire plasticising system.



Left: All-electric machines are well suited to production of flat optical parts such as Fresnel lenses

Sizing the barrel

Selecting the appropriate barrel is decisive in final part quality as parameters such as shot weight, stroke utilisation, residence time and the required injection moulding pressure are of special importance. The shot weight is determined by the part design and material specifications and should be used to select a screw size that will provide a stroke utilisation in the ideal range of between 20% and 60% (and certainly no more than 75%).

An appropriately sized barrel and screw will, depending on the cycle and the dwell time of the melt in the barrel, deliver a homogeneous preparation of plastic material. A poorly selected barrel will result in too long a dwell time, which will lead to damage and discoloration of the polymer and a subsequent deterioration in optical function.

Injection moulding pressure must also be considered very closely in the design and configuration of the system as most transparent materials used in the optical sector are highly viscous. Holding pressure should be assessed accordingly.

The mould environment

The mould and its immedidate environment determines the consistent and lasting cleanliness of all components. Unnecessary hardware and areas that can harbour contaminants should be avoided. In some cases, encapsulated or metal-clad clamping or unloading systems incorporating laminar flow cabinets and self-contained peripherals may be used to keep the production area permanently clean. It is also worth considering antistatic paint for the machine.

Hydraulic components should be kept well away from the moulding area and from locations where parts are handled or deposited to minimise risk of contaimination. For the same reason, all pneumatic valves should be provided with adequate fine mesh filter systems. And temperature control hoses should be kept as short as possible while maintaining operational safety.

Machine selection

The decision of whether to use full-hydraulic, all-electric or hybrid drive concepts will depend on a number of factors, with shot weight, component geometry, holding times, required precision and cleanliness being among the prime considerations. Generally, all-electric machine axes provide an order of magnitude improvement in precision over hydraulics and are able to provide parallel machine movements with no special modifications. The latter is an essential requirement where simultaneous compression moulding processes are operated via the clamping unit of the machine.

Due to the mostly mechanical power transmission, mould approach positions are maintained in a very precise and stable manner in an all-electric design. This accurate action is especially effective in production of small prisms or lenses with surface accuracies in the region of 2-3 microns. Flat, thin-walled optical parts carrying Fresnel or micro-structures on their surface can be manufactured very effectively by compression moulding using an electrically powered clamping unit.

Production of thick-walled lenses normally does not need such accurate controlled movements and the cushioning characteristic of the hydraulic oil can help to smooth out changes of velocity and pressure within the injection and holding pressure profile. Slow and smooth movements generally yield better results in optical moulding.

However, the major benefit of hydraulic injection moulding machines is their ability to maintain long holding pressures high levels. Hydraulic machines also make compression moulding with high embossing nips possible. Both are very useful techniques – and sometimes the only techniques – capable of compensating for the enormous shrinkage involved in moulding thick-walled lenses.

Ultimately, it makes sense to make a detailed product-related comparison of potential machine concepts to determine which is best for the specific product that will be manufactured.

Demand for high optical quality plastic components will continue to grow and machine and process developments will make it easier and more economical to meet the requirements of this market. However, producing high precision optics at the required quality and cost will remain a challenging task that will continue to test the skills of processors.

Above: Thick wall optical parts require high level moulding expertise

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