Analysis of the Injection Overmoulding Process for Polymer Lenses by use of a Specially Designed Mould

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Abstract

The form accuracy of injection moulded polymer optics that can be used for various applications such as illumination with LEDs is always influenced by shrinkage. The production of such optics in two steps by using the injection overmoulding process is described and analyzed as a means for significantly reducing the shrinkage of the final polymer part.

1 Introduction

The demand for polymer optics is increasing constantly due to the growing use of LED technology. For many applications form accuracies of a few micrometers are necessary to achieve the desired results. As shrinkage is inherent in the injection moulding process it can be difficult to achieve such form accuracies depending on the shape of the part.

2 Shrinkage in the injection moulding process

In the injection moulding process the plastified material is injected in the mould where it cools down to a specific temperature before the part is ejected. Shrinkage occurs while the part cools down in the mould and also while it cools down to ambient temperature after being ejected.

There are different approaches for minimizing or compensating shrinkage. For certain geometries long hold pressure times can help to increase the form accuracy. A more complex, but in many cases more useful approach is the use of the injection compression moulding process [1]. The material is injected in a pre-enlarged cavity and then compressed by an additional movement of the machine or a movable component in the mould. As this movement can be quite slow the shrinkage can be compensated for quite a long period of time. However, there are limitations to this process especially for parts with strong variations of wall thickness.

A requirement for all approaches to minimize or compensate shrinkage is a reproducible process. It is then also possible to compensate the inevitable shrinkage by iteratively modifying the mould inserts. However, the measurement data feedback and the reworking of the mould inserts is quite complex and time-consuming.

3 Overmoulding process for polymer optics

The overmoulding process offers another possibility of how to minimize the form error. It consists of two injection moulding processes. In the first process the core of the final part is moulded. In the second step the pre-moulded part is covered with another layer of material. As the second layer is rather thin the main proportion of the volume of the final part is moulded in the first process (Figure 1).

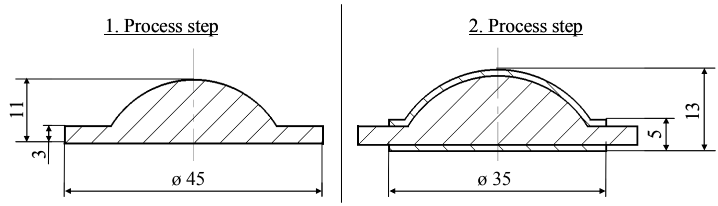

Figure 1: Injection overmoulding process for flat-convex lens (dimensions in mm)

The shrinkage that occurs during the first process is compensated by the second injection moulding process so that only the shrinkage that occurs in the second injection moulding process is relevant for the form error of the final part. As the second layer is thin compared to the total thickness of the final part the shrinkage that occurs in the second injection moulding process is significantly smaller.

The cycle time can be quite low for both processes. As it is not necessary to reach very high form accuracies with the first injection moulding process it is only necessary to retain the part in the mould until it has a sufficient form stability. As the surface is melted by the injection of the hot material in the second process step it is also not necessary to have optimum surface quality in the first process. This means that the mould temperature can be fairly low for the first process and this also enables a shorter cooling time. The second injection moulding process determines the form accuracy and the surface quality of the final part. As this layer is rather thin the cooling time for this process can also be relatively short.

Therefore, with a smart combination of the cycle times of both injection moulding processes it is possible to decrease the netto production time for the final part [2].
Another significant advantage of the overmoulding process considering shrinkage compensation is that this approach can be used for simple geometries as well as for rather complex geometries. Differences in the wall thickness of the final part have no influence on the applicability of the approach.
An important aspect that has to be considered is that the core of the part and the second layer can have different inner properties. Therefore the determination of process parameters for both injection moulding processes can be a challenging task depending on the geometry of the part.

4 Design of a mould for the analysis of the overmoulding process

A mould has been designed for analyzing the potential of the overmoulding process for optical parts with different geometries. The mould includes a cavity for moulding the core of the final part and another cavity for moulding the second layer of the part. With this mould it is possible to fill either the first or the second cavity. Figure 2 shows the design of the mould. Due to the design of the runner it is possible to put the pre-moulded part into the second cavity and to mould the second layer as shown in Figure 1.

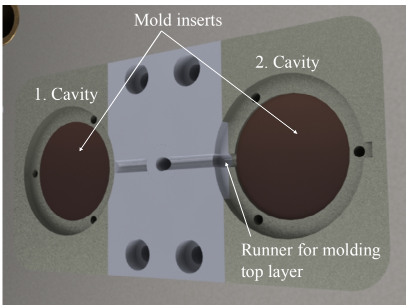

Figure 2: Mould for injection overmoulding process

5 Analysis of injection overmoulding process

The injection overmoulding process has been analyzed for a plano-convex lens in polymethylmethacrylate (PMMA) as shown in Figure 1. Using the conventional injection moulding process it was not possible to achieve good form accuracies on the flat side of the lens. The deformation has been determined by measuring the Peak-to-Valley-value with a tactile sensor to be more than 200 µm for the conventional injection moulding process. By using the injection overmoulding process the form accuracy of the flat side of the lens could be improved significantly. A form error of less than 10 µm could be achieved by overmoulding a layer with a thickness of 1 mm in the second injection moulding process with cooling times of 60 seconds for each process step. With a cooling time of 180 seconds even form accuracies of less than 5 µm could be achieved for the flat side of the lens. The form accuracy for the convex side could be improved from about 50 µm with the conventional injection moulding process to less than 20 µm for a cooling time for the second process step of 60 seconds and less than 10 µm for 180 seconds with the overmoulding process.

6 Potential of injection overmoulding process for different components

The mould that has been designed and manufactured allows for the detailed analysis of the overmoulding process for different geometries. The first results for a simple part are very promising. It could be shown that the form accuracy of the part can be significantly increased by using the overmoulding process. There are no obvious influences between the layers. However, this has to be verified by analyzing the optical function of the parts. The high potential of the overmoulding process will also be analyzed for the use of polycarbonate (PC) and for more complex parts.

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References:

[1] T. Walther, R.-U. Müller: Limitless Coining, Kunststoffe International 11/2009, page 16-20

[2] M. Döbler, C. Klinkenberg, R. Protte: All Systems Go for White Light, Kunststoffe International 4/2009, page 59-62