Friedrich-Alexander-Universität
Technische Fakultät

INSTITUTE OF POLYMER TECHNOLOGY
Prof. Dr.-Ing. Dietmar Drummer

Compression Induced Solidification and Micro Injection Molding

Barcode zu Ansprech-partner und Infomaterialien

Compression Induced Solidification

Motivation

Optical lenses often exhibit large varying component thicknesses, which is why they cannot be produced with conventional polymer processing techniques. In the standard processing methods for polymers, sink marks and internal inhomogeneities such as residual stresses and density variations occur due to the simultaneous presence of the solid and the molten state during cooling (Fig. 1) and their varying coefficients of expansion. Compression induced solidification (CIS) provides the possibility to reduce or even avoid these undesirable component defects.

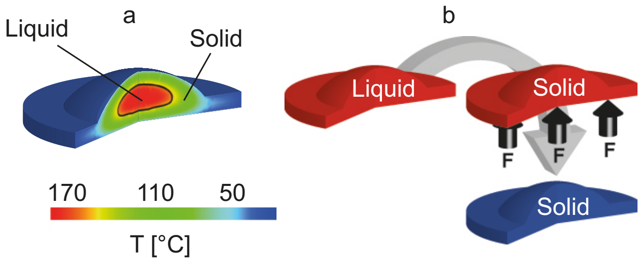

Fig. 1: a) Different phases of the polymer (liquid and solid) during standard injection molding

b) Solidification of the melt via pressure and subsequent cooling during CIS

Solidification by pressure

The concept developed at the Institute of Polymer Technology (LKT) is based on simultaneous solidification of the hot melt in the whole cavity solely by pressure. Thereafter, the compressed and solidified melt is cooled down (Fig. 1). The separation of the parallel processes of cooling and solidification during polymer processing is made possible by the pressure-dependent glass transition temperature range of polymers, which shifts to higher temperatures with higher pressure. At the time of solidification, i.e. when the glass transition is exceeded due to the pressure level, the component is subjected only to the significantly lower coefficient of expansion of the solid state. This single-phase cooling minimizes effects due to locally different shrinkage coefficients. The technique leads to better dimensional accuracy and homogeneous inner component properties (Fig. 2 and Fig. 3).

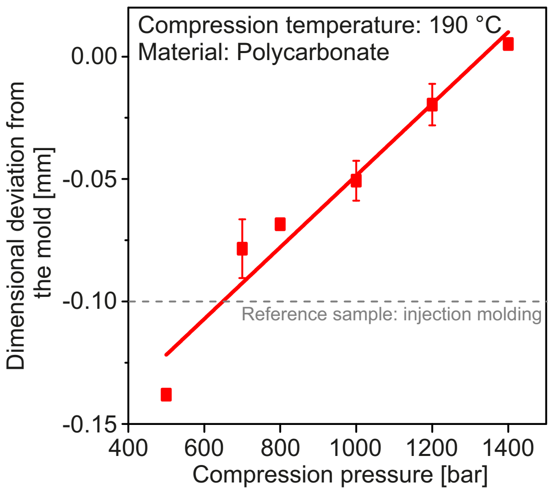

Fig. 2: Dimensional deviation of the component from the mold

Process Strategy

At the beginning of the process, the mold cavity with dynamic temperature control is set to a temperature higher than the glass transition temperature of the polymer and is filled with melt. Subsequently the melt cools down to mold temperature in the cavity. A pressure is then applied to the melt, which is so high that the mass is solidified by falling below the vitrification line (glass transition). The dynamic mold temperature control is then used to cool down the solidified component to demolding temperature while remaining a constant cavity volume or constant pressure. The compression causes an adiabatic temperature increase, which makes it necessary to adjust the pressure in order to achieve solidification, i.e. to exceed the freezing line.

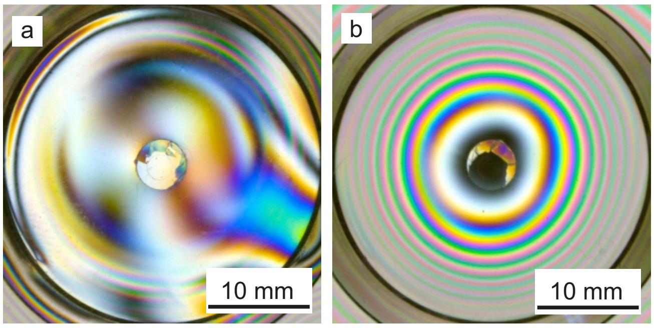

Fig. 3: Photoelastic image with circular polarized light, component thickness: 18 mm
a) Reduced internal stresses of a component produced via CIS

Micro Injection Molding

Motivation

In the field of micro and thin-wall technology, injection molding has become the method of choice for producing components at a very high technical level. Nevertheless, the potential of most common semi-crystalline thermoplastics is usually not fully utilized. The main reason for that is the used cooling strategy. With increasing ratios of surface to volume at the transition from large to small and thin geometries, an increased heat loss through the mold wall occurs. The associated differences in thermal history lead to a change in internal structure associated with changes in component properties. Hence, a thorough process control is vital in injection molding. An increase in mold temperature can improve the crystallization for semi-crystalline polymers, which might lead to a higher stiffness and strength while reducing the elongation at break. Since the main areas of application for polymer micro parts are medical technology, movable components of optical systems, micro gears in micro fluidics, biotechnology and electronics or micro electro-mechanical systems, the tribological behaviour of such components is also of particular interest. Thus, the improved crystallinity as a result of the increased mold temperature can lead to a decrease in wear and an increase in the allowable number of load cycles for gears, while the friction behavior remains unchanged.

Potentials of Dynamic Tempering

Based on gears made of Polyoxymethylene (POM), Fig. 4 shows the influence of the mold temperature on the formation of the morphology and the required cycle time. For technically challenging components, a cavity temperature of 100 °C is common. A resulting skin layer can only be avoided by increasing the temperature to 140 °C. Therefore, the required longer cooling phase doubles the cycle time for the tested gear-wheel. Using a dynamic temperature control, injection can take place at a high mold temperature at the level of the crystallization temperature of ~ 150 °C (POM). Mold and part are simultaneously cooled down at high cooling rates leading to a possible eject after a total cycle time of less than 20 s.

Components with Locally Different Properties

In addition to influencing the crystalline structure of the entire component, current research at LKT deals with the development of a new mold system which allows for local heating using segmented heating ceramics. Therefore, different mold temperatures within one cavity can be realized to manufacture components with locally different properties. Results for studying the morphological characteristics (Fig. 5) correlate well with the resulting mechanical properties (Fig. 6). Injection molded Polyamid 6 microplates show that it is possible to generate components with locally varying properties (which can be attributed to the different sizes of the crystalline structures) by choosing different temperature cavity areas. Besides achieving an increase in the degree of crystallization, an increase in the tensile modulus by the order of 30 % can be reached.

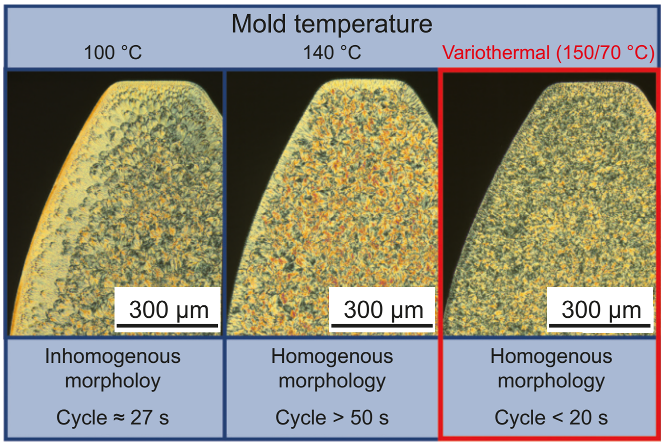

Fig. 4: Influence of the mold temperature on the resulting morphology and cycle time of an injection molded gear wheel

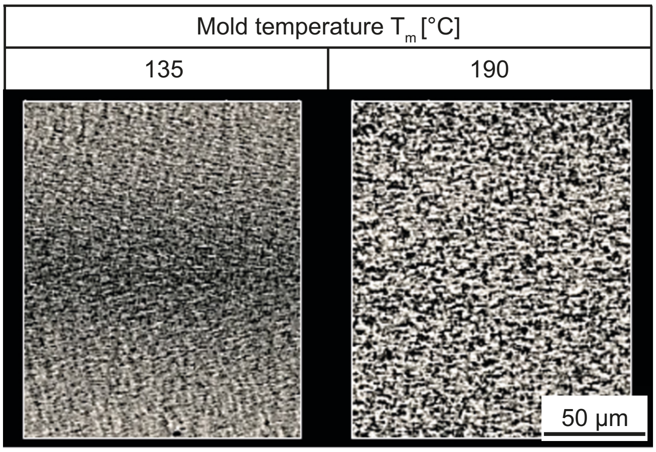

Fig. 5: Morphology of an injection molded component manufactured at different mold temperatures

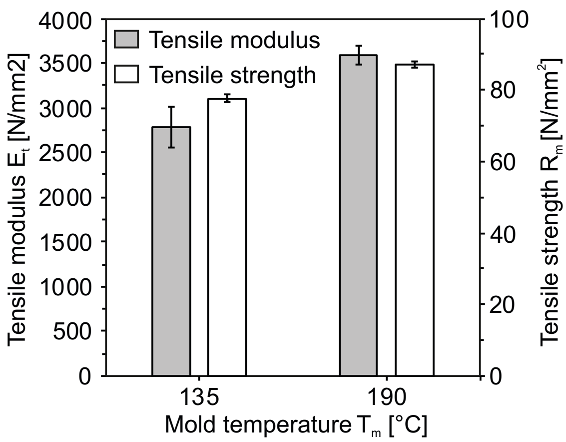

Fig. 6: Tensile modulus and tensile strength of an injection molded component manufactured at different mold temperatures

Research Objects and Service for Industry

- Thermoplastic micro injection molding
- Process related cooling rates with Fast Scanning Calorimetry (FSC)
- Viscosity measurements with high pressure capillary rheometry
- Structural analysis of semicrystalline microparts
- Stress optical images of amorphous components

| Institute of Polymer Technology | Am Weichselgarten 10 | 91058 Erlangen-Tennenlohe, Germany
| Phone: +49 9131 85 710 00 | Fax: +49 9131 85 710 07 | Mail: lkt-info@fau.de
| https://www.lkt.tf.fau.eu/