Facts About. Industrial gases for better injection molding.

Linde Gas

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Gas injection molding

Hollow sections, temperature control, foaming – the use of nitrogen or carbon dioxide in injection molding processes is constantly increasing due to many economical and technical benefits.

In the gas injection molding process (GIM), nitrogen is injected under high pressure into the melted polymer that has not yet completely filled the mold. The gas displaces the melt from the core of the molded part and presses it against the cavity wall. This creates a void in the core of the part – the amount of material used and the molded part weight drop considerably. After solidification of the molded part, the gas is released.

**Benefits of gas injection molding (GIM):**
- Improved product quality, specifically, better surface finish, no sink marks, less warpage, greater dimensional accuracy
- Shorter cycle time because of faster cooling
- Reduced clamping force requirement

Until now, the major problem with GIM has been compressing the gaseous nitrogen to high pressures economically and with a high degree of purity. This operation requires a great deal of energy and significant maintenance on the compressors. In addition, the oil lubrication in the compressors contaminates the nitrogen, reduces product quality and process reliability.

A suitable supply of high-pressure nitrogen significantly reduces the costs for injection molding. The pressure boosting system DESY® 300/100, developed and patented by Linde (see graph 2), offers an interesting alternative to the traditional method of nitrogen supply.

DESY® 300/100 compresses liquid nitrogen to a pressure of up to 300 bar. The liquid nitrogen then vaporizes in a high-pressure evaporator. A very low energy consumption in combination with absolutely pure and oil-free gas are the main advantages of this system.

In contrast to conventional cryo-pumps, the system automatically adjusts to the amount of gas used – even in the event of highly variable consumption. When higher pressures are needed (over 300 bar), an auxiliary compressor that requires only little energy can be added.

**Advantages of DESY® 300/100:**
- Very low energy requirements due to cost-effective liquid compression
- The unchangingly high quality of the injection-molded parts because of the very pure and oil-free nitrogen
- DESY® 300/100 supplies exactly the quantity of nitrogen which is required by the user, even when strong fluctuations in demand occur
- Compact design
- Low installation and operating costs

Gas injection molding (GIM) produces hollow sections in a variety of injection-molded parts, e.g., fridge handles or office chairs.
Graph 1: Nitrogen supply solutions for gas injection molding; PSA stands for “pressure swing adsorption”

Graph 2: In combination with a high-pressure evaporator, Desy® 300/100 is a practical nitrogen supply system for gas injection molding.
Gas injection molding (GIM) can also be augmented with inner cooling. The inner cooling process developed and patented by Linde gives additional advantages in the production of cheaper, lighter and stronger injection-molded parts. It can be used for any product where the hollow section is shaped like a pipe, e.g., all kinds of handles or similar products.

The inner cooling technology utilizes the high-pressure nitrogen which is already available at the GIM processor at ambient temperatures. This nitrogen flows in a controlled way through the existing gas channel, removing heat from the inside of the molded part. This results in considerably shorter cooling and, consequently, shorter cycle times.

Reductions of up to 30% have been documented, with only a one- to three-fold increase in nitrogen consumption. In addition, the inner surfaces of the molded parts are smoother, and the dimensional accuracy of the products is much better than in a conventional GIM process.

When considering internal cooling, the amount of heat to be removed from the inside of the product should be compared with the amount of heat removed by the mold. In conventional GIM processes, the heat capacity of nitrogen usually suffices to cool the molded product, but increasing demands on efficiency and product design require additional cooling from the inside.

Linde’s new technique with inner cooling achieves greater cooling through additional gas flow. After normal gas injection, the flow of nitrogen to the primary injector is interrupted and the injector is opened to the ambient air. Simultaneously, nitrogen is introduced through a second gas injector at the opposite end of the gas channel. This nitrogen flows through the entire gas channel in the molded product and exits through the primary injector, which then functions as a discharge port. For proper operation of such a system, the pressure and flow rate of the nitrogen must be controlled exactly.

Graph 3: Gas injection molding inner cooling. Better heat removal by the use of secondary injectors and additional nitrogen
The benefits of inner cooling:

- Cycle time reduction of up to 30%
- Higher quality, i.e., smaller statistical variations for dimensional accuracy, weight and shape of the products
- Smoother inner surface of the products
- High cost efficiency (low investment and operating costs)
- Easy installation
- Products with more complicated forms can be molded

The costs associated with additional hardware and nitrogen consumption as well as the costs to convert the mold, mainly installation of the second gas injector, are hardly worth considering when compared to the resultant cycle time savings. To utilize inner cooling on existing molding machines that are already equipped for gas injection, a second gas injector must be placed on the side opposite the original gas inlet. Whether additional hardware is needed depends on the type of gas injection employed as well as on the molded part.
CO₂-Spot Cooling

CO₂ spot cooling is suited for all products where the cooling and cycle times are supposed to be reduced while maintaining high quality. In particular, it improves the cooling of “hot spots” in a mold: very thin sections, small cores or localized areas with increased wall thickness.

Mold temperature control that is distributed uniformly throughout a mold is decisive for high quality and short cycle times. Water cooling has only little effect when the space available for cooling channels is limited. Temperature control in long, thin cores or other poorly accessible sections of a mold leads to problems. The use of CO₂ cooling for such hot spots thus complements water cooling at precisely those locations in the mold where conventional temperature control cannot be employed effectively.

Based on years of experience with cooling technologies, Linde, in cooperation with ISK Iserlohner Kunststofftechnologie GmbH, developed and refined CO₂ cooling for conventional steel. Liquid CO₂ flows at high pressure (approx. 60 bar) through thin, flexible capillary tubes (outside diameter 1.6 mm or less) to the intended location. Upon expansion of the CO₂, a snow-gas mixture with a high cooling capacity forms at a temperature of -79 °C. The CO₂ pulls heat from the mold steel and exits the mold as a gas through appropriate outlets.

Thus, cooling and cycle times can be reduced significantly (the latter by up to 50 %). The high efficiency of this cooling technique, along with the low investment costs and simple installation, make CO₂ cooling very attractive – both for new injection molds and for retrofitting already existing molds.

TOOLVAC®

Toolvac® is a special cooling technique that utilizes porous steel molds and replaces cooling water with carbon dioxide. As a result of the porosity of the steel, the CO₂ is distributed uniformly throughout the mold and in this way removes heat more effectively. The microporous steel can also be employed for venting in order to avoid the so-called dieseling.
Microcellular foaming

Microcellular foams have uniform cell structures with very small bubbles (less than 100 µm) and better mechanical properties compared to conventional foam. In microcellular foaming, carbon dioxide or nitrogen serve as physical blowing agents metered at high pressures of up to 500 bar.

There are a number of processes on the market that differ from one another primarily in how the blowing agent is metered, where it is introduced and how it is mixed with the polymer. In general, the blowing agent is introduced into the injection unit, where it mixes with the melt (MuCell process from Trexel, Inc.) or it can be injected after the screw in an separate mixer (ErgoCell process from Demag Plastics Group and Optifoam process from Sulzer Chemtech AG).

The foam parts have a porous core and solid skin. Their primary benefits: foam parts are considerably lighter than solid parts, require up to 30 % less material, show less tendency to warp and have no sink marks. The lower viscosity of the mixture also requires less clamping force from the injection molding machine. A disadvantage is that the surfaces of such parts are not suitable for high-gloss applications.

Microcellular foam forms when there is a large number of cell nuclei in the polymer, with or without the presence of additional nucleating agents, e.g., talc or glass fibers. The blowing agent that is injected into the polymer melt dissolves at a high temperature and a high pressure and forms a single-phase solution with this melt. A large number of small cells forms that grows simultaneously and to the same extent as the blowing agent begins to diffuse. Upon injection into the cavity, the pressure drops abruptly, the blowing agent becomes highly supersaturated in the polymer, and foam begins to form. The rate at which the pressure drops must be very high, because otherwise larger bubbles tend to form.

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Getting ahead through innovation.

With its innovative concepts, Linde Gas is playing a pioneering role in the global market. As a technology leader, it is our task to constantly raise the bar. Traditionally driven by entrepreneurship, we are working steadily on new high-quality products and innovative processes.

Linde Gas offers more. We create added value, clearly discernible competitive advantages, and greater profitability. Each concept is tailored specifically to meet our customers’ requirements – offering standardized as well as customized solutions. This applies to all industries and all companies regardless of their size.

If you want to keep pace with tomorrow’s competition, you need a partner by your side for whom top quality, process optimization, and enhanced productivity are part of daily business. However, we define partnership not merely as being there for you but being with you. After all, joint activities form the core of commercial success.

Linde Gas – ideas become solutions.