International Communications in Heat and Mass Transfer 38 (2011) 304–312

Contents lists available at ScienceDirect

International Communications in Heat and Mass Transfer

journal homepage: www.elsevier.com/locate/ichmt

Gas-assisted mold temperature control for improving the quality of injection molded parts with fiber additives☆

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ARTICLE INFO

Available online 4 December 2010

Keywords:
Dynamic mold temperature control
Gas-assisted heating
Surface heating

ABSTRACT

A rapid heating cycle has the advantage of improving product quality in injection molding. In this study, gas-assisted mold temperature control (GMTC) was combined with cool water to achieve dynamic mold surface temperature control. By applying the GMTC system on the mold of a rectangular plate, the advantages of using GMTC for injection molding were evaluated and compared with the traditional injection molding process using different gas gap sizes and gas flow capacities. The effect of GMTC on the quality of the part was also studied. Results showed that when GMTC was used, the heating rate can reach 28 °C/s. For an initial mold temperature of 60 °C, and an air gap size of 8 mm, after 6 s heating, the mold surface temperature can reach 147.8 °C, 167.2 °C, and 229 °C with gas flow capacities of 100, 200, and 300 l/min, respectively. When the gas gap size is changed from 4 mm to 8 mm, the uniformity of temperature distribution shows a clear improvement. When GMTC was used for injection molding of parts with fiber additives, the part surface was clearly improved.

1. Introduction

Injection molding is one of the most widely used processing technologies in the manufacturing of plastic products. Among typical molding parameters, mold surface temperature is critical. At higher mold surface temperatures, the surface quality of the part will improve. However, the cooling time increases as mold surface temperature rises lengthening cycle times. A lower mold surface temperature reduces cooling time, but does not benefit part surface quality. Thus, a critical goal of current research is to increase the mold surface temperature while maintaining a reasonable cycle time.

In recent years, the requirement for much thinner, lighter molded parts with better mechanical performance is of increasing importance to manufacturing firms. Consequently, many new injection molding technologies have been investigated [1–5]. In traditional injection molding, the cavity surface did not require heating. After the filling process was finished, the melt was cooled by cold water in the cooling system. In such a process, the quality of the product is not high, and the surface often has many problems. With the application of rapid heat cycle molding (RHCM), the cavity temperature in the filling period can be increased, which helps the melt flow more easily into the mold, resulting in better packing. At the same time, the melt flow ability can increase and melt viscosity can be maintained at a lower value. In addition, surface brightness and hardness also improve. Therefore, rapid heat cycle molding (RHCM) is proposed as an efficient solution.

For the heating process in injection molding, several types of heating systems are in use. The most inexpensive way to achieve high mold temperature is to use hot water at a temperature as high as 90 °C or 100 °C for both heating and cooling. If the mold temperature needs to be higher than 100 °C, either a high pressure water supply system or mold temperature control by hot oil may be used [6]. The former may damage the channel connection and safety may be an issue after a long-term use, while the latter may not be energy-efficient due to the low heat transfer coefficient of oil. Local mold heating using an electric heating element is sometimes used to assist in high mold temperature control, especially for thin-wall products. However, this requires extra design and tool costs [7]. Further, a heater is usually used for auxiliary heating and is limited to increasing the mold temperature roughly several dozen degrees centigrade. Studies have used water vapor to heat the mold—a specially-designed mold. This approach increased the mold temperature from 30 °C to 110 °C and helped the melt easily fill the cavity to reduce defects in the product [8,9]. However, in a real mold, the heating and cooling channels are different. Therefore, both the heating and cooling efficiency are affected. In addition, with this design, the mold is far more complex, increasing the cost of tooling.

For direct heating of the mold surface, a coating on the cavity surface consisting of TiN and Teflon has been shown to reduce the heat transfer from the melt to the mold material, increasing the temperature on the

☆ Communicated by W.J. Minkowycz.

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doi:10.1016/j.icheatmasstransfer.2010.11.001

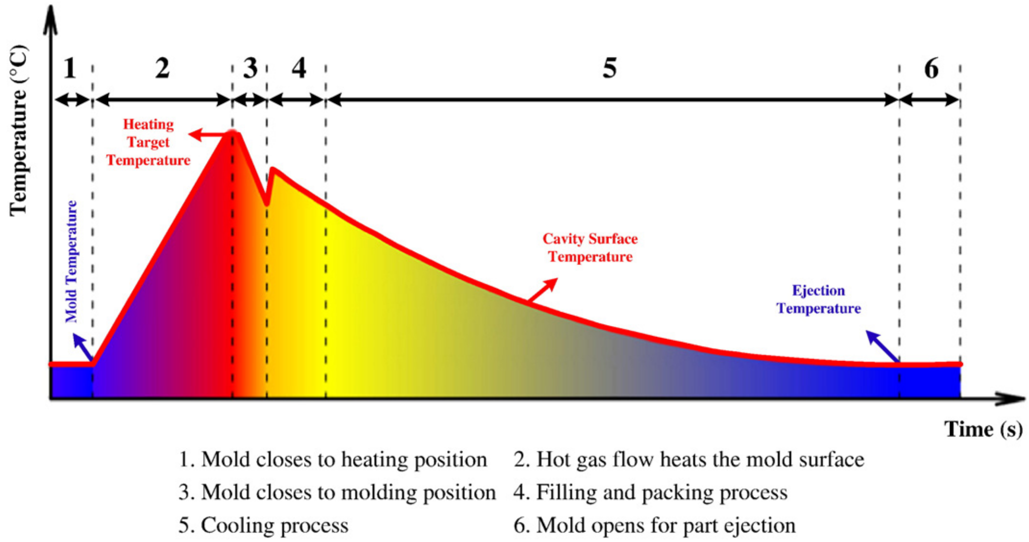

Fig. 1. General process of gas-assisted mold surface heating in injection molding.

cavity surface by 25 °C [10,11]. Similarly, an electromagnetic induction coil has been used to heat the cavity surface to reduce the weld line, shrinkage, and other defects of the part surface [12,13]. Further, an infrared heating system has also been applied for heating the mold surface. This system can heat the surface of one or two mold halves depending on the design [14,15]. In a recent application of surface heating, hot air flowing into a simple model of a mold cavity and the heating capacity of the gas was evaluated [16]. The hot gas can rapidly raise the mold surface temperature from 60 °C to 120 °C within 2 s. However, the associated mold temperature reaches saturated values when the heating time exceeds 4 s. Under set heating parameters (hot gas temperature 500 °C, gas flow capacity 400 l/min, and heating time 4 s) inserted with a nickel plate and coated with a ZrO_2 thermal insulation layer, the heating rate reaches roughly 30 °C/s.

The advantage of gas heating is its high heating rate, which reduces cycle time. However, the mold must be appropriately designed if gas surface heating is used. If the product geometry is complex, more equipment is needed to calculate the parameters for a high quality product. While simulation and experiment with a simple model of rapid mold surface temperature control using gas-assisted heating systems

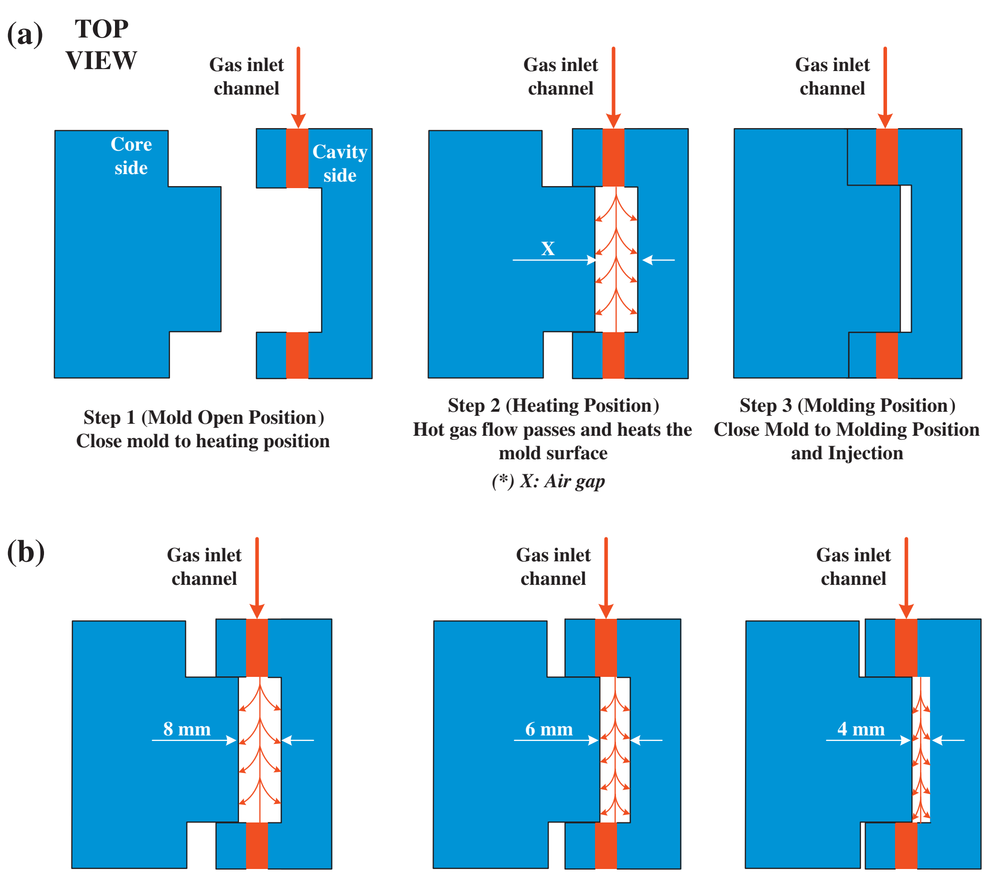

Fig. 2. Mold position in the heating stage (a) and different gas gap size (b) of GMTC process.