DESIGN AND FABRICATION OF A NANOCOMPOSITE MOLD

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INTRODUCTION

Blow molding is one of the popular manufacturing processes used for production of hollow plastic parts (Figure 1). Traditionally, expensive metal molds are used for this process; a significant part of the mold cost is due to the intricate machining of the large metal block. In the current manufacturing environment, the part designs are changing rapidly, requiring frequent changes of the mold. Lower production volumes can benefit from a tooling material that can be fabricated or machined easily. Nanocomposites of carbon nanofiber in a thermoplastic matrix offer significant improvements in thermal and mechanical properties, and near net shape fabrication; therefore they are potential candidates for making molds for polymer products. The primary issues for polymer matrix composite molds are the mechanical strength, stiffness, hardness, and the thermal properties. The mechanical properties of the mold material must be adequate for machining details of the part; and thermal conduction in the mold must provide rapid cooling for solidification of the polymer part being produced in the composite mold. This paper describes the design and fabrication of a nanocomposite mold for making a polymer part ("plastic wheel") by the blow molding process.

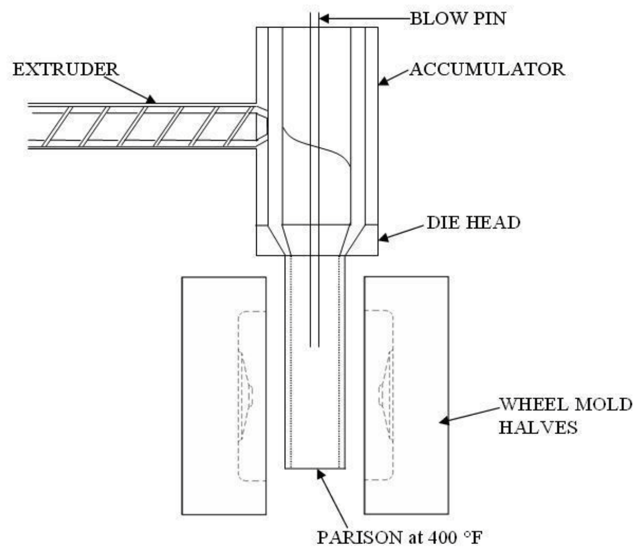

Fig 1: Schematic of Extrusion blow molding for a plastic wheel, showing the extruder, the parison and the two mold halves (Blow Molding, 2006; Alam et al., 2009)

MOLD DESIGN AND FABRICATION

The composite mold material being studied in this project was developed at University of Dayton Research Institute (UDRI, Dayton, OH). It is made by combining carbon nanofibers produced by Applied Sciences, Inc. (ASI, Cedarville, Ohio) with an epoxy matrix. The nanocomposite mold was designed by thermo-mechanical simulations using several commercial softwares. The purpose of the simulations was to evaluate different coolant geometries so that the part solidifies within a reasonable cycle time. The part must also develop sufficient mechanical strength so that it can be removed from the mold at the end of the cycle time.

Thermal Design

The thermal design process used the ALGOR software to predict the cooling history of the "wheel" part for different coolant paths, and this gave an estimate of the cycle time (Alam et al., 2009).

From the results of the thermal simulation, a design was selected with straight cooling channels at the bottom of the mold, and circular cooling tubes on the sides of the mold. In Figure 2, the mold geometry is shown along with the cooling channels and the temperature profile in the mold.

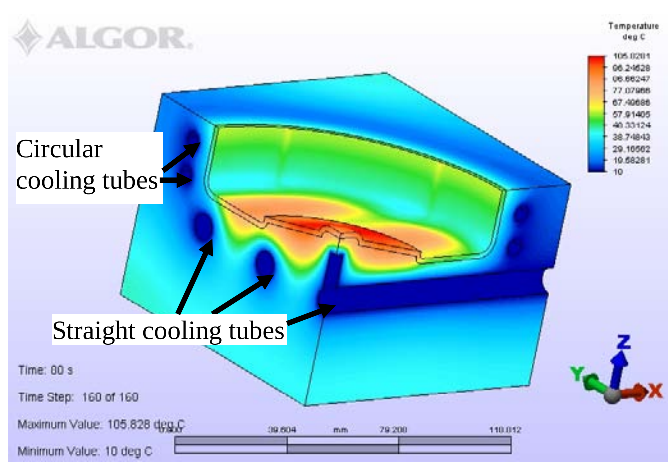

Figure 2: Thermal simulation of one quarter of the mold (Source: Garg, 2009)

Mold fabrication

A mold core was built using the nanocomposite material at the UDRI facility using a compression mold. The mold core was then placed on a metal mounting support and connected with coolant pipes as shown in Figure 3.

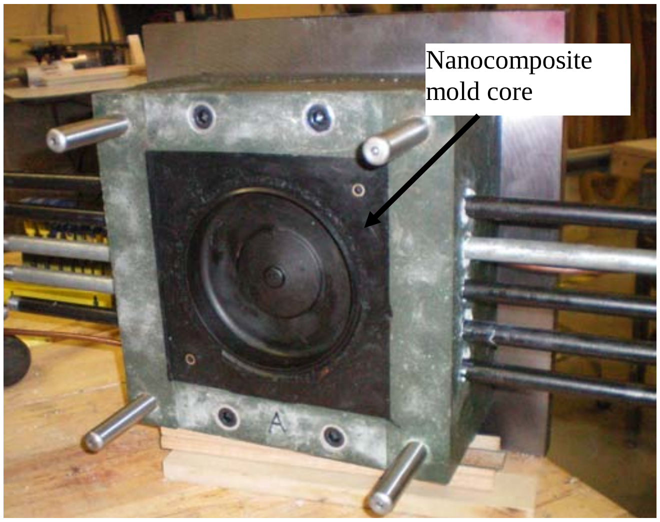

Figure 3: (b) Picture of one half of the fabricated mold with the nanocomposite mold core. (Source: Garg, 2009)

Thermo-mechanical simulation

The thermal design was then followed by a stress analysis of the polymer wheel during the blow molding process. This analysis was carried out by using POLYFLOW and B-SIM software.

B-SIM is a commercially used software in the blow molding industry. The preprocessor files for the molding process were created and sent to Compuplast (Mississauga, Canada), for B-SIM simulation. Compuplast modified the preprocessor files to get the desired result. In B-SIM simulation, the full mold was studied instead of solving one-eighth of the mold as it was done in Polyflow.

B-SIM simulation starts with two moving halves of the mold which pinches the parison and then parison starts to expand to form the wheel. The two molds meet each other and pinch the parison in about 1 second. The air pressure increases linearly in 5 seconds to a maximum constant value of 400 kPa. The diameter of the parison for B-SIM simulation was taken to be 60 mm with a mean thickness of 5 mm.

The initial thickness of the parison is 5 mm. After complete inflation, the thickness of the blown product varies from 1.1 mm to 5 mm. The thickness variation in the blown wheel is shown in Figure 4. The maximum thickness of the blow molded wheel is in the central region, where the part is about 5 mm thick. It was determined that the Von-Mises stress for the final expanded parison varies from 0 MPa to 4 MPa (Garg, 2009). These stress values are small compared to the strength of the polymer.

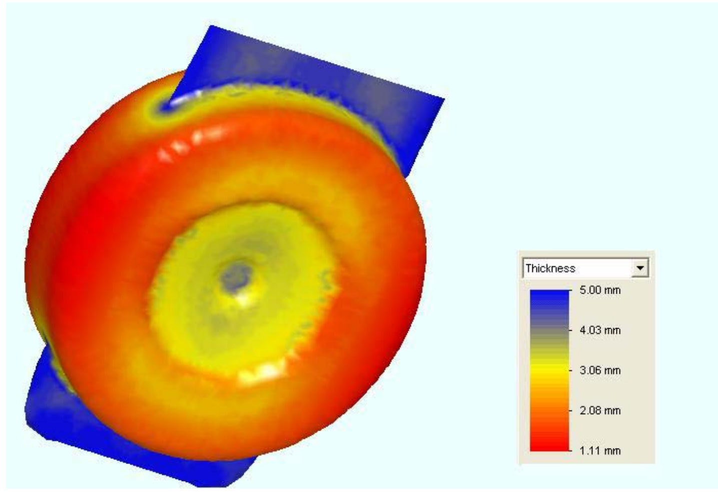

Figure 4: Thickness profile in the blow molded wheel (Perdikoulias, 2009; Garg, 2009)

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