

Low-density rotomoulded polymer foams

S.F. Bush*, O.K. Ademosu

Polymer Engineering Research Laboratory, University of Manchester Centre for Manufacture, PO Box 88, Manchester M60 1QD, UK

Received 20 October 2004; accepted 24 January 2005

Available online 9 March 2005

Abstract

Solid polymer foams are well-known materials used to provide insulation, packaging impact protection, low slip shoe soles and so on. This paper examines the nature of the foams produced when combined with the process of rotomoulding, long established as the means by which hollow polymer shapes are made. Rotomoulding refers to the fact that a mould with a meltable or sinterable powder inside it is heated and rotated about two axes at right angles to distribute the powder over the inside of the mould to form a skin. This heating phase is followed by a cooling phase.

The aim of the research reported here is to determine the conditions under which a hollow moulding with a skin made from one polymer powder, in this case low density polyethylene, can be made at the same time as a foam made from another polymer is formed to fill the cavity but not to penetrate through the skin. The foam in this case is polystyrene with around 6% (w/w) *n*-pentane pre-absorbed. The whole system is referred to as the Rotofoam©process.

Experiments on both the laboratory and the full industrial scales are reported. The Rotofoam©laboratory kinetics rig allows the foam development to be seen by eye and by camera as a glass mould undergoes the two axes rotations. Temperatures inside the foam and in the mould are monitored via a system of slip rings and hollow axles.

Examination by SEM allows the micro-development of the foam to be seen and linked to a simple shoebox-like model of a foam cell which correlates well with overall foam density measurements. The model also ties together the heat flow needed to expand the foam and heat the polystyrene and polyethylene, with the heat transfer rates calculated from the material conductivities, the material path lengths and the imposed temperature difference between mould and foam.

Finally, the paper reports the results obtained by the use of foam control agents — hydrated salts in this case — which by release of steam during the heating phase act to retard the pentane-driven foam expansion until the polyethylene skin is formed. The diffusion of the steam through the cell walls into the foam cavities is briefly discussed.

© 2005 Elsevier B.V. All rights reserved.

Keywords: Polymer foams; Heat conduction; Rotomoulding; Sintering

1. Introduction

Polymer foams are widely used in the manufacturing and construction industries to provide thermal insulation and/or to increase bending stiffness to weight ratios of large panels. The principal polymer foam systems used are expanded polystyrene and polyurethane. The former is commonly found in polystyrene cups where the combination of heat insulation and adequate stiffness is a great improvement

over the PVC alternative. Expanded polystyrene foam is the standard form of solid packaging with densities in the 17–50 kg/m³ range. Polyurethane foams have a wide range of applications ranging from relatively dense foams used in shoe soles where their friction properties are the best of any common material, to low-density foams used in refrigeration where special formulations provide a “self-skinning” property. In this case, the reaction of the isocyanate and polyol constituents is controlled by the catalyst used to ensure that for a given blowing agent, a solid (closed cell) surface is obtained next to the metal of the refrigerator cavities being filled.

* Corresponding author. Tel.: +44 161 200 5700; fax: +44 161 200 5701.
E-mail address: s.f.bush@umist.ac.uk (S.F. Bush).

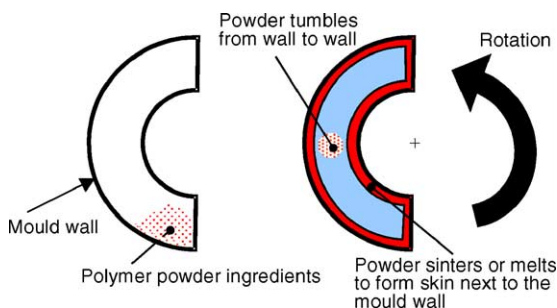


Fig. 1. Mechanism of skin formation in Rotomoulding process: for a post-protector shown in cross-section.

Rotomoulding is the principal process for making hollow shapes ranging from tennis balls to dustbins (where one end of the moulding is cut off to make the lid). In rotomoulding, polymer in powder form is introduced into a mould which is then closed and rotated either about two axes simultaneously or about one axis combined with a rocking back and forth motion along another perpendicular axis. Under this action, powder is distributed more or less uniformly over the inside of the mould by a combination of gravity and centrifugal forces (Fig. 1). The powder is typically linear low-density polyethylene (LLDPE) in the range 100–250 microns mean effective diameter. Its initial distribution in the mould is not usually important.

If the mould temperature is set with appropriate regard to the melting temperature range of the polymer powder, a viscous molten layer is built up next to the mould surface which gradually extends inward. Subsequently reducing the mould temperature to below the polymer melting point will give a solid skin which allows the hollow form to be removed, without permanent distortion. However, shrinkage will occur, typically in the range 1.5–2.5% linearly. This shrinkage means (a) that the moulding must be removed quickly once cooled sufficiently, and (b) the mould must be over-sized to produce a part to specified size. While these features are present to some degree in all moulding processes, the rotomoulding process poses particular challenges because of the size of many of the parts made.

The focus of the present paper is the process whereby a solid low density polymeric foam (20–100 kg/m³) is created in the air spaces of hollow shapes as the walls themselves are formed from a different polymer, in essentially one operation which also results in a greatly reduced shrinkage. This process is Rotofoam©[1]. The experiments and results described below have been obtained starting with polystyrene (PS) 100–200 μm beads containing about 6% (w/w) of *n*-pentane. This is progressively driven off in the temperature range 60–80 °C thereby expanding the beads into a solid foam.

Fig. 2 shows the process of foam formation in diagrammatic form for the ‘post-protector’ shape of Fig. 1. Under the blowing action of the pentane, the polystyrene beads expand about 15–20 times by volume fusing together at their boundaries, while in parallel the LLDPE walls (or skin) are formed

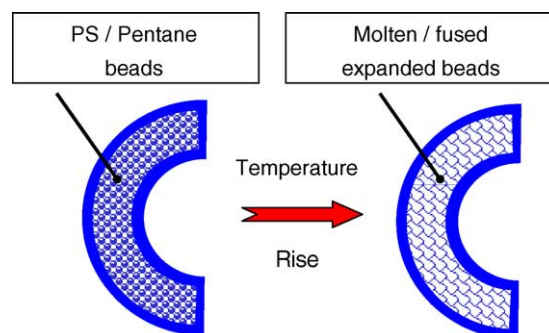


Fig. 2. Foam formation in the Rotofoam© process.

from melted or softened powder, which subsequently fuses into a solid surface.

The overall process depends on the temperatures applied at the inside mould surfaces (i.e. the outside of the walls of the moulding in Fig. 2) and within the moulding cavity itself so that the skin can substantially form before the foam expands significantly.

In a well-established injection moulding process, steam at around 2–3 bar pressure is introduced through tiny holes in the walls of a mould as the PS/pentane melt is injected into it [2]. Used in this way, steam is sometimes referred to as an additional blowing agent [3,4] but for the timescales involved it is likely that the steam’s principal effect is to heat and soften the PS, thereby allowing the pentane to expand it faster.

The Rotofoam© process, on the other hand, uses pressurised water vapour not to accelerate the cell expansion process but to retard it (Section 2.2). The process uses what is termed a foam control agent (FCA) in the form of hydrated powders from which water vapour is evolved at temperatures above that at which the blowing agent (pentane) is evolved but below 100 °C where the PS softens significantly. The hydrated powder is introduced into the mould either with the LLDPE and polystyrene powders at the beginning of the moulding cycle or later in the cycle. No particular mixing process is involved in either case. The initial proportion of *n*-pentane in polystyrene is maintained at 6% to keep the final foam density unchanged when the FCA is used.

Overall then the objective of the process is to obtain a wall or skin of polyethylene of adequate thickness in different shapes together with a solid low-density foam of consistent cell size. This requires knowledge of foam expansion rates and structures at a sequence of temperatures with different powder quantities, initial sizes and concentration of FCA.

2. Laboratory experiments

2.1. Description of the Rotofoam kinetics rig

Fig. 3 shows the laboratory rotational moulder which can continuously monitor the temperatures inside the oven and

Download English Version:

<https://daneshyari.com/en/article/9675787>

Download Persian Version:

<https://daneshyari.com/article/9675787>

[Daneshyari.com](https://daneshyari.com)