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Thermal Characterization of Microwave Assisted Foaming of Expandable Polystyrene

Caracterización térmica de poliestireno expandible manufacturado con microondas

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Abstract

Microwave range had been widely used for heating processes. In this work theoretical and experimental results on manufacturing of expandable polystyrene using specific frequencies of 2.45 GHz are presented. Simulations of temperature distribution were performed using the software *Comsol Multiphysics*®. In order to increase the material absorption to microwaves, several solvents as ethanol, a mixture of ethanol/water and hydrogen peroxide were tested. Temperature distribution inside material was measured with an infrared laser sensor. Microwave heating allows *Expanded Polystyrene Styrofoam* (EPS) molding in 180 seconds, reaching a considerable manufacturing time reduction compared with traditional processes where drying time may take up to one day.

Keywords:

- microwave
- manufacture and polystyrene

Resumen

El rango de microondas se ha utilizado ampliamente para procesos de calentamiento. En este trabajo se presentan estudios teóricos y prácticos de la manufactura de poliestireno expandible mediante calentamiento por microondas a 2.45 GHz. Se realizaron simulaciones de incremento de temperatura y su distribución en el material utilizando el software Comsol Multiphysics®. Con la finalidad de incrementar la absorción del material a microondas, se realizaron experimentos con diferentes solventes tales como etanol, agua oxigenada y agua purificada. Se midió la distribución de temperatura dentro del material mediante un sensor de láser infrarrojo. El calentamiento por microondas del material permite el espumado del poliestireno expandible (EPS) en 180 segundos, alcanzando una reducción considerable del tiempo de fabricación en comparación con procesos tradicionales en los cuales el tiempo de secado puede durar hasta un día.

Descriptores:

- *microondas*
- *manufactura y poliestireno*

Introduction

Polystyrene foam is a polymer produced from styrene monomer known as *styrofoam*; their use in food and electronics packaging, airplane and automotive parts, sporting equipment, among others, it has become a trend last years due to its different advantages as light weight (reduced bulk density), easy to form, low thermal conductivity, and low cost of production (Warsiki *et al*., 2012; Tsivintzelis *et al*., 2007). Commercial interest in polymeric foams has been increased due to new emerging applications and the ability to foam a variety of polymeric materials or composites. Despite their success, the continuous growth in research of foamed polymers into new markets depends on the ability to enhance control over its mechanical structure and performance (Emami *et al*., 2014).

Conventional polymer foaming process usually consist of polymer matrix saturation with a fluid (solvent) and its volatilization by increasing temperature, which induce phase separation, resulting in formation (nucleation) and growth of pores inside the polymer matrix (Tsivintzelis and Panayiotou, 2013). Polystyrene foaming has been extensively studied, for example, recently Nistor *et al*. (2013) prepared micro-cellular PS foams and studied the influence of toluene residua on the foam structure, using CO_2 as high-pressure inductor. They observed that foam heat insulation properties improve with increasing porosity, and that toluene residua increased the porosity by increasing the cell sizes and lowering the thickness of the compact skin at the film surface. Gutiérrez *et al*. (2014), foamed polystyrene using limonene solutions as solvent and CO_2 as foaming agent. They studied the effect of pressure, temperature, concentration of the solution, contact time and vent time over the diameter of cells, its standard deviation and the cells density, observing that the most suitable conditions to foam polystyrene from limonene solutions were 90 bar, 30°C, 0.1 g of Polystyrene/ml limonene, 240 min contacting and 30 min venting. Thus, foaming process strongly depends on solvent type and how temperature is raised. Usually, natural gas or fossil fuels are used in this process. However, constant increase in their prices and the pollution factor leads to finding new and clean (non-toxic) manufacturing techniques. Electromagnetic waves ranging from radiofrequency to microwaves could be an efficient alternative option for processes involving heating increase in polymers (Mallakpour and Rafiee, 2011). Sen *et al*. (2011), used microwave irradiation as the source of energy for expansion process and 2-propanol as expansion agent, however, they did not studied the thermal effects which have a direct impact in the quality of the product.

This work present thermal characterization profile of EPS manufacturing using microwaves as the source of heating throughout polystyrene foaming, and using ethanol, a mixture of ethanol/water and hydrogen peroxide as expansion agents. Advantages of this method includes fast heating, low-cost process, and independence of fossil fuels.

Methods and procedures

In order to characterize thermal profile, experimental and numerical simulations using *Comsol Multiphysics®* were performed.

Experimental foaming process

Samples of 130 ml commercial expandable polystyrene with a density of 20 kg/m^3 and thermal conductivity of 0.35 W/m·K were utilized. To increase the radiation absorption, experiments in conjunction with three sol-