GRADED FOAMS BY INJECTION MOLDING

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Graded foams are unique systems with a structure that transitions gradually, offering varying properties and characteristics in one or more directions. Graded foams possess functional characteristics, combining advanced properties with reduced density, making them highly desirable for a wide range of applications [1]. At the state of the art, single gradient foams can be produced on a small scale by methods relying on the use of additives or polymer mixing [2]. Other methods are based on stratification by glueing layers having different densities and/or compositions [3,4]. These methods are complex, not versatile, not easily scalable and have a high environmental impact.

Graded foams produced by gas foaming of thermoplastic polymers, on the contrary, are more compatible with the manufacturing sector[5]. Thermoplastic foams are produced on the industrial level by standardized processes such as extrusion foaming, compression molding, rotational molding, foam injection molding (Figure 1, right), expandable bead molding and others [6]. However, there are no techniques allowing the fabrication of large volumes of complex geometry products having a porosity and/or density-graded distribution in more directions.

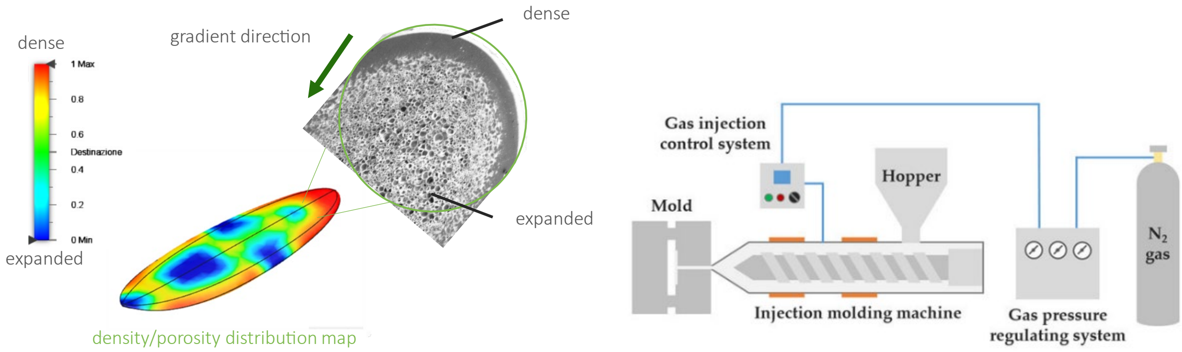

Figure 1. Example of density distribution map in the case of a surfboard (left); schematic diagram of the actual microcellular foam injection molding process (right) [7].

This PhD thesis project focuses on the scaleup of graded foaming technology to the industrial level and is aimed to study and define the main aspects involved in the production of graded foams by foam injection molding.

Injection molding is a versatile manufacturing process that offers exceptional geometry flexibility for the production of thermoplastic parts. It involves injecting molten plastic material into a precise mold cavity under high pressure, allowing for the creation of complex and intricate shapes with consistent accuracy. Foam injection molding combines the principles of injection molding with foam production. A physical foaming agent or a chemical blowing agent is introduced into the molten polymer within the injection molding machine. The mixture is then injected into a mold, where the foaming agent expands to form a foamed part. One notable characteristic of foam injection molding is the inherent uncontrollability of the foaming process. The expansion and distribution of the foaming agent within the mold cavity can be challenging to precisely control, leading to random variations in foam density, cell size, and structure. This unpredictability poses a unique challenge in achieving consistent and desired foam properties. The uncertainty of the mentioned process also opens up opportunities for innovation and the development of unique foam structures by graded foaming.

The graded foaming technique is based on predicting and designing the foam density distribution to optimally respond to the applied load, which is defined according to the product's application, by using simulation software that employs finite element analysis and topology optimization features. The software returns a map indicating the areas most interested in the load handling and the corresponding density and/or porosity needed to meet the requirements (Figure 1, left). The output of the study educates the process conditions to be achieved during the graded foam injection molding process.

The present PhD project is expected to find a solution to precisely control the graded distribution in the foam cellular structure, study the chemical-physical and operating aspects driving the process, outline a production plant layout and manufacture such optimized graded foam products by injection molding. The characterization of the products' properties will also be addressed by specific testing according to the applications of interest.

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