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Micromechanical Analysis of Flexible Low Density Open-cell Foam with Unit Cell in Moulding Process Using Finite Element Method

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Abstract

To investigate the compressive effects through microscopic features of flexible low-density open-cell PU foam during moulding process, FE simulation of deformation based on a regular dodecahedron cell unit with uniaxial compression behavior is undertaken to examine the mechanical properties of the vertical loading direction, and to facilitate the incorporation of solid PU material properties and variations in cell geometry. By the use of a factorial design, the mean strut thickness of solid struts has a positive non-linear effect on the maximum reaction force as compared against cell size with a negative non-linear effect. The Young's modulus of solid polymers had a positive linear effect on the response while the Poisson's ratio had the least impact on the response. Development of a simplified cell unit can model the behavior of open-cell PU foam under uniaxial compression which is an effective way to understand the mechanical behavior of foam during moulding process.

Keywords: Moulding; Mould Head; Numerical Simulation; Foam

1 Introduction

Due to the particularities of the performance and mechanics of viscoelastic behavior, a number of studies have investigated the mechanical behavior and microstructures of foam materials. In the 1980s, Christensen and Feng modeled the viscoelastic behavior of foam by analytical approaches [1]. Gibson and Ashby compiled all of the most relevant theories and physical models for many different types of cellular structures [2]. In order to represent the heterogeneous foam structures in a more realistic manner, it was essential to use numerical models [3]. More and more researchers have been using numerical simulation to explore the relationship between the microstructure and

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bulk properties of foam [4]. While some are concentrated on using beam elements to simplify the microstructure [5, 6], Shulmeister and Van der Burg adopted tetrahedral finite elements to produce the microstructure of elastic-plastic foam and the structural deformation was obtained from tomography [7]. For modeling larger deformation foam, a simplified geometrical model, called the cell unit, was used by Meguid etc. [8].

The most common model of cellular solids is Voronoi tessellation generated from distributions of 'seed points' in space. The concept first appeared in the research of Dirichlet in 1850 and Voronoi in 1908.The subsequent cellular models have been proven to be body-centered cubic, face-centered cubic and hexagonal close-packed lattices which are similar to those in the actual foaming process [9-11]. In recent years, many research studies have focused on the "tetrakaidecahedral" foam model which was originally proposed as aspace filling polyhedron that has equal volume [12].

Due to the uniform cell structure of the foam, simulations on a single cell unit of the foam have been performed, which revealed that a pressure drop can be simulated very well [13, 14]. This structure is similar to the cells existed widely with a statistical distribution of a face shape [15]. The cells of the model have uniform partition space, filled space, low anisotropy (the Young's modulus varies by less than 10% with direction of loading) and satisfies the Plateau's law of foam equilibrium [16]. The study of single-cell models probably provides a more effective way to understand the relationship between local cell characteristics and bulk properties [13, 14]. The results can mainly illustrate some of the basic mechanisms of deformation during moulding process.

2 Finite Element Model

Foam cells are the basic unit of PU foam material.Through observation from a microscope and a literature review [17], it was found that the cell structure of flexible PU foam is more similar to a regular dodecahedron (Fig. 1). Each foam cell consists of 12 pentagon windows and 30 struts in total. Each pentagon window is surface bonded by 5 struts. Real foam structures more frequently assume the shape of a 12-hedron, which has regular pentagons as faces.If this structure is selected as the basic simulation model, the results obtained would not only be more objective and accurate, but also conform to the requirements of development and production.

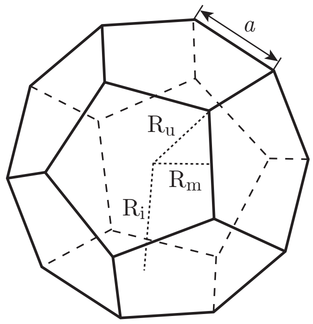

Fig. 1: Dimensions of a regular dodecahedron [17]

In this paper, a model is created using commercial FEA software, ANSYS 13.0 (ANSYS, USA). The modeling starts with the key points defined by the coordinates. The points were then connected with straight lines according to the shape of a 12-hedron. In case of real foam