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Multi-objective optimization of converting process of auxetic foam using three different statistical methods

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Abstract

This paper studies the optimization of converting process parameters of conventional foam into the auxetic. The control factors of converting process are heat temperature, pressure and time. The aim of this study is to achieve an optimum combination of these control factors for obtaining maximum stiffness and minimum negative Poisson's ratio as the desired responses. A series of experiments were implemented based on the Taguchi orthogonal array design. In order to determine the optimum control factors level, three different multi-objective optimization methods i.e. grey relational analysis, fitness function and desirability function were employed. The optimum combinations achieved form all methods were verified through the confirmation tests. Although outcomes of all these methods, in the case of both Poisson's ratio and stiffness, were in a good agreement with the confirmation tests, however the result of grey relational analysis had the minimum mean error percentage. Also, all these methods reported the pressure, heat temperature and time as the first, second and third level of significance, respectively. This study allows manufacturer to select the optimization procedure appropriately and produce the auxetic foam with minimum waste material.

Keyword: auxetic foam, negative Poisson's ratio, gray relational analysis, desirability function, fitness function.

1. Introduction

Conventional materials have most the positive Poisson's ratios (PPR) meaning under extension of the axial direction of the material, a compression will be happened along the transverse direction, and vice versa [1]. In contrast, there are another generation of materials which are unexpectedly exhibit a lateral expansion/compression during apply longitudinal stretch/contraction namely display negative Poisson's ratios (NPR) [2, 3]. Auxetic materials are not so unfamiliar and auxeticity property has been reported for a broad range of metallic and non-metallic materials [4-7]. The NPR aspect of an auxetic structure gives the gainer several notable mechanical and physical properties e.g. more fracture toughness, better strength, appropriate acoustic treatment, better energy dissipation and absorption, upgraded damping and indentation resistance. [8-12].

The first generation of auxetic foams [13] generally considered as the open cell structure, are a category of auxetic materials which were welcomed owing to the reasonable price, ease of accessibility and fabrication technique [12, 14, 15]. There are several studies on perceiving the behavior of this type of material [16, 17]. Some researches in the field indicate that regular foams such as iso-density foam exhibit auxetic behavior under high compressive strains [18, 19]. However, the summary of reports in this area shows that the converting conventional foams to the auxetic leads to improve the mechanical properties than the primary material for both types of polymeric and metallic foams [2]. Most of improvements have been straightly assigned to the increase in density owing to the volumetric compression ratio (VCR) applied and the transformation in the structure of cells [15, 20]. Hence, some mechanical properties of foam such as volumetric change under strain (Poisson's ratio), stiffness (Young's modulus), compressibility (bulk modulus) and rigidity (shear modulus) may experience dramatic variations [21, 22]. Stiffness and NPR are simultaneously considered to design some safety facilities such as energy absorbers [23], thin-wall crash-box [24] and sport helmets [25-30].

To calculate the stiffness of foams ASTM D3574-95 [31] is completely clear. Poisson's ratio (PR) of a material normally can be specified by a strain gauge. Nevertheless, foams are flexible solids and using this technique is not

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