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Short communication: test equipment

A new biaxial compression fixture for polymeric foams

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ABSTRACT

This article presents a new biaxial compression test fixture designed for polymeric foam materials. The main advantage of the new fixture is that it is designed for uniaxial testing machines, therefore the biaxial compression measurement does not require a multiaxial test system. The geometries of the fixture and the test specimen, respectively, ensure equibiaxial loading conditions. In order to demonstrate the performance of this new device, equibiaxial measurements of a polymeric foam material are presented. The particular material under consideration is a closed-cell polyethylene foam. In addition, the relation between uniaxial compression tests and equibiaxial compression tests are presented.

1. Introduction

There are different strategies in order to characterize the mechanical response of polymeric foam materials. One of the approaches to describe the material behaviour is to investigate their microstructures. The well-known book of Gibson & Ashby [1] provides an excellent overview of the mechanics of cellular solids from a microstructural point of view. However, to simulate the mechanical response of polymeric foam materials under certain loadings and boundary conditions, the use of Finite Element Analysis (FEA) may be thought to be a more efficient approach. In order to use FEA for polymeric foam materials, a continuum constitutive model is required. Depending on the particular polymeric foam material, the constitutive model may be composed of elastic, viscous and plastic components. In addition, the constitutive equation must be able to be used in finite strain deformations. The visco-hyperelastic constitutive model has been found to be an accurate approach to characterize the mechanical bahaviour of elastomers [2–6].

It is well-known, that the hyperelastic characterization of elastomers may lead to unwanted instabilities and difficulties. If only uniaxial tension (or compression) test data is used to obtain the material parameters of the applied particular hyperelastic model, then the simulated biaxial response may have very poor accuracy. The recent paper by Steinmann et al. gives an excellent overview of this issue [7]. Therefore, in order to accurately characterize the hyperelastic constitutive model, the availability of biaxial test data is crucial [8,9]. Additional test experiments serve more information about the material characteristics, which can be used to describe more precisely the material behaviour [10,11].

There are several test fixtures designed for biaxial tension of polymeric materials [12–17]. In contrast to the various biaxial tension fixtures, biaxial compression fixtures are rarely published. An example for biaxial compression equipment is given in [18]. However, it must be noted that this equipment is a multiaxial system with two loading directions.

The demand for a compression test fixture which can be easily attached to an uniaxal testing machine (such as INSTRON 3345 single column testing system) is, therefore, obvious. The author of this article has not found any article presenting a biaxial test fixture for uniaxial testing machines. Therefore, the lack of this type of fixture was the stimulus to design an equibiaxial test fixture mainly for polymeric foam materials.

The outline of the paper is as follows: in Section 2, the design of the new biaxial test fixture is presented; Section 3 shows biaxial compression data obtained using the new biaxial compression fixture; Section 4 summarizes the results.

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2. Design

The starting idea in designing the compression test fixture was to design it to be as simple as possible without using any moving parts. The proposed design is made of two comb-like parts made of steel, which can slide into each other. The CAD model of the fixture is illustrated in Fig. 1 and Fig. 2. The nearly frictionless sliding is achieved by leaving small gaps between the forks.

When the test specimen is properly placed in the fixture, the kinematical constraints ensure equibiaxial loading situation. Since the forks are perpendicular to each other, it follows that the equibiaxial loading force applied to the specimen is equal to $F/\sqrt{2}$, where F is the loading force acting on the fixture, as illustrated in Fig. 3.

The constraint between the forces holds also for the displacements. Thus, the equibiaxial extension corresponding to the crosshead's displacement u is $u/\sqrt{2}$. The constructed biaxial compression fixture is shown in Fig. 4.

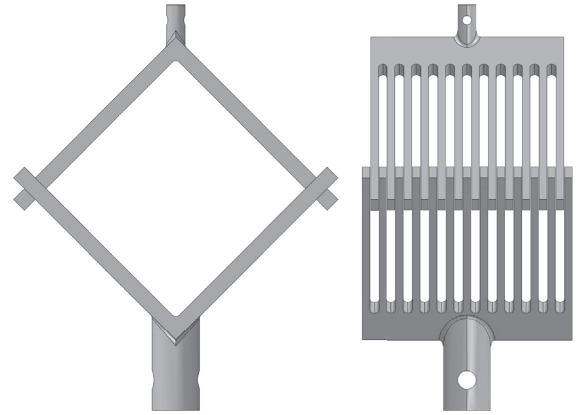

Fig. 2. 3D CAD modell of the biaxial compression test fixture. Front view and side view.

3. Measurements

3.1. Kinematics of uniaxial and equibiaxial compression

Fig. 5. illustrates the uniaxial and equibiaxial compressions for a cube specimen with edge dimension L_0.

The principal stretches and the nominal stresses (or engineering stress) in the loading directions are

$$\lambda^{\mathrm{U}} = 1 + \varepsilon^{\mathrm{U}} = 1 - \frac{u^{\mathrm{U}}}{L_0}, \quad \lambda^{\mathrm{B}} = 1 + \varepsilon^{\mathrm{B}} = 1 - \frac{u^{\mathrm{B}}}{L_0}, \tag{1}$$

$$P^{\mathrm{U}} = \frac{F^{\mathrm{U}}}{L_0^2}, \quad P^{\mathrm{B}} = \frac{F^{\mathrm{B}}}{L_0^2}, \tag{2}$$

where the upper index U refers to the uniaxial case, whereas the upper index B refers to the equibiaxial case. Let the crosshead's displacement be denoted by u and let F be the force acting on the load cell (see Fig. 3.). It follows that the nominal stress and the principal stretch corresponding to the equibiaxial case can be calculated as

$$P^{\mathrm{B}} = \frac{F^{\mathrm{B}}}{L_0^2} = \frac{F}{\sqrt{2}L_0^2}, \quad \lambda^{\mathrm{B}} = 1 - \frac{u^{\mathrm{B}}}{L_0} = 1 - \frac{u}{\sqrt{2}L_0}. \tag{3}$$

It must be noted that, for anisotropic material, the nominal stresses P_1^B and P_2^B are not equal for equibiaxial extension. In this report, the nominal stress corresponding to the equibiaxial loading

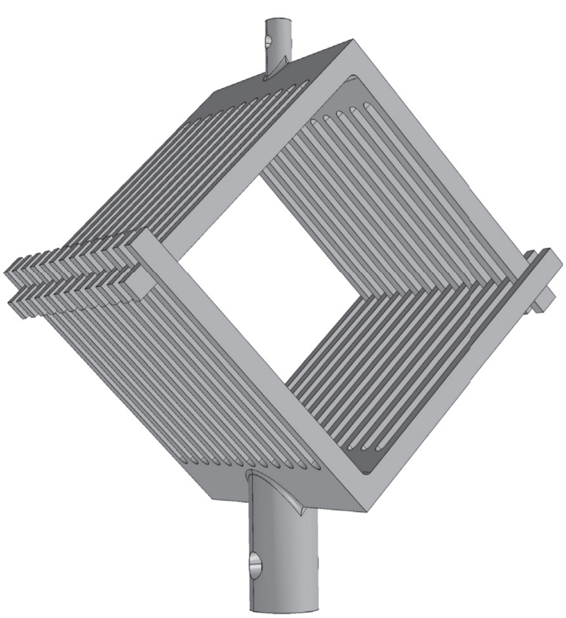

Fig. 1. 3D CAD modell of the biaxial compression test fixture.

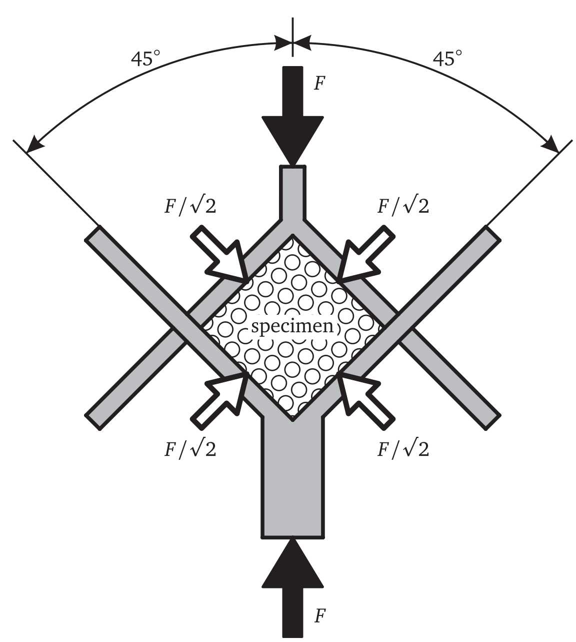

Fig. 3. Kinematical constraint for the loading force.