INFLUENCE OF TEMPERATURE AND SPEED OF LOADING ON FOAMS BEHAVIOUR

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1. Introduction

Foam materials have a cellular structure and hence behave in a complex manner, especially under conditions of progressive crush. This crush behaviour is dependent on the geometry of the microstructure and on the characteristics of the parent material. Foam materials are often used as cores in sandwich construction, and in this application the material can be subjected to multi-axial stresses prior to and during crush. Well-known advantages of cellular materials are their excellent ability for energy adsorption, good damping behaviour, sound absorption, excellent heat insulation and a high specific stiffness. A good knowledge of the behaviour of different grades of foams is important for being able to design high performance sandwich composites adapted to the special needs of a particular application [1, 2].

Polyurethane (PU) foam is an engineering material for energy absorption and has been widely used in many applications such as packaging and cushioning. The mechanical behaviour of PU foams has drawn attention to engineers and researchers. The mechanical response of rigid PU foams under compression in the rise and transverse direction gives different deformation responses in each direction which are attributed to the anisotropy in the internal cellular structure. Enhancements have been developed to take into account the specific foam behaviour [3-4]. A modern approach is micro-modelling, in which the actual cellular structure is modelled [5].

2. Experimental Testing

Tests (traction, compression, and shear) have been performed on three different foams, having the densities of 35, 93 and 200 kg/m³. The three grades of PU foams were subjected to compressive testing at a loading speed which varied from 2 mm/min up to 40000 mm/min at three different temperature levels: -60 °C (use of the foam as a core material for sandwich composites in aerospace applications), 23 °C (ambient temperature) and 80 °C (in hot environment).

SEM (Fig. 1) analyses show the morphology of such closed cell PU foams. Different cell sizes and voids are observed.

Fig. 1: Morphology of the 93 and 200 kg/m³ foams

The used equipment was a hydraulic testing machine produced by MTS, being capable of testing speeds up to 6 m/s. The specimens were crushed up to 90 % strain in order to analyze...
carefully the densification zone, and then unloaded at a speed of 0.6 mm/min. The rate of acquisition has been increased as the loading rate was increased, while during unloading the acquisition has been done at 0.5 Hz proven to be sufficient for a correct data representation. The unloading speed was independent of the loading speed also in order to study the viscoelastic effects.

3. Sample of Obtained Results

Hereby only very few results are presented for the response of the 200 kg/m\(^3\) foam on the rise direction at the three temperatures for speeds of 2, 54, and 500 mm/min (Fig. 2). As temperature of testing is diminished (-60 °C) yielding stress is increasing with a greater difference between the upper and lower limits, and the foam has a hardening response in the plateau region with a more evident fragile crushing of the cell walls.

![Fig. 2: Influence of loading conditions on rise direction for the 200 kg/m\(^3\) foam](image)

When increasing the speed of loading in compression (on the same rise direction) up to 40000 mm/min we can notice that the upper yielding limit is constantly increasing at the three tested temperatures. If we use a logarithmic scale for the representation of the speeds, at 23 °C and 80 °C the slope of the interpolation lines (Fig. 3) is practically the same, regardless the speed. At -60 °C the slope is increasing due to a different behaviour of the foam at speeds greater than 20000 mm/min. Therefore, different local mechanisms in the crushing of the foam are produced.

![Fig. 3: Influence of the speed of loading at different temperatures on the upper yielding stress](image)

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5. References