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Test method

Novel mechanical characterization method for deep sea buoyancy material under hydrostatic pressure

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ABSTRACT

Syntactic foams, used in submersibles and in pipelines for deep sea oil wells, must be resistant to the severe conditions of the deep sea environment. As these foams will be in service for at least 20 years, their qualification testing is crucial. However, their mechanical characterization under real conditions of use is a challenge. In deep sea, the main loading is hydrostatic compression, however there is no standard procedure for testing material under pure hydrostatic pressure. The aim of this paper is to present a new characterization technique based on buoyancy loss measurement under hydrostatic pressure. To validate the method, two different syntactic foams (one brittle and one ductile) have been tested. Their behaviours under hydrostatic pressure have been followed by the proposed technique. The results from this innovative characterization technique have been compared to those of traditional uniaxial compression tests performed on the same materials.

1. Introduction

The oceans represent more than 70% of the surface of the earth and most of them remain unexplored. This is due both to technological challenges as well as economic reasons. However, with the increase of the oil barrel price, deep sea oil wells become economically viable. This leads to the development of new technologies and materials for exploration and exploitation purposes. As an example, syntactic foams have been developed in the 1960's for buoyancy in deep sea exploration applications [1,2]. They are one of the main components of the Ifremer manned submersible, Nautile, which can go down to 6000 m, shown in Fig. 1. Syntactic foams are made of fillers embedded in a polymeric matrix. The fillers are often hollow glass spheres in the micrometer range. Glass microspheres have been described in detail by Ruckebush [3]. Depending on the nature of the components, the syntactic foams' functional properties are light weight, high hydrostatic strength and long term integrity in a deep sea environment. Syntactic foams are also used for their thermal insulation properties in deep sea oil exploitation [4]. Indeed, in deep sea, oil has to be kept above 40°C in order to avoid the formation of wax and hydrates, and to maintain the flow. Syntactic foams are used in various other applications. Bibin has recently provided an exhaustive review of their applications and uses [5]. To be used in harsh environment, the materials have to be qualified in conditions simulating the conditions of use. In deep sea, the structures are subjected to high mechanical stresses. The characterization of the mechanical behaviour of syntactic foam is of primary interest and it has been extensively studied during the last decade. Most of the published studies refer to uniaxial compressive behaviour, e.g; Kim [6], Gupta [7,8], Karthikeyan [9], Song [10], Tagliava [11], Aureli [12], Poveda [13], Porfiri [14]. However, in the case of buoyancy for

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Fig. 1. Ifremer manned submersible Nautile.

submarine structures, the loading condition is hydrostatic compression. If the material used is coated or bonded to a surface, it is also subjected to deviatoric stresses. To a first approximation, the behaviour of submarine foam can be evaluated by hydrostatic compression testing. However, as far as the authors are aware, there is no standard equipment for material characterization under purely hydrostatic compression at high pressure. The aim of the present work is to provide a new methodology for the evaluation of the mechanical behaviour of syntactic foams under such loading. For this study, two syntactic foams made with the same glass microspheres are used: glass epoxy syntactic foam (GSEP) and glass syntactic polyurethane (GSPU). The material itself will not be extensively described in this work; these two syntactic foams, both industrially used, have simply been chosen for their differences in behaviour (one ductile and one brittle). In the first part of this paper, the foams will be studied by a traditional uniaxial compression test method. In the second part, the development of the new characterization technique will be presented and the foams will be characterized. Finally, a comparison between the results from both techniques will be reported.

2. Materials

The syntactic foams studied in the present work are designated as GSEP and GSPU. For both materials, the fillers are glass hollow microspheres grade S38 from 3M™. The two foams were made by casting. Their specific gravities are 0.72 and 0.86, respectively. The volume content of microspheres is around 55% for the GSEP and 25% for GSPU.

3. Traditional tests

3.1. Test method

Uniaxial compression tests are frequently used to provide information on the behaviour of the syntactic foams. Standards are available [15,16], but sample geometry is not strictly defined. Usually, a straight cylinder is preferred, but a specially designed dumbbell geometry presents the advantages of localizing the maximum deformation in the calibrated part of the specimen and limiting the edge effects in the load introduction area. In the present work, these two geometries have been tested. Their descriptions are given in Table 1.

Table 1
Sample geometry for uniaxial compression test.

Type	Shape	Diameter (mm)	Length (mm)	Calibrated length (mm)
1	Right cylinder	12.5	25	25
2	Dog bone cylinder	13	65	27

Tests were performed at 20°C ± 1°C and 50 RH%, with a 200 kN capacity electro-mechanical test frame with a loading rate of 2 mm/min. Samples were equipped with strain gauges, and an axial extensometer was also mounted.

Digital Image Correlation (DIC) was used on some specimens. DIC allows the measurement of the strain field versus applied load from high resolution images. The equipment used was an Aramis 5M system from the GOM Company. The 3D mode was used and the calibration panel was 90*72 mm^2. For type 1 specimens, the axial line covers the whole length of the sample. For type 2 specimens, the area analyzed covers half of the length. The position 0 corresponds to the central part of both types of samples as shown in Fig. 2.

3.2. Results of traditional tests

The behaviour of both materials, GSEP and GSPU, under uniaxial compression has been investigated, as shown in Fig. 3.

The stress-strain curves of GSEP and GSPU show a non linear response for the two geometries. However, the behaviour of the two materials is significantly different.

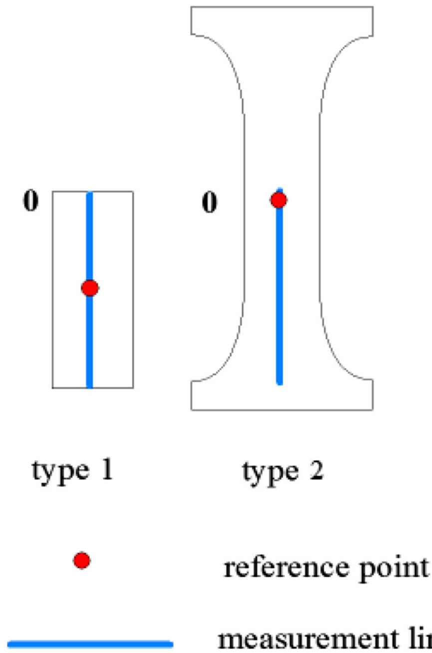

Fig. 2. Compression sample geometry and location of measurement.