System nanoporous media – non-wetting liquid, as a basis for the development of shock damper

A A Belogorlov, V D Borman, V A Byrkin, D A Paryohin and V N Tronin

National Research Nuclear University MEPhI (Moscow Engineering Physics Institute), Kashirskoe highway 31, Moscow, 115409, Russia

E-mail: AABelogorlov@mephi.ru

Abstract. In this work the method of system nanoporous medium – non-wetting liquid testing for damping devices presented. The method was tested for four systems nanoporous medium – non-wetting liquid. As a nanoporous medium was used commercial samples produced by Sigma-Aldrich hydrophobic silica Fluka 60 C8, Fluka 100 C8, Fluka 100 C18 and Fluka 90 C18. As a non-wetting liquid was used distilled water. These systems have been investigated in the temperature range $20 \div 60°$ C, the maximum energy of impact was 100 J. According to the method, time, power and energy characteristics of the process of non-wetting liquid intrusion - extrusion was determined. Also presented the dependences of impact processes characteristics on temperature.

1. Introduction

Recent studies have shown that systems "nanoporous medium – non-wetting liquid" are promising for use in damping devices and storage of mechanical energy [1-5]. One of the basic requirements for such devices it is stable work in a given temperature range without critical settings changing. At the same time, the requirements must be carried out to limit impacts on the protected object. For devices that can be used system "nanoporous medium – non-wetting liquids" power values, energy and time characteristics of the system depends on the choice of nanoporous media and non-wetting liquid [6-11]. It is also shown that such systems tend to change performance parameters under the influence of external action [12,13].

The aim of this study was to test promising methods of analysis using different porous media for absorbing mechanical energy devices. Also as part of this work we investigated the effect of surface modification and pore size of porous media on the process of filling nanoporous media by non-wetting liquid under pulsed pressure changes at a given temperature and energy of impact.

To determine the time, energy and power characteristics of the process of filling nanoporous medium by non-wetting liquid was used developed in MEPhI technique [14]. Distilled water was used as a non-wetting liquid, and industrially manufactured hydrophobized silica Fluka 60 C8, Fluka 100 C8, Fluka 100 90 Fluka C18 and C18 were used as the nanoporous media, differ an average pore size and surface modification.

2. Experiment

2.1 Nanoporous media

The nanoporous media under study were commercially available silica gels with a random structure of pores obtained in the sol–gel process Fluka 60 C8 - Silica gel 60 C_8, Reversed phase (Sigma-Aldrich catalogue # 18948), Fluka 100 C8 - Silica gel 100 C_8, Reversed phase (Sigma-Aldrich catalogue # 60755), Fluka 90 C18 - Silica gel 90 C_{18}, Reversed phase (Sigma-Aldrich catalogue # 60757) and Fluka 100 C18 - Silica gel 100 C_{18}, Reversed phase (Sigma-Aldrich catalogue # 60756). Using the pycnometry (Ultrapyc 1200e, Quantachrome Instruments) and porometry (Autosorb IQ, Quantachrome Instruments) methods [15], we determined the density (ρ), specific surface area (S_p), specific volume of pores (V_p), and average pore size within the cylindrical model of pores ($<R>$).The results are presented in Table 1.

Table 1. Characteristics of the porous media under study

Nanoporous medium	ρ, g/cm^3	V_p, cm^3/g	S_p, m^2/g (BET)	$<R>$, nm	Modificator's length [16], nm
Fluka 60 C8	1,9685	0,38	230	1,9	1,2
Fluka 90 C18	1,5975	0,36	148	2,7	2,45
Fluka 100 C18	1,6125	0,46	183	3,9	2,45
Fluka 100 C8	1,7603	0,56	267	3,9	1,2

2.2 Experimental bench and measurement procedure

The experimental stand was a base plate on which the strain gauge load cell (*F*) with a measuring range of 10 N ÷ 10 kN with measurement error is less than 0.5% and the upper plate. The base plate and top plate are connected to the uprights. Steel cables, on which load of 10 kg can freely move, is tensioned between the plates. On one of the pillars slide-wire gauge displacement (*l*) is fixed with a measuring range of 0÷140 mm with a margin of error of less than 0.05%. Assembled pressure chamber was placed on the force sensor. Inside the chamber, the porous medium is located a given weight, and the remaining volume of the chamber is filled with liquid (distilled water). The chamber was sealed through a sealing system of moving rod. This rod was connected by the plate with rod of displacement sensor. After the fall of the load at a predetermined height relative to the rod chamber, a rod inside the chamber starts to move, creating an overpressure therein by changing the internal volume of the chamber. When this strain gauge recorded the force acting on the support, and, consequently, the pressure in the chamber $p = F / S$, where *S* - the rod area. Changing the internal volume of the chamber respectively defined by a movement sensor as $V = l \cdot S$. Data from the force and displacement sensors were recorded every 20 microseconds in the file and subsequently processed. To investigate the process at different temperatures chamber was equipped with temperature control system. The temperature inside of chamber was maintained by the thermostat LOIP FT-316-40 with accuracy ± 0.2 ° C. More information about measuring system and the measurement procedure are described in [14].

Experimental results of pressure change in the chamber *p(t)* and the internal chamber volume *V(t)* from the time shown in Fig. 1. Power, time and energy characteristics of the systems is also determined according to the procedure described in [14].
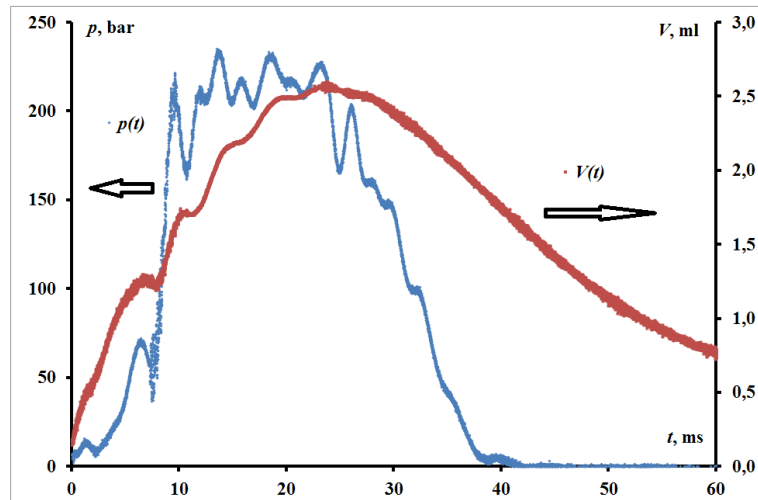
Figure 1. The cell pressure and the internal volume change in time

(Sample Fluka 100 C18, impact energy 30 J and T = 40 ° C)

Intrusion time of the porous medium by non-wetting liquid, characteristic filling pressure and the specific dissipated energy were identified by the experimental. The experiments were performed at temperatures of 20 ÷ 60 ° C and the energy of impact 20 ÷ 100 J.

3. Results and discussion
Figures 2-7 summarizes the results of investigated systems.

Figure 2. Typical filling pressure at T = 40 °C and impact energy = 40 J for systems Fluka 90 C18, 100 C18, C8 100, and 100 J for the system Fluka 60 C8
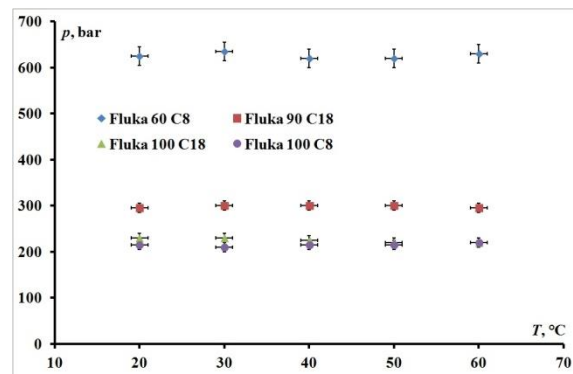

Figure 3. Typical filling pressure of investigated systems. Impact energy 40 J for systems Fluka 90 C18, 100 C18, C8 100, and 100 J for Fluka 60 C8 system at the temperature range 20 ÷ 60 °C

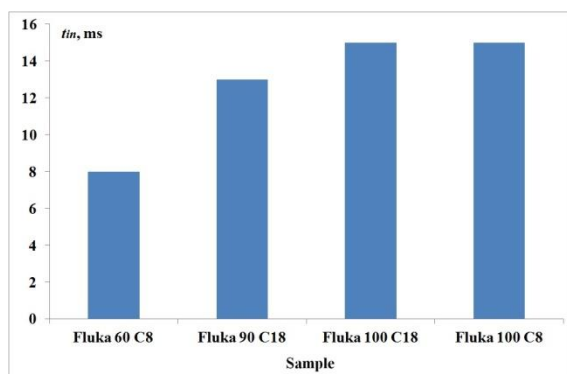**Figure 4.** Typical intrusion time at T = 40 °C and impact energy = 40 J for investigated systems

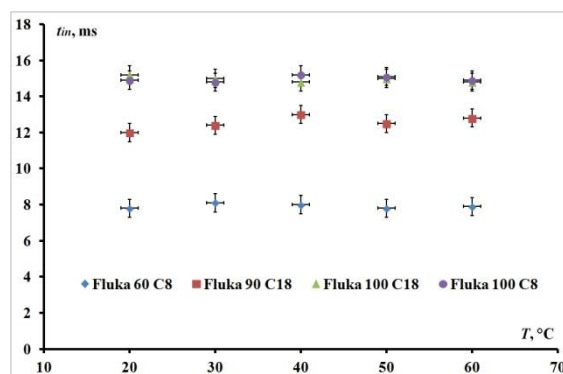**Figure 5.** Typical investigated systems intrusion time. Impact energy 40 J for investigated systems at the temperature range 20 ÷ 60 °C
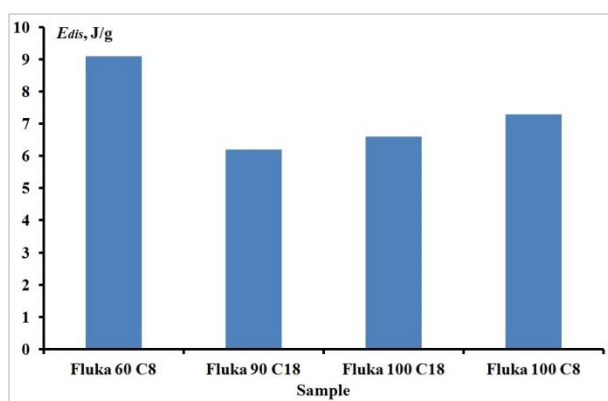

Figure 6. Typical dissipated energy at T = 40 °C and impact energy 40 J for systems Fluka 90 C18, 100 C18, C8 100, and 100 J for the system Fluka 60 C8
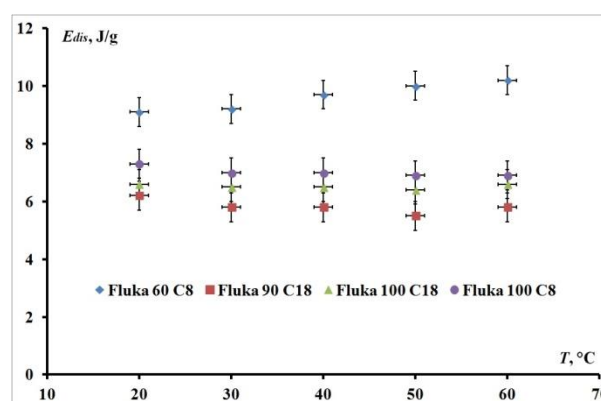

Figure 7. Typical dissipated energy of investigated systems. Impact energy 40 J for systems Fluka 90 C18, 100 C18, C8 100, and 100 J for Fluka 60 C8 system at the temperature range 20 ÷ 60 °C

Typical pressure decrease (Fig. 2) with radius increase (Table 1) and modificator chain length decrease (in case of similar radii (Table 1). But typical pressure (Fig. 3), within the error limits, does not depend on temperature in temperature range 20 ÷ 60 °C.

Typical liquid intrusion time increase (Fig. 4) with radius increase (Table 1) and modificator chain length decrease (in case of similar radii (Table 1). But typical liquid intrusion time (Fig. 5) also does not depend on temperature, within the error limits, in temperature range 20 ÷ 60 °C.

Typical dissipated energy (Fig. 6) does not have straight dependence on radius and modificator chain length (Table 1). Typical dissipated energy (Fig. 7) also does not depend on temperature, within the error limits, in temperature range 20 ÷ 60 °C.

Increasing the temperature from 20 to 60 °C has no significant effect on the absorption characteristics of the process of mechanical energy, but fluid characteristics such as surface tension and viscosity are reduced from 72 to 66 mN/m and 1.002 to 0.467 10^{-3} Pa s, respectively [26]. However, the typical filling pressure and intrusion time does not change within an error. Therefore, we can conclude non-viscous liquid transport in porous media. This confirms, on independent samples, the earlier results on the test specimen Libersorb 23 [14].

Acknowledgements

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