Proceedings of the 14th Symposium on Experimental Stress Analysis and Materials Testing

Edited by
Liviu Marsavina

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Selected, peer reviewed papers from the
14th Symposium on Experimental Stress Analysis and Materials Testing with the Occasion of 90 Years of Strength of Materials Laboratory from POLITECHNICA University Timisoara
May 23-25, 2013, Timisoara, Romania

Edited by

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Preface

In 2013 the Strength of Materials Laboratory from POLITEHNICA University of Timisoara reaches its 90th anniversary. The Strength of Materials Laboratory was opened in 1923 in the presence of King FERDINAND and Prime Minister I. C. BRATIANU. The lab was equipped with the support of the Rector of Politehnica School from Timisoara professor Traian LALESCU and Strength of Materials professor C. C. TEODORESCU. First tests with students were held in 1923, and the first student "*Laboratory notebook*" was published in 1924. In 1931 the laboratory was visited by King CAROL the Second and Prime Minister Nicolae IORGA. Over the years the Laboratory has developed considerably and now represents one of the main facilities in the West part of Romania for materials testing, experimental and numerical stress analysis.

To celebrate this anniversary **POLITEHNICA University of Timisoara**, **Fundatia POLITEHNICA** and **Romanian Association on Experimental Stress Analysis (ARTENS)** organized the 14th **Symposium on Experimental Stress Analysis and Materials Testing** in Timisoara from 23 to 25 May 2013. The conference which was attended by scientists from 12 countries (Austria, Belgium, Finland, Germany, Italy, Poland, Romania, Serbia, Slovakia, Slovenia, Spain, UK) represents a forum for latest researches on experimental and numerical stress analysis aspects, material testing, fracture, fatigue, biomechanics, vibration and noise fields. The conference program consists in one plenary session and 11 paralel sessions. This volume represents a collection of papers presented at the conference. The proceedings are structured on five parts: Experimental Stress Analysis and Materials Testing, Analytical and Numerical Stress Analysis, Biomechanical Applications, Civil Engineering Applications, and Mechanical Behavior of Cellular Materials.

The Editor would like to thank the members of the Local Organizing Committee and International Scientific Committee for help and support, which were essential to the success of the conference. Also the support of our sponsors is greatly acknowledged.

Editor
Prof. Liviu MARSAVINA
Timișoara, December 2013

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CHAPTER 1:

Experimental Stress Analysis and Materials Testing

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APPARATUS FOR MEASURING DYNAMIC BULK COMPLIANCE OF TIME-DEPENDANT MATERIALS

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Keywords: polymers, time-dependant materials, volumetric behavior, bulk behavior, harmonic excitation, experimental setup, dynamic bulk compliance

Abstract. This paper describes a novel apparatus for measuring dynamic bulk compliance $B^*(\omega)$ of time-dependant materials. System can measure dynamic bulk compliance at room temperature, at pressures up to 100 ± 1,5 bar and frequencies from 100 Hz to 1000 Hz. Functionality of the apparatus is demonstrated by performing measurements of dynamic bulk compliance for two different materials, i.e., polyvinyl acetate (PVAc) and thermoplastic polyurethane (TPU). Measurements were conducted at room temperature, atmospheric pressure and frequencies from 100 Hz to 1000 Hz.

Introduction

The use of polymers as engineering materials has significantly increased in the past decades. Their rapid expansion is the result of better general, economic and environmental suitability, with which they can complement and/or substitute conventional materials. During the production phase and later on in utilization they are exposed to different environmental conditions (i.e., different temperatures, pressures and humidity) that affect their volumetric behavior. Therefore, understanding of the volumetric response is important in numerous engineering processes (e.g. high pressure injection molding) [1] and applications (e.g. noise and vibration reduction applications) [2].

Numerous researchers have measured uniaxial and shear response on many polymeric systems over the last few decades. Disproportionately little attention has been given to measuring bulk response of these systems, since commonly used assumptions of time or frequency independence of the volumetric properties served analysts well. However, increasing demands for higher material performance at elevated pressures and temperatures do not allow such simplification. Recent research findings addressing volumetric behavior pointed out the potential need for more careful characterization of time-dependant or dynamic bulk response [3].

For this reason, a novel measuring system for investigation of bulk behavior of time-dependant materials under harmonic loadings was developed on the basis of the research works of McKinney and Belcher, 1963 [4]; Deng and Knauss, 1997 [3] and Sane and Knauss, 2001 [5]. The newly developed measuring system can simultaneously measure real (storage) component $B'(\omega)$ and imaginary (loss) $B''(\omega)$ component of the dynamic bulk compliance, $B^*(\omega)$, which is unknown for most of the time-dependant materials.

This paper presents the measuring capabilities and additional/optional upgrades of one of the few experimental setups that are worldwide available for the characterization of viscoelastic bulk characteristics under harmonic excitation.

Experimental methodology

Measuring principle. Measurement of dynamic bulk compliance $B^*(\omega)$ takes place in the cavity of a pressure chamber, filled with an incompressible medium (oil), where there is uniform hydrostatic

pressure. Sinusoidal signal in the form of AC voltage at respective frequency excites a piezoelectric disk (transducer), which acts as an actuator and causes compression waves that travel through the transmitting medium and a polymeric sample. A second piezoelectric disk, which acts as a pressure sensor, perceives compression waves in the form of amplitude and phase (phase is shifted due to measurements of time-dependant materials) [3], Fig 1.

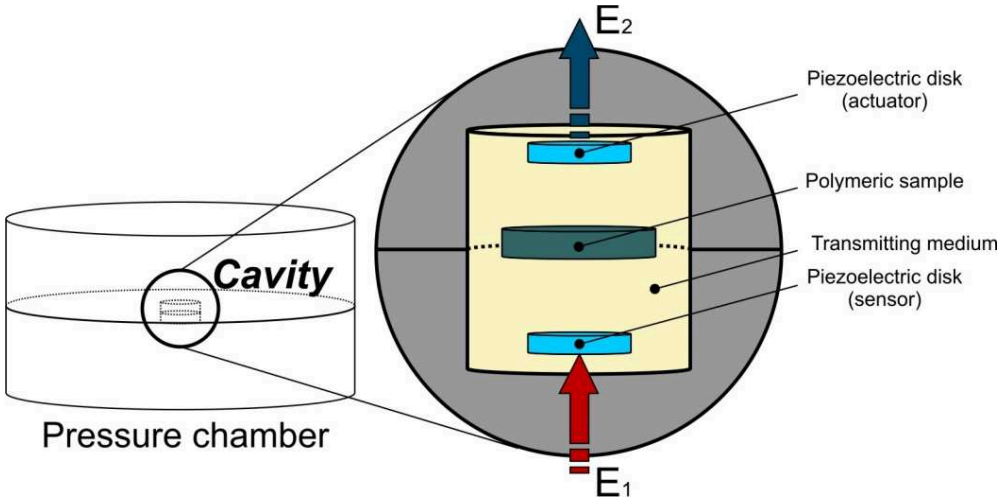

Figure 1: Schematic of pressure chambers cavity and associated parts [3]

Both piezoelectric disks are mechanically coupled with sum of compliances (compressibilities) of the sample, transmitting medium, actuator, sensor, elements in the cavity and cavity itself. Ratio between driving voltage E_1 for the first piezoelectric disk, and the output voltage E_2 from the second piezoelectric disk is given as the sum of piezoelectric disk constants (actuator and sensor) and the sum of several compliances in the complex form [3-5]:

$$\left(\frac{E_1}{E_2}\right)^* = \mathrm{C}^* + \mathrm{D}^*(B_\mathrm{S}^* - B_\mathrm{M})V_\mathrm{S}, \tag{1}$$

where B_M is adiabatic volumetric compliance (compressibility) of transmitting medium, B_S^* complex dynamic bulk compliance of sample and V_S volume of sample. C^* and D^* are complex constances, that are defined through internal calibration at each temperature, hydrostatic pressure, frequency and calibration sample with known compliance (compressibility).

Such method allows direct measurements of volume change under sinoidal hydrostatic pressure at the time of volumetric deformation of the polymeric sample. From the obtained results we can calculate real (storage) component $B'(\omega)$ and imaginary (loss) $B''(\omega)$ component of the dynamic bulk compliance $B^*(\omega)$. However, the following assumptions must be taken into account:

1. length of the cavity must be much smaller than the wave length of compression wave; this ensures that pressure is uniform (constant) inside the cavity;
2. force transferred to the sample is essentially hydrostatic pressure;
3. complex compliances (compressiblities) of piezoelectric disks, cavity, wires, sample and transmitting medium are additive (can be summed);
4. transmitting medium by which the polymeric sample is excited is incompressible.

Experimental setup. Experimental setup for measuring dynamic bulk compliance $B^*(\omega)$ of time-dependant materials can be divided in 3 major subsystems. These subsystems are hydraulic, electronic and thermal subsystem [3], Fig. 2. Each of these subsystems performs a specific function and is essential for the operation of apparatus and its measurement accuracy.

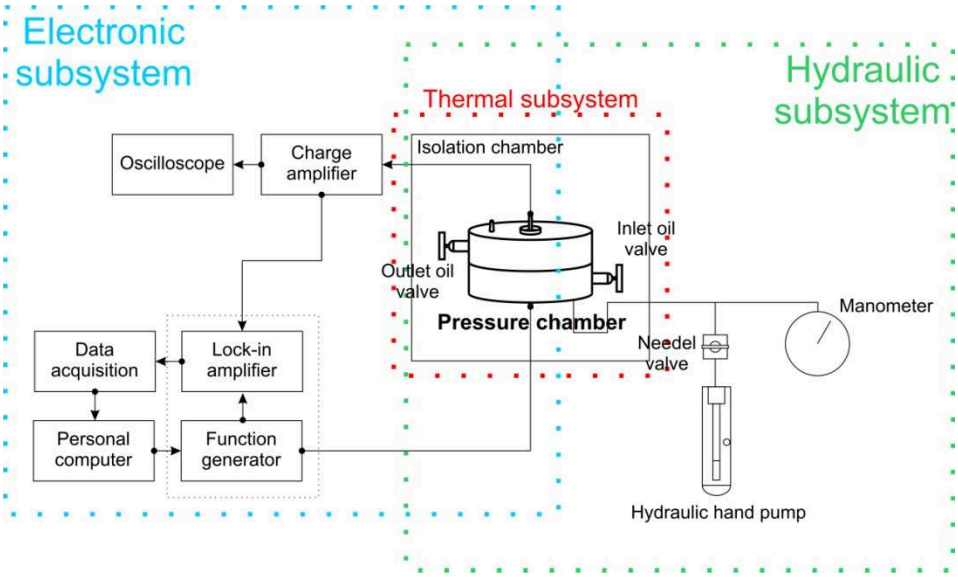

Figure 2: Components of experimental setup for measuring dynamic bulk compliance $B^*(\omega)$ of time-dependant materials [3]

Hydraulic subsystem is needed to supply transmitting medium into the pressure chamber and also to pressurize hydraulic subsystem. This subsystem should be absolutely sealed, since it should prevent leakage of transmitting medium. Upper limitation of the system for setting up the hydrostatic pressure is up to 700 bars.

Electronic subsystem ensures generation of the signal, transmission, filtering and acquisition of the signal. Input signal for the first piezoelectric that acts as an actuator is generated by the function generator within the large frequency range from 0,001 to 100 kHz with the amplitude up to 5V. Output signal coming from the second piezoelectric that acts as the pressure sensor is sent to the charge amplifier (high pass filter with low cut-off frequency at 10 Hz), and further on to the lock-in amplifier that measures complex components of sinusoidal signal simultaneously at a given frequency. Obtained data is further sent to a personal computer.

Thermal subsystem contains isolation chamber, which enables measurements at constant room temperature. Isolation chamber minimizes environmental temperature variations, and thus ensures constant hydrostatic pressure inside pressure chambers cavity during measurements.

Procedure and materials. Apparatus is in the prototype state and can measure dynamic bulk compliance $B^*(\omega)$ at the following boundary conditions: room temperature ± 1 °C, pressure range from 1 to 100 bar ± 1,5 bar and frequency range from 100 to 1000 Hz. Measurements were carried for two different materials, i.e., polyvinyl acetate (PVAc) and thermoplastic polyurethane (TPU).

Results

Figure 3 presents results of dynamic bulk storage $B'(\omega)$ and loss $B''(\omega)$ compliances for two different materials; PVAc and TPU. Measurements were conducted at room temperature, atmospheric pressure and frequency range from 100 Hz to 1000 Hz. Volume of the samples was 0,0128 cm^3. For both materials (PVAc and TPU) it is clear that storage and loss components of complex dynamic bulk compliance $B^*(\omega)$ are constant within the whole frequency measuring range, and no transition is observed. Storage component $B'(\omega)$ of TPU has higher value (approximately 1,1 GPa^{-1}) than PVAc, which means TPU is more compressible. Loss components $B''(\omega)$ for both materials are almost zero, which means that materials do not exhibit damping at particular boundary conditions. Maximum error of dynamic bulk storage compliance $B'(\omega)$ for PVAc is 7% and for TPU 5,7 %. Maximum error of dynamic bulk loss compliance $B''(\omega)$ for both materials is greater than averaged value which indicates that we cannot precisely detect smaller values of dynamic bulk compliance components with the apparatus at the current state.