Archives of Materials Science and Engineering

Volume 28
Issue 7
July 2007
Pages 413-416

International Scientific Journal
published monthly as the organ of
the Committee of Materials Science
of the Polish Academy of Sciences

Ultrasonic methods in diagnostics of polyethylene

G. Wróbel, Ł. Wierzbicki*
Division of of Metal and Polymer Materials Processing,
Institute of Engineering Materials and Biomaterials, Silesian University of Technology,
ul. Konarskiego 18a, 44-100 Gliwice, Poland
* Corresponding author: E-mail address: lukasz.wierzbicki@polsl.pl

Received 30.03.2007; published in revised form 01.07.2007

ABSTRACT

Purpose: The aim of the work was to find relationship between the ultrasonic wave velocity and the strenght and stess in a polyethylene specimens.

Design/methodology/approach: The experiments have been performed in three distinct phases. During the first phase, typical polyethylene was ageing to get different mechanical properties. In the second phase, strength and ultrasonic properties of composite was testing. In the last of phases we compare changes of properties.

Findings: The experimental results showed relationship between velocity of ultrasonic wave and strength and stress in a polyethylene specimens.

Research limitations/implications: In the future test will be necessary to use more precise testing equipment. Perhaps we will use other ultrasonic probes of lower frequency. In this experiment we used 2 MHz probes. It is necessary to run an experiment with more specimens. Further work is needed in the correlations between ultrasound and stress area.

Practical implications: The results of the investigation have shown possibility of using ultrasonic method to diagnosis of strength changes in polymers materials. This method allowed to test working parts of machines or buildings, without destruction.

Originality/value: The results of the investigations allow to confirm, that ultrasonics can be used to non-destructive testing of the strength and Young's modulus changes.

Keywords: Engineering polymers; Properties; Mechanical properties; Non-destructive testing

MATERIALS

1. Introduction

Nondestructive testing methods are one of the most dynamically developing branches of diagnosis and science in general.

In those applications, in which polymer materials are subject to a heat and mechanical load, it is essential to test the strength characteristics of the composites in use with non-destructive methods. That enables contemporaneous status check of the structure and makes it possible to replace the bivalent evaluation scale (good – bad) with an incessantly gradable strength degradation scale for a material [1-3].

The procedure of ultrasonic tests on objects comprises passing waves into objects, scanning objects by moving a head over their surface and detecting signals (impulses) caused by waves passed through objects.

The basic rule in such tests is to know dependencies between the value of an ultrasonic parameter being measured (for example, the velocity of an ultrasonic wave) and the tested property of the internal structure of a polymer materials. Dependencies between acoustic parameters and structural properties of a polymer materials are usually determined empirically, based on measurements of standard samples with precisely defined and known structural parameters [4].

Characteristic parameters for an ultrasonic wave, which can be its diagnostic features, are [5-9]:

- propagation velocity C (C_L- longitudinal velocity; C_T – transverse velocity; C_s- superficial velocity):

$$C_L = \sqrt{\frac{E(1-\nu)}{\rho(1+\nu)(1-2\nu)}} \tag{1}$$

$$C_T = \sqrt{\frac{E}{2\rho(1-\nu)}} = \sqrt{\frac{G}{\rho}} \tag{2}$$

$$C_S = \frac{0.87+1.12\nu}{1+\nu} \cdot \sqrt{\frac{E}{2\rho(1-\nu)}} \tag{3}$$

where: E – Young's module, G- coefficient of rigidity ρ-density, ν - Poisson's coefficient;

- amplitude damping factor α:

$$\frac{dA}{A} = \alpha dx \tag{4}$$

where: A- wave amplitude;

- kinetic damping factor γ:

$$\frac{dI}{I} = -\gamma dx \tag{5}$$

where; I – wave intensity.

The method to measure velocity of the passing wave, as well as to measure the thickness of the element, are based on the same testing device. Most of flaw detectors allow to measure the time during which the wave passes through the material and, based on the knowledge how fast a wave propagates, also the thickness of the sample.

Most of the time, the measurements are carried out using the echo method and singular or dual heads. Dual heads are used for measurements of objects with curved, defective or corrosion-inflicted surface [9-15].

Experts in ultrasonic testing procedures suggest use of the transition method, especially for less homogeneous materials or for those affected with corrosive processes. However, this method requires use of a set of two opposite-oriented heads. Structure of a subject being tested does not always give access from both sides. These disadvantages are balanced by easier interpretation and repeatability of results given by the flaw detector.

Based on the measurement of velocity and absorption coefficient of ultrasonic waves propagated in the sample volume, volumetric wave acoustics methods allow to acquire a variety of data concerning the structure of the substance. Velocity and absorption coefficient of ultrasonic waves in a solid body depend on mutual interactions of atoms, molecules or groups of molecules. Virtually every change in the structure of matter causes a change in the interaction amongst vibrating oscillators, which is followed by a change in ultrasonic wave propagation parameters. Apart from microstructural changes, the acoustic characteristics of a material can also be influenced by degradation being a result of accumulated microdamages caused by working conditions put on the structure [3].

Description of the issue of microdamages accumulation process in polymers materials creates a basis for efficiency of ultrasonic diagnostics in the load capacity wear evaluation process of a polymer material.

2. Experimental

The materials, procedure and apparatus used to obtain experimental data are described below

2.1. Materials

Polyethylene specimens were cut from plate 8 x 1500 x 3000 mm size. Specimens dimension are 8 x 20 x 250 mm. Surface of specimens were smooth to remove all burrs.

2.2. Procedure

Polyethylene specimens were ageing to diversification mechanical properties and next strength and ultrasounds test.

2.3. Ageing of polyethylene

Environmental conditions assumed for the tests consisted of a corrosive medium of water.

During the tests, it was assumed that the temperature was a constant. The condition was fulfilled, except for a short period of time (3 hours) when the temperature rose.

The ageing process was conducted in the temperature of boiling water.

Tests were divided into four series. Each series had different time measuring points, respectively 48, 96, 192 and 288 hours.

Time measuring point 0 was set for comparison.

2.4. Strength and density tests

Strength tests of the composite material were carried out according to the PN-EN ISO 527-1 standard. Strength of the specimens was measured using a Fritz Heckert FPZ 100/1 machine. Condition of test:

– speed 20mm/min,
– scale of deformation 2:1,
– range of force 10 kN.

Changes of density were carried out according to methodology of the PN-EN ISO 62 standard: „Plastics. Designation of absorbing capacity."

The samples were weighted with an analytical balance with accuracy of reading of 0.001 g. The measurements were made before ageing of samples and after a period of time not longer than 30 minutes subsequent to taking out the samples from the corrosive bath.

2.5. Ultrasonic velocity measurement

Ultrasonic velocity in the specimens was measured using a MG 2000S ultrasonic thickness meter (AZ Industry Supplier, Warsaw, Poland). The schematic view of ultrasonic investigation is shown in Fig. 1.

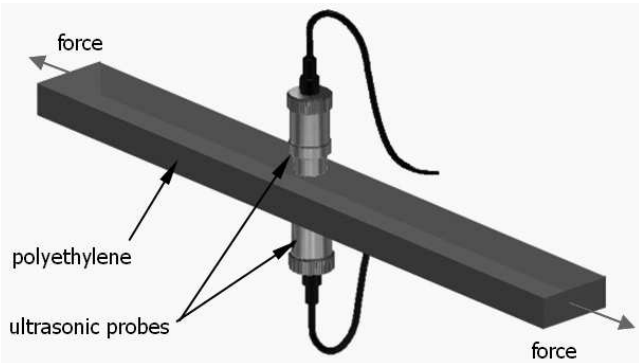

Fig. 1. Scheme of the ultrasonic testing

The device has a build-in function to measure the propagating time. The ultrasonic instrumentation was operated in the time-of-flight mode using through-transmission technique.

For longitudinal velocity measurements, two standard probes of 2 MHz frequency was used. The accuracy of velocity measurements was within ± 1 ms^{-1}.

As a coupling medium at the probes-specimen interface, the USG-gel (Centrum Medicum Poland) was applied. The ultrasonic velocity (c) was calculated dividing the specimen thickness (h) by the time-of-flight (τ) of ultrasonic wave on the basis of well-known formula 1:

$$c = h / \tau \qquad (6)$$

Ultrasoud tests were made before and during the strength tests.

3. Results and discussion

Strength changes in correlation with acoustic properties of the material describing equation (Fig. 2) :

$$\sigma_{max} = -260{,}0852+0{,}0001\ Cr^2 - 0{,}0001\ C^2r^4 \qquad (7)$$

where: C – longitudinal velocity of ultrasound, r – density.

Third picture (Fig. 3) shows changes of velocity of ultrasound propagation proceed during stretching the specimens. Presented results are preliminary and require specify in future tests. However run experiment shows possibility of the ultrasound test to estimate stress of polymers working elements.

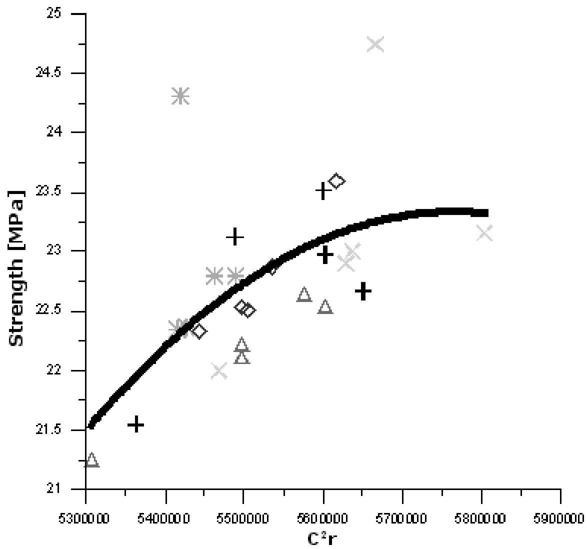

Fig. 2. Relationship between product of the ultrasonic wave velocity and density, and strength: + - speciment no boiling, ◊ - speciment after 48 hours of boiling; Δ - speciment after 96 hours of boiling; × - speciment after 192 hours of boiling; * - speciment after 288 hours of boiling

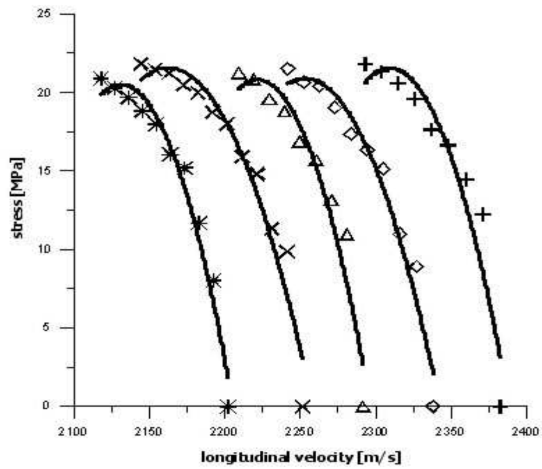

Fig. 3. Relationship between the stress and the ultrasonic wave in few specimens.

4. Conclusions

Run experiments shows posibility of use ultrasound test to estimate strength and stress of polyethylene. Some dispersion of results (fig 2.) obligate to future develop a method of testing polymer materials. In order to find unique correlations between strength and ultrasound properties more test are needed.

Authors of this paper are planning in the future tests check posibilityof use ultrasound test to measure stress in polymer materials.

References

[1] G. Wróbel, Ł. Wierzbicki, Ultrasounds in the diagnosis of strength changes in laminates put in ageing conditions. Proceedings of the 3rd Scientific Conference "Materials, Mechanical and Manufacturing Engineering", M3E'2005, Gliwice-Wisła, 2005, 575-580 (in Polish).

[2] G. Wróbel, Ł. Wierzbicki, Ultrasonic methods in diagnostics of glass-polyester composites, Journal of Achievements in Materials and Manufacturing Engineering 20 (2006) 203-206.

[3] S. Mackiewicz, Ultrasounds testings of the composites materials, Scientific Conference on Ultrasounds materials testing, Zakopane 1995, (in Polish)

[4] M. Rojek, J. Stabik, G. Wróbel, Ultrasonic methods in diagnostics of epoxy-glass composites. Journal of Materials Processing Technology 162-163 (2005) 121-126.

[5] J. Obraz, Ultrasonic Testing of Materials, WNT, Warsaw 1983, (in Polish).

[6] G. Wróbel, Ł. Wierzbicki, S. Pawlak, Ultrasonic quality evaluation method for polyester glass laminated materials, Proceedings of the 11th International Scientific Conference on Contemporary "Achievements in Mechanics, Manufacturing and Materials Science", CAM3S'2005 Gliwice – Zakopane, 2005, (CD-ROM).

[7] J. Stabik, M. Rojek, S. Sokół, Fatigue and ultrasonic testing of epoxy-glass composites, Journal of Achievements in Materials and Manufacturing Engineering 20 (2006) 183-186.

[8] Zhi Wei, Xiaojun Zhou, Yaodong Cheng.: Acoustoelastic determination of local surface stresses in polymethylmethacrylate, Applied Acoustics 61 (2000) 477-485.

[9] C. Potel, T. Chotard, J.F. Belleval, M. Benzeggagh, Characterization of composite material by ultrasonic methods, Composites Part B, 1998, 159-169.

[10] J. Deputat, Nondestructive testing of new materials. Scientific Conference on Nondestructive Testing of Materials, Zakopane 2004 (in Polish).

[11] R. Chandra, S.P. Singh, K. Gupta, Damping studies in fiber-reinforced composites - a review, Composite Structures 46 (1999) 41-51.

[12] S. Ochelski, Experimental methods in mechanics of construction composites, WNT, Warsaw 2004 (in Polish).

[13] L.A. Dobrzański, Engineering Materials and Materials Design, Fundamentals of Materials Science and Physical Metallurgy, WNT, Warsaw, 2006 (in Polish).

[14] L. Holliday, Composite Materials, Elsevier Science Limited 1966.

[15] K. Maslov, Y. R. Kim, K. V. Kinra, J. N. Pagano, A new technique for the ultrasonic detection of internal transverse cracks in carbon-fibre/bismaleimide composite laminates, Composite Science and Technology 60 (2000) 2185-2190.