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Ultrasonic methods in diagnostics of epoxy-glass composites

M. Rojek, J. Stabik, G. Wróbel

Department of Mechanical Engineering, Silesian University of Technology, ul. Konarskiego 18A, 44-100 Gliwice, Poland, email: jozef.stabik@polsl.pl

Abstract: A method and results of ultrasonic diagnostics of polymer materials subjected to thermal ageing are presented. It may be directly employed in the testing of construction elements made of polymeric composites. For quantitative interpretation of results, it is necessary to know diagnostic dependences individually identified for each tested material.

Keywords: Glass reinforced composites, Ageing, Ultrasonic testing;

1. INTRODUCTION

During working period composites change their properties and characteristics. These changes are by rule of a degrading character [1]. Usually surface changes precede inner degradation processes. When degradation occurs in a dispersive way within the element's volume a classical inspection of a structure's condition may not reveal any dangerous conditions. Therefore, there is a need of searching non-destructive methods of investigation of the degradation degree. Authors made such an attempt using ultrasonic technique.

In the field of ultrasonic testing of composites, ultrasound’s physical nature as a mechanical wave is used [2-6]. Parameters that may constitute diagnostic characteristics include [2,7] propagation velocity, amplitude and energetic damping coefficients. A hypothesis being the basis of the developed here research is as follows: For polymeric fibre reinforced composites, there is correlation between strength degradation degree being the effect of thermal ageing process and a change in a value of selected diagnostics characteristics of an ultrasound wave coming through tested composite material. In order to confirm the formulated hypothesis, epoxy-glass fibre reinforced composite was exposed to thermal ageing and then tested using non-destructive ultrasonic method and destructive bending method.

2. ULTRASONIC AND DESTRUCTIVE TESTS

2.1. Material and procedure

Epoxy-glass reinforced composite TSE-6 („IZO-ERG” S.A., Poland) was tested. It was produced by impregnation of glass woven fabric followed by drying and pressing.

Before ageing a group of samples was subjected to ultrasonic testing, thus identifying the initial values of ultrasound diagnostic characteristics and to destructive tests of static bending, thus identifying the initial values of flexural strength. The rest of samples were subjected to thermal ageing in air at three temperatures: 180°C, 200°C, 220°C. At defined time intervals the group of heated samples was cooled and subjected to the same ultrasonic and bending tests. Two types of samples were used: 220x20x10mm and 50x25x4,5mm. Ultrasonic tests were carried out with the defectoscope UMT-12 (ULTRAMET S.c., Poland). Single 2 MHz ultrasonic head was used. A sound wave velocity (V) through a sample was measured. Test pieces with dimensions 220x20x10mm were tested perpendicularly to reinforcement layers. Test pieces with dimensions 50 x 25 x 4,5mm were also tested perpendicularly to reinforcement layers (direction “a”) and additionally in two directions parallel to these layers (“b” and “c”). After ultrasonic tests, samples underwent a destructive three point bending test perpendicularly to reinforcement layers. The test was carried out on the FPZ 100/1 tensile strength machine ("Haeckert", Germany) in accordance with the EN ISO 178. The flexural strength, Rg, and the modulus of elasticity, Eg, were calculated.

2.2. Results and discussion

Flexural strength, flexural modulus and ultrasound wave velocity were correlated with ageing time at subsequent ageing temperatures for test pieces with 10mm thickness. Approximation functions in form of first order polynomials were chosen. Correlation coefficients (R) ranging from 0,866 to 0,959 were obtained for Rg and V dependences and from 0,265 to 0,742 for the Eg dependences. For all investigated properties significant decrease with ageing time was observed. Broad scatter of results of elasticity modulus tests results first of all from the scatter of the tested composite properties. Obtained results indicate that on the basis of changes in V one can infer the change in flexural strength of the composite, Rg (Fig. 1). Approximation of the V(Rg) dependences for consecutive temperatures was conducted using functions in the form of first order polynomials. Correlation coefficients (R) ranging from 0,860 to 0,875 were obtained. Results can be acknowledged as very satisfactory. Minor variations between approximation lines indicate the possibility of describing all tests results with one common dependence. Linear least squares approximation of all data for V(Rg) dependence is graphically presented in the Fig. 1 with a continuous line**.** The obtained correlation coefficient was 0,837.

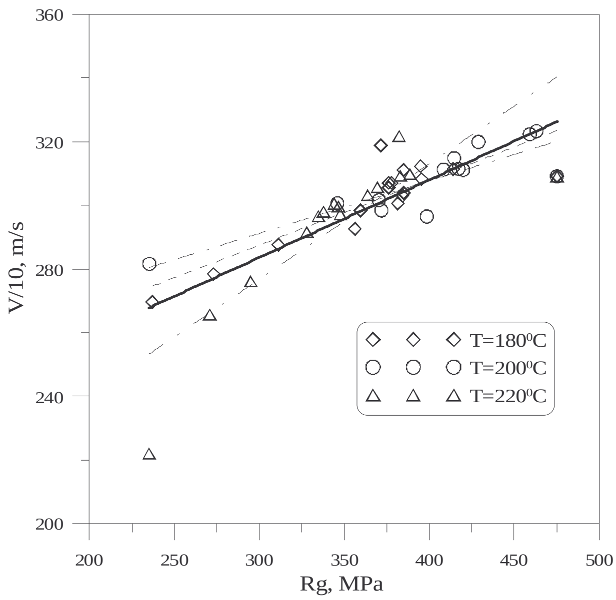

Figure 1. Relation of propagation velocity with flexural strength of the tested 10mm thick laminate.

The same procedure was repeated for laminate 4,5mm thick. Elastic modulus data were no longer taken into account. Correlation coefficients (R) ranging from 0,867 to 0,975 were obtained. Because degree of reinforcement in “b” and “c” direction was almost the same, results for Vb were very similar to Vc. Dependences of Rg and V on ageing time for 4,5mm thick laminate were similar to those obtained for 10mm thick laminate. It confirms previously made observation that on the basis of changes in a ultrasound propagation velocity one can infer the change in flexural strength of the tested composite. Fig. 2 and 3 show relations between Rg and V in “a” and “c” directions. Also for these results an approximation of the V(Rg) dependences were conducted using first order polynomials. Correlation coefficients (R) ranging from 0,787 to 0,931 were obtained. Graphically results are presented as broken lines in Fig. 2 and 3. Minor variations between approximation lines for selected testing directions once more indicate the possibility of describing tests results with common dependences. Obtained relations are represented on Fig. 2 and 3 by continuous lines. Correlation coefficients (R) were 0,88 and 0,83. For the purpose of this study it is important that all analysed relations have similar character. Due to unambiguousness of the V representation in Rg, one can conclude the usefulness of non-destructive ultrasound wave propagation velocity measurement for determining the degree of degradation of strength properties of composites reinforced with glass fibres. Elaborated method may be directly employed in the testing of degree of strength degradation of construction elements made of fibre reinforced polymeric composites. However, for quantitative interpretation of ultrasonic testing results, it is necessary to know diagnostic dependences individually identified for each tested material.

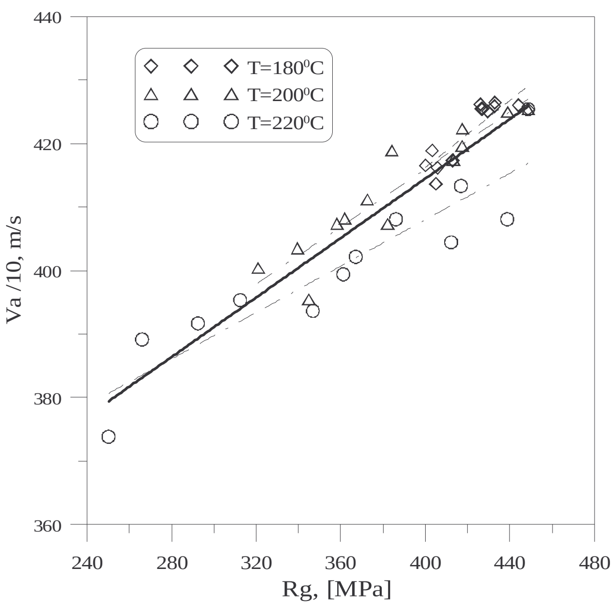

Figure 2. Relation of propagation velocity Va with flexural strength of the tested 4,5mm thick laminate.

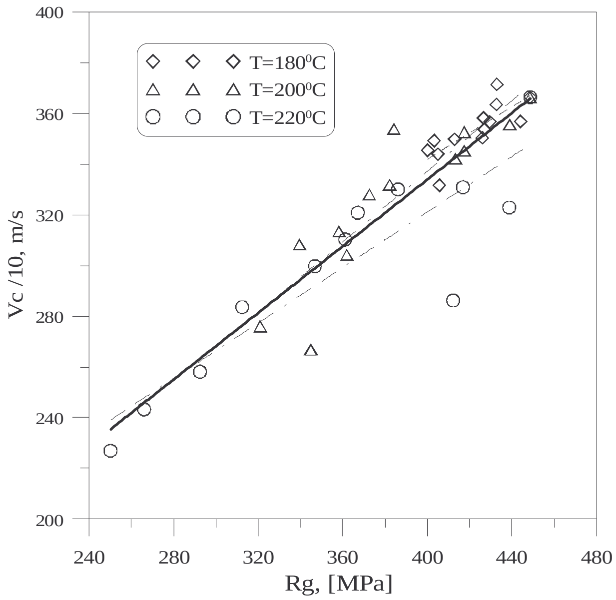

Figure 3. Relation of propagation velocity Vc with flexural strength of the tested 4,5mm thick laminate

3. CONCLUSIONS

Ultrasonic tests results together with experimentally determined unequivocal relation between wave propagation velocity and flexural strength of the tested material form the basis of the non-destructive diagnostics method of plastic material load capacity.

The method may be directly employed in the testing of construction elements made of polymeric composites. However, for quantitative interpretation of results, it is necessary to know diagnostic dependences individually identified for each tested material.

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