STUDY ON VIBRATION PROPERTIES OF COMPOSITE MATERIALS

S. ERSOY*
Marmara Univerrsity Technology Faculty Goztepe Kampüsü Mechatronic Engineering Department, . Kadıköy - İstanbul

The polymeric materials are used in a wide variety of fields for their several surpassing properties. The mechanical properties of polymers are, however, strongly influenced by various environmental factors. One of the principles for estimating the long-term behaviour of polymers may be a time–temperature superposition (equivalence), based on the viscoelastic properties of polymers varying with time and temperature. This is accepted that viscoelastic properties of flax in the epoxy materials related to some modes in the time/temperature domain. This relations are presented some formulas as WLF, Arrhenius and etc. In this work these theoretical attempt to understand the nature vibration behaviour depend to frequency-temperature relationship.

(Received July 29, 2017; Accepted November 24, 2017)

Keywords: vibration, composite, elasticity modulus

1. Introduction

The damped vibration responses of complex structural dynamics such as sandwich beam structures with viscoelastic layers [1, 2] are usually analysed in either frequency or time domain. In the frequency domain analysis, the external excitation force is expressed as harmonic force so that the imaginary part is automatically defined [3]. But, in the time domain analysis, the external excitation force is real contrary to the complex-valued dynamic equation system. In order to maintain the consistency in the complex-valued dynamic equation system, the real-valued external impulse force can be converted into an analytic force signal by defining the imaginary force signal using Hilbert transform. Meanwhile, a state-space formulation in the modal superposition approach to solve the time response of the damped dynamic system leads to two poles which are radial symmetry in the complex plane [4-6].

Scott and others work on effect of the degree of cure on the viscoelastic properties of vinyl ester resin. When they were characterized in the temperature and frequency domains (obtained by time – temperature superposition) [7]. In the other works the thermal expansion behaviour was investigated by dynamic mechanical analysis at a fixed of 1 Hz where was accomplished by conducting the time-temperature superposition experiments using [8].

The other works can be resolved by conducting a range of short-term creep tests and applying accurate prediction methods to the results. Short-term creep testing was conducted on viscoelastic polyurethane foam, a material commonly used in seating and bedding systems. Tests were conducted over a range of temperatures, providing the necessary results of allow for the generation of predictions of long-term creep behaviour using time –temperature superposition [9]. Borg and Paakkönen work on Temperature effect on the linear viscoelastic models with time – temperature superposition. [10].

The analysis of the viscoelastic properties of polymeric surfaces has attracted considerable attention in recent years, due to the applications on adhesives, lubricants, biosensors and protective coatings. An alternative approach to explore viscoelastic behaviour regards the study of changes in adhesion with temperature. The authors have recently shown that the effects of viscoelasticity, plasticity and viscoelasticity can be minimized by a proper choice of the experimental conditions. For instance, it was shown that performing nano indentations at high loading rates allows to get

*Correcsponding auhtor: sersoy@marmara.edu.tr

residual imprints that are much smaller than the penetration at full load, thus suggesting that under these conditions indentations are dominated by elastic behaviour with negligible irreversible deformation [11]. In a recent work which performed a viscoelastic characterization in both the time and temperature domains, studying the variation of the elastic modulus with experimental time and temperature. These pioneer works, however, have made some simplifications such as using the ‘frequency’ to characterize the time-dependent behaviour [12].

It is well known that the mechanical behaviour of polymers arising from indentations becomes significantly different when using different loading rates [13], a fact that could apparently be related to the viscoelastic response of the material. However, when using low loading rates, the residual imprint may increase and become comparable to the penetration depth at full load [14].

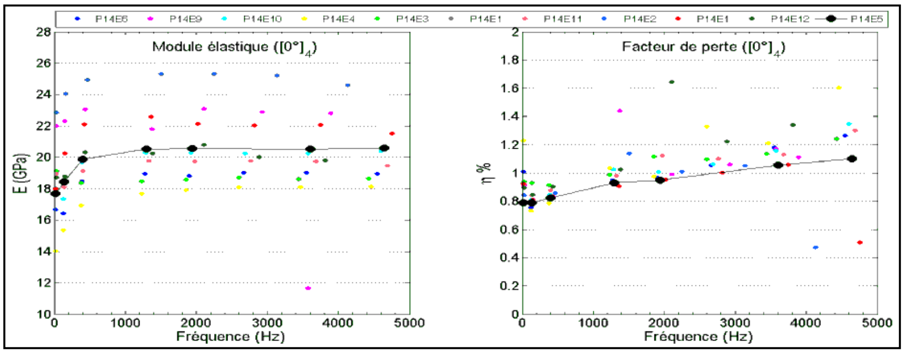
Under such conditions, it is hard to state that neither plasticity nor viscoplasticity is present when indenting complex polymeric materials, even though it was shown [15] for some samples (PS with very low molecular weight, lower than the critical one to develop entanglements) that the residual imprint is completely recovered, above the glass transition temperature, after at most 2 h. Hence, it becomes difficult to claim that the apparent differences in the force curves collected at various frequencies, i.e. loading rates, are fully viscoelastic.

Previously investigated the effects of moisture on the dynamic viscoelastic behaviour of epoxy resin, a typical thermosetting polymer, and examined the time–water content superposition for the saturated samples at various humidity’s. Because the viscoelastic factor (storage modulus) showed only a small change with the water content, the examination of this superposition was in adequate.

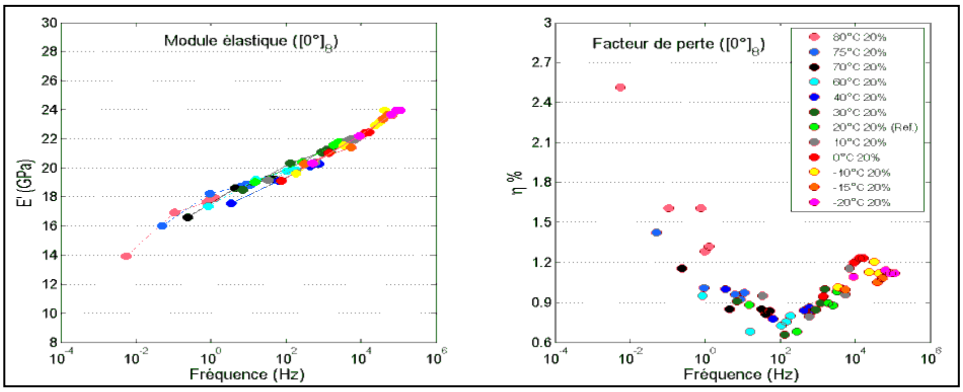
New materials was generated to this research which is flex/epoxy composite materials. The flax are arranged in different angles (0-45-90) and applied vibration laser test. All results obtained that include different temperature apply re-organized with superposition approaching. The outcome is evaluated with Abaqus Finite Element Programme and their results were combined with Matlab Programme.

1.1. Fiber-Reinforced Composites

There are a number of ways of further classifying fiber–matrix composites, such as according to the fiber and matrix type for example, glass-fiber-reinforced polymer composites (GFRP) or by fiber orientation. In this section, we utilize all of these combinations to describe the mechanical properties of some important fiber-reinforced composites. Again, not all possible combinations are covered, but the principals involved are applicable to most fiber-reinforced composites. We begin with some theoretical aspects of strength and modulus in composites that the fiber reinforcement can be classified as either continuous or discontinuous. In the next two sections. It describe the mechanical properties of these two classes of fiber reinforcement in composites, with the emphasis on reinforcement of polymer–matrix composites. Generally, the highest strength and stiffness are obtained with continuous reinforcement. Discontinuous fibers are used only when manufacturing economics dictate the use of a process where the fibers must be in this form for example, injection molding. We begin our description of discontinuous fiber-reinforced composites with some concepts related to the distribution of stresses that are independent of fiber composition. These developments will be limited to unidirectional aligned fibers that is, fibers with their axes aligned. First, we will concentrate on continuous, unidirectional fibers, and then the strength and modulus of discontinuous, unidirectional fiber-reinforced composites will be analysed [16].



(a)



(b)

Fig. 1 Elastic modulus (a) and loss factor (b) and under temperature for 0° angle fiber.

1.2 Frequency–temperature superposition

When temperature and frequency are variable, there is a requirement for a shifting rule that predicts the viscosity function at arbitrary T and Hz. This shifting rule allows the comparison of results from experiments under different temperature conditions and is the means by which the viscosity function can be applied to practical problems. The Arrhenius shifting rule was validated for shifting with respect to T and Hz.

2. Vibration Experimental Method

For this study, composite materials have been fabricated by thermo-molding with unidirectional flax fibers and epoxy resin SR8200. Plates are thermo-pressed under 7 bars pressure and a temperature of 60°C during 8h in order to reach a fiber content of 45%. 8-plys samples of 2.77x10x140 mm are prepared for each principal fibres direction laminate (4 samples / direction). First, the samples [0°], [90°] and [±45°] have been tested by vibration analyses to extract the elementary ply viscoelastic properties. Second, a quasi-isotropic laminate [45//90/0] has been also characterized.

The second step vibration tests should be done on a clean surface. Equipment calibrations should be checked and must be recalibrated if necessary. Material dimensions should be checked again the length, width and thickness dimensions should be recorded. Material tests to be applied should be done with precision measuring instruments such as calipers and micrometers measuring points. Vibration apparatus is 4 cm wide. This measure is subtracted from the total length of the sample. Separately for each side of a sample is measured. So the remaining length is divided into 2 equal parts. Each piece will be divided into five equal parts (fig. 2.)

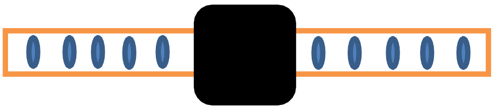


Fig. 2. Test samples in shaker

Piece from every angle parallel to the ground and as a threshold are connected. When securing, the adapter must be set carefully. During the tightening process and apparatus sensors that are sensitive to impact or force should not be used to create a negative situation. Connecting fastening apparatus must be carried out in accordance with the order given Fig. 3.

Fig. 3. Shaker assembled

Vibration analysis system is shown at Fig. 4. System operation is as follows;

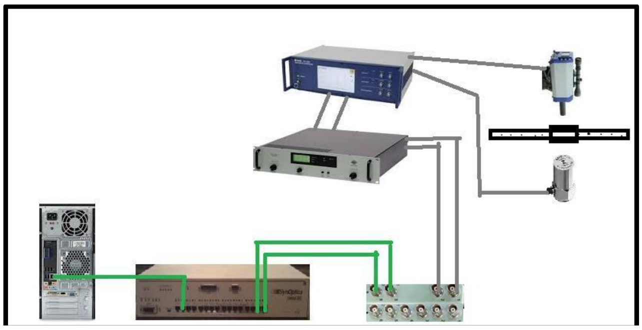
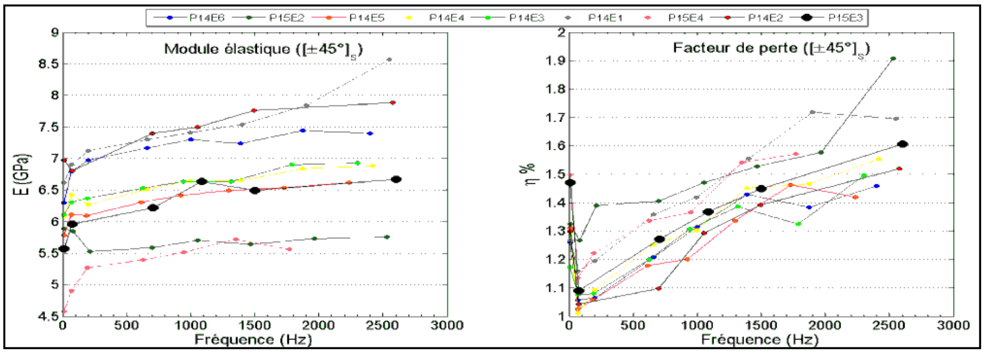


Fig. 4. Laser Test System

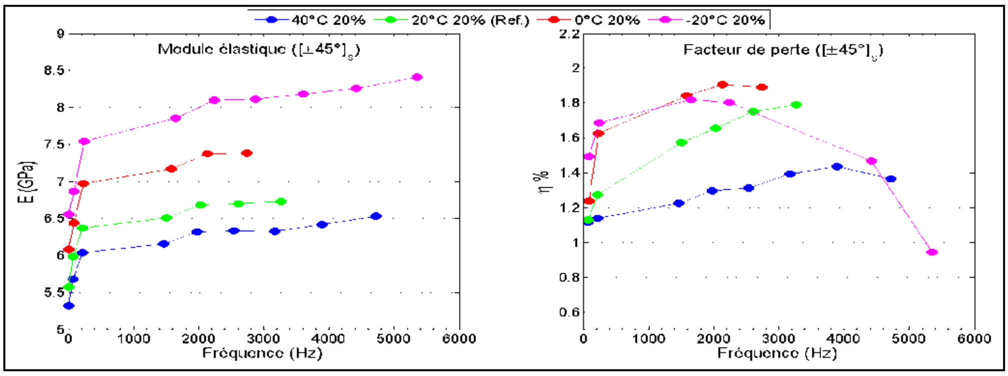
The system was started as; (Velocity – S –Load – vibration measurement set installed (Focus – Position). Bruel & Kjaer software is used. Software processing steps are as follows: Measurement – Front End - Signals – Accelometer, Laser, Image Genea, 3-8 Output.

3. Research results

The vibration test applied for 0, 45 and 90 degree fiber positions. Each degree test was conduct separately. The tests were released on two parameter which are temperature and humidity. The test performed presented in graphics in figure 5 for elastic modulus and loss factor. These graphics shows (fig 5) that Elastic Modulus (a) is maximum at 0° where elastic modulus is almost 20 GPa between 0 – 5000 Hz steady. It can see loss facture is about 1%. The 0° angle fibers effect was not caused stable behaviour (c). The maximum lost factor released at high temperature. Under room temperature and its close point had a low lost factor.



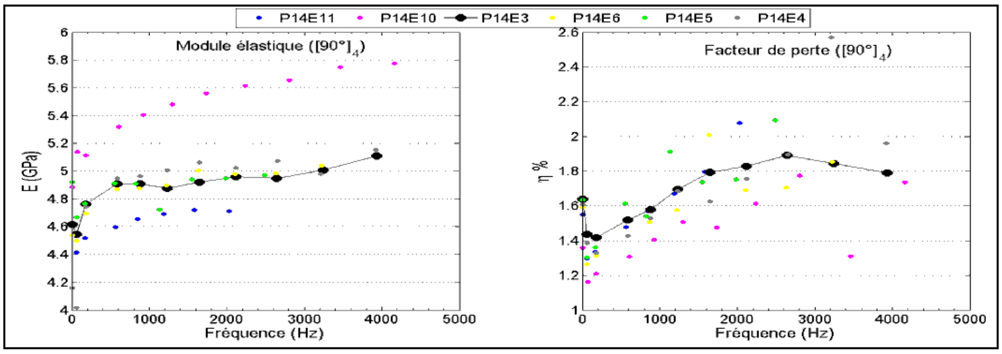
(a)



(b)

Fig. 5. Elastic modulus (a) and loss factor (b) and under temperature for 45° angle fiber

It seen that 45° fiber angle ratio mean went to from 6 to 6.5 GPa till 2500 Hz. This ratio lower than 0°. Meanwhile the lost factor was going to 1.1 to 1.5 linearly. This was limited at 2500 Hz. In this angle was caused to increase proportional with frequency. These values for 90° it seen that it is compatible with literature survey. 90° fiber angle is caused to loss mechanical properties. In here elastic module is and 4.5-5 GPa and loss facture is similar Ludwig equation as between 1.4% and 1.8%



(a) *(b)*

Fig. 6. Elastic modulus (a) and loss factor (b) and under temperature for 90° angle fiber

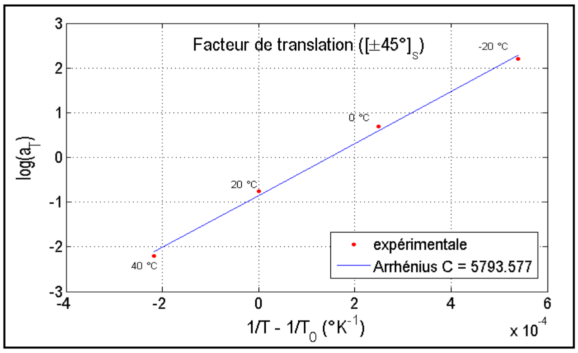


Fig. 7. Superposition with Arrhenius equation for 45° angle fiber

45 degrees are central in this study where we translate vibration data with Arrhenius equation in different temperature points. Figure 8 shows experimental and theoretical results. This graphic was formed superposition approaching. Finally the selected 45° samples process Matlab and formed with superposition approaching. The elastic modulus increase to lower the temperature of the high temperature. And it seen alike behaviour in loss factor graphic. But -20 degree temperature was not homogeneous distribution.

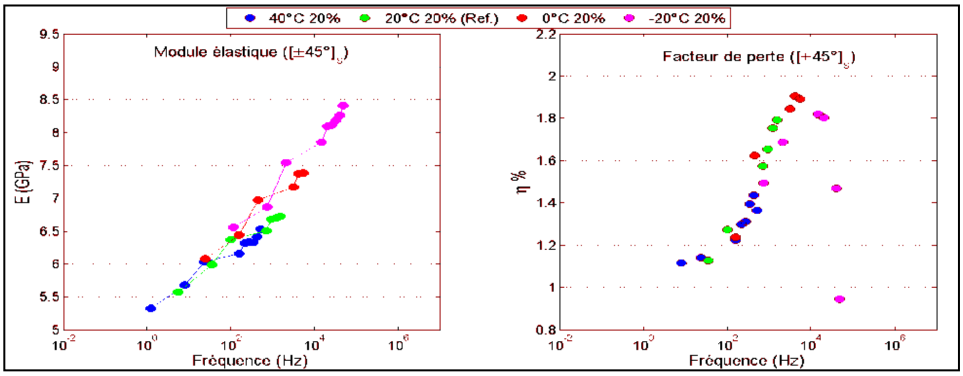


Fig. 8. Final results for selected samples for 45°.

4. Conclusion

The presented characterization method allows the measurement of moduli and loss factor of unidirectional composite beams in a large band frequency range (10 - 3500 Hz). On this range, storage modulus increases by 6-10% and loss factor increases by 46-51%. Based on the elastic-viscoelastic correspondence principle, classical laminates theory has been used to predict the linear viscoelastic behaviour of a quasi-isotropic laminate composite. The results show a 10% storage modulus overestimation but an accurate prediction of the laminate loss factor frequency.

References

[1] M.G. Sainsbury, R.S. Masti, Finite Elem. Anal. Des. **43,** 175 (2007).
[2] M.Z. Kiehl, C.P.T. Wayne Jerzak; Shock Vib. **8,** 123 (2001).
[3] S. H. Baea, J. R. Choa,b,n, W.B. Jeonga; Finite Elem. Anal. Des. **90**, 41 (20014).
[4] J. Inaudi, N. Makis, Time-domain analysis of linear hysteretic damping, Earthq. Eng. Struct. Dyn. **25,** 529 (1996).
[5] J.T. Chen, D.W. You, Hysteretic damping revisited, Adv. Eng. Softw. **28**, 165 (1997).
[6] M. Johansson, The Hilbert Transform, Växjö University, 1999 (Master thesis).

[7] T.F. Scott, W.D. Cook, J.S. Forsythe; European Polymer Journal **44**, 3200 (2008).
[8] Y. He; Thermochimica Acta **439,** 127 (2005).
[9] C. Briody, B. duignan, S. Jerrams, S. Ronan; Polymer Testing **31,** 1019 (2012).
[10] T. Borg, E.J. Paakkönen; Linear Viscoelastic Modals; Journal of Non – Newtonian Fluid Mechanics, **166,** 24 (2010).
[11] D. Tranchida, Z. Kiflie, S Acierno and S Piccarolo; Meas. Sci. Technol. **20**, 1 (2009).
[12] B Cappella, S K Kaliappan, H. Sturm Using AFM force–distance curves to study the glass-to-rubber transition of amorphous polymers and their elastic−plastic properties as a function of temperature Macromolecules **38,** 1874 (2005).
[13] V. V. Tsukruk, V. V. Gorbunov, Z. Huang, S. A. Chizhik, Dynamic microprobing of viscoelastic polymer properties Polym. Int. **49**, 441 (2000)
[14] D Tranchida, S Piccarolo, M Soliman, Macromolecules **39,** 4547 (2006).
[15] I. Karapanagoptis, D. F. Evans, W. W. Gerberich, Polymer **43**, 1343 (2002)
[16] Brain S. Mitchell; An Introduction to Materials Engineering and Science; Wiley, 2004 USA