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Experimental characterization and modelization of the relaxation and complex moduli of a flexible adhesive

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ABSTRACT

In this paper, the experimental characterization and modelization of the relaxation and complex moduli of the flexible adhesive ISR 70-03 by means of dynamic mechanical thermal analysis technique (DMTA) is presented. Firstly, the procedure followed to obtain and to validate the test specimens is described. Next, the linearity concerning material behavior related to strain level and test specimen thickness is analyzed. Then, relaxation and dynamic master curves under tension strain are built-up by means of a procedure based on the time–temperature superposition principle. Finally, these master curves are modelized using a generalized Maxwell model and a fractional derivative model. As a result, models capable of taking together into account the influence of time, temperature and strain level are proposed.

1. Introduction

Traditional joint technologies, as screwing, riveting, welding among others, have very little interest for vibration control, because they are only able to introduce low damping in some specific frequency ranges [1–5]. On the contrary, adhesive joints are used in structural noise control due to its capability to introduce effective modal damping below 1 kHz [6]. Concretely, the manufacturer of the present adhesive suggests the application in order to improve sealing, shock-absorbing and insulating properties [7]. In fact, the authors have employed this material to improve the vibroacoustic ride comfort of an elevator installation, but the results are still unpublished.

Most of adhesive materials show viscoelastic behavior [8,9]. The energy dissipation in a viscoelastic material (VEM) becomes from the phase difference between the stress σ and the strain ε. The simplest way to represent this behavior in frequency domain is trough the complex modulus approximation, which can be obtained from the relationship between the stationary harmonic stress $\sigma(t)$

$$\sigma(t) = \sigma_0 e^{i\omega t}, \tag{1}$$

and the stationary harmonic strain $\varepsilon(t)$ given by

$$\varepsilon(t) = \varepsilon_0 e^{i(\omega t - \varphi)}, \tag{2}$$

σ_0 being the stress amplitude, ε_0 the strain amplitude, ω the excitation frequency and φ the phase delay. Therefore the frequency domain stress–strain relationship $\tilde{\sigma}(\omega) - \tilde{\varepsilon}(\omega)$ results in

$$\tilde{\sigma}(\omega) = E^*(\omega)\tilde{\varepsilon}(\omega), \tag{3}$$

where the complex modulus $E^*(\omega)$ can be written as

$$E^*(\omega) = E'(\omega) + iE''(\omega) = E'(\omega)[1 + i\eta(\omega)], \tag{4}$$

$E'(\omega)$ representing the storage modulus, $E''(\omega)$ the loss modulus and $\eta(\omega)$ the loss factor, which can be calculated as

$$\eta(\omega) = \frac{E''(\omega)}{E'(\omega)}. \tag{5}$$

Although, the complex modulus E^* depends on temperature, excitation frequency, amplitude, pre-stress and relative humidity among others, temperature, frequency and amplitude being the most relevant factors [9]. Concerning the frequency dependence, the ASTM E 756-04 "Standard Test Method for Measuring Vibration-Damping Properties of Materials" [10] details the methodology needed to characterize the mechanical behavior of non-selfsupporting viscoelastic materials in the 0.05–5 kHz frequency range, implying the use of multimaterial Oberst beam specimens are needed. Nevertheless, the main inconvenience of ASTM E 756-04 standard consists on introducing additional damping or mass through the excitation or through the measurement devices. Besides, Fasana [11] put into evidence that the direct application of

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