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Fractional viscoelastic behaviour under stochastic temperature process.

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Abstract

This paper deals with mechanical behaviour of a linear viscoelastic material modelled by the fractional Maxwell model and subject to a Gaussian stochastic temperature process. Two methods to evaluate the response in terms of strain of the mechanical behaviour under a deterministic stress of a material subjected to a varying temperature are presented. The first method consist in calculate the response making the material parameters change at each time step due to the temperature variation. The second, takes advantage of the Time Temperature Superposition Principle to lighten the calculations. Then a stochastic characterisation for the Time Temperature Superposition Principle method has been proposed for a Gaussian stochastic process.

A numerical example based on the experimental results of an epoxy resin at different temperatures is exploited to simulate a creep test under a Gaussian stochastic temperature process with assigned power spectral density function in order to show first the comparison between the two presented methods, and secondly the accuracy of the stochastic characterisation proposed.

Keywords: fractional calculus, linear viscoelasticity, Time-Temperature Superposition Principle, Gaussian stochastic process

1. Introduction

Commonly real materials do not show simple purely elastic or purely viscous behaviour. Specifically, under constant stress, the strain tends to increase with time, thus exhibiting the so-called creep phenomenon. Conversely, under constant strain, material stress decreases with time, that is it relaxes. These two phenomena constitute the basis of a complex behaviour, known as viscoelasticity, which occurs in many different materials of everyday use, including steel, wood, concrete, rubbers and polymers. Notably, creep and relaxation functions (that is, strain time history under constant unitary stress and the stress time history under constant unitary strain, respectively) are linked by the well-known Boltzmann superposition integral, a convolution integral in which the kernel is the relaxation function or the creep function. Further, these two functions strongly depend on the temperature, as well. In this context, many research efforts have been focused on the modelling of the viscoelastic behaviour, and this topic still attracts the attention of researchers involved in various fields of engineering and material science.

Usually, classical mechanical models such as Kelvin-Voigt, Maxwell, standard linear solid and Zener models, are employed to characterise the viscoelastic behaviour [1, 2]. All these models are obtained by appropriate combination of springs and dashpots, thus involving integer order operators, and may provide a first assessment for the representation of the viscoelastic phenomenon. Further, taking into account the Boltzmann superposition integral, they all yields creep and relaxation functions which are exponential in nature.

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