Influence of thermal cycle on viscoelastic material response

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1. INTRODUCTION & OBJECTIVE

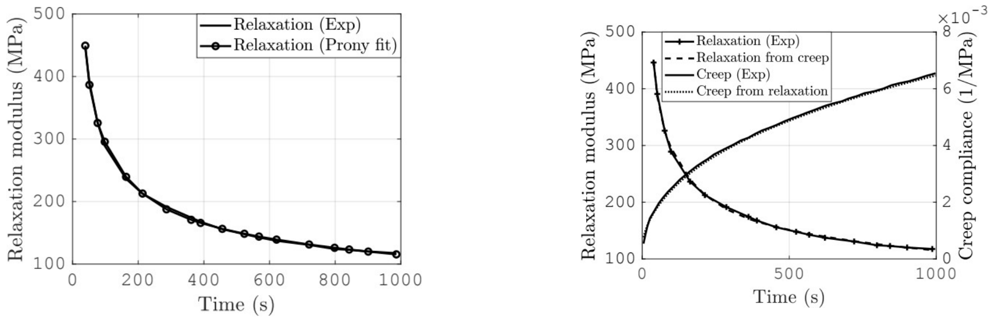
The application of viscoelastic (VE) material is being seen in many areas, and their behaviour not only depends on time but also temperature. Many polymers exhibit identical behaviour when loaded for a short time at a high temperature or loaded for an extended period at a low temperature, thus making it possible to model them by time-temperature superposition (TTS). Solid rocket propellants (SRP) are a type of VE material, and they are stored for a long time at different geographical locations. The SRP experiences temperature change during storage depending on their location, storage period, and facility, thus changing their mechanical properties. It is thus warranted to model VE material considering the influence of thermal cycles on their constitutive response. Several studies are also done recently in VE modelling through master curve and Williams–Landel-Ferry (WLF) constants [1, 2].

The *objective* of present work is to study the thermal cycle influence on VE material constitutive response. The time-dependent behaviour of VE material is modelled by Prony exponential series function. A *novel* method is used to get non-negative Prony coefficients. The displacement control experiments (relaxation) are difficult to conduct for stiff materials, load control experiments (creep) are thus performed. It is thus important to correctly convert creep compliance into relaxation modulus and vice versa. A correct interconversion novel method is derived in detail and validated by various experimental results. A time-temperature superposition is used to obtain a master curve for VE material using horizontal shift factors. WLF equation constants are further computed. The *novelty* of present work is to show the correctness of WLF constants verifying with a predefined shift factor, which is generally not shown in the available literature [1]. The temperature dependence of VE material is finally coupled with a stress update algorithm through pseudo-time concept (without considering ageing). The one-dimensional model results are presented and will be extended to three-dimensional case in a near future.

2. RESULTS & HIGHLIGHTS OF IMPORTANT POINTS

Curve fitting for relaxation modulus is done ensuring non-negative Prony series coefficients and is validated against sample creep and relaxation results as shown in Fig. 1a. The inter-conversion method, as shown in Fig. 2, is validated against the experimental result in Fig. 1b ([1]).

Horizontal shift factors are obtained by TTS principle and then used to compute WLF constants. The master curve is obtained, as shown in Fig. 3a, implying one can get the material properties over a longer period. The correctness of WLF constants is further validated in a novel manner highlighting the limitation of linearization process (Fig. 3b), which is generally adopted in the literature. The WLF constants can also be used to get material properties at different temperatures over a large time period.



(a) (b)

Fig. 1: (a) Prony series fit for relaxation data, (b) inter-conversion plots

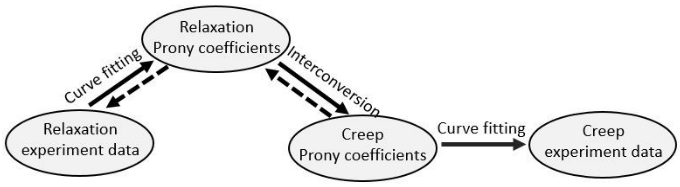
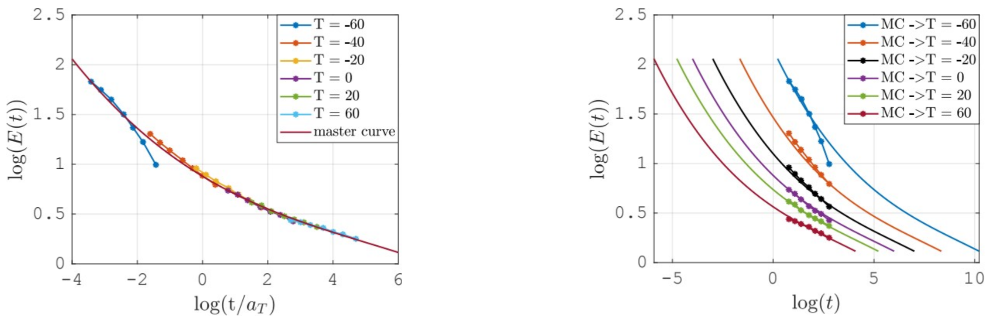


Fig. 2: Inter-conversion process



(a) (b)

Fig. 3: (a) Master curve (b) shifting of master curve by WLF constants

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