VISCOELASTIC ANALYSIS OF THICK-WALLED COMPOSITE TUBES FOR OFF-SHORE APPLICATIONS

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KEYWORDS: Viscoelasticity, Modelling, Thick-walled cylinders, Fatigue loading

ABSTRACT

A methodology for viscoelastic analysis of thick-walled composite tubes is presented. Using lamina-level properties and incorporating relaxation spectrum through use of the generalized Maxwell model, the model predicts the stress relaxation of a composite tube subjected to applied strain, internal and external pressure, and temperature loading.

Composite materials are a promising technology for increasing the depths at which off-shore platforms can operate. Of obvious concern though is the long-term behavior of the material and of the structure. Top tension riser is a potential application, particularly for deepwater and ultra-deepwater applications, because reduced weight and lower stiffness could reduce or possibly eliminate the need for tensioners. However, verification is needed to ensure that viscoelastic effects, caused by sustained positive strains, do not cause a situation where a reduced displacement results in a compressive load on the wellhead. This is shown schematically in Figure 1.

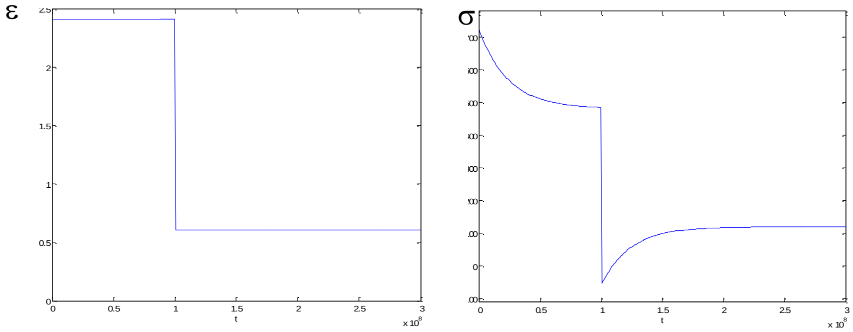

Fig. 1: Schematic of negative loading resulting from positive force

To examine this possibility, a simple approach is proposed based on the static elastic thick-walled tube. Using compatibility, strain-displacement, and equilibrium equations, the static elastic problem is formulated (see, for example, [1]). By applying Hooke's Law, global force and couple equilibriums, stress and displacement continuity between layers, and internal and external boundary conditions, one arrives at 2*n+2 equations with 2*n+2 unknowns, where "n" is the number of lamina.

One possibility for solving this problem for the viscoelastic case is to formulate this problem in the frequency, i.e. Laplace, domain, solve for the necessary unknowns, and perform the inverse Laplace transform (i.e. [2-3]). However, for the variety of boundary conditions experienced by a riser, this technique becomes quite complicated. Thus, the current method proposes only degrading the moduli with time based on a generalized Maxwell model, shown in Figure 2. Thus, rather than a constant, the moduli take the form:

$$E(t) = E^{\infty} + \sum_{i=1}^{j} \left(E^{0} - E^{i}\right) e^{-t/\tau_i} \qquad (1)$$

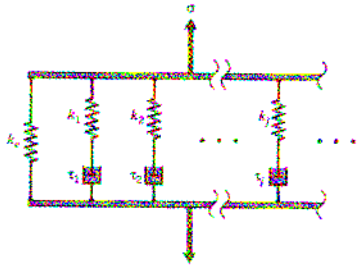

Fig. 2: The generalized Maxwell Model

Thus, the moduli at time "t" are found, and the relatively simple static problem is solved.

Because the model is linear, the response to a variety of loadings and loading spectrums can be found using superposition of loads. For example, the spectrum shown in Figure 3a can be decomposed into the various components, and the effect of each component at each time step can be found, and the results summed. In this fashion, load history from not just constant strain but also ramps, oscillations, and Heaviside functions can be incorporated.

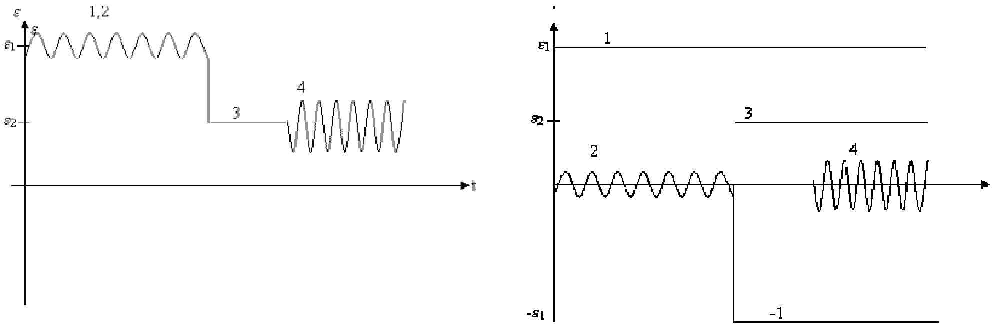

Figure 3 a) Loading spectrum and b) decomposed spectrum

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