Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 144 (2016) 374 – 381

Procedia Engineering

www.elsevier.com/locate/procedia

12th International Conference on Vibration Problems, ICOVP 2015

# A state space viscoelastic shaft finite element for analysis of rotors

Smitadhi Ganguly[a]*, A.Nandi[b], S.Neogy[b]

[a]Department of Mechanical Engineering, Hooghly Engineering and Technology College, Hooghly 712103, India
[b]Department of Mechanical Engineering, Jadavpur University, Kolkata 700032, India

**Abstract**

The present work proposes a new shaft element for viscoelastic rotors in a spinning frame. The Maxwell-Wiechert viscoelastic material model which has one elastic branch and several parallel Maxwell branches of elastic and viscous elements in series is considered here. This model considers additional internal or damping variables between elastic and viscous elements. Here, the stress depends not only on the elastic strain and elastic strain rate but also on additional strains and their rates. In the present work, it is assumed that these additional strains can be derived from continuous fictitious displacement variables in the same way as the elastic strains are derived from the actual displacement variables. These continuous fictitious displacements in turn are interpolated from their nodal values using the conventional beam shape functions. Therefore, in addition to the standard degrees of freedom, extra degrees of freedom are defined at the nodes.

© 2016 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the organizing committee of ICOVP 2015

*Keywords:* Viscoelastic rotor; Maxwell-Wiechert model;

## 1. Introduction

It is well-known that for viscoelastic components subjected to harmonic loading, a frequency-domain analysis is most suitable. Here one directly uses the frequency-dependent storage modulus and loss coefficient in the material model. However, for other type of loadings, a time dependent viscoelastic material model is essential, particularly in the context of finite element analysis. A considerable amount of work has already been done in this direction [1, 2, 3, 4]. The GHM method [5] is especially suitable for using with finite element analysis. Physically, this method uses additional over-damped oscillators. The inertia, stiffness and damping of the oscillators can be determined from experimental data [6]. More recently, Adhikari [7, 8, 9, 10, 11, 12] has studied similar energy dissipation in structures in great detail and used the term non-viscous damping. Genta and Amati [13] has applied the concept of non-viscous damping in the field of rotor dynamics.

The present work considers a Maxwell Wiechert viscoelastic model. Then it presents a simple technique for incorporating this in a finite element model. If one obtains the finite element matrices from any commercial or in-

1877-7058 © 2016 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer-review under responsibility of the organizing committee of ICOVP 2015
doi:10.1016/j.proeng.2016.05.146

house software, then he has to simply append those matrices to use it for a viscoelastic material. Unlike the GHM method, there is no need of elimination of the rigid body modes.

## 2. Analysis

A Maxwell-Wiechert model is a standard representation for a viscoelastic material. The Maxwell Wiechert model has one spring in parallel with a number of parallel Maxwell elements (Figure 1). A Maxwell element contains a spring and a damper in series. The stress-strain relation for the material can be extracted considering stress as the force and strain as displacement in this spring-damper combination. In each Maxwell branch, an additional damping degree of freedom is considered between the spring and the damper.

The stress-strain relation for the viscoelastic material is expressed as follows:

$$\sigma = E\varepsilon_c + \eta_1(\dot{\varepsilon}_c - \dot{\varepsilon}_{b1}) + \eta_2(\dot{\varepsilon}_c - \dot{\varepsilon}_{b2}) \tag{1}$$

$$\eta_1(\dot{\varepsilon}_c - \dot{\varepsilon}_{b1}) = E_1\varepsilon_{b1} \tag{2}$$

$$\eta_2(\dot{\varepsilon}_c - \dot{\varepsilon}_{b2}) = E_2\varepsilon_{b2} \tag{3}$$

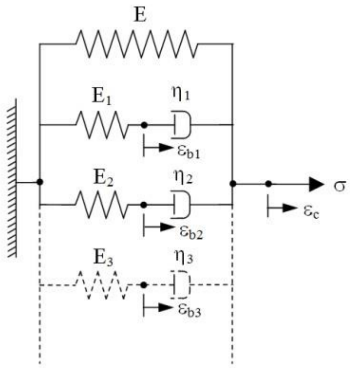


Fig. 1. The Maxwell Wiechert model with three Maxwell branches

### 2.1. Finite element formulation

It is assumed that like the actual strain $\varepsilon_c$, the additional variables $\varepsilon_{bi}$ as shown in Figure 1, can also be obtained from an additional displacement-like variables $w_{by}$ and $w_{bz}$.

$$\varepsilon_c = -\left(y\frac{\partial^2 w_{cy}}{\partial x^2} + z\frac{\partial^2 w_{cz}}{\partial x^2}\right) \tag{4a}$$

$$\varepsilon_b = -\left(y\frac{\partial^2 w_{by}}{\partial x^2} + z\frac{\partial^2 w_{bz}}{\partial x^2}\right) \tag{4b}$$

For an Euler-Bernoulli beam, while the actual strain is determined from the relation (4a), the additional strain can be determined from additional continuous displacement variables $w_{by}$ and $w_{bz}$ (Eq. (4b)).

Download English Version:

https://daneshyari.com/en/article/853787

Download Persian Version:

https://daneshyari.com/article/853787

Daneshyari.com