

Mechanical characterization of composites and biological tissues by means of non-linear filtering

Citation for published version (APA):

Hendriks, M. A. N., Oomens, C. W. J., Janssen, J. D., & Kok, J. J. (1988). Mechanical characterization of composites and biological tissues by means of non-linear filtering. In S. N. Atluri, & G. Yagawa (Eds.), *Computational mechanics '88 : theory and applications : proceedings of the international conference on computational engineering science (ICES), April 10-14, 1988, Atlanta, USA* (Vol. 2, pp. 61.vii.1/2). Springer.

Document status and date:

Published: 01/01/1988

Document Version:

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy

If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.

Mechanical Characterization of Composites and Biological Tissues by Means of Non-Linear Filtering

M.A.N. Hendriks, C.W.J. Oomens, J.D. Janssen and J.J. Kok

Eindhoven University of Technology, The Netherlands

Introduction

Constitutive models to characterize fibre-reinforced composites and biological tissues are complex and usually contain a large number of parameters. A common way to measure these parameters is to load samples of a simple shape in such a way, that a homogeneous stress and strain distribution is obtained in some part of the sample. In this way a direct coupling between stress and strain is possible. However, such a procedure has disadvantages when used for composites or biological materials:

- Due to the complex mechanical behaviour it is hardly possible to create a simple stress and strain field. Hence the field equations can only be solved numerically.
- As many unknown parameters are to be determined (due to anisotropy, non-linear visco-elastic behaviour) the number of experiments needed for a sufficient characterization is enormous.
- Most biological materials have inhomogeneous properties, so homogeneous strain distributions can not be obtained.

Here we follow a different approach, which does not require a homogeneous strain distribution. It is assumed that measurements of the strain distribution are available and that the field equations can be solved numerically.

Theory

Assuming that a constitutive model for the material under investigation and a numerical procedure to solve the field equations are available, the problem is to find a column \underline{x} of unknown parameters from the equation:

$$\underline{y}(t) = \underline{Y}(\underline{x}, \underline{w}(t), t) + \underline{v}(t) \quad (1)$$

where: \underline{y} = a column of measured displacements, \underline{w} = a column of model errors, \underline{v} = a column of measuring errors, t = time, \underline{Y} = some non-linear function. The function \underline{Y} is not explicitly available, but we assume that it is possible to calculate \underline{y} for given \underline{x} by means of some numerical procedure, such as the finite element method.

Making use of an approximate non-linear filter procedure (Jazwinski, [1]) we obtain minimum variance estimates for the parameters, $\hat{\underline{x}}$:

$$J = \text{Expectation}\{ (\hat{\underline{x}} - \underline{x})^T (\hat{\underline{x}} - \underline{x}) \} \rightarrow \text{minimum} \quad (2)$$

Example

The procedure has been used to characterize a transversally isotropic elastic material. Figure 1 shows a simulation of an experiment by means of a finite element calculation, in which plane stress is assumed. The displacements of the markers, artificially disturbed with noise, are used to determine four parameters out of one single experiment. Figure 2 shows the estimates for the model parameters as a function of the number of finite element calculations used in the optimization process. The horizontal straight lines indicate the real values of the parameters.

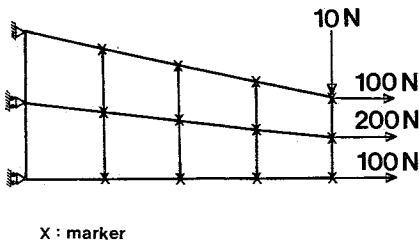


figure 1

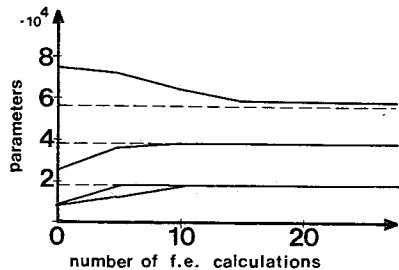


figure 2

This and other experiments showed that the method offers an interesting tool for a quick characterization of complex materials.

References

1. Jazwinski A.H.: Stochastic processes and filtering theory. New York and London: Academic Press 1970