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On the identification of microstretch elastic moduli of materials by using vibration data of plates

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Abstract

In the present work, the vibration problems of rectangular plates modeled by Eringen's microstretch theory are investigated for the identification of the upper bounds of the microstretch moduli of the plate material. The calculated frequencies of the plates are obtained by extending the Ritz method to the microstretch plates. The three dimensional (3D) vibration analysis of the plates shows that some additional frequencies occur among the classical frequencies as characterizing the microstretch effects. Then it is also observed that these additional frequencies disappear and only the classical frequencies remain with the increasing values of microstretch constants. The inverse problem is established for the identification of the upper bounds of the microstretch elastic constants as an optimization problem where an error function is minimized.

Keywords: Microstretch constants; Plate vibration; Natural frequencies; Inverse method

1. Introduction

It is well known that the material response to external effects depends on to its inner structures, when the material having complex inner structure like composite materials reinforced with chopped elastic fibers, polymers, porous media and micro damaged materials, etc., so the linear theory of elasticity is unable to explain the behavior of such materials. Eringen's microstretch theory [1] relies on the idea that every particles of the material can make both micro rotation and volumetric micro elongation in addition to the bulk deformation of the material. And it is more convenient to model the materials that possess heterogeneous structures, by the inclusion of such microstructure which could affects the overall behavior of the materials and reflects the physical realities much better than the classical theory.

Success of the attempts on understanding of mechanical behavior of such structures usually depends on the correctness of the choice of system parameters of the structures. Because of its simplicity, the static tests are used to determine the properties of the materials, traditionally, but many drawbacks of the static method such as being slow and expensive, requiring many samples, having non-uniform stress/strain fields makes it

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unattractive. Dependence of the dynamic response of the medium to the material properties gives us an alternative approach for the determination of such material constants [2–10].

The present study aims to determine the upper bounds of the microstretch elastic properties of the linear homogeneous isotropic microstretch materials from experimental vibration data by the use of similar procedure given above references [2–10]. The analysis based on a linear, small-strain, 3D microstretch theory is used and Ritz method is extended to this case. Following Zhou et al. [11], the triplicate Chebyshev polynomial series multiplied by proper boundary functions are used to describe the plate deflections. The frequency equations of the vibrating microstretch plate are obtained and a method is given to identify the upper bounds of the properties of microstretch plate.

The wave propagation problems in micropolar and microstretch media are discussed in [12,13], and it is shown that two and three new waves which are not found in the classical theory appear in micropolar [14] and microstretch [1] cases, respectively. In this work, some additional frequencies due to the microstretch character are observed among the classical frequencies similar to the above phenomenon. These additional frequencies disappear when the microstretch material constants are taken as zero and only the classical frequencies remain. More importantly, we also observed that these additional frequencies are more sensitive to the change of the micro elastic constants than the classical frequencies. Therefore, the values of the additional frequencies rapidly increase by the change of the micro constants and then considerable amount of additional frequencies move out among the classical frequencies under consideration. In the meantime, the values of the classical frequencies remain same up to some certain values of the micro properties, but these frequencies begin to deviate after these values of micro constants. Few numbers of additional frequencies may remain in the interval of the classical frequencies under consideration. This phenomenon tells us that the microstructure become more dominant and starts to affect the macro properties. For instance, considering this model as presenting a damaged body, we may conclude the growth and the development of micro cracking start to affect the macro properties of the body. Thus we may define these threshold values as the upper bounds for the material parameters. In another words, the material is not a microstretch body anymore. After these threshold values of the micro elastic constants, the material looses its microstretch character and this is the key point of the present study which will be used to construct an optimization problem to determine the upper bounds of the microstretch properties.

We perform an optimization problem starting from the key point explained above. Since the frequencies depend on to the material parameters, the minimization condition of the difference of the calculated classical frequencies with the experimental data gives us the possibility of finding unknown material coefficients. But an important point in this problem is the existence of additional frequencies due to the micro effects among the classical frequencies. Since there is no experimental data for the micromorphic material, the number of these additional frequencies should be also minimized. So the obtained values of the constants will be regarded as upper bounds of their values. Thus, two different objectives will be considered in the optimization problem.

The objective function of the optimization problem is chosen as the superposition of these two objectives. Although, it is better to use the gradient based algorithms to solve optimization problems, here we employed the direct search algorithm due to the computational difficulties of the derivatives. Initial values of the design parameters are obtained by the use of genetic algorithm (GA), which are necessary to initiate the procedure.

As far as we know, there is no attempt to determine the microstretch elastic properties of the materials from the experimental vibration data until now. In the literature, Srinivas [15] firstly presented a study on the vibration analysis of simply supported plates modeled with Eringen's micropolar plate theory [16] and observed the existence of some additional frequencies due to the micropolar character of the plate. Wang and Zhou [17] shown that four different types of natural frequencies exist in a micropolar plate. Lakes [18] and Gauthier [19] obtained some micropolar material constants from the experiments and Chiroiu and Munteanu [20] determined the micropolar elastic properties from the experimental frequencies by the use of genetic algorithm, but their results do not seem very reasonable.

2. Fundamental equations and wave propagation in microstretch medium

The constitutive equations for a linear homogeneous and isotropic microstretch elastic solid are given by Eringen [21] as