THE IDENTIFICATION OF THERMO-MICROSTRETCH MODULI OF MATERIALS BY THE USE OF VIBRATION DATA OF PLATES

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Extended Abstract

As it is well known that the material response to external effects depends on the structure and motions of its inner structures. So, the linear theory of elasticity is unable to explain the behavior of many materials having complex microstructure like, micro damaged materials. The main purpose of this work is to determine the unknown material coefficients of thermo-microstretch bodies which is can be used to model micro damage. Because, damage occurs when the atomic bonds break at the micro structural level. These microscopic alteration effects the macroscopic thermodynamical material properties like elastic softening, decreased conductivity, plastic yield surface alteration etc. In order to take into account these deterioration processes in engineering design, a microscopic modeling becomes necessary.. One of such theories is proposed by Eringen and Suhubi [1,2] which is known as micromorphic theory .

The other important point of the damage problems is thermal effects. Experiments show that temperature strongly affects the damage, especially in the brittle region. Then the thermal effect should be taken into account in a model proposed for damaged bodies.

When switching from a macroscopic to a microscopic approach a very serious difficulty occurs from the practical problems point of view as the lack of sufficient knowledge for some of the material properties. This seriously limits the development of the microscale models. With other way of saying, micromorphic models have great advantages in modeling physical realities with a minimum ambiguity and arbitrariness, but unfortunately they are computationally and mathematically inefficient in practical engineering applications. Even in the linearized form, micromorphic theory is rather complicated, only few problems have been solved in the general formulation. Because of this reason, several further simplifications are considered. One of these simplified theories is the very well theory of micropolar solids proposed by Eringen [3] which allows rotational motion about its center of mass and the motion of the center of mass itself. But this approach is not very convenient to describe many problems in micro damage. Thus, we have to find an other theory to describe such microeffects, in between two limits of the microstructural theories; namely micromorphic theory on one end and micropolar theory on the other end. One of such approaches which is more convenient to describe the damaged phenomenon with thermal effects is the theory of thermo-microstretch solids. This theory is also very important in widening of the domain of

application of the micromorphic theory. Microstretch solid is defined by Eringen [4] by including the microstructural extensions and contractions to the deformation field as well as the rigid rotations in the microstructural level.

The other important point of the damage problems is thermal effects. As it is well known, the example of a glass that is broken into pieces on being filled by hot tea which shows a brittle fracture under the condition of nonhomogeneous heating which means that the bodies being heated are expending and the inner heated layers exert some pressure on still cool external glass layers which results in the appearance of strong tensile stresses. If glass has a small scratch its out side surface, stress can reach the critical value. Similarly a thermal shock caused by inhomogeneous heating or cooling of the structure can initiate the propagation of pre-existing cracks in the absence of any mechanical loading. On the contrary, in many instances the action of temperature stresses as favorable because it removes, completely or partially, the stress concentration at the crack tip caused by external mechanical loads. Experiments show that temperature strongly affects the damage and the time to rupture, especially in the brittle region. This makes the problem of brittle fracture of solids whose temperature is nonhomogeneous both important from practical point of view and nontrivial from theoretical examinations. Then the thermal effect should be taken into account in a model proposed for damaged bodies.

Tthe static tests are usually used to determine the elastic properties of the materials, because the idea is simple. But many drawbacks of the static method such as being slow and expensive, requiring many samples, having non uniform stress/strain fields bring it unattractive. Dependence of the dynamic response of the materials on the elastic properties gives us an alternative approach for determining these constants. It is possible to identify the classical elastic properties from vibration tests and a great number of techniques based on experimental vibration data have been proposed, recently [5-12].

In our earlier three works [11,12] we focused on the determination of the unknown material coefficients of microstructured bodies and found some upper limits to these unknowns quantities. Main idea in these works was to use a method to find the upper bounds of the microstretch elastic moduli of the plates. The three dimensional (3-D) vibration analysis of the plates have been done by the use of Ritz Method, and then it has been shown that some additional frequencies exist among the frequencies obtained from the classical theory of elasticity due to the microstretch characterization and also it is shown that these additional frequencies disappear and only the classical frequencies remain, when the microstretch constants are taken as zero. The present work is an extension of our previous papers to thermomicrostretch materials and he main purpose is to determine the upper bounds of the additional unknown properties of the material dur thermal effects.

In many works, the wave propagation in a micropolar and a microstretch medium is discussed in [13-14] and it has been shown that two and three new waves which do not appear in the classical theory of elasticity exist in a micropolar [15] and microstretch medium, respectively. In conformity with these new waves which do not occur in classical theory of elasticity, the additional frequencies due to microstretch character of the medium, which also do not appears in classical theory are observed among the classical frequencies. These additional frequencies disappear and only the classical frequencies remain, when the microstretch material constants are taken as zero. We also observed that these additional frequencies also begin to disappear while the microstretch material constants get bigger and finally completely disappeared when the constants exceed some threshold values and if these constants gets bigger than their threshold values, the classical frequencies also begin to deviate from their original values. We think that these threshold values may be considered as upper bounds for each of the constants and this is the key point of the present study which can be used to construct the optimization problem for determining upper bounds of the thermomicrostretch properties.

Secondly, an optimization problem is constructed starting from the key point explained above. In this problem two different objective occur. One is minimizing the least square distance between the classical frequencies obtained from numerical model and from experiments and the other is minimizing the number of the additional frequencies due to the thermomicrostretch theory. The objective function of the optimization problem is chosen as a superposition of these two objectives. Initial values of the design parameters, which are required to initiate the direct search algorithm, are obtained from the genetic algorithm (GA). Obtained results are compared with the available data.

References:

[1] **Eringen A.C., Şuhubi E.S.,** "Nonlinear theory of microelastic solids part I", Int. J. Eng. Sci., **5**, 189, 1964.

[2] **Şuhubi E.S., Eringen A.C.,** "Nonlinear theory of microelastic solids part II", Int. J. Engng. Sci., **5**, 389, 1964.

[3] **Eringen A. C.,** 1968. Theory of micropolar elasticity, *Fracture, an advanced treatise* (Ed. Leibowitz H.), Academic Press, New York.

[4] **Eringen A.C.,** "Microcontinuum field theories: foundations and solids", Springer Verlag, New York, 1999.

[5] **Sol H.,** 1986. Identification of anisotropic plate rigidities using free vibration data, *PhD Thesis*, Free University of Brussels.

[6] **Ayorinde E. O., Yu L.,** 2005. On the characterization of composite plates with vibration data, *Journal of Sound and Vibration*, **283**, 243-262.

[7] **Pedersen P., Frederiksen P. S.,** 1992. Identification of orthotropic material moduli by a combined experimental/numerical approach, *Measurement*, **10**, 113-118.

[8] **Mota Soares C. M., Moreira de Freitas M., Araújo A. L., Pedersen P.,** 1993. Identification of material properties of composite specimens, *Composite Structures*, **25**, 277-285.

[9] **Bledzki A. K., Kessler A., Rikards R., Chate A.,** 1999. Determination of elastic constants of glass/epoxy unidirectional laminates by the vibration testing of plates, *Composites Science and Technology*, **59**, 2015-2024.

[10] **De Wilde W. P.,** 1991. Identification of the rigidities of composite systems by mixed numerical/experimental methods, Numerical identification of composites (Eds. Vautrin A., Sol H.), *Elsevier Applied Science*, 1-15. London/New York.

[11] **Inan, E. and Kiris, A**. On the Identification of Microstretch Elastic Moduli of Materials by using Vibrational Data of Plates, (Ahmet Kiriş ile) "**Micromechanics of Materials**" **ASME Mechanics and Materials** Conference, Austin, TX, June 3-7, 2007.

[12] **Inan, E. and Kiris, A**. 3D Vibration Analysis of Microstretch Plates, 8th International Conference on Vibration Problems **–ICOVP- 2007**, 189-201, 1-3 February 2007, Springer

[13] **Parfitt V. R., Eringen A. C.,** 1969. Reflection of plane waves from the flat boundary of a micropolar elastic half space, *Journal of Acoustical Society of America*, **45**, 1258-1272.

[14] **Singh B., Kumar R.,** 1998. Wave propagation in a generalized thermo-microstretch elastic solid, *International Journal of Engineering Science*, **36**, 891-912.

[15] **Eringen A. C.,** 1968. Theory of micropolar elasticity, *Fracture, an advanced treatise* (Ed. Leibowitz H.), Academic Press, New York.