

# A 2-D DRBEM for Generalized Magneto-Thermo-Viscoelastic Transient Response of Rotating Functionally Graded Anisotropic Thick Strip

Mohamed Abdelsabour Fahmy\*

Faculty of Computers and Informatics, Suez Canal University, Ismailia, Egypt

Received 28 October 2012; received in revised form 05 December 2012; accepted 30 December 2012

## Abstract

A numerical model based on the dual reciprocity boundary element method (DRBEM) is extended to study the generalized magneto-thermo-viscoelastic transient response of rotating thick strip of functionally graded material (FGM) in the context of the Green and Naghdi theory of type III. The material properties of the strip have a gradient in the thickness direction and are anisotropic in the plane of the strip. An implicit-implicit staggered strategy was developed and implemented for use with the DRBEM to obtain the solution for the displacement and temperature fields. The accuracy of the proposed method was examined and confirmed by comparing to the obtained results with those known before. In the case of plane deformation, a numerical scheme for the implementation of the method is presented and the numerical computations are presented graphically to show the effect of the rotation on the temperature and displacement components.

**Keywords:** generalized magneto-thermo-viscoelasticity, rotation, anisotropic, functionally graded material, dual reciprocity boundary element method

## References

- [1] M. Biot, "Thermoelasticity and irreversible thermo-dynamics," *J. Appl. Phys.*, vol. 27, pp. 249-253, 1956.
- [2] H.W. Lord and Y. Shulman, "A generalized dynamical theory of thermoelasticity," *J. Mech. Phys. Solids*, vol. 15, pp. 299-309, 1967.
- [3] A. E. Green and K. A. Lindsay, "Thermoelasticity," *J. Elast.*, vol. 2, pp. 1-7, 1972.
- [4] A. E. Green and P. M. Naghdi, "On undamped heat waves in an elastic solid," *J. Therm. Stresses*, vol. 15, pp. 252-264, 1992.
- [5] A. E. Green and P. M. Naghdi, "Thermoelasticity without energy dissipation," *J. Elast.*, vol. 31, pp. 189-208, 1993.
- [6] A. Berezovski, G.A. Maugin, "simulation of thermoelastic wave propagation by means of a composite wave-propagation algorithm," *J. Comput. Phys.* vol. 168, pp. 249-264, 2001.
- [7] S. C. Misra, S. C. Samanta and A. K. Chakrabarti, "Transient magnetothermoelastic waves in a viscoelastic half-space produced by ramp-type heating of its surface," *Comput.Struct.*, vol.43, pp. 951-957, 1992.
- [8] A. M. El-Naggar, A. M. Abd-Alla, M. A. Fahmy and S. M. Ahmed, "Thermal stresses in a rotating non-homogeneous orthotropic hollow cylinder," *Heat Mass Transfer*, vol. 39, pp. 41-46, 2002
- [9] A. M. El-Naggar, A. M. Abd-Alla, and M. A. Fahmy, "The propagation of thermal stresses in an infinite elastic slab," *Appl. Math.Comput.*, vol. 157, pp. 307-312, 2004.
- [10] A. M. Abd-Alla, A. M. El-Naggar and M. A. Fahmy, "Magneto-thermoelastic problem in non-homogeneous isotropic cylinder," *Heat Mass Transfer*, vol. 39, pp. 625-629, 2003.
- [11] A. M. Abd-Alla, M. A. Fahmy, and T. M. El-Shahat, "Magneto-thermo-elastic stresses in inhomogeneous anisotropic solid in the presence of body force," *Far East J. Appl. Math.*, vol. 27, pp. 499-516, 2007

\* Corresponding author. E-mail address: mafahmy2001@yahoo.com

Tel.: 00201114873487

- [12] A. M. Abd-Alla, M. A. Fahmy, and T. M. El-Shahat, "Magneto-thermo-elastic problem of a rotating non-homogeneous anisotropic solid cylinder," *Arch. Appl. Mech.*, vol. 78, pp. 135-148, 2008.
- [13] M. A. Fahmy, "Effect of initial stress and inhomogeneity on magneto-thermo-elastic stresses in a rotating anisotropic solid," *JP J. Heat Mass Transfer*, vol. 1, pp. 93-112, 2007.
- [14] M. A. Fahmy, "Thermoelastic stresses in a rotating non-homogeneous anisotropic body," *Numerical Heat Transfer. Part A: Applications*, vol. 53, pp. 1001-1011, 2008.
- [15] M. A. Fahmy, "Transient magneto-thermo-visco-elastic stresses in a rotating non-homogeneous anisotropic solid with and without moving heat source," *J. Eng. Phys. Thermophys.*, vol. 85, pp. 874-880, 2012.
- [16] M. A. Fahmy, "Finite difference algorithm for transient magneto-thermo-elastic stresses in a non-homogeneous solid cylinder," *Int. J. Mater. Eng. Technol.*, vol. 3, pp. 87-93, 2010.
- [17] M. A. Fahmy, "Influence of inhomogeneity and initial stress on the transient magneto-thermo-visco-elastic stress waves in an anisotropic solid," *World J. Mech.*, vol. 1, pp. 256-265, 2011.
- [18] M. A. Fahmy and T. M. El-Shahat, "The effect of initial stress and inhomogeneity on the thermoelastic stresses in a rotating anisotropic solid," *Arch. Appl. Mech.*, vol. 78, pp. 431-442, 2008.
- [19] H. Yan, Y. Liu, "An efficient high-order boundary element method for nonlinear wave-wave and wave-body interactions," *J. Comput. Phys.* vol. 230, pp. 402-424, 2011.
- [20] M. Shariyat, S. M. H. Lavasani, M. Khaghani, "Nonlinear transient thermal stress and elastic wave propagation analyses of thick temperature-dependent FGM cylinders, using a second-order point-collocation method," *Appl. Math. Modell.*, vol. 34, pp. 898-918, 2010.
- [21] A. M. Afsar and J. Go, "Finite element analysis of thermoelastic field in a rotating FGM circular disk," *Appl. Math. Modell.*, vol. 34, pp. 3309-3320, 2010.
- [22] G. M. Zhang and R. C. Batra, "Wave propagation in functionally graded materials by modified smoothed particle hydrodynamics (MSPH) method," *J. Comput. Phys.*, vol. 222, pp. 374-390, 2007.
- [23] A. G. Arani, R. Kolahchi, A. A. M. Barzoki and A. Loghman, "Electro-thermo-mechanical behaviors of FGPM spheres using analytical method and ANSYS software," *Appl. Math. Modell.*, vol. 36, pp. 139-157, 2012.
- [24] A. Khosravifard, M.R. Hematiyan and L. Marin, "Nonlinear transient heat conduction analysis of functionally graded materials in the presence of heat sources using an improved meshless radial point interpolation method," *Appl. Math. Modell.*, vol. 35, pp. 4157-4174, 2011.
- [25] T. Rangelov, Y. Stoyanov and P. Dineva, "Dynamic fracture behavior of functionally graded magneto-electroelastic solids by BIEM," *Int. J. Solids Struct.*, vol. 48, pp. 2987-2999, 2011.
- [26] F. X. Zhou, S. R. Li and Y. M. Lai, "Three-dimensional analysis for transient coupled thermoelastic response of a functionally graded rectangular plate," *J. Sound Vib.*, vol. 330, pp. 3990-4001, 2011.
- [27] M. A. Fahmy, "A three-dimensional generalized magneto-thermo-viscoelastic problem of a rotating functionally graded anisotropic solids with and without energy dissipation," *Numer. Heat Transfer, Part A: Applications*, vol. 63, pp. 713-733, 2013.
- [28] M. A. Fahmy, "Generalized magneto-thermo-viscoelastic problems of rotating functionally graded anisotropic plates by the dual reciprocity boundary element method," *J. Therm. Stresses*, vol. 36, pp. 1-20, 2013.
- [29] D. Nardini and C. A. Brebbia, "A New approach to Free Vibration Analysis Using Boundary Elements," *Proceedings 4th International Conference on Boundary Element Methods*, Springer, 1982, pp. 312-326.
- [30] C. A. Brebbia, J. C. F. Telles and L. Wrobel, "Boundary element techniques in Engineering," New York: Springer-Verlag, 1984.
- [31] L. C. Wrobel and C. A. Brebbia, "The dual reciprocity boundary element formulation for nonlinear diffusion problems," *Comput. Methods Appl. Mech. Eng.*, vol. 65, pp. 147-164, 1987.
- [32] P. W. Partridge, C. A. Brebbia and L. C. Wrobel, "The dual reciprocity boundary element method," Southampton: Computational Mechanics Publications, 1992.
- [33] P. W. Partridge and L. C. Wrobel, "The dual reciprocity boundary element method for spontaneous ignition," *Int. J. Numer. Methods Eng.*, vol. 30, pp. 953-963, 1990.
- [34] M. A. Fahmy, "Implicit-explicit time integration DRBEM for generalized magneto-thermoelasticity problems of rotating anisotropic viscoelastic functionally graded solids," *Eng. Anal. Boundary Elem.*, vol. 37, pp. 107-115, 2013.
- [35] M. A. Fahmy, "Application of DRBEM to non-steady state heat conduction in non-homogeneous anisotropic media under various boundary elements," *Far East J. Appl. Math.*, vol. 43, pp. 83-93, 2010.
- [36] M. A. Fahmy, "A time-stepping DRBEM for magneto-thermo-viscoelastic interactions in a rotating nonhomogeneous anisotropic solid," *Int. J. Appl. Mech.*, vol. 3, pp. 1-24, 2011.

- [37] M. A. Fahmy, "Numerical modeling of transient magneto-thermo-viscoelastic waves in a rotating nonhomogeneous anisotropic solid under initial stress," *Int. J. Model.Simul. Sci. Comput.*, vol. 3, pp. 125002, 2012.
- [38] M. A. Fahmy, "Transient magneto-thermo-elastic stresses in an anisotropic viscoelastic solid with and without moving heat source," *Numer. Heat Transfer, Part A: Applications*, vol. 61, pp. 547-564, 2012.
- [39] M. A. Fahmy, "The effect of rotation and inhomogeneity on the transient magneto-thermo-visco-elastic stresses in an anisotropic solid," *ASME J. Appl. Mech.*, vol. 79, pp. 051015, 2012.
- [40] M. A. Fahmy, "A time-stepping DRBEM for the transient magneto-thermo-visco-elastic stresses in a rotating non-homogeneous anisotropic solid," *Eng. Anal.Boundary Elem.*, vol. 36, pp. 335-345, 2012.
- [41] M. A. Fahmy, "Transient magneto-thermoviscoelastic plane waves in a non-homogeneous anisotropic thick strip subjected to a moving heat source," *Appl. Math. Modell.*, vol. 36, pp. 4565-4578, 2012.
- [42] L. Gaul, M. Kögl and M. Wagner, "Boundary element methods for engineers and scientists," Berlin: Springer-Verlag, 2003.
- [43] C. Farhat, K. C. Park and Y. Dubois-Pelerin, "An unconditionally stable staggered algorithm for transient finite element analysis of coupled thermoelastic problems," *Computer Methods in Applied Mechanics and Engineering*, vol. 85, pp. 349-365, 1991.
- [44] J. Sladek, V. Sladek, P. Solec, and Ch. Zhang, "Fracture analysis in continuously nonhomogeneous magneto-electro-elastic solids under a thermal load by the MLPG," *Int. J. Solids Struct.*, vol. 47, pp. 1381-1391, 2010.
- [45] M. A. Fahmy, "Thermal stresses in a spherical shell under three thermoelastic models using FDM," *Int. J.Numer.Methods Appl.*, vol. 2, pp. 123-128, 2009.

