Wang, Xianhui; **Li, Fanglin**; **Zhang, Bo**; **Yu, Jiangong**; **Zhang, Xiaoming**

Wave propagation in thermoelastic inhomogeneous hollow cylinders by analytical integration orthogonal polynomial approach. (English) Zbl 1481.74382

Appl. Math. Modelling 99, 57-80 (2021).

Summary: A new solving procedure based on the Legendre polynomial series is developed to investigate the longitudinal guided waves in fractional order thermoelastic inhomogeneous hollow cylinders. Different from the available Legendre polynomial approach, integrals are calculated by the explicit and simple expressions to replace the numerical solutions. The solutions according to the global matrix method (GMM) are also derived for the first time to verify the effectiveness of the presented approach. Comparison of the CPU time indicates that the computational efficiency of the new solving procedure has a huge improvement. Then, the guided wave phase velocity dispersion curves, attenuation curves, displacement and temperature distributions for functionally graded hollow cylinders with different fractional orders, flexural orders, radius-thickness ratios and gradient fields are analyzed. It is found that the attenuation coefficients of flexural longitudinal modes rapidly decrease when the flexural torsional mode curve is close to the flexural longitudinal mode curve. Furthermore, notable influence of the flexural order on attenuation curves mainly occurs at the cut-off frequencies and mutation frequencies. In addition, a smaller radius-thickness ratio implies a larger attenuation, and the temperature amplitudes of flexural torsional mode are more and more close to those of longitudinal mode when the radius-thickness ratio decreases.

MSC:

74J05 Linear waves in solid mechanics
35Q74 PDEs in connection with mechanics of deformable solids

Keywords:

thermoelastic guided wave; analytical integral; Legendre polynomial; fractional order; hollow cylinder; attenuation

Full Text: DOI

References:

[1] Predoi, M. V., Guided waves dispersion equations for orthotropic multilayered pipes solved using standard finite elements code, Ultrasonics, 54, 7, 1825-1831 (2014)

[2] Li, Y. Q.; Wei, P. J.; Wang, C. D., Dispersion feature of elastic waves in a 1-D phononic crystal with consideration of couple stress effects, Acta Mech., 230, 6, 2187-2200 (2019) · Zbl 1428.74102

[3] Zhang, X. M.; Li, Z.; Wang, X. H., The fractional Kelvin-Voigt model for circumferential guided waves in a viscoelastic FGM hollow cylinder, Appl. Math. Modell., 89, 299-313 (2021)

[4] Yu, J. G.; Wu, B.; He, C. F., Guided thermoelastic waves in functionally graded plates with two relaxation times, Int. J. Eng. Sci., 48, 12, 1709-1720 (2010)

[5] Yang, Z. Y.; Liu, K.; Zhou, K., Investigation of thermo-acoustoelastic guided waves by semi-analytical finite element method, Ultrasonics, 106, Article 106141 pp. (2020)

[6] Al-Qahtani, H. M.; Datta, S. K., Laser-generated thermoelastic waves in an anisotropic infinite plate: exact analysis, J. Thermal Stresses, 31, 6, 569-583 (2008)

[7] Li, C. L.; Han, Q.; Liu, Y. J., Thermoelastic wave characteristics in a hollow cylinder using the modified wave finite element method, Acta Mech., 227, 6, 1711-1725 (2016) · Zbl 1341.74152

[8] Venkatesan, M.; Ponnusamy, P., Wave propagation in a generalized thermoelastic solid cylinder of arbitrary cross-section immersed in a fluid, Int. J. Mech. Sci., 49, 6, 741-751 (2007)

[9] Erbay, S.; Şuhubi, E. S., Longitudinal wave propagation in a generalized thermoelastic cylinder, J. Thermal Stresses, 9, 3, 279-295 (1986)

[10] Li, Y.; Zhang, P.; Li, C., Fractional order and memory-dependent analysis to the dynamic response of a bi-layered structure due to laser pulse heating, Int. J. Heat Mass Transfer, 144, Article 118664 pp. (2019)

[11] Hollkamp, J. P.; Sen, M.; Semperlotti, F., Analysis of dispersion and propagation properties in a periodic rod using a space-fractional wave equation, J. Sound Vib., 441, 204-220 (2019)

[12] Sheorana, S. S.; Kundu, P., Fractional order generalized thermoelasticity theories: A review, International Journal of Advances in Applied Mathematics and Mechanics, 3, 4, 76-81 (2016) · Zbl 1367.74004

[13] Tiwari, R.; Mukhopadhyay, S., On harmonic plane wave propagation under fractional order thermoelasticity: an analysis of fractional order heat conduction equation, Mathematics and Mechanics of Solids, 22, 4, 782-797 (2017) · Zbl 1371.74142

[14] Deswal, S.; Kalkal, K. K., Plane waves in a fractional order micropolar magneto-thermoelastic half-space, Wave Motion, 51, 1, 100-113 (2014) · Zbl 07026854

[15] Kumar, R.; Gupta, V., Wave propagation at the boundary surface of an elastic and thermoelastic diffusion media with fractional order derivative, Appl. Math. Modell., 39, 5-6, 1674-1688 (2015) · Zbl 1443.74203

[16] Kumar, R.; Gupta, V., Plane wave propagation and domain of influence in fractional order thermoelastic materials with three-phase-lag heat transfer, Mech. Adv. Mater. Struct., 23, 8, 896-908 (2016)

[17] Abbas, I.; Alzahrani, F.; Abdalla, A. N., Fractional order thermoelastic wave assessment in a nanoscale beam using the eigenvalue technique, Strength Mater., 51, 3, 427-438 (2019)

[18] Lefebvre, J. E.; Zhang, V.; Gazalet, J.; Gryba, T., Legendre polynomial approach for modeling free-ultrasonic waves in multilayered plates, J. Appl. Phys., 85, 7, 3419-3427 (1999)

[19] Zheng, M. F.; He, C. F.; Lu, Y., State-vector formalism and the Legendre polynomial solution for modelling guided waves in anisotropic plates, Journal of Sound Vibration, 412, 372-388 (2018)

[20] Zhang, X. M.; Zhang, C. J.; Yu, J. G., Full dispersion and characteristics of complex guided waves in functionally graded piezoelectric plates, J. Intell. Mater. Syst. Struct., 30, 10, 1466-1480 (2019)

[21] Yu, J. G.; Lefebvre, J. E.; Guo, Y. Q., Free-ultrasonic waves in multilayered piezoelectric plates: an improvement of the Legendre polynomial approach for multilayered structures with very dissimilar materials, Composites Part B: Engineering, 51, 260-269 (2013)

[22] Elmaimouni, L.; Lefebvre, J. E.; Zhang, V.; Gryba, T., A polynomial approach to the analysis of guided waves in anisotropic cylinders of infinite length, Wave Motion, 42, 2, 177-189 (2005) · Zbl 1189.74057

[23] Othmani, C.; Zhang, H.; Lu, C. F., Effects of initial stresses on guided wave propagation in multilayered PZT-4/PZT-5A composites: A polynomial expansion approach, Appl. Math. Modell., 78, 148-168 (2020) · Zbl 1481.74070

[24] Zheng, M. F.; Ma, H. W.; Lyu, Y., Derivation of circumferential guided waves equations for a multilayered laminate composite hollow cylinder by state-vector and Legendre polynomial hybrid formalism, Compos. Struct., 255, Article 112950 pp. (2020)

[25] Sharma, J. N.; Sharma, P. K., Free vibration analysis of homogeneous transversely isotropic thermoelastic cylindrical panel, J. Thermal Stresses, 25, 2, 169-182 (2002)

[26] Bagri, A.; Eslami, M. R., Generalized coupled thermoelasticity of disks based on the Lord-Shulman model, J. Thermal Stresses, 27, 8, 691-704 (2004)

[27] Lefebvre, J. E.; Yu, J. G.; Ratolojanahary, F. E., Mapped orthogonal functions method applied to acoustic waves-based devices, AIP Advances, 6, 6, Article 065307 pp. (2016)

[28] Wang, Z. X.; Guo, D. R., Introduction to special functions (2014), Peking University Press: Peking University Press Beijing

[29] Wu, C. S., Methods of Mathematical Physics (2015), Peking University Press: Peking University Press Beijing

[30] Gradshteyn, I. S.; Ryzhik, I. M.; Jeffrey, A., Table of integrals, series, and products (2007), Academic Press: Academic Press Pittsburgh · Zbl 1208.65001

[31] Al-Qahtani, H.; Datta, S., Thermoelastic waves in an anisotropic infinite plate, J. Appl. Phys., 96, 7, 3645-3658 (2004) · Zbl 1071.82015

[32] Nakamura, M., Elastic constants of some transition-metal-disilicide single crystals, Metallurgical \& Materials Transactions A, 25A, 331-340 (1994)

[33] Vogelgesang, R.; Grimsditch, M.; Wallace, J. S., The elastic constants of single crystal β-Si3N4, Appl. Phys. Lett., 76, 8, 982-984 (2000)

[34] Elmaimouni, L.; Lefebvre, J. E.; Zhang, V., Guided waves in radially graded cylinders: A polynomial approach, NDT&E International, 38, 5, 344-353 (2005)

[35] Yu, J. G.; Wu, B.; Chen, G. Q., Wave characteristics in functionally graded piezoelectric hollow cylinders, Archive of Applied Mechanics, 79, 9, 807-824 (2009) · Zbl 1176.74092