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Dynamic Response of Fractional-Order Thermal-Magnetic-Elastic Coupled Solids with Spherical Holes Based on Moore-Gibson-Thompson Theory

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ABSTRACT

This study establishes an innovative theoretical framework for thermo-magneto-elastic coupling, based on the generalized thermoelastic theory of Moore-Gibson-Thompson (MGT), and significantly extends the constitutive equation by introducing spatio-temporal nonlocal parameters to more accurately describe the thermodynamic behavior of materials under extreme conditions, such as ultrafast laser heating and micro-nano scale environments. This paper innovatively adopts tempered Caputo fractional derivatives to describe the memory effect of the system, which can more accurately describe complex thermodynamic processes and significantly enhance the physical authenticity of the model. The dynamic response of magneto-thermo-elasticity of spherical cavity structures under time-varying laser pulse heating is mainly studied, and the coupled control equations including nonlocal effects are established. The analytical solution is obtained by using Laplace transform combined with numerical inversion. Numerical analysis reveals the unique deformation mechanism and evolution law of thermal stress under thermal load, and it is found that the spatio-temporal nonlocal parameters significantly affect the propagation characteristics of thermal waves. These achievements not only deepen the understanding of magneto-thermo-elastic behavior, but also provide important theoretical guidance for engineering applications such as thermal management of microelectronic devices and reliability assessment of structures in extreme environments. The theoretical framework established in this study provides new ideas for the design of intelligent thermo-elastic materials and the solution of thermo-magneto-elastic coupling problems.

KEYWORDS

Moore-Gibson-Thompson heat equation; tempered caputo; laser pulse; spatial-temporal non-locality; spherical cavity

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