Thermodynamically consistent modified Lord-Shulman generalized thermoelasticity with strain-rate

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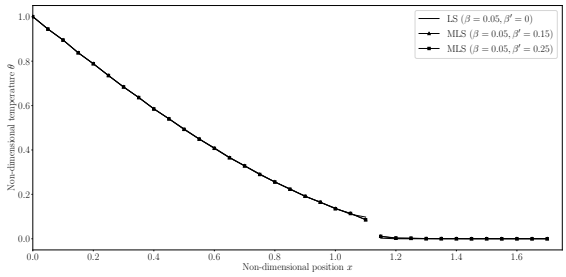
1 INTRODUCTION AND OBJECTIVE

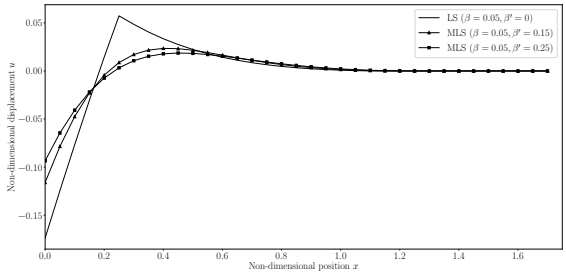
The analysis of thermoelastic wave propagation in continuum solids at micro/nano-seconds is especially significant for ultra-fast heating technologies, where strain relaxation effects will increase significantly. In most cases, it is commonly accompanied by a relatively small strain-rate; however, this is questionable in the environment of transient thermal wave propagation under the ultra-fast heating case. The present work is dedicated to constitutive modelling of a novel generalized thermoelasticity model by introducing an additional strain-rate term associated with a relaxation time parameter in the Lord-Shulman (LS) thermoelasticity [1]with the aid of an extended thermodynamics framework. As an application, the newly developed model is applied to a one-dimensional half-space problem which is traction free at one end; a time-dependent thermal shock is imposed at the same end to analyze transient responses of thermodynamic field variables (temperature, displacement, strain and stress). The inclusion of strain-rate in the LS model eliminates the probable propagating jump discontinuities of the strain and stress fields at the wavefront. The current work is expected to be useful in the mathematical modelling and numerical simulation of thermoelastic processes under an ultra-fast heating environment.

2 RESULTS AND HIGHLIGHTS OF IMPOINTANT POINTS

- The influence of the strain-rate term on the temperature field is negligible.
- The introduced strain-rate term makes the displacement field smooth, which is more reasonable for the continuum hypothesis of solid bodies.
- The introduced strain-rate term removes the probable jump discontinuities of the strain and stress fields in the Lord-Shulman (LS) thermoelasticity theory at the wavefront.
- The strain relaxation constant β' (non-dimensional form of the strain relaxation time τ) plays a prime role in restraining the displacement, strain and stress of the solid body.
- The MLS model is the generalized case of the phenomenological LS model, in which β' (non-dimensional form of τ) makes the transient responses of the thermodynamic field variable more accurate and rational compared to the LS model except for temperature. The understanding



(a) Variation of non-dimensional temperature with position for LS and MLS model



(b) Variation of non-dimensional displacement with position for LS and MLS model

of the physical essence of β' (non-dimensional form of τ) in the thermal wave phenomena will be lacking unless an experimental evidence for any elastic solid is provided.

References

[1] H. W. Lord, Y. Shulman, A generalized dynamical theory of thermoelasticity, Journal of the Mechanics and Physics of Solids 15 (5) (1967) 299–309.