Non-Fourier heat conduction and nonlocal theory, recent progress and application in thermal stress analysis

Zengtao Chen
Department of Mechanical Engineering, University of Alberta, Canada

Abstract:

High-energy pulse laser beams are widely used in additive manufacturing of metals, ceramics and other high-melting temperature materials, where the workpiece experiences sudden heating process with extremely high temperature gradient localized in the heating spot. Recent experimental and theoretical results have showed that thermal stress analysis based on the classical Fourier heat conduction and continuum mechanics will lead to a much more optimistic prediction of the thermomechanical behavior of the material than the actual situation. This overestimate in the thermomechanical response to transient, localized, high-energy heating process will eventually jeopardize the manufacturing and subsequent application of the additively manufactured products.

Non-Fourier heat conduction theories were proposed to address the transient heating process involving high temperature or temperature gradient, extremely low temperature, or heterogeneous material structures. This presentation summarizes some of our recent works on thermal stress analysis of transient heat process using non-Fourier heat conduction theories. Rationality of application of non-Fourier heat conductions and nonlocal continuum theory will be discussed first. Then some typical thermomechanical problems extracted from additive manufacturing will be solved to illustrate the advantages of these theories over the classical theories. In particular, nonlocal theory of continuum exhibits perfect applicability in dealing with localized heating process when combined with non-Fourier heat conduction.