This special section features contributions that address vibration and wave motion in a new way.

The classical models (linear and nonlinear) of vibration involve systems of ordinary and partial differential equations of integer order. Interpolation between first- and second-order models, for example, is possible using the tools of fractional calculus (integration and differentiation of arbitrary real order). Such tools are increasingly being applied to model the dynamics of complex materials and systems in mechanics, acoustics, and bioengineering.

This special section is motivated by our desire to bring together in one place a collection of articles that describe both the depth and breadth of fractional analysis in vibration and acoustics. The contributing researchers have shared their expertise and knowledge so that others can learn how to apply the methods of fractional calculus. We present both fundamental and applied studies spanning discrete and continuous systems and that involve fractional derivatives defined in both space and in time.

Fractional Derivatives in Time: A wide range of viscoelastic models have been proposed to interpret oscillatory motion in continuous and discrete systems. These constitutive models attempt to relate measurable phenomena to the underlying elasticity and damping of the material, both of which are typically rate (frequency) dependent. Historically, this area was first explored through the development of the “so-called” spring-pot dynamic model, which is simply a fractional order conflation of the spring and the dashpot. Since then, many studies have extended the model by adding the spring-pot as an element in a generalized Voigt model or Maxwell model of viscoelasticity. Such models have limitations, but in general, they accurately capture dynamic phenomena over multiple time scales and/or with broad spectral content, particularly for biological tissues and polymeric materials comprised of long chain molecules. For example, in medicine, fractional order viscoelastic models have shown the potential to provide new disease and treatment specific parameters (elastographic imaging) that more effectively predict underlying changes in tissue associated with developing pathology, such as liver cirrhosis and breast cancer.

Fractional Derivatives in Space: In principle, the wave equation can be generalized in both space and in time. The fractional order space derivatives provide specific information on nonlocal variation of material properties that influence particle motion and vibration. Surprisingly, analytical solutions to the fractional order wave equation are possible, and recently, they have been applied to model both the propagation and the damping of vibrations in complex, porous, and heterogeneous materials. Applications in materials testing in vibration damping and in acoustic modeling of the lung have been published, but the utility of this approach is not widely publicized. One goal of this special section is to introduce the analytical and numerical methods now available for analyzing vibration in complex materials.

While the applied mathematics community and many other application-driven researchers in mechanical engineering have begun to embrace fractional calculus—as a tool to model multiscale, complex systems—many researchers in the fields of acoustics and vibrations are largely unaware of the potential impact of this advancement in analysis tools. The papers presented in this special section can address this problem. The papers span a range of topics and techniques (e.g., harmonic oscillators, poroviscoelastic materials, power law attenuation, and continuous coupling interfaces). They are both analytical and numerical. The goal is to bring these topics to the attention of the JVA community and beyond, that is, to encourage a wider interest and awareness of this powerful analytical tool.

Finally, the editors wish to thank the authors who have submitted papers to this special section, the reviewers who have provided excellent comments, and the Editor and Publishers of ASME for supporting this opportunity to share new results in the emerging field of fractional calculus in vibration and acoustics.

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