

The Raymond D. Mindlin Lecture

Department of Civil Engineering & Engineering Mechanics, Columbia University
Engineering Mechanics Committee, ASCE Metropolitan Section
Engineering Mechanics Institute, ASCE

Are Configurational Forces Real Forces?



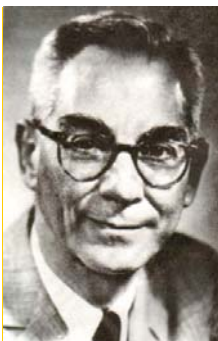
Professor Roberto Ballarini

Department of Civil and Environmental Engineering
University of Houston
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2:40-3:40 pm

214 Pupin Laboratories

Abstract: In the *Treatise on Natural Philosophy* of 1879, Thomson and Tait suggest that any attempt to supersede Newton's description of the laws of motion cannot but end in utter failure. A force is something that tends to alter a "body's" natural state of rest, or uniform motion along a straight line, with respect to an inertial observer. The structure of space as given to us in intuition is geometry; it is the possibility of visualizing forces with lines, and their geometrical composition, that facilitates the practical solution of most problems of mechanics. There are cases, however, for which the geometric visualization of such forces is not straightforward. A classical example is that of configurational forces, pioneered by Eshelby to describe the potential movement of defects within the solid state. From the variation of the free energy consequent to the movement of the defect, say an inclusion, an associated force can be inferred due to the natural tendency of the system to achieve lower potential states. However, as admitted by Eshelby himself, such a force is in some sense "fictitious": its existence is demonstrated starting from a consistent continuum theory of mechanics, but the same theory predicts that the resultant of the traction acting along the boundary of the inclusion is null. We show in paradigmatic examples amenable of generalization that a configurational force can be viewed as the resultant of the contact forces acting on the perturbed shape of an object of substance equivalent to the defect, and evaluated in the limit of the shape being restored to the primitive configuration. The expressions for the configurational forces on cracks and dislocations are in agreement with those determined using classical variational arguments. It is hoped that this somewhat novel approach, which has been applied by Bigoni and coworkers to illustrate configurational forces in structural components, may open a new prospective in the use of configurational forces by permitting their physical and intuitive visualization.

Biosketch: Dr. Roberto Ballarini is Thomas and Laura Hsu Professor and Chair of the Civil and Environmental Department at the University of Houston. Ballarini's multidisciplinary research focuses on the development and application of theoretical, computational and experimental techniques to characterize the response of materials to mechanical, thermal, and environmental loads. He is particularly interested in formulating analytical and computational models for characterizing fatigue and fracture of materials and structures. Ballarini's research has been applied to problems arising in civil engineering, mechanical and aerospace engineering, materials science, microelectromechanical systems, biological tissues and prosthetic design. He has published more than one hundred papers in refereed journals, including *Science* and *Nature*, and several of his research projects have been featured in the popular press, including the *New York Times*, *Science Times*, *American Scientist*, *Business Week*, *Financial Times*, and *Geo*. Ballarini served as President of the ASCE Engineering Mechanics Institute and serves as Editor of *ASCE Journal of Engineering Mechanics*. He is the recipient of the 2019 Raymond D. Mindlin Medal and the Case Western Reserve University-wide John S. Diekhoff Award for Distinguished Graduate Teaching.



The Department of Civil Engineering and Engineering Mechanics established the Mindlin Lecture to honor the pioneering contributions of Prof. Raymond D. Mindlin to the field of applied mechanics. His research encompassed photoelasticity and experimental mechanics; classical three-dimensional elasticity (e.g., Mindlin's problem); generalized elastic continua (strain-gradient and couple-stress theory); frictional contact and granular media; waves and vibrations in isotropic and anisotropic plates (Mindlin's Plate Theory); wave propagation in rods and cylinders; theory of electro-elasticity and piezoelectric crystal resonators, and crystal lattice theories.

A member of the National Academy of Engineering and the National Academy of Sciences, Prof. Mindlin received the National Medal of Science for applied mechanics and mathematics in 1979. He had been awarded the Medal for Merit in 1946, by President Harry S. Truman, for his work in developing the radio proximity fuse, a detonator for weapons used in offensive warfare that was a significant factor in World War II. ASCE created the **Mindlin Medal** in 2009.