

PUBLICATIONS:

BOOKS EDITED:

1. *Duality, Symmetry, and Symmetry Lost in Solid Mechanics: Selected Works of H. D. Bui*, ed. with A. Erlacher (Ecole Des Ponts Presse, France) 2011.
2. X. Markenscoff and A. Gupta, J. D. *Eshelby's Collected Works: The Mechanics of Defects and Inhomogeneities*, (Springer) 2016.
3. *Dislocations in Solids: Some Recent Advances*, ASME (New York) 1984.

RESEARCH AREAS

1) Dynamic micromechanics of defects:

The dynamics and evolution of defects with inertia, including dislocation motion, expanding inclusions and inhomogeneities with transformation strain, moving phase boundaries, in which she has an extensive body of work. The energetics (driving forces) and the evolution of the moving defects are governed by Noether's theorem of the calculus of variations in a variable domain, one of the important theorems of the 20th century. Recent results include the proof that the self-similarly expanding ellipsoidal inclusions preserve the constant stress property in the interior domain, and the proof that the static Eshelby tensor is a limiting case of the dynamic. The dynamic Eshelby tensor is thus obtained and it allows for the analytical solution of expanding ellipsoidal inhomogeneous inclusions with chemical phase change (Eshelby equivalent inclusion method) extended now to dynamics). For a solid containing a periodic distribution of defects, the energy dissipated in the unit cell is governed by the J, L, M integrals according to Noether's theorem and by asymptotic homogenization is carried to the macro-scale as macroscopic damage. This is going to be extended to dynamics. This new field can be called *Dynamic Eshelby Micromechanics*. More specifically:

Dislocation dynamics with inertia effects

(Publications # A.14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 34, 36, 38, 81, 83, 85, 105, 107, 108, 109, 110, 111, 116, 119)

Dislocation dynamics with inertia effects, screw, edge dislocations in general motion, generally expanding dislocation loops, also screw and edge dislocations in anisotropic solids in general motion, detailed treatment of the singularities for the near field (singular asymptotics of integrals for the logarithmic singularities). The transition from subsonic to supersonic /transonic motion of a Volterra dislocation was analyzed, and the "effective mass" of a moving Volterra dislocation was also obtained; both being classical long-standing problems in dislocation theory.

Expanding Eshelby inclusions/ inhomogeneities with transformation strain. (Publications # A. 113, 114, 117, 118, 122,124, 127, 130, 131, 132,133, 134) Solutions were obtained for generally dynamically (with inertia) expanding spherical Eshelby inclusions and plane

phase boundaries with transformation strain, as well as for expanding inhomogeneities with transformation strain (i.e. when the material properties change as the inclusion expands). The “**driving forces**,” i.e the energy-release rate required to create (dynamically) an incremental region of eigenstrain, or of an inhomogeneity with eigenstrain, were obtained.

Most recently, it is shown that self-similarly expanding Eshelby ellipsoidal inclusion preserves the constant stress Eshelby property in the interior domain where the particle velocity vanishes, and the Dynamic Eshelby Tensor is obtained. (in integral form). The Dynamic Eshelby Tensor for the spherical expanding inclusion under general eigenstrain is obtained in closed form. By a limiting procedure the static Eshelby Tensor of the ellipsoid is obtained from the dynamic one, making the Eshelby problem to have a true dynamic generalization. The Dynamic Eshelby Tensor allows for the solution of expanding inhomogeneities with chemical phase change when the elastic constants in the interior domain are changing as the inclusion expands.

Asymptotic homogenization (publications # A.123, A.125)

At the unit cell level the micro-crack interaction and growth is governed by the J integral (energy dissipation) and the micro-hole interaction and growth by the M integral. This energy dissipation at the micro-level is carried to the macro-level as macroscopic damage by asymptotic homogenization. Current efforts include the development of dynamic asymptotic homogenization for the dynamic damage evolution in order to account for the energy loss through the dynamic J and M integrals (for the early motion of the evolution of the defects) . This will extend the early work of Clifton and Markenscoff (1981) on elastic precursor decay and radiation from moving dislocations.

Inverse problem of Eshelby inclusions:

(Publications # A.61, 62, 63, 70, 94, also: 69, 70)

Proved that the ellipsoid is the only shape for which the Eshelby property of constant stress is maintained after perturbation of the inclusion domain, and also that polyhedra are excluded from having the Eshelby property.

2) Configurational forces

Configurational forces on moving defects

(Publications # A. 95, 107, 103, 108, 114, 115, 117, 120, 129,133)

The **self-forces** for moving defects, dislocations (“**effective mass**”) and phase boundaries with transformation strain (“**driving force**”) have been obtained. On the basis of Noether’s theorem, an interpretation of the **dynamic J integral** was given as necessary and sufficient condition for linear momentum to be preserved in the domain for any perturbation of the inhomogeneity position,

which settles the open issue of how loading and phase boundary velocity are related (**evolution equation**).

Conservation laws and integrals:

(Publications# A.74, 86, 92, 95, 100, 101, 102, 103, 104, 106, 120)

a. Conservation laws for incompatibility:

Based on Noether's theorem for a positive definite functional that has as Euler-Lagrange equations the **Beltrami-Michell compatibility equations** for the stress, new conservation laws were obtained that allow from surface data to determine the incompatibility content in the volume.

- a. Conserved integrals for couple-stress and micropolar elasticity (based on Noether's theorem) and interpretation as energy-release rates.
- b. Dual integrals based on complementary energies for elasticity and micropolar elasticity.

3) Singular asymptotics for thin ligaments

(Publications # A.30, 37, 39, 52, 55, 56, 75, 76, 99, C4)

The singular amplification of the stress as a function of the ligament thickness (for thin ligaments) has been obtained analytically for different geometries of ligaments (two holes, two cracks, etc.) and loadings, by newly developed singular asymptotics of series. The singular dependence of the stress is also found by matched inner and outer expansions. This amplification can account for the acceleration of the damage at the macroscale due to interaction of microcracks/micro-holes, in the framework of an asymptotic homogenization model.

4) The Cosserat Spectrum Theory of Elasticity (spectral theory of elasticity). (Publications # A.49, 51, 58, 59, 64, 65, 66, 67, 68, 72, 73, 89, 90, 91, 93)

The spectral theory of elasticity, initiated by the Cosserat brothers and mathematically developed by Mikhlín (1970) has been further developed both theoretically and by obtaining the eigenfunctions for the spherical shell, and applying the theory to problems in elasticity, thermoelasticity, viscoelasticity, and poro-elasticity. The spectral theory allows for the unique representation (due to the completeness of the eigenfunctions) of the solution in terms of the geometry, loading, and elastic properties.

Necessary and sufficient conditions for the Poisson's ratio dependence of the stress in multiply connected domains in the presence of body force loading have been also obtained generalizing the classical Michell conditions.

1. Theory of Elasticity.

(Publications# A.32, 33, 40, 41, 42, 45, 46, 47, 48, 50, 53, 54, 96)

The *wedge paradox* (and *Saint Venant's principle*) was viewed from the point of interaction of a load induced singularity (concentrated moment, dislocation dipole, etc.) and a geometric singularity (wedge vertex, crack tip), and a new interpretation was given to the paradox. Rigid line inclusions (coined *anti-cracks*) were considered as dual to cracks, and their interaction with load induced singularities was analyzed. Green's functions were given for point forces and dislocations in an infinite solid containing a rigid line inclusion.

Interface conditions in elasticity: expressing continuity of displacement in terms of strains through the continuity of curvature. Jump conditions and Cesaro integrals for slipping interfaces.

General conditions for the *reduction in the number of elastic constants* in the stress dependence of multi-phase composites with bonded and slipping inclusions under body force and boundary traction loadings.

6) Robotics

Publication# A.35 ("The Geometry of Grasping") provides the solution to the problem of the number of fingers required to hold an object of arbitrary geometry in any position (that had been open for over a hundred years): (12 fingers for general geometry, 7 fingers for polyhedra, 4 with friction); it is a classic, of permanent value to robotics with **392 citations** (according to Google Scholar). This was an open problem since Reuleaux, 1875.

7) Other topics

1. Hadamard instability analysis for coupled mechano-thermo-chemical systems. Conditions for "negative creep."

3. Publications # A.77, 78, 82, 84, 128)

4. Third and fourth order elastic constants (crystal symmetries)

(Publications # A.6, 9, 13, 11, 12, 13)

4. High Frequency Vibrations of crystal plates under large initial deformation

(Publications# A.1, 3, 5, 7)

Miscellaneous topics

PUBLICATIONS IN REFEREED JOURNALS:

138. X. Markenscoff "The Waves of Phase Change" *Phys. Rev. Lett* (under revision)
137. X. Markenscoff and L. Ni "The driving force on the boundary of a self-similarly expanding Eshelby spherical inclusion" *Int. J. Fracture* Volume 202 Page 129-134 (2016) DOI 10.1007/s10704-016-0146-2
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134. X. Markenscoff and L. Ni "The driving force on the boundary of a self-similarly expanding Eshelby inclusion" *Int. J. Frac.* (submitted)
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