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Mesomechanics of energy and mass interaction for dissipative systems

G.C. Sih*

Lehigh University, Bethlehem, PA 18015, USA
East China University of Science and Technology, Shanghai, 200237, China

Small and large specimen data cannot be connected because the respective theories are developed independently by different physical laws. The disparities are becoming more and more transparent as nanospecimen data cannot be brought up to the macroscopic scale. The inability to address quantum and gravitational field mechanics in a unified manner adds to the diversification. One of the apparent deficiencies is not being able to treat small (atomic) and large (galaxial) bodies by a common multiscale model for addressing nonequilibrium and nonhomogeneous conditions. The time of arrow must also be reflected to invoke finiteness of the life sustaining energy. The synergistic thought leads to a pulsating mass manifested by matter activated by energy absorption and dissipation. The near simultaneity of energy intake and outlet of physical systems resembles the pulsation arising from contraction and expansion. The pulses, caused by the fatigue of metals, are within the range of micropulsations of geomagnetic energy fluctuations. The dualism of energy absorption and dissipation provides a common dialogue for establishing multiscale shifting laws. Mass pulsation, coupled with the equivalence of motion and energy, gives a unique mass–matter relation, bypassing the diversities of current concepts and theories in physics and mechanics.

The scheme of scaling by segments such as pico, nano, micro and macro creates gaps among the scale ranges that requires cementation. Mesomechanics serves this purpose for developing scale shifting laws for connecting the gaps. Determination of energy density from velocity of physical systems was shown to be possible from the application of crack tip mechanics and ideomechanics. Four fundamental parameters ℓ, v, $\mathcal{M}$ and $\mathcal{W}$ are used. They stand, respectively, for the length, velocity, mass density and energy density. Their combinations can be formulated into unique mathematical groups. The three scale ranges: pico–nano, nano–micro and micro–macro are selected for demonstration. The objective is to explain real accelerated test data without making idealized assumptions for determining the life distributed over the three scale ranges.

In short, a nonclassical approach will be adopted to derive scale shifting laws consisting of the transitional functions $\mathcal{R}_j^{j+1}$ which stand for the mass ratios of the absorption energies $\mathcal{W}_j^{j+1}$ and dissipation energies $\mathcal{D}_j^{j+1}$. The notations j and $j+1$ stand for two successive scales: pico–nano, nano–micro and micro–macro. Hence, the mass ratios $\mathcal{R}_{\rm pi}^{\rm na}$, $\mathcal{R}_{\rm na}^{\rm mi}$ and $\mathcal{R}_{\rm mi}^{\rm ma}$ can be referred to as the transitional inhomogeneity coefficients. They make up the multiscale shifting laws $\mathcal{W}_j^{j+1} = \mathcal{R}_j^{j+1}\mathcal{D}_j^{j+1}$. Validation of the method involves connecting the accelerated test data at the different scales, say from pico to nano to micro to macro. A key step in this development is the use of an energy density dissipation function, the definition of which is scale invariant. Referred to the contraction and expansion of a control volume, energy is said to be absorbed and dissipated, respectively. The respective mass densities $\mathcal{M}_{\downarrow}$ and $\mathcal{M}^{\downarrow}$ may then be regarded to pulsate by contraction and expansion. Real fatigue data for the precracked 2024-T3 aluminum panels are used to derive energy loss by dissipation. Equivalency of mass and energy also enables numerical evaluation of mass loss.

Keywords: mass pulsation, multiscaling, scale shifting laws, small and large, material inhomogeneity, energy absorption, energy dissipation, multicomponent systems, nonequilibrium, micropulsation, dormant factors

1. Introduction

The connection of nanospecimen data to those for macrospecimens require the use of non-equilibrium and nonhomogeneous theories for open thermodynamic systems. Scaling shifting laws cannot be made if the physical laws for nano- and macrobodies differ. The current atomistic and continuum theories offers little or no support for they are also separated by scale size difference. Cosmophysics has been searching for the life of the universe with theories known as the Big Bang and black holes. These studies are not unrelated to the behavior of small and large constituents in materials science since the building blocks for all matter in the universe should be the same. The explanations, however, have diversified. Controversies arising from the paradox of the particle-wave dualism remain unresolved. Seemingly convincing tests showed that concentrated energy of the particle cannot coexist with the dispersed energy of the wave, leaving out the possibility that the precursor might

* *Corresponding author*
Prof. George C. Sih, e-mail: gcs1@lehigh.edu, gcs@ecust.edu.cn

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just be the experiment itself. Nature may appear as particles and also waves depending on the prevailing conditions, but not both at the same time. The school of I Ching or "Book of Changes" referred to by the Western world offers another view how nature is formed by quantities with opposing poles. Positron-electron, matter-antimatter, positive-negative and numerous others that can be paired. The direction of arrow associated with the transition from one side of the pole to the other, however, has been left open. Matter and antimatter could have coexisted and differentiated by an interface, the "twilight zone" within which the state of affairs is neither black nor white but remains blur. Fabrication of antiprotons has been contemplated [1]. The particle-wave can be considered as a pair of opposing poles, then the dualism can be assumed to exists by supposition, not because of the "double slit" experiment. Neither particle nor wave would prevail in the "mesoregion", an alternate description of the twilight zone.

The extraordinary complexity of nature may never be understood as a whole. Even a piecemeal approach for materials science applications can be overwhelmingly difficult. One recourse is to circumvent the inconsistencies of the past by recognizing the tangibles from the intangibles. Singularities, beyond human comprehension, will be admitted to represent events by revelation or limits unattainable by experiments. The crack tip is a useful conceptual tool for it has no dimension but it can absorb and dissipate energy, analogous to a source and sink. It can be associated with a singularity that has been known to serve a practical purpose in fracture mechanics. But there is other singularity such as that for dislocation at the atomic scale. Scaling is a matter of choice but, once decided, the book keeping system should be kept with consistency [2]. Different orders of singularity can be assigned to different physical systems at the appropriate scale. This is equivalent to having a theory for each scale range except that they are all connected. The results for one scale range can be shifted to another. In this way, the nanospecimen data can be translated to those for the macrospecimen. The process involves translating the material inhomogeneity for the nanospecimen to that for the macrospecimen. Empirical book keeping schemes lack the consistency provided by multiscale scale shifting laws that use transitional functions μ^*, σ^* and d^*, one for each of the three scale ranges. They correspond to pico–nano, nano–micro and micro–macro. The details can be found in crack tip mechanics [3] and ideomechanics [4]. A departure from Newtonian mechanics is that mass is assumed to be found from the velocity via the energy density regardless of scale size. A energy-mass relation derived from the ideograms is used. The ideograms can form mathematical groups involving the combination of ℓ, v, $\mathcal{M}$ and $\mathcal{W}$ which stand, respectively, for the length, velocity, mass density and energy density. Based on ideomechanics [4], many of the classical laws of physics are recovered in addition to their extension to nonequilibrium and nonhomogeneous conditions. A case in point is the kinetic molecular theory for open thermodynamic systems that can now be applied to analyze biological systems and to explore ecological successions. The mass density associated with energy absorption is distinguished from that with energy dissipation, based on the inherent difference of the corresponding time rates. The analogy can be made to inhaling and exhaling as in breathing. The energy densities $\mathcal{W}$ for absorption and $\mathcal{D}$ for dissipation give rise to pulsation of the mass densities $\mathcal{M}_{\downarrow}$ and $\mathcal{M}^{\downarrow}$, and hence the description "mass pulsation". Scale shifting laws [5, 6] are thus developed and expressed in terms of the transitional functions $\mathcal{R}_j^{j+1}$. The repeated character of mass pulsation is also related to the recent discovery of micropulsations [7] associated with geomagnetic energy fluctuations. Any schemes, connected with results from pico to macro, can no doubt be further extended from both ends to cover physical systems having even smaller and larger size scales.

Justification for the complete procedure can be further reinforced by the use of three additional controllable variables of secondary consideration. They are related to life span distribution, energy density and power density efficiencies for each of the three scale ranges. The time evolution properties of the multiscale material can thus be derived as a package and expressed in terms of the accelerated test data for a multicomponent system. The concept of "total reliability" [6] will also be needed to address the compatibility of the components with the whole system in terms of the energy and/or power efficiencies.

2. Irreconcilable difference of the atomic and field theory approach

The connotation "field theory" in continuum mechanics and space-time physics can have different interpretation. Ambiguities can result by assuming that a specific force–mass relation to be universal. The fallacy can continue with the failure of distinguishing a positive or negative surface flux Y in contrast to an attractive or repulsive body flux Z transmitted through the volume. Their balance may involve the positive or negative reactive flux X. The rate change of volume with surface $\mathrm{d}V/\mathrm{d}A$ relates Z to Y:

$$Y = X + Z\left(\frac{\mathrm{d}V}{\mathrm{d}A}\right)_{\mathbf{n}}, \tag{1}$$

where $\mathbf{n}$ is the normal to the area A. Equation (1) may be regarded as the connection of surface and bulk quantities. According to the traditional language of mechanics, Y would be the surface flux or force per unit area and Z the body force per unit volume. The term "body flux" is used in the spirit of the Gauss flux theorem associated with the Gauss law of gravity. That is to think of body force acting like surface flux in relation to a controlled volume. After all, surface and volume quantities are convertible mathemati-