# A DIRECT THEORY OF SHELLS AND LAMINATES WITH DISTENSIBLE THICKNESS

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## 1. General Framework

I advocate a comprehensive axiomatic framework for continuum mechanics (and, more generally, any branch of continuum physics), where the key move in devising any specific theory consists in the postulation of a distinguished continuous linear functional on the space of velocity fields available to that theory, which delivers the working expended (by outer and inner actions) on each velocity field. All basic features of the theory are then produced, according to a uniform format, by a few postulated properties of the working functional.

The basic balance law is provided by an *axiom of vanishing working*: the total working expended on any test velocity field should be zero. Such a principle is to be regarded as a selection rule on motions, once the pertinent constitutive information -- relating working to motion -- has been provided.

The role of invariance surfaces in a different and independent *axiom of invariance of the inner working under change of observer*: the density of the inner working expended on any *rigid* velocity field should be zero, for all conceivable motions. As it stands, this principle gives a selection rule on constitutive prescriptions, not on processes.

## 2. Shells and Laminates with Distensible Thickness

While referring to [1] for a general abstract statement of the ideas above, in this paper I intend to use that format for constructing an (exact) theory of shells -- modelled as two-dimensional continua endowed with a one-dimensional *affine* microstructure -- and a theory of laminates made up of a stack of like shells. It seems to me that such a presentation is both simpler and neater than conventional ones.

The assumed one-dimensional affine microstructure (or, equivalently, a single deformable director) mimics in a nice, even if coarse, way thickness changes, which are usually neglected in otherwise "refined" theories. The ability to model thickness vibrations should play a key role, for example, when considering piezoelectricity, or other coupled electro-mechanical phenomena.

As a second interesting application, I would mention multilayered shells: it seems disproportionate to me to allow for a finer description of the interface behaviour, without alleviating the germane constraint that laminae cannot suffer any transverse extension. In a joint paper [2], A. Tatone and I address this issue. With our approach, the inconsistency lamented -- but lightly dismissed -- in [3] simply melts away.

## 3. References


1. A. Di Carlo, A non-standard format for continuum mechanics, in R.C. Batra, M.F. Beatty (Eds.), *Contemporary Research in the Mechanics and Mathematics of Materials*, CIMNE, Barcelona (1996), 92-104.
2. A. Di Carlo, A. Tatone, Multilayered plates with debonding and laminae with distensible thickness. Paper contributed to this Conference.
3. Zh.Q. Cheng, A.K. Jemah, F.W. Williams, Theory for multilayered anisotropic plates with weakened interfaces. *Journal of Applied Mechanics*, 63 (1996), 1019-1026.