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# On the multiscale simulations by mixed finite element method in thermoelasticity

**Dubravka Mijuca**

Faculty of Civil Construction Management,
University UNION, Belgrade
Cara Dusana 62-64, 11000 Belgrade
dmijuca@fgm.edu.yu, www.fgm.edu.yu

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## ABSTRACT

The multiscale [1], robust, reliable and time efficient original primal-mixed finite element approach in thermo-mechanical solid mechanics [2, 3], ready to be bridged with numerical simulations procedures on atomistic level, or semi-coupled with numerical scheme in fluid mechanics, is presented. The first goal was to develop numerical simulation procedure which behaves reliably throughout the spatial and temporal scales [4] in semi–coupled heat transfer and elastostatics field problems, and which can be reliably used for simulation of multimaterial and multilayer structures. The condition was that no dimensional reduction is allowable, and that intrinsic material characteristic must be respected [5, 6] as much as it is possible in the present continuum mechanic framework. For example, the coating must be analyzed by the brick solid finite elements as the rest of the bulk material, in which case it will be very thin and therefore it will violate the aspect ratio restriction of the abundantly used primal finite element approaches (e.g. displacement finite element method). It is proven in [2, 3] that reliability of present approach relies on robustness of the underlying primal mixed finite element scheme, which is insensitive to distortion and extremely high ratio of the minimal and maximal axial dimensions of its finite elements in the mesh. As a novelty it is enabled that boundary conditions per dual variables can be prescribed directly as essential also, which is ideal framework for coupling between different physical problems, for example, in solid-fluid interaction fluid pressure on the solid structure can be added as an essential boundary condition per normal stress component, without any loss of accuracy. It is shown also, that intentionally enforced continuity of the dual (heat flux, stress) base functions, introduces smaller error on the surfaces of the material discontinuity than when it is left discontinuous everywhere in the body, or averaged by some local or global recovering schemes. Further, it is shown that there is no spurious beahaviour of solution variables in the vicinity of singularity. In order to identify the best technique to solve poorly scaled systems of linear equations arising in a present approach in a time-efficient manner, the combination of *HSL* direct sparse solvers and matrix scaling routines [8], is successfully utilized. The several industrial problems of interest will be elaborated as, composite sandwich plates with foam in its core, fiber-optic sensor embedded in composite material, nanoindentation where molecular dynamic is used in the region under nanoindenter, and an example of microcoated solid body.

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