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► To cite this version:

S. Wendling-Mansuy, J.L. Milan, M. Jean, P. Chabrand. Dynamical reorganization of the cytoskeleton during cell deformation analyzed by a divided medium based model. *Journal of Biomechanics*, 2006, Abstracts of the 5th World Congress of Biomechanics, 39 (Supplement 1), pp.S241. 10.1016/S0021-9290(06)83907-2 . hal-04463389

HAL Id: hal-04463389

<https://hal.science/hal-04463389v1>

Submitted on 12 Feb 2025

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Th, 17:00-17:15 (P46)

Dynamical reorganization of the cytoskeleton during cell deformation analyzed by a divided medium based model

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Various cellular functions such as migration, growth, proliferation are controlled by the dynamical reorganization of the cytoskeleton (CSK) which is known to be a hierarchical, pre-stressed and multi-modular filamentous structure. It is assumed that the changes in the CSK filamentous arrangement result from the equilibrium between the mechanical forces exerted through the extracellular matrix and the internal forces. The way the CSK reorganize during cell deformation and how the forces are transmitted through the cell remain still unclear.

We present herein a 2D CSK model based on divided medium theory to describe the dynamical reorganization of the pre-stressed CSK structure during cell deformation considering the main substructures of the CSK such as the cortical actin network, the focal adhesion complexes, the stress fibers lattice as well as the microtubules associated with the intermediate filaments networks. The CSK is modelled as a network of tension forces balanced by compression forces resulting from interactions between several nodes included in the cell medium. These interactions are driven by elastic law and cohesive contact law following unilateral condition.

The model shows the dynamical reorganization of the CSK by rapid changes in connectivity between nodes during the overall deformation and presents a mechanical behavior consistent with strain-hardening and prestress-induced stiffening obtained in other theoretical cellular models and biological measurements performed on cultured adherent cells reported in the literature. Removing one of the main CSK substructures induces in the model a loss of integrity and a decrease in prestress and stiffness, suggesting besides closely interdependencies between the CSK substructures. These first results suggest that this approach may be a useful and complementary tool for understanding cellular processes which involve CSK reorganization.