THEORY AND NUMERICS OF MECHANICALLY–INDUCED HEALING PROCESSES

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The basic aim of this contribution is the qualitative simulation of healing mechanisms in biological tissues. In contrast to engineering materials, biomaterials show the remarkable ability to adapt their microstructure to environmental changes. As a typical example, the local deposition of biomaterial leads to a densification of ground substance which in turn manifests itself in a significant local stiffening of the material. This mechanism of functional adaption is of particular relevance not only for growth in hard tissues such as bones but also for self–healing phenomena in damaged soft tissues e.g. wound healing of skin.

From a mechanical point of view, the biological tissue can be considered as an open system which is subjected to a permanent exchange with its outside world. Conceptually speaking, this interaction manifests itself in an enhanced balance of mass which has to account for a potential in– or outflow of matter as well as an additional mass source. These changes in mass obviously have an impact on all the other balance equations as well.

In the present work, we derive a theoretical and numerical framework for open system mechanics. Thereby, we shall focus on the one hand on the classical spatial motion problem which basically determines the density and the spatial motion field in response to given spatial forces. On the other hand, we are interested in the material motion problem, which aims at characterizing the material forces in response to a given density and deformation field. The computational evaluation of material forces has attracted increasing attention recently in the context of defect mechanics. In the biomechanical context, material forces can essentially be utilized to sense geometric or material imperfections. Pointing into the direction of a potential material deposition to decrease the local energy, material forces can be interpreted as a driving force for healing phenomena.

A consistent computational framework will be outlined to evaluate both, the spatial and the material motion problem in the context of the finite element method. The derived algorithm will be elaborated systematically by means of two prototype geometries subjected to three different representative loading scenarios: tension, torsion and bending. Particular focus will be dedicated to the discussion of the additional information provided by the material force method.