Coupling scales and adaptive refinement for simulation of bone-fixation interfaces using the Finite Cell Method

Ernst Rank*[1], Mohamed Elhaddad[1] , Nils Zander[1], Stefan Kollmannsberger[1], Jan S. Bauer[2] and Martin Ruess[3]

[1]Chair for Computation in Engineering
Technische Universität München
Arcisstr. 21, 80333 Munich, Germany
e-mail: rank@bv.tum.de, web page: http://www.cie.bgu.tum.de

[2]Abteilung für Neuroradiologie
Klinikum rechts der Isar der Technischen Universität München,
Ismaninger Str. 22, 81675 Munich, Germany

[3]Aerospace Structures and Computational Mechanics,
Delft University of Technology,
Kluyverweg 1, 2629 HS Delft, The Netherlands

ABSTRACT

In recent years many studies on the numerical simulation of bone-implant systems have been presented [1]. In general, a geometric model of a bone is derived from qCT-data, including its highly inhomogeneous material properties. Bone and implant are then meshed and simulated by finite elements. In the case of a fixation the zone of the bone close to the screw is of major interest. High forces are transmitted here and screw loosening is the major cause of surgical failure [2]. As the scale of interest for this interface region may be several orders of magnitude smaller than that of the bone, an adaptive refinement of the finite element mesh is mandatory for an accurate solution. Whereas this is already quite demanding in cases of a single simulation, it becomes prohibitively expensive if a sequence of many simulations in order to optimize type, position and pre-stress of an instrumentation shall be performed.

In this paper we will extend the recently developed Finite Cell Method [3], a high order embedded domain approach by a hierarchical refinement strategy in the regions of interest. Whereas the concept of the FCM completely relieves from the need to generate a finite element mesh, the hierarchical refinement yields an accuracy and a scale resolution which could not obtained by classical finite elements methods. We will discuss the basic properties of this adapted multi-scale method and demonstrate its feasibility for simulating bone-mechanics on the example of the fixation of a spinal segment.

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