Asymptotic modelling of articular contact

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ABSTRACT

Biomechanical contact problems involving transmission of forces across biological joints are of considerable practical importance in orthopedic surgery and many numerical models for contact interaction of articular cartilage surfaces in joints are available. At the same time, the necessity of analytical models becomes an important issue in developing improved understanding of load distribution in the normal and pathological joints, which affects the mechanical aspects of osteoarthritis. It is known that the joint degradation in the early stages of osteoarthritis may be reflected in changes of material properties of articular cartilage layers, which were observed to become thicker, softer, and more permeable. Thus, having at hand an analytical model of the joint, it is easy to predict the corresponding behavior of the important contact parameters such as the maximum contact pressure and the contact area during the evolution of osteoarthritis in its early stages.

When studying contact problems for real joint geometries, a numerical analysis, such as the finite element method, is necessary, since exact analytical solutions can be only obtained for a simple enough geometrical configurations. Such analytical solutions have been obtained for two-dimensional, or axisymmetric and simple geometries. On the other hand, analytical solutions for more complex geometries considered as benchmarks are of extreme importance for researchers as they allow verifying numerical computations made any commercial software that involves various complicated biomechanical models. Moreover, exact formulas allow also analyzing various trends in solution behaviors and determine its sensitivity with respect to material and geometrical parameters without heavy and time consuming numerical computations. These arguments show a strong need in evaluation of an exact solutions for the biomechanical problem exhibiting more complex geometry.

A new methodology for modeling tibio-femoral contact presented in this study is based on the recently developed asymptotic models of frictionless elliptical contact interaction between thin viscoelastic and biphasic cartilage layers. There is a large body of literature associated with contact interaction of thin layers. Even in the case of pure elastic behavior of the material, the contact problem presents significant difficulties for analytical solution. But the contact problem for biphasic layers is time-dependent, and such problems have not been widely investigated before, while their analysis requires development of novel asymptotic methods.

I.A. gratefully acknowledges the support from the European Union Seventh Framework Programme under contract number PIIF-GA-2009-253055.