An analytical model for frictionless contact between thin transversely isotropic viscoelastic layers with a migrating contact area: Application to repetitive movements of the knee joint during walking

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Abstract

Multibody dynamic simulations of periodic repetitive postural movements of a human body resulting from walking require modelling of the distributed internal forces generated by articular contact in joints. It is believed that dynamic and impact patterns of the contact pressures play an important role in the development and progression of knee joint osteoarthritis [1]. Thus, multibody dynamic models of the knee joint capable of predicting contact stresses would be useful for studying the mechanical aspects of this joint degenerative disease. In recent years, several multibody dynamic models for the tibio-femoral joint were developed [2, 3]. However, the majority of the available mathematical knee models are based on simplified assumptions considering the complexity of in-vivo knee articulations. A more realistic approach capable of predicting some of the fundamental properties of the human knee articulation was very recently developed in [3]. In this sense, the kinetics of the real knee articulation requires formulation of frictionless contact problem with a migrating contact area. An analytical model for modelling repetitive tibio-femoral contact presented in this study is based on the recently developed asymptotic models of frictionless elliptical contact interaction between thin biphasic [2] and viscoelastic [3] layers. While the subchondral bone is assumed to be rigid, we study different models for the articular cartilage which is considered to be a thin layer of transversely isotropic linear-elastic or viscoelastic (compressible or incompressible) material. The normal contact forces are determined analytically based on the exact solution for elliptical contact between thin viscoelastic compressible or incompressible cartilage layers. Several example contact problems are considered which illustrate the effects of viscoelastic properties on the accommodation mechanism in mechanical response of the articular cartilage layers subjected to repetitive mechanical loading in the knee joint during walking.

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