I. Goda, J.F Ganghoffer, S. Czarnecki, P. Wawruch, T. Lewiński

Optimal internal architectures of femoral bone based on relaxation by homogenization and isotropic material design

Mechanics Research Communications, DOI: dx.doi.org/10.1016/j.mechrescom.2016.06.007

Read online>>

Abstract

The influence of the loading conditions on the trabecular architecture of a femur is investigated by using topology optimization methods. The response of the bone to physiological loads results in changes of the internal architecture of bone, reflected by a modification of internal effective density and mechanical properties. The homogenization based optimization model is developed for predicting optimal bone density distribution, wherein bone tissue is assumed to be a composite material consisting of a mixture of material and void. The homogenization scheme treats the geometric parameters of the microstructures and their orientation as design variables and homogenizes the properties in that microstructure, which is generally anisotropic. The penalization of the optimal material density then leads to a classical optimal structure which consists of regions with bone material and regions without bone material. The IMD (Isotropic Material Design) approach is next applied to determine the optimal elasticity tensor in terms of the bulk and shear moduli as well for the present loading applied to the femoral bone sample. IMD is able to provide both the external shape and topology together with the optimal layout of the isotropic moduli. Both topology optimization methods appear to be complementary. Simulations of the internal bone architecture of the human proximal femur results in a density distribution pattern with good consistency with that of the real bone.