1st International Congress of Serbian Society of Mechanics,
10-13th April, 2007, Kopaonik

Invited Lecture

MODELING OF ULTRASONIC GUIDED WAVE PROPAGATION IN LONG BONES

Vasilios C. Protopappas[1] , Maria G. Vavva[1,2], Dimitrios I. Fotiadis[1,3], Konstantinos N. Malizos[4] and D.Polyzos[5]

[1]Unit of Medical Technology and Intelligent Information Systems, Dept. of Computer Science, University of Ioannina, GR 451 10 Ioannina, Greece.
e-mail: me00642@cc.uoi.gr, fotiadis@cs.uoi.gr,
[2]Dept. of Material Science and Engineering, University of Ioannina, GR 451 10 Ioannina, Greece
e-mail: mvavva@cc.uoi.gr
[3]Biomedical Research Institute – FORTH, GR 451 10 Ioannina, Greece
[4]Dept. of Orthopaedics, Medical School, University of Thessaly, GR 412 22 Larissa, Greece
e-mail: kmalizos@otenet.gr
[5]Dept. of Mechanical Engineering and Aeronautics, University of Patras, GR 26 500, Patras, Greece
e-mail: polyzos@mech.upatras.gr

Abstract:

Guided waves are considered as a significant tool in the ultrasonic evaluation of osteoporosis, and recently in the monitoring of fracture healing process. This work, presents a numerical study of guided wave propagation in two-dimensional (2D) and three-dimensional (3D) models of intact and healing bones. First, we describe a two-dimensional model of an isotropic bone-mimicking plate in which the healing course was simulated as a 7-stage process. Then, in order to take into account the effect of the overlying soft tissues, the model was assumed to be immersed in fluid (fluid-loaded boundary conditions). The callus was an inhomogeneous material consisting of six ossification regions with properties changing during healing. However, the healing course was simplified to a 3-stage process. In both models (free and fluid-loaded) the representation of the corresponding theoretically predicted Lamb waves was performed using time-frequency (t-f) signal analysis. Finally, a three-dimensional finite element bone model was developed to address more realistic geometrical conditions. The irregular 3D geometry and the anisotropy of bone were taken into consideration. The fracture callus tissue was again modeled as an inhomogeneous material consisting of six ossification regions and the healing course progressed in 3-stages. The dispersion of guided modes predicted for a hollow cylinder (tube modes) was again represented in the t-f domain. We also examined the effect of callus consolidation on the propagation characteristics. We showed that the first arriving signal (FAS) corresponded to a non-dispersive lateral wave and as such, it could not characterize the callus tissue throughout its thickness. Conversely, the dispersion of guided waves in the 2D model was influenced by the mechanical and structural changes during the healing process and also by the surrounding tissues. The complex 3D geometry and the anisotropy of the bone had also a significant impact on the propagation of guided modes.

Key words: bone fracture healing, guided waves, time-frequency analysis, computational models