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WYDZIAŁ MECHANICZNY TECHNOLOGICZNY

Instytut Mechaniki i Inżynierii Obliczeniowej

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Wieloskalowe modelowanie tkanki kostnej

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SUMMARY

The work concerns the multiscale modeling of bone tissue. To conduct the structural analyses at micro and macro scales, the numerical homogenization algorithm and Finite Element Method (FEM) are used. The numerical models of bone tissue are built on the basis of tomography and microtomography data. Created model of the cancellous bone microstructure allowed the identification of bone material parameters in micro scale using evolutionary algorithms with experimental and numerical data. The effective anisotropic material parameters of trabecular bone on the macro level are calculated using method for applying the periodic boundary conditions for non-periodic FEM volume meshes and numerical homogenization method. The main directions of orthotropy for the bone tissue in the human femoral head are identified using a coordinate system transformation for elasticity tensor of trabecular bone sample. The material parameters of nonlinear hipoelastic constitutive material model are calculated for the simplified orthotropic structure. The results of conducted analyzes and numerical simulations are used in the optimal design problem of cancellous bone scaffolds, tailored to the individual patient and the implantation site. At the stage of the numerical modeling and structure optimization of the implant, the additive manufaturing method of the bone scaffold is included. The three-scale numerical model and evolutionary algorithm are used to optimize the implant structure in terms of mechanical requirements, as well to ensure the patients new bone tissue formation and overgrowth of the scaffold. Multiscale analysis of human proximal femur with implanted personalized bone scaffold was performed. The results of the calculated strain fields are in range of strains in human bone tissue in vivo, during the daily activities.