主 論 文 要 旨

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論文題名

MODELING AND PARAMETER ESTIMATION OF RHEOLOGICAL OBJECTS FOR SIMULTANEOUS REPRODUCTION OF FORCE AND DEFORMATION

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主論文要旨

There are many deformable objects in our living life demonstrated rheological behaviors, such as human organs and tissues, cloths, clays, and various food products. Many applications has been involved, including computer aided surgery, robotics, and food automation. Rheological object has both elastic and plastic properties. Due to the presence of residual deformation, it is difficult to model rheological objects.

This thesis aims at modeling and parameter estimation of rheological objects for simultaneous reproduction of both rheological force and deformation. Physically-based models were firstly investigated for describing rheological behaviors and were summarized into two groups: serial and parallel models. Generalized constitutive laws of both groups were formulated. Analytical expressions of rheological forces and residual deformation were derived for parallel models. We found a contradiction between the reproduction of rheological force and deformation. To solve this problem, a dual-moduli viscous element was introduced.

2D and 3D FE dynamic models were derived and then extended to deal with non-uniform layered objects and contact interaction as well. Criterions for detecting the contact and losing contact moments were established. In addition, to cover large deformation and rotation motion, FE model with nonlinear Green strain tensor was developed and simulation results were presented as well.

Methods for estimating physical parameters were proposed based on nonlinear optimization, which aims at minimizing the difference between simulation results and experimental measurements. Basically, two ideas were investigated. One is based on iterative FE simulation and the other is based on the straightforward calculation of rheological force by taking the advantages of parallel physical models. We have mixed both methods for estimating the parameters of FE model with dual-moduli viscous elements.

Various experiments with commercial available clay and Japanese sweets materials were performed to validate our FE models and parameter estimation methods. By introducing dual-moduli viscous elements into our FE model, we successfully reproduced both rheological forces and deformation behaviors simultaneously.