

Large-Scale Viscoelastic Analysis

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Abstract

In the phase II:GeoFEM/Snake, development is more focused on solid earth simulations. Many solid earth models are being plugged in GeoFEM at this stage. This paper shows recent research for module development of large-scale viscoelastic analysis with kinematic earthquake cycle in three dimensional heterogeneous medium.

Formulation of visco-elastic model and FEM analysis

This section outlines the formulation of viscoelastic model which is Standard Linear Solid model (3 elements model). Equation(1) shows the constitutive equation of viscoelastic model in GeoFEM. $\bar{\nu}, \mu, \lambda, \bar{\mu}, \bar{\lambda}$ in equation (1) should be set for Maxwell, Voigt, Standard linear models.

$$\{\sigma\} + \bar{\nu}\{\dot{\sigma}\} = 2\mu\{\varepsilon\} + \lambda\{\varepsilon_v\} + 2\bar{\mu}\{\dot{\varepsilon}\} + \bar{\lambda}\{\dot{\varepsilon}_v\} \quad (1)$$

Where, $\varepsilon_v = \varepsilon_{xx} + \varepsilon_{yy} + \varepsilon_{zz}$. Above-mentioned 5 parameters is expressed by basic elastic constants (Poisson ratio: ν Rigidity: μ Viscosity: η) which is used as basic constants in geological area. Time discretized constitutive equation is obtained by using the central difference method as follows,

$$\{\Delta\sigma\} = [S] \{\Delta\varepsilon\} - \frac{\Delta t}{\Delta t/2 + \bar{\nu}} \{Re\} \quad (2)$$

$$S_{ii} = \frac{1}{\Delta t/2 + \bar{\nu}} \left\{ \Delta t (\lambda/2 + \mu) + \bar{\lambda} + 2\bar{\mu} \right\} \quad (i = 1 \sim 3) \quad (3)$$

$$S_{ii} = \frac{1}{\Delta t/2 + \bar{\nu}} (\Delta t \mu/2 + \bar{\mu}) \quad (i = 4 \sim 6) \quad (4)$$

$$S_{ij} = \frac{1}{\Delta t/2 + \bar{\nu}} (\Delta t \lambda/2 + \bar{\lambda}) \quad (i \neq j, i = 1 \sim 3) \quad (5)$$

$$\{Re\} = \{\sigma\}_t - 2\mu\{\varepsilon\}_t - \lambda\{\varepsilon_v\}_t \quad (6)$$

By using Equation(2), virtual work is as follows,

$$\int_{\Omega} [\delta\varepsilon] [S] \{\Delta\varepsilon\} dV + \int_{\Omega} [\delta\varepsilon] \left[\{^{(n)}\Delta\sigma\} - \frac{\Delta t}{\Delta t/2 + \bar{\nu}} \{^{(n)}Re\} \right] dV - \int_{\Gamma} [\delta u]^{(n+1)} \{f_o\} dS = 0 \quad (7)$$

FEM analysis is based on equation (7).

Kinematic earthquake cycle is expressed by dislocation on plate surface. The dislocation is constrained by inner force which is obtained by using equation (2) for dislocation displacement. Dislocation of subduction and earthquake can be handled in fault analysis module(static_contact) in GeoFEM.

Analysis system

Dislocation calculation flow

Dislocation calculation is handled in fault analysis module as follows,

```
Program static_contact
  read subduction and earthquake data
  do /* time integration loop */
    calc inner dislocation force
    stress recover
    make stiff
    call parallel solver
  until end of simulation
```

parallel handling of subduction and earthquake data

GeoFEM can not handle subduction and earthquake data type by GeoFEM mesh data type. Subduction and earthquake data is handled as specific data type for dislocation analysis. Subduction and earthquake data should also be read as parallel data. Fault analysis module can handle the subduction and earthquake data as parallel data using extended utility subroutine for partitioning and reading. Figure 1 shows the viscoelastic analysis system with kinematic earthquake cycle.

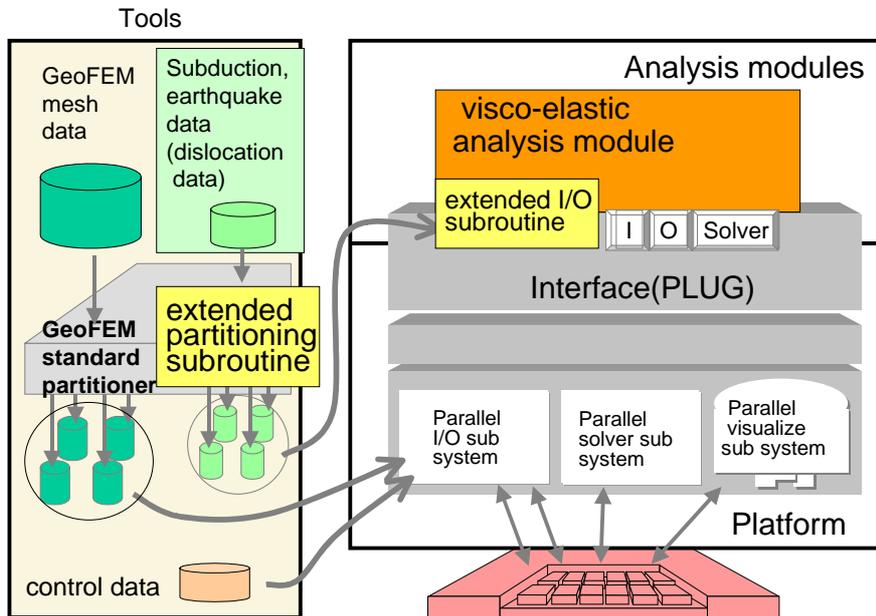


Figure 1: Viscoelastic analysis system with kinematic earthquake cycle

Results

1.37 MDOFs viscoelastic analysis of Southwest Japan model has been completed by parallel computation. In this case for 1 step analysis, computational resource is as follows, total elapsed time; 601 sec, solver elapsed time; 411 sec, number of solver iteration; 531, file volume;

75.2 MB(1 region), 91 MB(32 regions), memory; 79.1 MB (PE). More detail computational resource will be reserched.

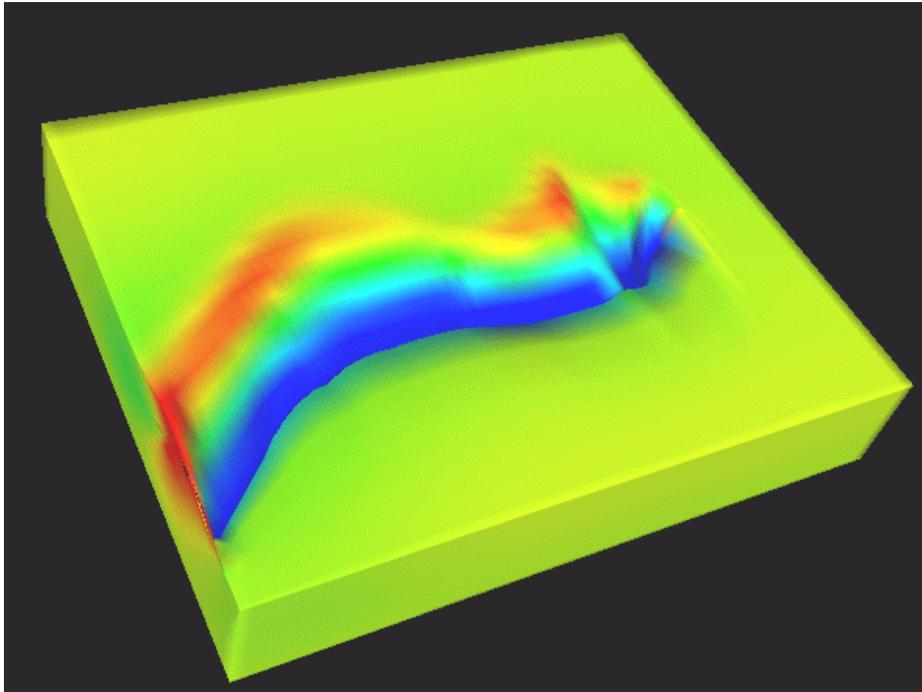


Figure 2: 1.37 MDOFs visco-elastic analysis of Southwest Japan model

This research is being accomplished under the collaborative work between RIST/GeoFEM and Nagoya univ. group.

References

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