Numerical Modeling of Dynamic 3D Processes

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Numerical modeling of Arctic problems
Migration of iceberg
Picture of Ship’s Damage

Collision between the ice-breaker and the ice-hummock
Impact of the ice hummock's keel on the seabed and on the underwater pipelines.

M.A. Naumov, D.A. Onishchenko, Presentation
Gazprom VNIIGAZ LLC
Destruction of the iceberg under intense dynamic impacts
Destruction of the iceberg under intense dynamic impacts
The flow of ice floes towards the rack of fixed oil-extracting platform
Collision between the iceberg and the fixed oil-extracting platform
Structure of Ice-hummocks
Ice-hummock model
Seismic exploration in the conditions of the Arctic shelf
Strimmer

- 3D
- P-waves
- High performance
Seabed stations

- 3D/4C
- High price
- High comprehension of obtained data
Geophysical prospecting by electric means – seabed stations

The leader of volume of work

6 components of the EM field (important for 3D inversion)

Not smaller than 50 m

EMGS, http://www.emgs.no
Geophysical prospecting by electric means - strimmers

- High performance
- No deeper than 300 m
- One axial component of the field: Ex
- Frequency and time domain
Multilayered geological medium
Complicated interfaces
Complicated interfaces
Complicated interfaces
Seismic prospecting at the Arctic shelf
Wave pattern in the ice
Wave pattern in the water
Wave pattern in the ground
Wave pattern in the carbon reservoir
Problem definitions

- Source in the ice
- Source in the ice, without reservoir
- Source at the seabed
- Source at the seabed, without reservoir
Wave patterns
Seismograms from ice receivers, $V_y$

Source in the ice

Source in the ice, without reservoir

Source at the seabed

Source at the seabed, without reservoir
Seismograms from seabed receivers, $V_y$

- Source in the ice
- Source in the ice, without reservoir
- Source at the seabed
- Source at the seabed, without reservoir
Source at the bottom, without the reservoir
Numerical simulation in geology
Numerical simulation in geology
Cavities of various shape
The array of subvertical fluid filled cracks
The array of subvertical fluid filled cracks

The distance between cracks/ the length of cracks

- 0.5
- 1.0
- 1.5
- 2.0
- 3.0
- 4.0
Simple fluid filled cavity

Reflected P-wave

Wave from the source

Reflected wave
The numerical solution of collision problems
Collision with multilayered barrier

0 degrees (no rhs)

30 degrees

50 degrees

70 degrees
Penetration of striker into curved barrier
Aircraft collision with the pillar
Multilayer barrier
Multilayer barrier
Numerical modeling of composite materials
Composite materials

- Microstructure
  - Matrix and filler
  - Types of fibers and their orientations
  - 3D structure of fibers
The impact on the stringer
The destruction of steel body during ricochet impact
Numerical modeling in Medicine
Head damage

Dependence from the angle

\[ \alpha = -90^\circ \]

Maximum compression, \( 3 \cdot 10^4 \text{ Па} \)

Maximum stretching, \( 3 \cdot 10^4 \text{ Па} \)

Maximum shear stress, \( 5 \cdot 10^3 \text{ Па} \)
Comparison with clinical results
Knee injury
Body armour and human chest
Numerical modeling of seismic stability
Seismic stability of the building

Absolute velocity (left) and destruction zones (right) in red
Seismic stability of river plant
Seismic stability of the building
Love and Rayleigh waves

Love waves

Steps: 160

Steps: 325

Rayleigh waves

Step: 183

Step: 397
Numerical modeling of non-destructive railway control
Dynamic impact on the rail
The influence of karst inclusions in the ground above the railway
Non-destructive railway control

Without crack

1 mm

5 mm

10 mm

40 mm

74 mm
Robot-technique
Robot-technique
Robot-technique
Robot-technique
Robot-technique
Robot-technique
Grid-characteristic method
Grids

- Triangular unstructured grid
- Grids with various average step
Grids

- Curvilinear grids
- Tetrahedral grids
System of equations describing elastic and acoustic waves

- **Elastic waves:**
  \[
  \rho \partial_t \mathbf{v} = \left( \nabla \times \mathbf{\sigma} \right)^T \\
  \partial_t \mathbf{\sigma} = \lambda \left( \nabla \times \mathbf{v} \right) \mathbf{I} + \mu \left( \nabla \otimes \mathbf{v} + \nabla \otimes \mathbf{v} \right)^T
  \]

  \(\rho\) density, \(\mathbf{v}\) velocity in the elastic media, \(\mathbf{\sigma}\) stress tension, \(\lambda, \mu\) Lame’s parameters,

  \[c_p = \left( \frac{\lambda + 2\mu}{\rho} \right)^{1/2}\] speed of P-waves,

  \[c_s = \left( \frac{\mu}{\rho} \right)^{1/2}\] speed of S-waves.

- **Acoustic waves:**
  \[
  \rho \partial_t \mathbf{\dot{v}} = \nabla p \\
  \partial_t p = c^2 \rho \left( \nabla \times \mathbf{\dot{v}} \right)
  \]

  \(\rho\) density, \(\mathbf{\dot{v}}\) velocity in the acoustic media, \(p\) pressure, \(c\) speed of sound.
Boundary and interface conditions

**Boundary**

- Given traction: \( \sigma p = f \)
- Given velocity of boundary: \( \vec{v} = \dot{V} \)
- Mixed boundary conditions
- Absorbing boundary conditions

**Interface**

Continuity of the velocity and traction:
\[
\vec{v}_a = \vec{v}_b = \dot{V}, \quad \sigma_a = -\sigma_b
\]

Free sliding conditions:
\[
\vec{v}_a \times p = \vec{v}_b \times \dot{p}, \quad \sigma_p^a = \sigma_p^b, \quad \sigma_\tau^a \neq \sigma_\tau^b
\]

The interface condition between acoustic and elastic bodies
Thank you for your attention!