The Benchmarks: The Problem, Versions 6 and 7

Comparisons
The Problem, Versions 6 and 7  (January-February 2007)

Dynamic Rupture in a Bi-Material World

Vertical strike-slip fault is the boundary between two materials. On the far side of the fault, \( V_p, V_s \), density = \( V_{p1}, V_{s1}, \rho_1 \), On the near side of the fault, \( V_p, V_s \), density = \( V_{p2}, V_{s2}, \rho_2 \)
The Problem, Version 6

Earth's surface $Vp_1, Vs_1, \rho_1$

15 km

$3 \text{ km}$

$3 \text{ km}$

$30 \text{ km}$

$3 \text{ km}$

Strong

Weak

$Vp_2, Vs_2, \rho_2 = 6000 \text{ m/s}, 3464 \text{ m/s}, 2670 \text{ kg/m}^3$

$Vp_1, Vs_1, \rho_1 = Vp_2 / 1.6, Vs_2 / 1.6, \rho_2 / 1.2$

$= 3750 \text{ m/s}, 2165 \text{ m/s}, 2225 \text{ kg/m}^3$
The Problem, Version 7

\[ V_{p2}, V_{s2}, \rho_2 = 6000 \text{ m/s}, \ 3464 \text{ m/s}, \ 2670 \text{ kg/m}^3 \]
\[ V_{p1}, V_{s1}, \rho_1 = \frac{V_{p2}}{1.2}, \ \frac{V_{s2}}{1.2}, \ \frac{\rho_2}{1.0} \]
\[ = 5000 \text{ m/s}, \ 2887 \text{ m/s}, \ 2670 \text{ kg/m}^3 \]
Rupture Dynamics Code Validation
Source Physics for The Problem, Versions 6 and 7

In the 3 km x 3 km Nucleation Patch, at t=0:
The initial shear stress, 81.6 MPa > the initial static yield strength, 81.24 MPa

Outside the Nucleation Patch, but on the fault, at t=0:
The initial shear stress, 70.0 MPa < the initial static yield strength, 81.24 MPa

Right after Nucleation (t>0):
All stresses become time-dependent, all propagation is spontaneous, and friction follows a linear slip-weakening fracture criterion, so that Failure occurs when & where shear stress (t) >= (μ(t) faultslip) x (normalstress(t)).

Outside of the 30km x 15 km fault area, for all t:
The rupture stops at the 30km x 15 km boundaries of the fault plane because the static coefficient of friction is very high (strong material)
Rupture Dynamics Code Validation

Station Locations for The Problem, Versions 6 and 7

Stations are located at each side of the split nodes so that there are 10 stations total
# Rupture Modelers and Codes

## The Problem, Versions 6 and 7
(Results Submitted by February 8, 2007)

<table>
<thead>
<tr>
<th>3D Code</th>
<th>Code User(s)</th>
<th>TPV6 Spacing (m)</th>
<th>TPV7 Spacing (m)</th>
<th>Code Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EqSim</td>
<td>Aagaard</td>
<td>100</td>
<td>100</td>
<td>Aagaard Finite Element</td>
</tr>
<tr>
<td>AWM-Olsen</td>
<td>Cruz Atienza/Olsen</td>
<td>100</td>
<td>100</td>
<td>Olsen Finite Difference</td>
</tr>
<tr>
<td>dfm</td>
<td>Dalguer/Day</td>
<td>100</td>
<td>100</td>
<td>Day Finite Difference</td>
</tr>
<tr>
<td>dfm</td>
<td>Day/Dalguer</td>
<td>50</td>
<td>50</td>
<td>Day Finite Difference</td>
</tr>
<tr>
<td>EQdyna</td>
<td>Duan</td>
<td>100</td>
<td>100</td>
<td>Duan Finite Element</td>
</tr>
<tr>
<td>MDSBI</td>
<td>Dunham</td>
<td>100</td>
<td>100</td>
<td>Dunham Spectral Boundary Integral</td>
</tr>
<tr>
<td>SGFD</td>
<td>Dunham2</td>
<td>100</td>
<td>100</td>
<td>Dunham Finite Difference</td>
</tr>
<tr>
<td>SORD</td>
<td>Ely</td>
<td>100</td>
<td>100</td>
<td>Ely Irregular-grid Support-Operator</td>
</tr>
<tr>
<td>Kase</td>
<td>Kase</td>
<td>100</td>
<td>100</td>
<td>Kase Finite Difference</td>
</tr>
<tr>
<td>BI</td>
<td>Liu/Lapusta</td>
<td>100</td>
<td>100</td>
<td>Lapusta/Liu Spectral Boundary Integral</td>
</tr>
<tr>
<td>MAFE</td>
<td>Ma</td>
<td>100</td>
<td>100</td>
<td>Ma Finite Element</td>
</tr>
<tr>
<td>DYNA3D</td>
<td>Oglesby</td>
<td>150</td>
<td>150</td>
<td>Oglesby Finite Element</td>
</tr>
<tr>
<td>FDMSPLIT</td>
<td>Pitarka</td>
<td>100</td>
<td>100</td>
<td>Pitarka Finite Difference</td>
</tr>
<tr>
<td>ABAQUS</td>
<td>Templeton/Bhat</td>
<td>100</td>
<td>100</td>
<td>ABAQUS Finite Element/Explicit</td>
</tr>
</tbody>
</table>
The Problem, Version 6
Comparisons

\[ Vp_2, \quad Vs_2, \quad \rho_2 = 6000 \text{ m/s}, \quad 3464 \text{ m/s}, \quad 2670 \text{ kg/m}^3 \]

\[ Vp_1, \quad Vs_1, \quad \rho_1 = \frac{Vp_2}{1.6}, \quad \frac{Vs_2}{1.6}, \quad \frac{\rho_2}{1.2} \]
\[ = 3750 \text{ m/s}, \quad 2165 \text{ m/s}, \quad 2225 \text{ kg/m}^3 \]
Rupture Front Times
Look at contour plots on
http://scecdadata.usc.edu/cvws
Problem: tpv6 (The Problem, Version 6)
File: cplot (rupture contour plot)
Synthetic Seismograms
Look at time-series
on
http://scecdata.usc.edu/cvws
apply filter to time-series
The fault plane

Stations are located at each side of the split node

Feb. 12, 2007  SCEC Workshop
Problem: tpv6 (The Problem, Version 6)
File: nearest-120dp000 (near side, strike -12.0 km, depth 0.0 km)
Field: h-vel (horizontal velocity)
Problem: tpv6 (The Problem, Version 6)
File: nearest-120dp000 (near side, strike -12.0 km, depth 0.0 km)
Field: h-vel (horizontal velocity).

- dalguer (Luis Dalguer)
- ely (Geoff Ely)
- ma (Shuo Ma)
Problem: tpv6 (The Problem, Version 6)
File: nearsl-120dp900 (near side, strike -12.0 km, depth 0.0 km)
Field: h-vei (horizontal velocity)

---

```
-6 -4 -2 0
```

```
0 5 10 15
```

---

```
-agaard (Brad Aagaard)
dalguer (Luis Dalguer)
duan (Benchun Duan)
daly (Geoff Daly)
ma (Shuo Ma)
```
Stations are located at each side of the split node
Problem: tvp6 (The Problem, Version 6)

File: nearest120dp000 (near side, strike 12.0 km, depth 0.0 km)

Field: h-vel (horizontal velocity)

---

**Diagram:**

- **xlabel:** time
- **ylabel:** horizontal velocity

Legend:
- **black** (Brad Aagaard)
- **red** (Benchun Duan)
Problem: tpv6 (The Problem, Version 6)
File: nearst120dp000 (near side, strike 12.0 km, depth 0.0 km)
Field: h-vel (horizontal velocity)
Problem: tpv6 (The Problem, Version 6)
File: nearest120dp000 (near side, strike 12.0 km, depth 0.0 km)
Field: h-vel (horizontal velocity)

Graph showing horizontal velocity over time for different users:
- aagaard (Brad Aagaard)
- dalguer (Luis Dalguer)
- duan (Benchun Duan)
- ely (Geoff Els)
- ma (Shuo Ma)
The Problem, Version 7
Comparisons

\[
\begin{align*}
V_{p2}, V_{s2}, \rho_2 &= 6000 \text{ m/s}, \ 3464 \text{ m/s}, \ 2670 \text{ kg/m}^3 \\
V_{p1}, V_{s1}, \rho_1 &= V_{p2} / 1.2, \ V_{s2} / 1.2, \ \rho_2 / 1.0 \\
&= 5000 \text{ m/s}, \ 2887 \text{ m/s}, \ 2670 \text{ kg/m}^3
\end{align*}
\]
Rupture Front Times
Look at contour plots on
http://scecdata.usc.edu/cvws
Problem: tpv? (The Problem, Version 7)

File: cplot (rupture contour plot)

---

**Distance Along Strike**

**Distance Down-Dip**

- **aagaard** (Brad Aagaard)
- **duan** (Benchun Duan)
Problem: tpv7 (The Problem, Version 7)
File: cplot (rupture contour plot)

---

0.5E+04
distance down-dip

1.0E+04

1.5E+04

-1E+04
distance along strike

---

- atienza (Victor Cruz Atienza)
- dalguer (Luis Dalguer)
- day (Steve Day)
- dunham (Eric Dunham)
- pitarka (Arben Pitarka)
Problem: tspv7 (The Problem, Version 7)
File: cplot (rupture contour plot)

---

(distance along strike)

distance down-dip

- aagaard (Brad Aagaard)
- atienza (Victor Cruz Atienza)
- dalguer (Luis Dalguer)
- day (Steve Day)
- duan (Benchun Duan)
- dunham (Eric Dunham)
- ely (Geoff Ely)
- ma (Shuo Ma)
- pitarka (Arben Pitarka)
Synthetic Seismograms
Look at time-series
on
http://scecdatalab.usc.edu/cvws
apply filter to time-series
Stations are located at each side of the split node.
Problem: tpv7 (The Problem, Version 7)
File: nearst-120dp000 (near side, strike -12.0 km, depth 0.0 km)
Field: h-vel (horizontal velocity)
Problem: tpf7 (The Problem, Version 7)

File: nearest-120dp000 (near side, strike -12.0 km, depth 0.0 km)

Field: h-vel (horizontal velocity)
Stations are located at each side of the split node.
Problem: tps? (The Problem, Version 7)
File: nears120dp000 (near side, strike 12.0 km, depth 0.0 km)
Field: h-vel (horizontal velocity)
Problem: tpv7 (The Problem, Version 7)
File: nearat120dp000 (near side, strike 12.0 km, depth 0.0 km)
Field: h-vel (horizontal velocity)

- atienza (Victor Cruz Atienza)
- dalguer (Luis Dalguer)
- day (Steve Day)
- dunham (Eric Dunham)
- pitarka (Arben Pitarka)
TIME FOR ......
Lively Discussion
Future Plans (Group Discussion)

New Benchmarks?

Website Additions?

Famous SRL Article?
The End