Guidance and FAQ for Modelers for TPV8 and TPV9

February 29, 2008

Contents:

1 Assigning Stresses to Split Nodes

Most codes will lay out a grid of split nodes on the fault plane, and assign initial normal and shear stresses to each split node. The following rules explain how to assign the stresses.

Rule 1: For split nodes located inside the 3000m by 3000m nucleation patch.

The initial stress is calculated based on the location of the split node:

Initial normal stress = 7378 Pa × down-dip depth.

Initial shear stress = 1×10^6Pa + (1.005 × 0.760 × 7378 Pa × down-dip depth)

Here, *down-dip depth* is the split node's distance down-dip, in meters.

Rule 2: For split nodes located on the border of the nucleation patch.

The initial stress is calculated using the formulas in Rule 1, as if the split node were inside the nucleation patch.

Rule 3: For split nodes located inside the 30000m by 15000m faulting area, but outside the nucleation patch and not on the earth's surface.

The initial stress is calculated based on the location of the split node:

Initial normal stress = 7378 Pa × down-dip depth.

Initial shear stress = 0.55 × 7378 Pa × down-dip depth

Here, *down-dip depth* is the split node's distance down-dip, in meters.

Rule 4: For split nodes located on the earth's surface (the top border of the 30000m by 15000m faulting area).

You need to calculate the initial stress for these nodes. It should *not* be zero.

Each split node represents a patch of the fault surface. For TPV8 and TPV9, the initial stress varies linearly with depth. Although the initial stress is zero at the split node's location, it is *not* zero on the corresponding patch of fault surface. The initial stress assigned to the split node should be an average of the initial stress over the corresponding patch of fault surface. The manner in which the average is calculated will vary, depending on the design of your code.

Example: For most finite-element codes, the initial stress should be calculated as follows, where *node spacing* is the down-dip spacing between split nodes, in meters:

Initial normal stress = 7378 Pa × node spacing / 3.

Initial shear stress = 0.55 × 7378 Pa × node spacing / 3

Rule 5: For split nodes located on the side or bottom border of the 30000m by 15000m faulting area.

The initial stress is calculated using the formulas in Rules 3 and 4, the same as if the node were inside the faulting area.

Note: This implies that split nodes located on the border of the faulting area are able to slip. So the strength barrier is not located at the border of the faulting area, rather, it is located one node spacing away from the faulting area.

Rule 6: For split nodes located outside of the 30000m by 15000m faulting area.

These split nodes are not allowed to slip. You may set the static yield stress to a very large value, or do whatever is appropriate in your code to prevent these split nodes from slipping.

2 Applying Cohesion in the Friction Law

Benchmark problems TPV8 and TPV9 use linear slip weakening with cohesion.

This friction law has four parameters:

μ_s = static coefficient of friction

μ_d = dynamic coefficient of friction

d_0 = slip weakening distance

c = cohesion

Initially, the split node is locked. Failure occurs, and the node begins to slip, when:

shear stress > c + (μ_s × normal stress)

When the split node has slipped a total distance d, the coefficient of friction is:

$\mu = \mu_s + (\mu_d - \mu_s) \times d / d_0$ if $d <= d_0$

$\mu = \mu_d$ if $d >= d_0$

While the split node is slipping, the shear stress on the fault is:

shear stress = c + (μ × normal stress)

where μ is the slip-varying coefficient of friction given above.

3 Frequently Asked Questions

Why did you change the friction law?

Beginning with TPV8, we are using stresses that are a linear function of depth, which means that near the earth's surface the stresses are very small.

In TPV8 test runs without cohesion, we found that the P-waves triggered secondary nucleations at the earth's surface all along the fault trace. This has not yet been observed in nature. So we added cohesion to make the benchmark more realistic, by suppressing these secondary P-wave induced nucleations. Even with cohesion, there may still be some S-wave induced nucleations at the earth's surface in TPV8.

Why is a special rule needed to apply stresses to split nodes at the earth's surface (rule 4 above)?

Each split node represents a patch of the fault surface. Ideally, each node should be assigned a stress equal to the average stress over the patch.

For a node not located at the earth's surface, the patch extends both up-dip and down-dip from the node, and the average stress is equal to the stress at the node's location.

But for a node at the earth's surface, the patch extends only down-dip from the node. So the average stress on the patch is not equal to the stress at the node's location. Therefore a special rule is required for these nodes.

Note: The formula needed to calculate the average stress depends on the design of your code.

So why didn't you apply the same averaging procedure for nodes on the border of the nucleation zone, averaging over a patch partly inside and partly outside the nucleation zone (rule 2 above)?

We did this to remain consistent with previous benchmark problems, which all used our rule 2.

Note: Since first publishing this document, we have discovered that in fact some modelers apply such an averaging procedure, and some don't.

Why do TPV8 and TPV9 have off-fault stations on both sides of the fault? These problems are symmetric, so you really don't need stations on both sides of the fault.

Upcoming benchmark problems TPV10, TPV11, and TPV12 will not be symmetric, because they use a dipping fault. Our plan is to use exactly the same set of stations for all the problems TPV8 through TPV12. This will make things simpler in the long run.