Hercules Benchmarks

In progress

Leonardo Ramirez-Guzman

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Introduction

In the present document summarize some examples tailored to test the Hercules (see, Tu *et al*., 2006).

Benchmarks

B1.-A dipole in a homogeneous full space.

The properties are summarized in Table 1. No damping is included. The reference solution is computed evaluating numerically the convolution of the analytical solution of a planar dislocation with strike= 0, dip= 90 and rake =0. The slip rate function is triangle with raise time T_r = 1 s and M_W= 4.242716. The value of the moment is arbitrary in this case.

The domain is a 30 x 30 x 30 km. The stations are recorded in the plane x-y with a 250 m space grid.

ρ(*kg/m3*)	V_p	V_s	*Q*
1500	3474	2000	Infinity

Table B1

Figure 1.- Coarse mesh. All elements have the same size.

Figure 2.- Displacements and Fourier spectrum.

Note.- You need to recompile Hercules changing in common.mk such that SOLVE_CFLAGS = -DBOUNDARY.

Source Input example

```
################################################################################
#                                                                              #
# source.in:  Source quantities input file to CMU FEM toolchain.               #
#             Lines start with # are comments. Empty lines are ignored.        #
#                                                                              #
# Revised version that facilitate parameter conversions.                       #
# Leonardo Ramirez 2006                                                        #
#                                                                              #
################################################################################

################################################################################
#
#  FILTER RELATED (ONLY BUTTERWORTH )
#
################################################################################

source_is_filtered     = 0

threshold_frequency    = .3

number_of_poles        = 22

################################################################################
#
#  SOURCE DESCRIPTION
#
################################################################################

type_of_source = point

source_function_type = quadratic

average_risetime_sec = 4.0

moment_amplitude =  7.2E+12
#moment_magnitude = 3.0

# 0-lon lat 1- cartesian
lonlat_or_cartesian = 1

hypocenter_x = 15000

hypocenter_y = 15000

hypocenter_depth_m = 15000

source_strike_deg = 90

source_dip_deg = 0
```

```
source_rake_deg = 0
```

B2.-A dipole: layer on a half space. No damping

This problem is named LOH.1 in the SCEC benchmarks. I changed the frequency content via T.

Material Properties.- Table B2 summarizes the properties. Both Q's are infinite everywhere.

Thicknes	ρ(***kg/m3***)	V_p	V_s
1000	2600	4,000	2,000
Inf	2700	6,000	3,464

Table B2

Figure 3.- Coarse mesh.

Figure 4.- Displacements and Fourier spectrum.

Source.-Point dislocation. The only non-zero moment tensor component is Mxy (equal to Myx), which has value $M_0=10^{18}$ Nm. Moment-rate time history is $M_0*(t/T_2)*\exp(-t/T)$, where T=2 sec. (Equivalently, the moment time history is $M_0*(1-(1+t/T)*\exp(-t/T))$, where T=2sec).

Source Depth = 2000 m. That is, taking the epicenter as the origin, the source is at (0,0,2000).

```
################################################################################
#                                                                              #
# source.in:  Source quantities input file to CMU FEM toolchain.               #
#             Lines start with # are comments. Empty lines are ignored.        #
#                                                                              #
# Revised version that facilitate parameter conversions.                       #
# Leonardo Ramirez 2006                                                        #
#                                                                              #
################################################################################

################################################################################
#
#  FILTER RELATED (ONLY BUTTERWORTH )
#
################################################################################

source_is_filtered     = 0

threshold_frequency    = .3

number_of_poles        = 22

################################################################################
#
#  SOURCE DESCRIPTION
#
################################################################################

type_of_source = point

source_function_type = exponential

average_risetime_sec = 2

moment_amplitude =  1E18
#moment_magnitude = 3.0

# 0-lon lat 1- cartesian
lonlat_or_cartesian = 1

hypocenter_x = 15000

hypocenter_y = 15000

hypocenter_depth_m = 2000

source_strike_deg = 0

source_dip_deg = 90

source rake deg = 0
```

B3.-A small earthquake in the Terashake domain. Comparison SDSC and Data

The terashake domain is defined by the coordinates

-121	*34.5*
-118.951292	*36.621696*
-113.943965	*33.122341*
-116.032285	*31.082920*

Material Properties.*-The Data base was constructed using the SCEC CVM model 4 and quake etree tools (Taborda et al,)*

Figure 5

Figure 6

Figure 7

```
##############################################################################
#                                                                            #
# source.in:  Source quantities input file to CMU FEM toolchain.             #
```

```
#             Lines start with # are comments. Empty lines are ignored.       #
#                                                                              #
# Revised version that facilitate parameter conversions.                       #
# Leonardo Ramirez 2006                                                        #
#                                                                              #
################################################################################


################################################################################
#
#  FILTER RELATED (ONLY BUTTERWORTH )
#
################################################################################

source_is_filtered     = 0

threshold_frequency    = .3

number_of_poles        = 22


################################################################################
#
#  SOURCE DESCRIPTION
#             Event ID: 14179736 (Ml5.1, 1 Sep 2005)
#
################################################################################

type_of_source = point

source_function_type = quadratic

average_risetime_sec = 1.474

#moment_amplitude =  5.82E+16
moment_magnitude = 5.11

# 0-lonlat   1-cartesian
lonlat_or_cartesian = 0

hypocenter_lat_deg = 33.16

hypocenter_long_deg =-115.62

hypocenter_depth_m  = 5000

source_strike_deg   = 241

source_dip_deg      = 77

source_rake_deg     = -15

################################################################################
#
#  Given the corners we make a mapping to localize the source in the "box
#  domain". The interpolation is linear. If lonlat_or_cartesian = 1 it is not
#  necessary
#
################################################################################

domain_surface_corners =
 -121.0        34.5
 -118.951292   36.621696
 -113.943965   33.122341
 -116.032285   31.082920
```

B4.-A small earthquake in the Terashake domain. Comparison SDSC and Data

```
################################################################################
#                                                                              #
# source.in:  Source quantities input file to CMU FEM toolchain.               #
#             Lines start with # are comments. Empty lines are ignored.        #
#                                                                              #
# Revised version that facilitate parameter conversions.                       #
# Leonardo Ramirez 2006                                                        #
#                                                                              #
################################################################################


################################################################################
#
# FILTER RELATED (ONLY BUTTERWORTH )
#
################################################################################

source_is_filtered = 1

threshold_frequency    = .5

number_of_poles        = 22


################################################################################
#
# SOURCE DESCRIPTION
#
################################################################################

source_function_type = discrete

type_of_source = srfh

number_of_point_sources = 1

domain_surface_corners =

 -121.0        34.5
 -118.951292   36.621696
 -113.943965   33.122341
 -116.032285   31.082920
```

domain_surface_corners	The list of the corners of the surface Lon1 Lat1 Lon2 Lat2 Lon3 Lat3 Lon4 Lat4

Appendix

Source parameters description

Type of source and filter parameters.-Four types of formats are allowed and a Butterworth filter is implemented in Hercules. The options are as follow

Parameter	**Description**
source_is_filtered	0 if no filtering 1 if the source is filtered
threshold_frequency	the frequency threshold
number_of_poles	the number of poles in the Butterworth filter
type_of_source	point plane planewithkinks srfh

type_of_source = *Point*

This type of source is a good representation for small earthquakes.

Parameter	**Description**
source_function_type	Is the function that describes the slip time history. Hercules has implemented the following: ramp sine quadratic ricker exponential discrete (only if srhf)
average_risetime_sec	The meaning differs depending on the source function type, but in most of them is the time the dislocation takes to reach its maximum value of slip.
Moment_amplitude	M0 you can give either this quantity or Mw
Moment_magnitude	Mw
Lonlat_or_cartesian	GMT system Cartesian system
hypocenter_x or hypocenter_lat_deg	Location of the source
hypocenter_y or hypocenter_long_deg	
hypocenter_depth_m	
Source_strike_deg	Strike
Source_dip_deg	Dip
Source_rake_deg	Rake
If Lonlat_or_cartesian == 0	

domain_surface_corners	The list of the corners of the surface Lon1 Lat1 Lon2 Lat2 Lon3 Lat3 Lon4 Lat4

type_of_source = *SRFH*

Is the Standard Rupture Fault format in Hercules

Parameter	**Description**
source_function_type	Is the function that describes the slip time history. Hercules has implemented the following: ramp sine quadratic ricker exponential discrete (only if srhf)
number_of_point_sources	
domain_surface_corners	The list of the corners of the surface Lon1 Lat1 Lon2 Lat2 Lon3 Lat3 Lon4 Lat4
Files	
coords.in	A list (size = number_of_point_sources) of coordinates with Lon[0] Lat[0] Depth[0] Lon[1] Lat[1] Depth[1] … … …
area.in	
strike.in	
dip.in	
rake.in	
slip.in	
Slipfunction.in	Slip function for every point source, the format: np delay dt s[0] … s[np] … A linear interpolation is assumed and if necessary the last value will be repeated.