



Class 2016-05-16-(001)

Report date: May 16, 2016 11:10:39 AM

Contents

- 1. **Global Definitions**
 - 1.1. [Parameters 1](#)
 - 1.2. [Variables](#)
- 2. **Component 1**
 - 2.1. [Definitions](#)
 - 2.2. [Geometry 1](#)
 - 2.3. [Weak Form PDE 1](#)
 - 2.4. [Mesh 1](#)
- 3. **Study 1**
 - 3.1. [Time Dependent](#)
 - 3.2. [Solver Configurations](#)
- 4. **Results**
 - 4.1. [Data Sets](#)
 - 4.2. [Tables](#)
 - 4.3. [Plot Groups](#)

1. Global Definitions

Date: May 12, 2016 1:06:57 PM

Global settings

Name	Class 2016-05-16-(001).mph
Path	C:\Users\sony\Comsol-X\Comsol-class-2016\001\class_2016-05-16-(001).mph
COMSOL version	COMSOL 5.2 (Build: 220)
Unit system	SI

Used products

COMSOL Multiphysics

1.1. Parameters 1

Parameters

Name	Expression	Value	Description
L1	0.005[m]	0.005 m	Length
R	L1/4	0.00125 m	radius
mu	0.001[Pa*s]	0.001 Pa*s	viscosity
kl	5[GPa]	5E9 Pa	shear modulus (1/2)
kV	50[GPa]	5E10 Pa	bulk modulus (1/2)
tr0	-10[GPa*s^-1]	-1E10 Pa/s	traction

1.2. Variables

1.2.1. Variables 1

Selection

Geometric entity level: Entire model

Name	Expression	Unit	Description
trac	tr0*t	Pa	

2. Component 1

Date: Apr 9, 2015 3:27:51 PM

Component settings

Unit system	SI
Geometry shape order	automatic

2.1. Definitions

2.1.1. Variables

Variables (Main)

Selection

Geometric entity level: Entire model

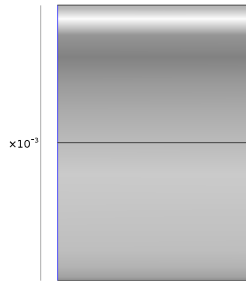
Name	Expression	Unit	Description
Dp11	1 + u1x		
Dp21	u2x		
Dp31	u3x		
Dp12	u1y		
Dp22	1 + u2y		
Dp32	u3y		
Dp13	u1z		
Dp23	u2z		
Dp33	1 + u3z		
f11	Dp11		
f21	Dp21		
f31	Dp31		
f12	Dp12		
f22	Dp22		
f32	Dp32		
f13	Dp13		
f23	Dp23		
f33	Dp33		
B11	f11*f11 + f12*f12 + f13*f13		
B12	f11*f21 + f12*f22 + f13*f23		
B13	f11*f31 + f12*f32 + f13*f33		
B21	f21*f11 + f22*f12 + f23*f13		
B22	f21*f21 + f22*f22 + f23*f23		
B23	f21*f31 + f22*f32 + f23*f33		
B31	f31*f11 + f32*f12 + f33*f13		
B32	f31*f21 + f32*f22 + f33*f23		
B33	f31*f31 + f32*f32 + f33*f33		
detF	-(f13*f22*f31) + f12*f23*f31 + f13*f21*f32 - f11*f23*f32 - f12*f21*f33 + f11*f22*f33		
J	detF		
f1	B11 + B22 + B33		
f2	(f1^2 - (B11^2 + B12^2 + B13^2 + B21^2 + B22^2 + B23^2 + B31^2 + B32^2 + B33^2))/2		
cfF11	-(f23*f32) + f22*f33		
cfF12	f23*f31 - f21*f33		
cfF13	-(f22*f31) + f21*f32		
cfF21	f13*f32 - f12*f33		
cfF22	-(f13*f31) + f11*f33		
cfF23	f12*f31 - f11*f32		

cff31	-(f13*f22) + f12*f23		
cff32	f13*f21 - f11*f23		
cff33	-(f12*f21) + f11*f22		
cfDp11	cff11		
cfDp21	cff21		
cfDp31	cff31		
cfDp12	cff12		
cfDp22	cff22		
cfDp32	cff32		1/s
cfDp13	cff13		
cfDp23	cff23		
cfDp33	cff33		
finv11	cff11/detF		
finv21	cff12/detF		
finv31	cff13/detF		
finv12	cff21/detF		
finv22	cff22/detF		
finv32	cff23/detF		
finv13	cff31/detF		
finv23	cff32/detF		
finv33	cff33/detF		
f11t	u1xt		1/s
f21t	u2xt		1/s
f31t	u3xt		1/s
f12t	u1yt		1/s
f22t	u2yt		1/s
f32t	u3yt		1/s
f13t	u1zt		1/s
f23t	u2zt		1/s
f33t	u3zt		1/s
Dv11	f11t*finv11 + f12t*finv21 + f13t*finv31		1/s
Dv21	f21t*finv11 + f22t*finv21 + f23t*finv31		1/s
Dv31	f31t*finv11 + f32t*finv21 + f33t*finv31		1/s
Dv12	f11t*finv12 + f12t*finv22 + f13t*finv32		1/s
Dv22	f21t*finv12 + f22t*finv22 + f23t*finv32		1/s
Dv32	f31t*finv12 + f32t*finv22 + f33t*finv32		1/s
Dv13	f11t*finv13 + f12t*finv23 + f13t*finv33		1/s
Dv23	f21t*finv13 + f22t*finv23 + f23t*finv33		1/s
Dv33	f31t*finv13 + f32t*finv23 + f33t*finv33		1/s
S11	(Se11 + Sdiss11)		Pa
S21	(Se21 + Sdiss21)		Pa
S31	(Se31 + Sdiss31)		Pa
S12	(Se12 + Sdiss12)		Pa
S22	(Se22 + Sdiss22)		Pa
S32	(Se32 + Sdiss32)		Pa
S13	(Se13 + Sdiss13)		Pa
S23	(Se23 + Sdiss23)		Pa
S33	(Se33 + Sdiss33)		Pa
Se11	2*k1j^(-2/3)*(f11 - (i1/3)*finv11) + 2*kV*(j - 1)*cff11		Pa
Se12	2*k1j^(-2/3)*(f12 - (i1/3)*finv21) + 2*kV*(j - 1)*cff12		Pa
Se13	2*k1j^(-2/3)*(f13 - (i1/3)*finv31) + 2*kV*(j - 1)*cff13		Pa
Se21	2*k1j^(-2/3)*(f21 - (i1/3)*finv12) + 2*kV*(j - 1)*cff21		Pa
Se22	2*k1j^(-2/3)*(f22 - (i1/3)*finv22) + 2*kV*(j - 1)*cff22		Pa
Se23	2*k1j^(-2/3)*(f23 - (i1/3)*finv32) + 2*kV*(j - 1)*cff23		Pa
Se31	2*k1j^(-2/3)*(f31 - (i1/3)*finv13) + 2*kV*(j - 1)*cff31		Pa
Se32	2*k1j^(-2/3)*(f32 - (i1/3)*finv23) + 2*kV*(j - 1)*cff32		Pa
Se33	2*k1j^(-2/3)*(f33 - (i1/3)*finv33) + 2*kV*(j - 1)*cff33		Pa
Sdiss11	cff11*Tdiss11 + cff21*Tdiss12 + cff31*Tdiss13		Pa
Sdiss12	cff12*Tdiss11 + cff22*Tdiss12 + cff32*Tdiss13		Pa
Sdiss13	cff13*Tdiss11 + cff23*Tdiss12 + cff33*Tdiss13		Pa
Sdiss21	cff11*Tdiss21 + cff21*Tdiss22 + cff31*Tdiss23		Pa
Sdiss22	cff12*Tdiss21 + cff22*Tdiss22 + cff32*Tdiss23		Pa
Sdiss23	cff13*Tdiss21 + cff23*Tdiss22 + cff33*Tdiss23		Pa
Sdiss31	cff11*Tdiss31 + cff21*Tdiss32 + cff31*Tdiss33		Pa
Sdiss32	cff12*Tdiss31 + cff22*Tdiss32 + cff32*Tdiss33		Pa
Sdiss33	cff13*Tdiss31 + cff23*Tdiss32 + cff33*Tdiss33		Pa
T11	(Te11 + Tdiss11)		Pa
T21	(Te21 + Tdiss21)		Pa
T31	(Te31 + Tdiss31)		Pa
T12	(Te12 + Tdiss12)		Pa
T22	(Te22 + Tdiss22)		Pa
T32	(Te32 + Tdiss32)		Pa
T13	(Te13 + Tdiss13)		Pa
T23	(Te23 + Tdiss23)		Pa
T33	(Te33 + Tdiss33)		Pa
Te11	2*k1j^(-5/3)*(B11 - i1/3) + 2*kV*(j - 1)		Pa
Te12	2*k1j^(-5/3)*B12		Pa
Te13	2*k1j^(-5/3)*B13		Pa
Te21	2*k1j^(-5/3)*B21		Pa
Te22	2*k1j^(-5/3)*(B22 - i1/3) + 2*kV*(j - 1)		Pa
Te23	2*k1j^(-5/3)*B23		Pa
Te31	2*k1j^(-5/3)*B31		Pa
Te32	2*k1j^(-5/3)*B32		Pa
Te33	2*k1j^(-5/3)*(B33 - i1/3) + 2*kV*(j - 1)		Pa
Tdiss11	mu*(Dv11 + Dv11)		Pa
Tdiss12	mu*(Dv12 + Dv21)		Pa
Tdiss13	mu*(Dv13 + Dv31)		Pa
Tdiss21	mu*(Dv21 + Dv12)		Pa
Tdiss22	mu*(Dv22 + Dv22)		Pa
Tdiss23	mu*(Dv23 + Dv32)		Pa
Tdiss31	mu*(Dv31 + Dv13)		Pa
Tdiss32	mu*(Dv32 + Dv23)		Pa
Tdiss33	mu*(Dv33 + Dv33)		Pa
TSpH	(T11 + T22 + T33)/3		Pa
phi	k1j^(-2/3)*i1 - 3 + kV*(j - 1)^2		Pa

2.1.2. Selections

Left Face

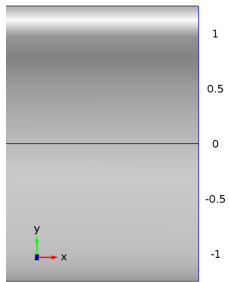
Selection type
Explicit
Selection
Boundary 1



Left face

Right Face

Selection type
Explicit
Selection
Boundary 6



Right face

2.1.3. Coordinate Systems

Boundary System 1

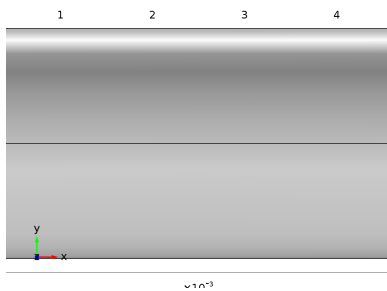
Coordinate system type	Boundary system
Tag	sys1

Coordinate names		
First	Second	Third
t1	t2	n

Settings

Description	Value
Reverse normal direction	On
Axis	Manual
Tangent direction	{root.t1x, root.t1y, root.t1z}

2.2. Geometry 1



Geometry 1

Units

Length unit	m
Angular unit	deg

Geometry statistics

Description	Value
Space dimension	3
Number of domains	1
Number of boundaries	6
Number of edges	12
Number of vertices	11

2.2.1. Cylinder 1 (Cyl1)

Position

Description	Value
Position	{0, 0, 0}

Axis

Description	Value
Axis type	x - axis

Size and shape

Description	Value
Radius	R

Height L1

2.2.2. Point 1 (Pt1)

Point	
Description	Value
Point coordinate	{0, 0, 0}

2.2.3. Point 2 (Pt2)

Point	
Description	Value
Point coordinate	{L1, 0, 0}

2.2.4. Point 3 (Pt3)

Point	
Description	Value
Point coordinate	{L1/2, 0, 0}

2.3. Weak Form PDE 1

Used products
COMSOL Multiphysics



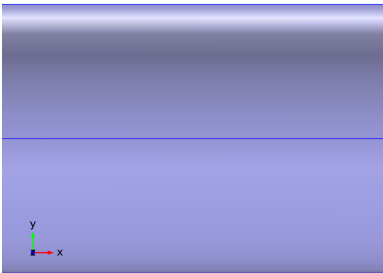
Weak Form PDE 1

Selection	
Geometric entity level	Domain
Selection	Domain 1

Settings	
Description	Value
Shape function type	Lagrange
Element order	Quadratic
Value type when using splitting of complex variables	Real
Dependent variable quantity	Length (m)
Source term quantity	None
Unit	m ⁻²

Variables				
Name	Expression	Unit	Description	Selection
w1.nx	nx		Normal vector, x component	Boundaries 1-6
w1.ny	ny		Normal vector, y component	Boundaries 1-6
w1.nz	nz		Normal vector, z component	Boundaries 1-6
w1.nxmesh	root.nxmesh		Normal vector (mesh), x component	Boundaries 1-6
w1.nymesh	root.nymesh		Normal vector (mesh), y component	Boundaries 1-6
w1.nzmesh	root.nzmesh		Normal vector (mesh), z component	Boundaries 1-6

2.3.1. Weak Form PDE 1



Weak Form PDE 1

Selection	
Geometric entity level	Domain
Selection	Domain 1

Equations

$$0 = \int_{\Omega} \text{weak } \partial^2 v$$

Settings	
Description	Value
Weak expressions	{-(S11*test(u1x) + S12*test(u1y) + S13*test(u1z)), -(S21*test(u2x) + S22*test(u2y) + S23*test(u2z)), -(S31*test(u3x) + S32*test(u3y) + S33*test(u3z))}

Shape Functions

Name	Shape function	Unit	Description	Shape frame	Selection
u1	Lagrange (Quadratic)	m	Dependent variable u1	Material	Domain 1
u2	Lagrange (Quadratic)	m	Dependent variable u2	Material	Domain 1
u3	Lagrange (Quadratic)	m	Dependent variable u3	Material	Domain 1

Weak Expressions

Weak expression	Integration order	Integration frame	Selection
{-(S11*test(u1x)+S12*test(u1y)+S13*test(u1z))}	4	Material	Domain 1
{-(S21*test(u2x)+S22*test(u2y)+S23*test(u2z))}	4	Material	Domain 1

-(S31*test(u3x)+S32*test(u3y)+S33*test(u3z)) 4 Material Domain 1

2.3.2. Zero Flux 1

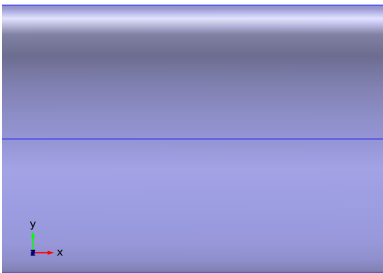


Zero Flux 1

Selection	
Geometric entity level	Boundary
Selection	Boundaries 2-6

Equations
 $-n \cdot \text{flux} = 0$

2.3.3. Initial Values 1

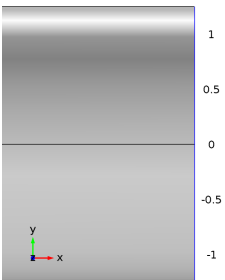


Initial Values 1

Selection	
Geometric entity level	Domain
Selection	Domain 1

Settings	
Description	Value
Initial value for u1	0
Initial time derivative of u1	0
Initial value for u2	0
Initial time derivative of u2	0
Initial value for u3	0
Initial time derivative of u3	0

2.3.4. Weak Contribution 1



Weak Contribution 1

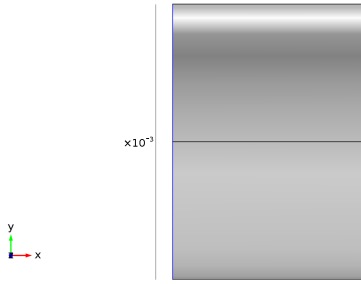
Selection	
Geometric entity level	Boundary
Name	Right face
Selection	Boundary 6

Settings	
Description	Value
Weak expression	trac*test(u1)
Use automatic quadrature settings	On

Weak Expressions

Weak expression	Integration order	Integration frame	Selection
trac*test(u1)	4	Material	Boundary 6

2.3.5. Constraint 1



Constraint 1

Selection	
Geometric entity level	Boundary
Selection	Boundary 1

Equations

$$0 = R$$

$$g_{\text{reaction}} = \left(\frac{\partial \pi}{\partial \mathbf{u}} \right)^T \boldsymbol{\mu}$$

$$\mathbf{u} = [u_1, u_2, u_3]$$

$$\boldsymbol{\mu} = [\mu_1, \mu_2, \mu_3]^T$$

Settings	
Description	Value
Bidirectional constraint, R = 0	{-u1, 0, 0}
Apply reaction terms on	All physics (symmetric)
Use weak constraints	Off
Constraint method	Elemental

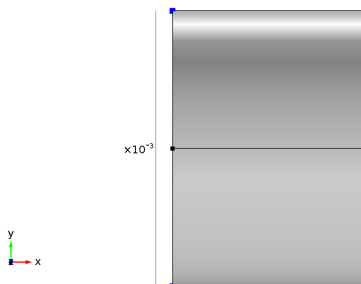
Variables

Name	Expression	Unit	Description	Selection
w1.R_u1	-u1	m	Bidirectional constraint, R = 0	Boundary 1
w1.R_u2	0		Bidirectional constraint, R = 0	Boundary 1
w1.R_u3	0		Bidirectional constraint, R = 0	Boundary 1

Shape Functions

Constraint	Constraint force	Shape function	Selection
-u1	test(-u1)	Lagrange (Quadratic)	Boundary 1
0	0	Lagrange (Quadratic)	Boundary 1
0	0	Lagrange (Quadratic)	Boundary 1

2.3.6. Pointwise Constraint 2



Pointwise Constraint 2

Selection	
Geometric entity level	Point
Selection	Points 1, 5

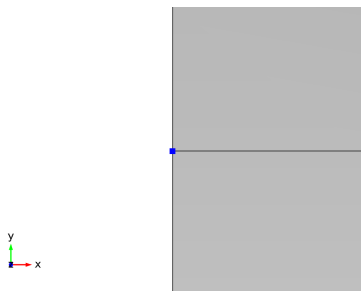
Settings

Description	Value
Apply reaction terms on	All physics (symmetric)
Constraint expression	-u3
Constraint method	Nodal
Shape function type	Lagrange
Element order	Quadratic

Shape Functions

Constraint	Constraint force	Shape function	Selection
-u3	test(-u3)	Lagrange (Quadratic)	Points 1, 5

2.3.7. Pointwise Constraint 3



Pointwise Constraint 3

Selection

Geometric entity level	Point
Selection	Points 2, 4

Settings

Description	Value
Apply reaction terms on	All physics (symmetric)
Constraint expression	-u2
Constraint method	Nodal
Shape function type	Lagrange
Element order	Quadratic

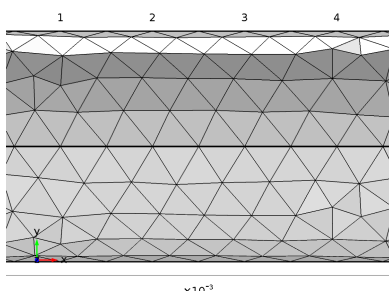
Shape Functions

Constraint	Constraint force	Shape function	Selection
-u2	test(-u2)	Lagrange (Quadratic)	Points 2, 4

2.4. Mesh 1

Mesh statistics

Description	Value
Minimum element quality	0.3257
Average element quality	0.7726
Tetrahedral elements	3020
Triangular elements	564
Edge elements	72
Vertex elements	11



Mesh 1

2.4.1. Size (Size)

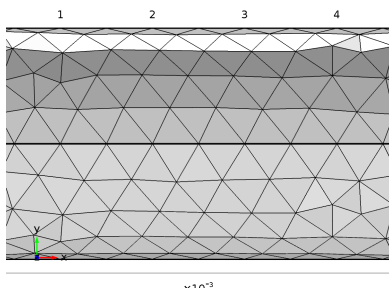
Settings

Description	Value
Maximum element size	5.0E-4
Minimum element size	9.0E-5
Curvature factor	0.6
Resolution of narrow regions	0.5
Maximum element growth rate	1.5

2.4.2. Free Tetrahedral 1 (Ftet1)

Selection

Geometric entity level	Remaining
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Free Tetrahedral 1

3. Study 1

Computation information

Computation time	1 min 9 s
CPU	Intel(R) Core(TM) i7 CPU M 640 @ 2.80GHz, 2 cores
Operating system	Windows 7

3.1. Time Dependent

Study settings

Description	Value
Include geometric nonlinearity	Off

Times	Unit
range(0,0.1,1)	s

Physics and variables selection

Physics interface	Discretization
Weak Form PDE 1 (w)	physics

Mesh selection

Geometry	Mesh
Geometry 1 (geom1)	mesh1

3.2. Solver Configurations

3.2.1. Solver 1

Compile Equations: Time Dependent (St1)

Study and step

Description	Value
Use study	Study 1
Use study step	Time Dependent

Dependent Variables 1 (V1)

General

Description	Value
Defined by study step	Time Dependent

Dependent Variable U1 (Comp1.u1) (Comp1_u1)

General

Description	Value
Field components	comp1.u1

Dependent Variable U2 (Comp1.u2) (Comp1_u2)

General

Description	Value
Field components	comp1.u2

Dependent Variable U3 (Comp1.u3) (Comp1_u3)

General

Description	Value
Field components	comp1.u3

Time-Dependent Solver 1 (T1)

General

Description	Value
Defined by study step	Time Dependent
Time	{0, 0.1, 0.2, 0.30000000000000004, 0.4, 0.5, 0.6000000000000001, 0.7000000000000001, 0.8, 0.9, 1}

Advanced

Description	Value
Allow complex numbers	On

Log

Time-Dependent Solver 1 in Study 1/Solver 1 (sol1) started at 16-mag-2016 11:07:16.

Time-dependent solver (BDF)

Number of degrees of freedom solved for: 13911.

Symmetric matrices found.

Scales for dependent variables:

Dependent variable u1 (comp1.u1): 0.99

Dependent variable u2 (comp1.u2): 0.98

Dependent variable u3 (comp1.u3): 1

Step	Time	Stepsize	Res	Jac	Sol	Order	Tfail	NLfail	LinErr	LinRes
0	0	- out	2	3	2		0	0	0	0
1	0.001	0.001	3	4	3	1	0	0	1.1e-010	2.5e-013
2	0.002	0.001	4	4	4	1	0	0	8.8e-011	3e-014
3	0.004	0.002	5	4	5	2	0	0	1.2e-010	3.2e-014
4	0.008	0.004	6	5	6	1	0	0	1.1e-010	3.1e-014
5	0.016	0.008	7	6	7	1	0	0	7.5e-011	3e-014
6	0.032	0.016	8	7	8	1	0	0	1.1e-010	3.1e-014
7	0.064	0.032	9	8	9	1	0	0	5e-011	3.1e-014
-	0.1	- out								
8	0.128	0.064	10	9	10	1	0	0	5.4e-011	3.1e-014
-	0.2	- out								
9	0.228	0.1	12	9	12	1	0	0	3.8e-010	5.5e-014
-	0.3	- out								
10	0.328	0.1	13	9	13	1	0	0	3e-010	4.7e-014
-	0.4	- out								
11	0.428	0.1	14	9	14	1	0	0	4e-010	5.3e-013
-	0.5	- out								
12	0.528	0.1	20	10	20	1	0	0	9.6e-010	1.6e-013
-	0.6	- out								
13	0.628	0.1	21	10	21	1	0	0	9.2e-010	3.8e-013
-	0.7	- out								
14	0.728	0.1	22	10	22	1	0	0	5.9e-010	1.8e-013
-	0.8	- out								
15	0.828	0.1	28	11	28	1	0	0	2.9e-010	8.7e-014
-	0.9	- out								
16	0.928	0.1	29	11	29	1	0	0	2.3e-010	1.4e-013
-	1	- out								
17	1.028	0.1	30	11	30	1	0	0	1.4e-010	1.5e-013

Time-stepping completed.

Time-Dependent Solver 1 in Study 1/Solver 1 (sol1): Solution time: 64 s (1 minute, 4 seconds)

Physical memory: 1.25 GB

Virtual memory: 1.39 GB

Fully Coupled 1 (Fc1)

General

Description	Value
Linear solver	Direct

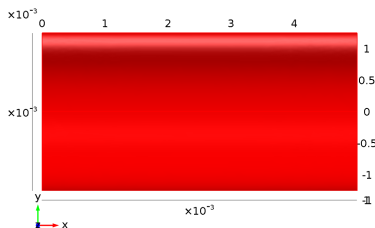
4. Results

4.1. Data Sets

4.1.1. Solution 1

Solution

Description	Value
Solution	Solver 1
Component	Save Point Geometry 1



Data set: Solution 1

4.2. Tables

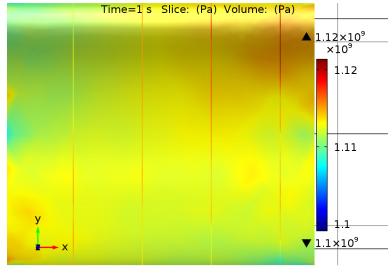
4.2.1. Evaluation 3D

Interactive 3D values

Evaluation 3D			
x	y	z	Value
-8.6736E-19	0.0032884	1.6999E-4	-7.5258E9
0.0081112	-0.0050750	-0.0015708	-7.7746E9
0.0085370	0.0021355	-0.0012978	-0.0020809

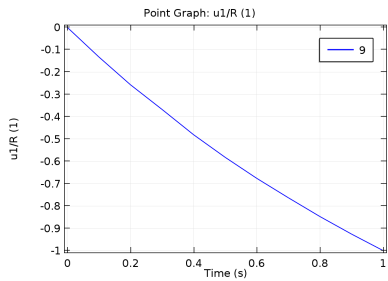
4.3. Plot Groups

4.3.1. 3D Plot Group 1



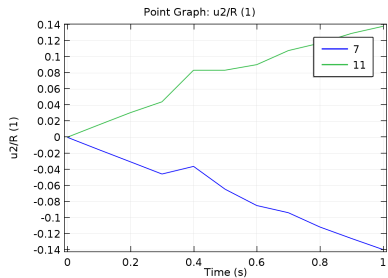
Time=1 s Slice: (Pa) Volume: (Pa)

4.3.2. 1D Plot Group 2



Point Graph: u1/R (1)

4.3.3. 1D Plot Group 3



Point Graph: u2/R (1)