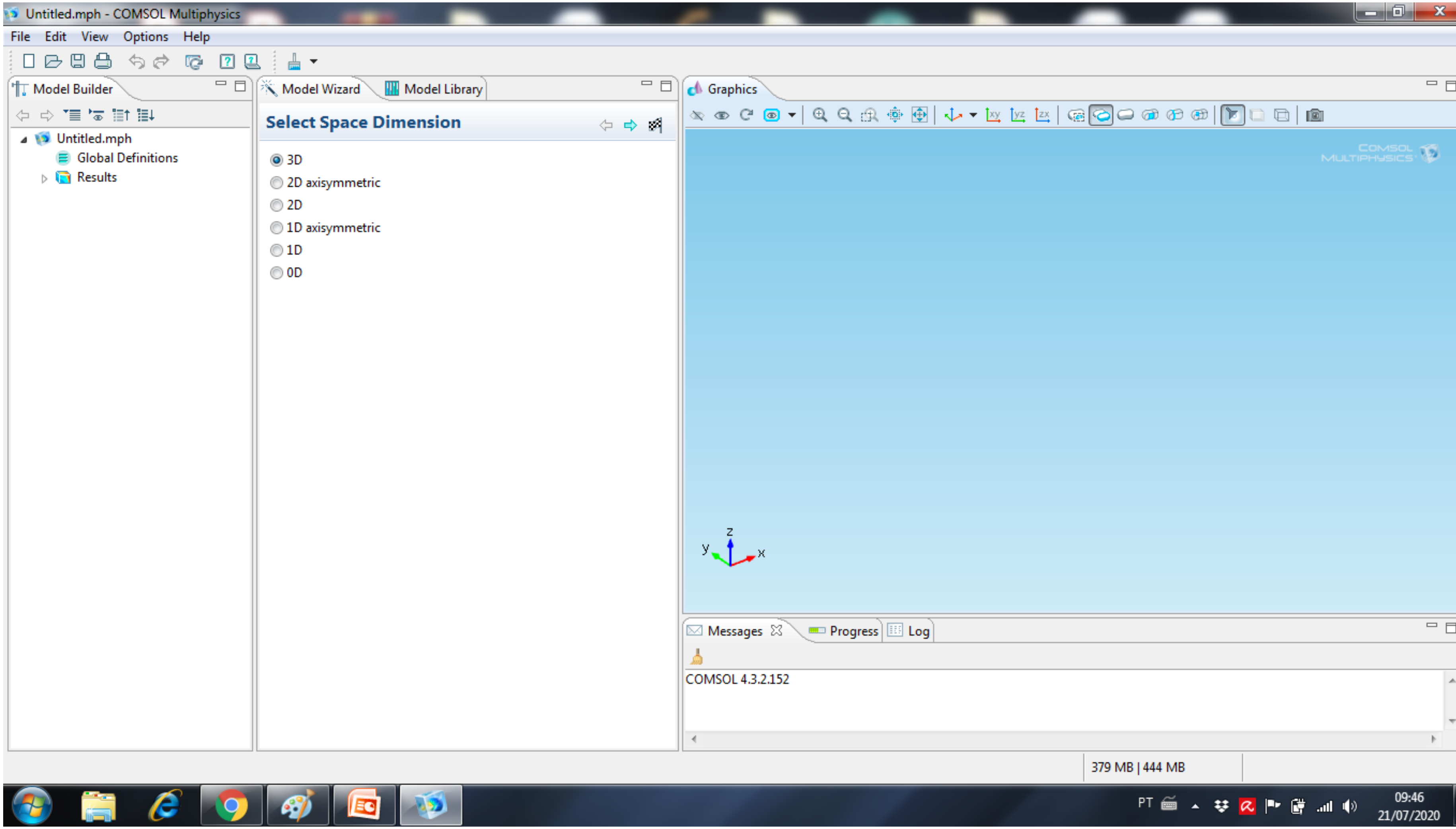
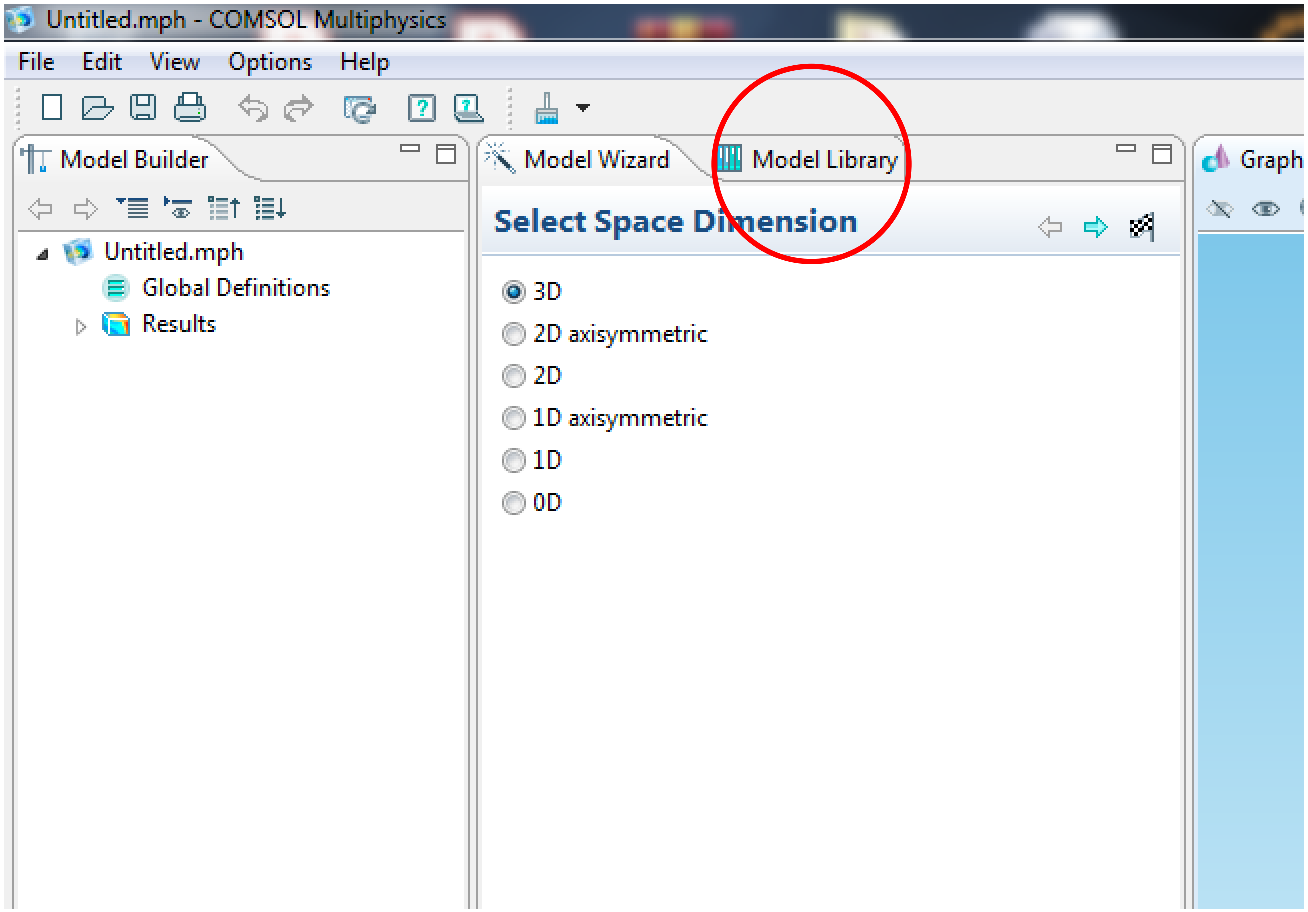
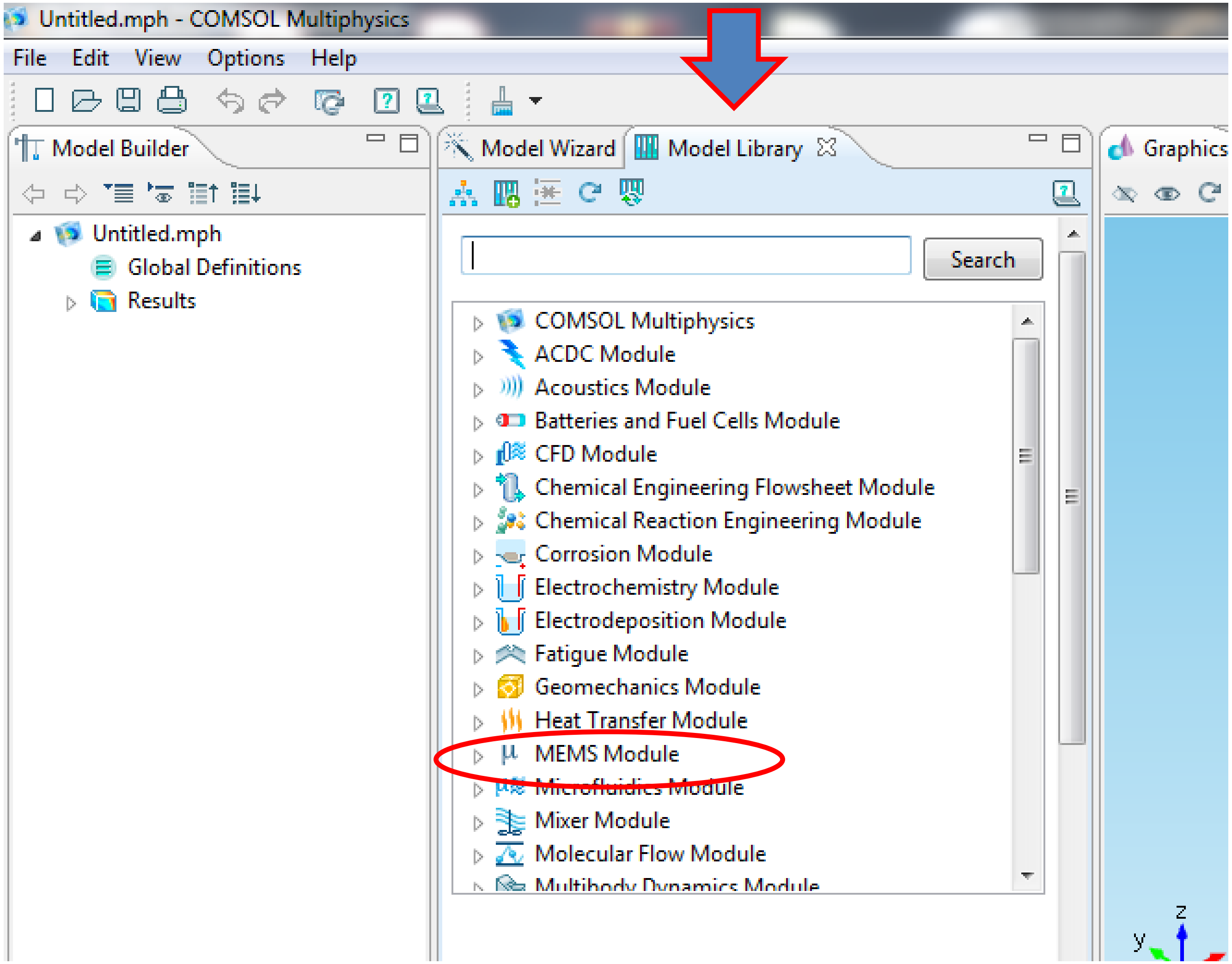
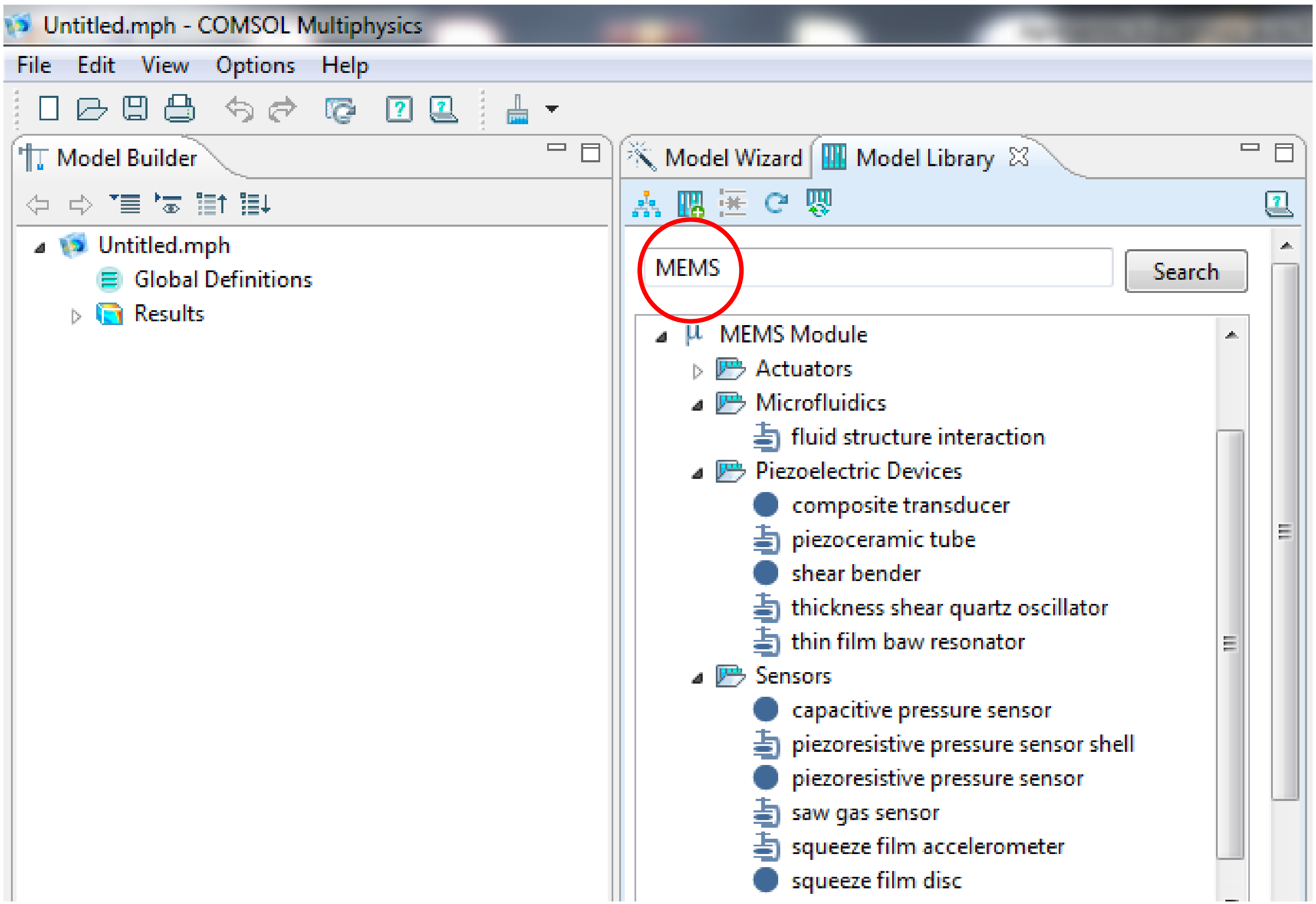
COMSOL

Aluno: Maurício Isoldi
Orientador: Prof. Dr. Ronaldo D. Mansano

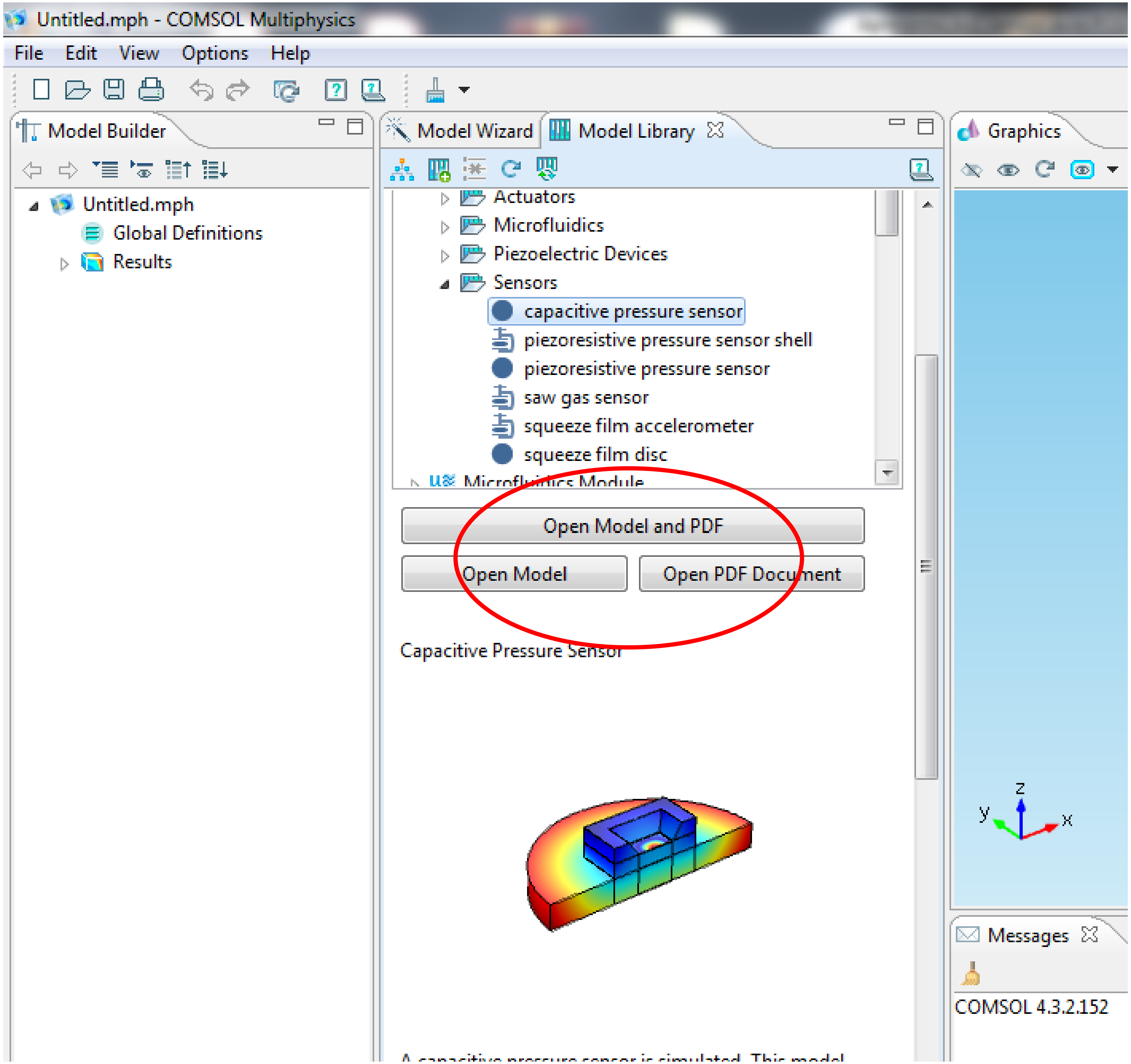

Untitled.mph - COMSOL Multiphysics
File Edit View Options Help
Model Builder
Untitled.mph
Global Definitions
Results
Model Wizard
Model Library
Select Space Dimension
3D
2D axisymmetric
2D
1D axisymmetric
1D
0D
Graphics
COMSOL MULTIPHYSICS
z
y
x
Messages
Progress
Log
COMSOL 4.3.2.152
379 MB | 444 MB
PT
09:46
21/07/2020


Untitled.mph - COMSOL Multiphysics
File
Edit
View
Options
Help
Model Builder
Untitled.mph
Global Definitions
Results
Model Wizard
Model Library
Select Space Dimension
3D
2D axisymmetric
2D
1D axisymmetric
1D
0D
Graph


Untitled.mph - COMSOL Multiphysics
File
Edit
View
Options
Help
Model Builder
Untitled.mph
Global Definitions
Results
Model Wizard
Model Library
Graphics
Search
COMSOL Multiphysics
ACDC Module
Acoustics Module
Batteries and Fuel Cells Module
CFD Module
Chemical Engineering Flowsheet Module
Chemical Reaction Engineering Module
Corrosion Module
Electrochemistry Module
Electrodeposition Module
Fatigue Module
Geomechanics Module
Heat Transfer Module
MEMS Module
Microfluidics Module
Mixer Module
Molecular Flow Module
Multibody Dynamics Module
z
y



Untitled.mph - COMSOL Multiphysics
File
Edit
View
Options
Help
Model Builder
Untitled.mph
Global Definitions
Results
Model Wizard
Model Library
MEMS
Search
MEMS Module
Actuators
Microfluidics
fluid structure interaction
Piezoelectric Devices
composite transducer
piezoceramic tube
shear bender
thickness shear quartz oscillator
thin film baw resonator
Sensors
capacitive pressure sensor
piezoresistive pressure sensor shell
piezoresistive pressure sensor
saw gas sensor
squeeze film accelerometer
squeeze film disc


Untitled.mph - COMSOL Multiphysics
File Edit View Options Help
Model Builder
Untitled.mph
Global Definitions
Results
Model Wizard
Model Library
Actuators
Microfluidics
Piezoelectric Devices
Sensors
capacitive pressure sensor
piezoresistive pressure sensor shell
piezoresistive pressure sensor
saw gas sensor
squeeze film accelerometer
squeeze film disc
Open Model and PDF
Open Model
Open PDF Document
Capacitive Pressure Sensor
Graphics
Messages
COMSOL 4.3.2.152

Capacitive Pressure Sensor

Introduction

Capacitive pressure sensors are gaining market share over their piezoresistive counterparts since they consume less power, are usually less temperature sensitive and have a lower fundamental noise floor. This model performs an analysis of a hypothetical sensor design discussed in Ref. 1, using the electromechanics interface. The effect of a rather poor choice of packaging solution on the performance of the sensor is also considered. The results emphasize the importance of considering packaging in the MEMS design process.

Model Definition

The model geometry is shown in Figure 1. The pressure sensor is part of a silicon die that has been bonded to a metal plate at 70°C. Since the geometry is symmetric, only a single quadrant of the geometry needs to be included in the model and the symmetry boundary condition can be employed.

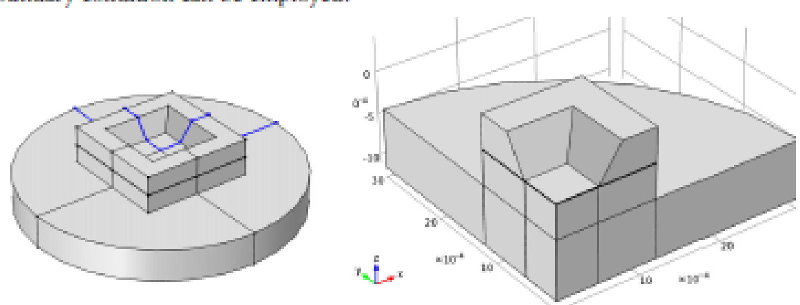
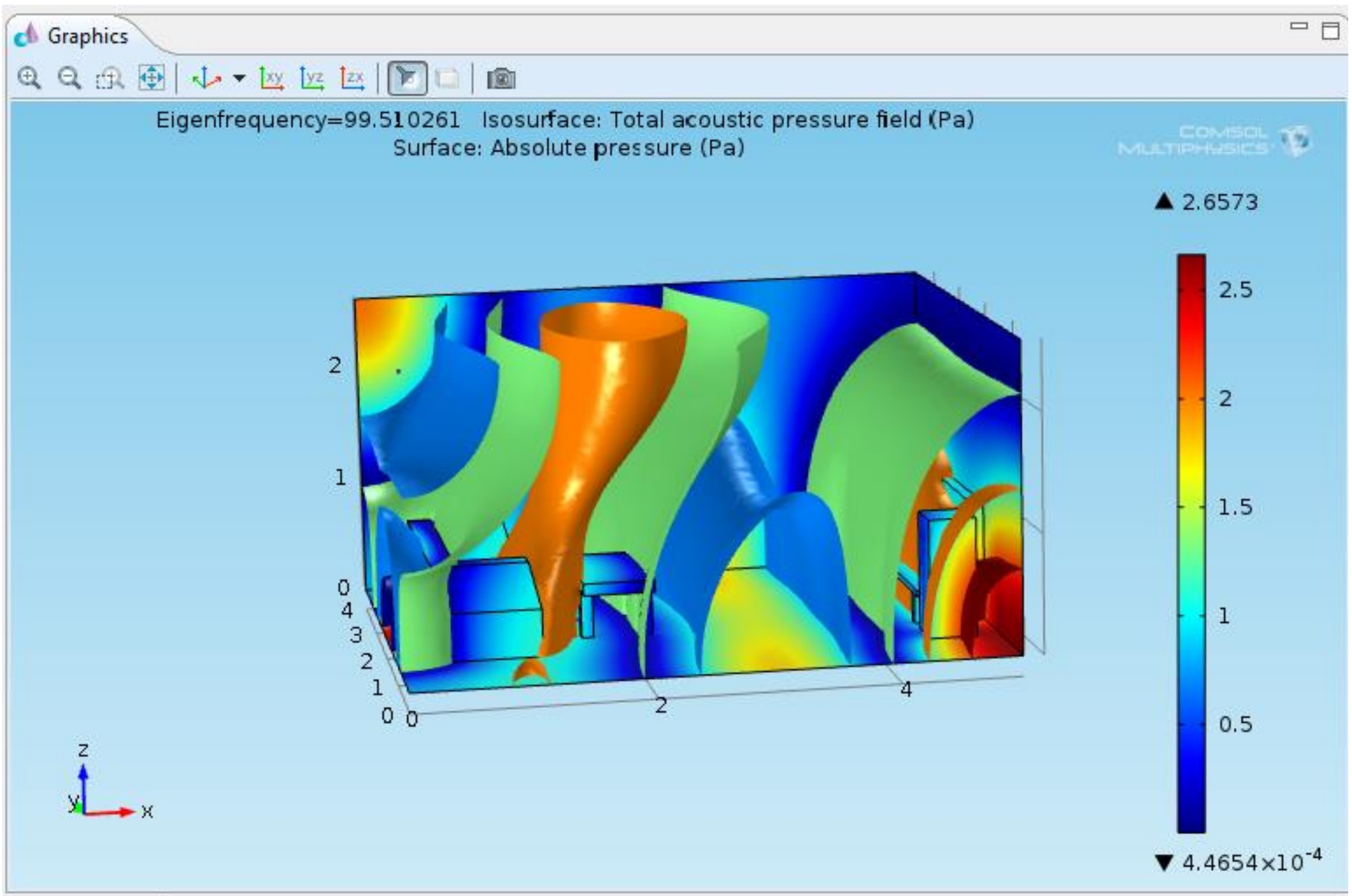


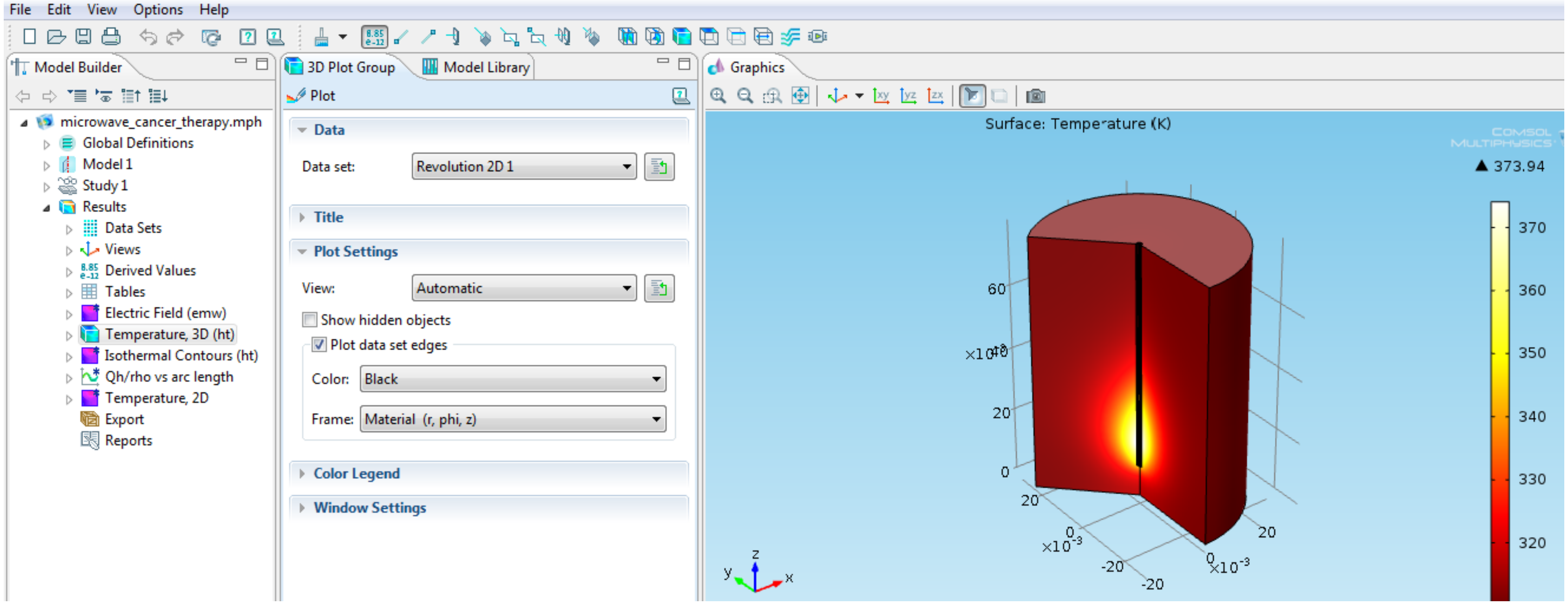
Figure 1: The model geometry. Left: The symmetric device geometry, with one quadrant highlighted in blue, showing the symmetry planes. Right: In COMSOL only the highlighted quadrant is modeled, and the symmetry boundary condition is used on the cross section

Exemplos de simulações

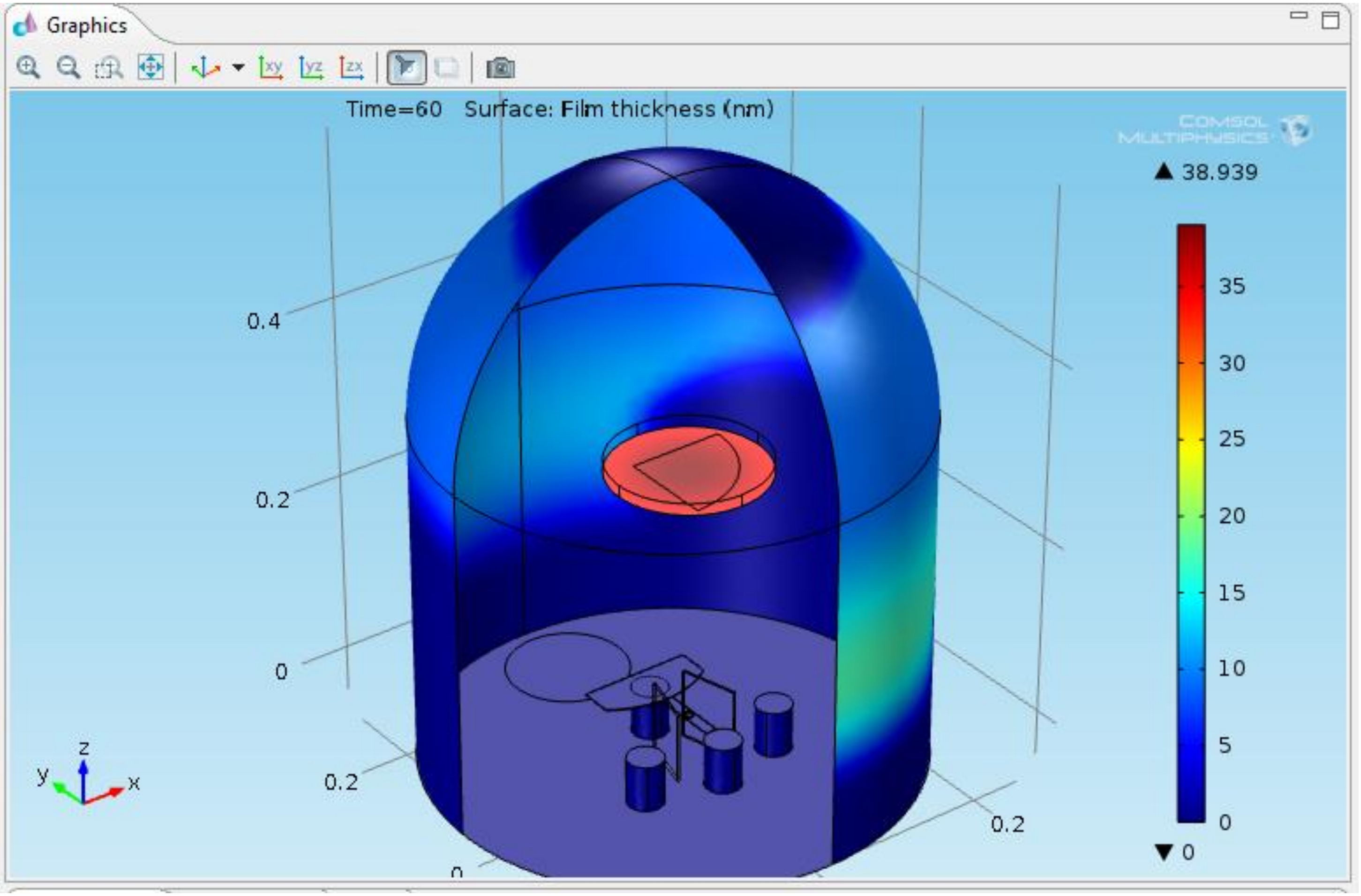
Acústica


Graphics
Eigenfrequency=99.510261 Isosurface: Total acoustic pressure field (Pa)
Surface: Absolute pressure (Pa)
COMSOL MULTIPHYSICS
▲ 2.6573
2.5
2
1.5
1
0.5
▼ 4.4654×10^-4
2
1
0
4
3
2
1
0 0
2
4
z
y
x

Microwave cancer therapy



Evaporador



Graphics
Time=60 Surface: Film thickness (nm)
▲ 38.939
35
30
25
20
15
10
5
0
▼ 0
0.4
0.2
0
0.2
0.2
z
y
x

PDF

Evaporator

Introduction

This model shows how to compute the film thickness deposited on a wafer from an evaporative source.

Model Definition

Gold is evaporated from a thermal source at a temperature of 2000 K onto a substrate held on a fixed surface. The deposited film thickness on the substrate and the chamber walls is computed. The model geometry is shown in Figure 1.

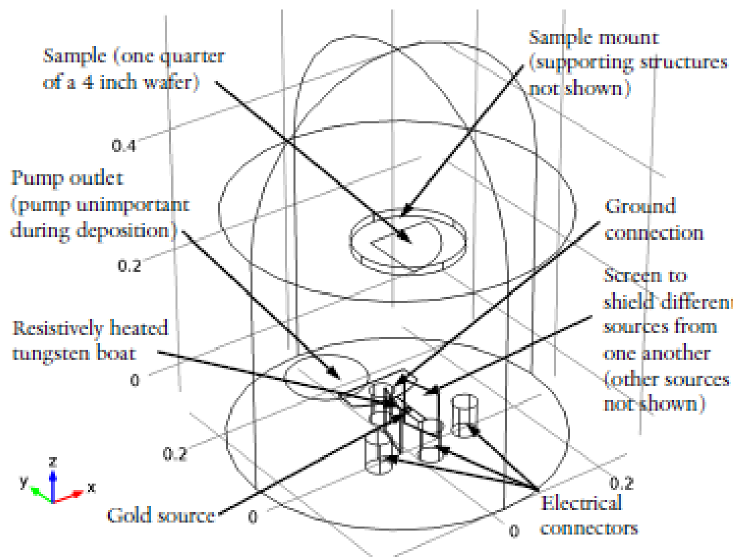
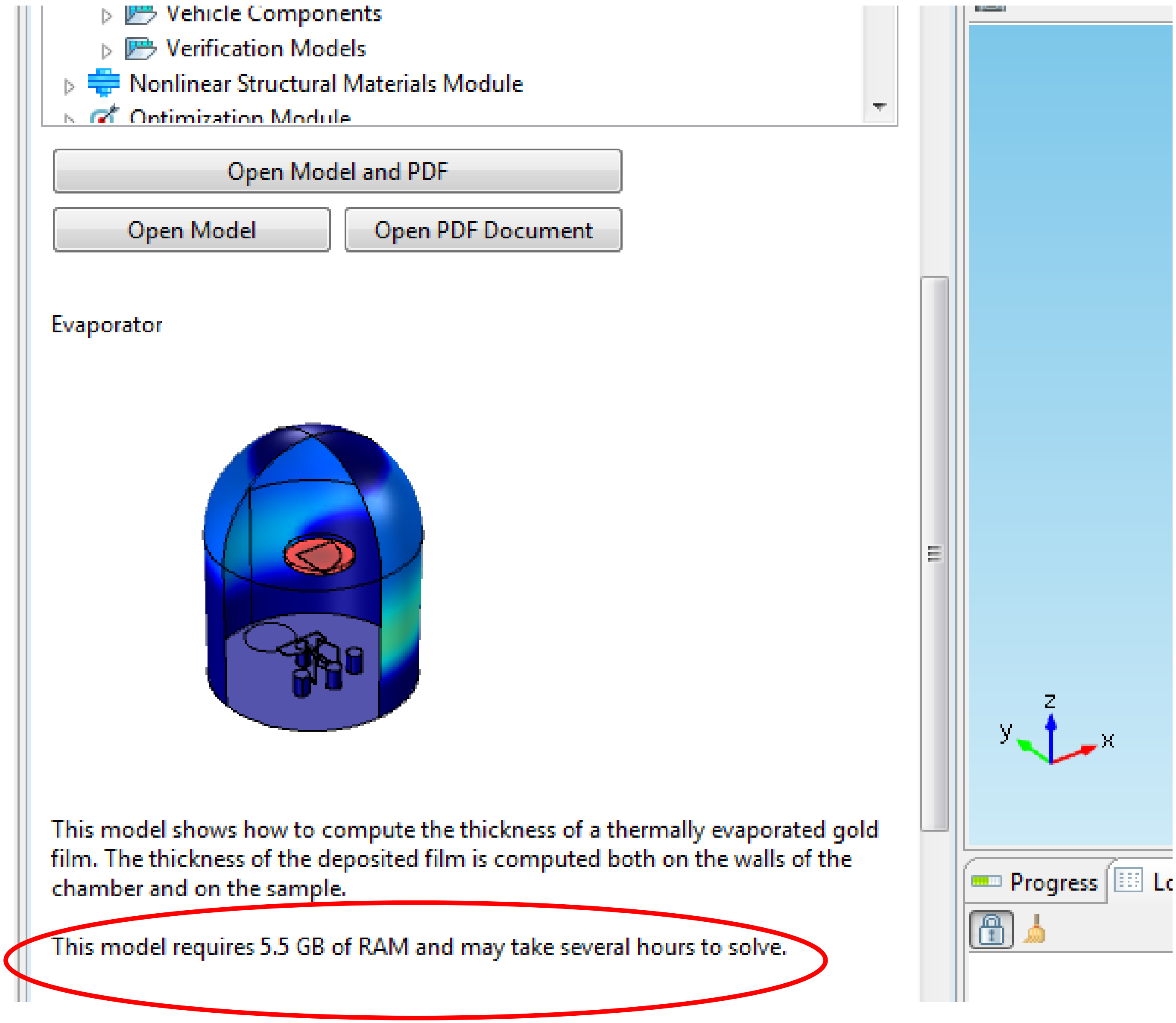
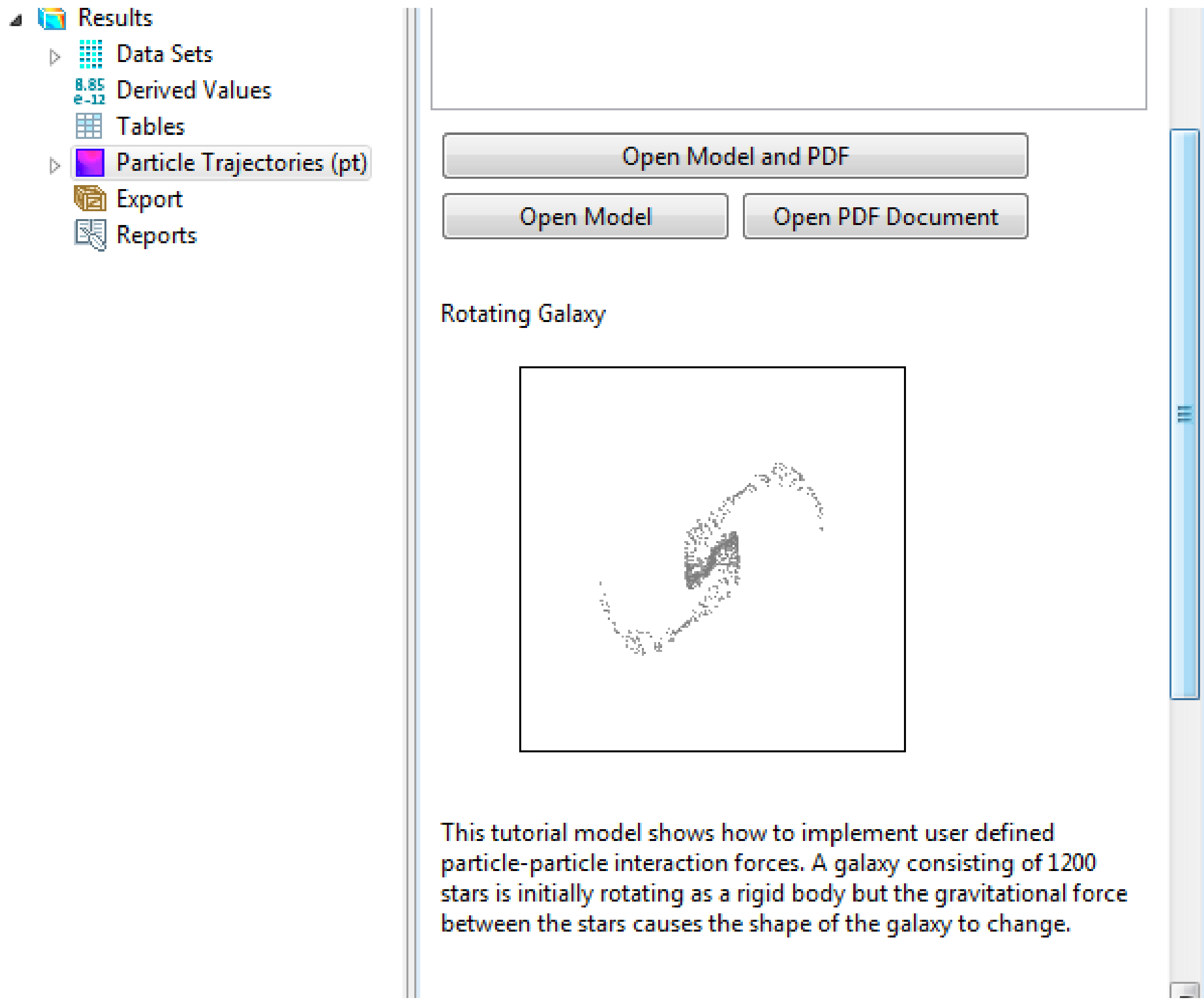
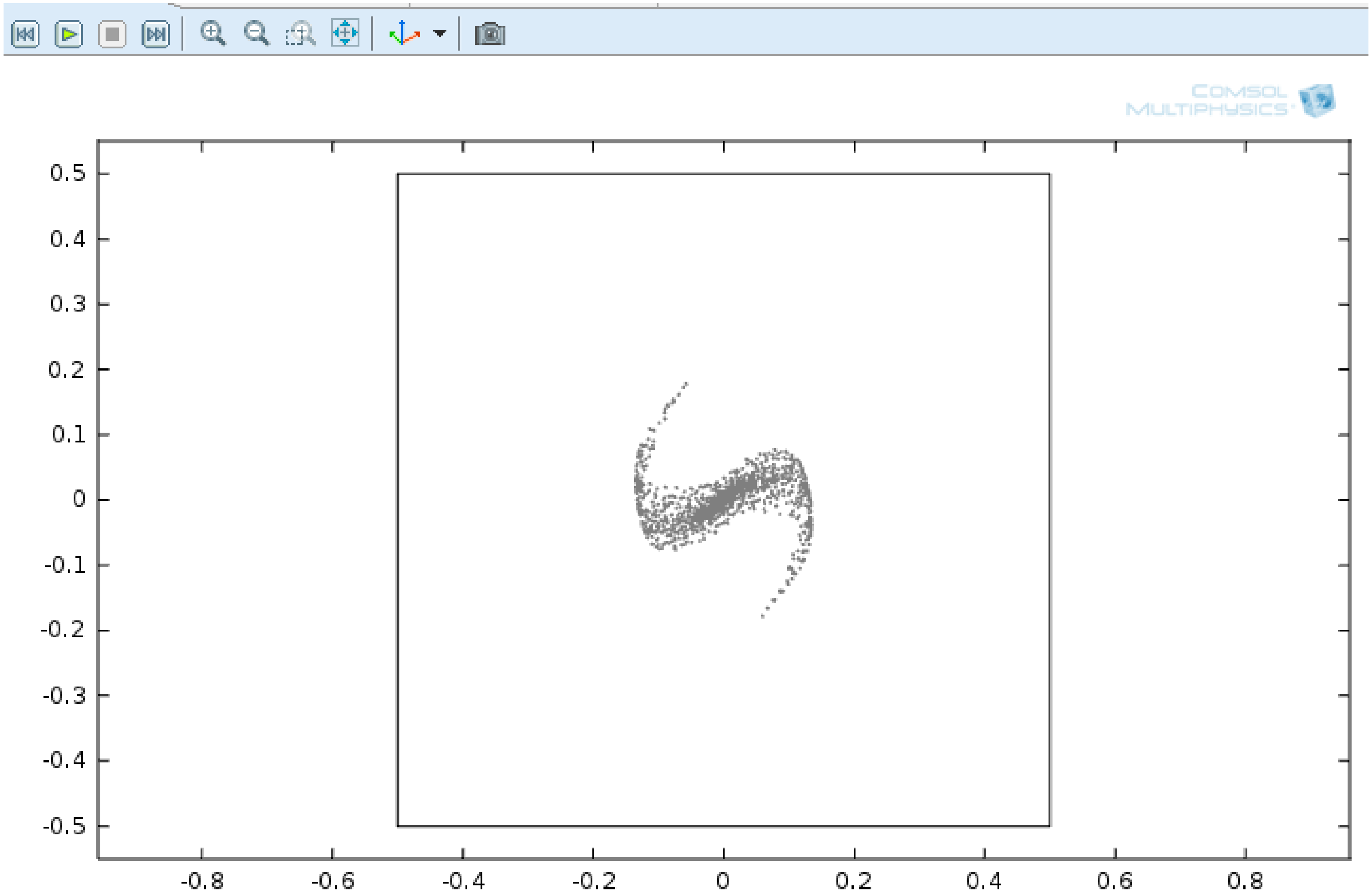


Figure 1: Model geometry. Various components of the evaporator are labeled.


Vehicle Components
Verification Models
Nonlinear Structural Materials Module
Optimization Module
Open Model and PDF
Open Model
Open PDF Document
Evaporator
This model shows how to compute the thickness of a thermally evaporated gold film. The thickness of the deposited film is computed both on the walls of the chamber and on the sample.
This model requires 5.5 GB of RAM and may take several hours to solve.
z
y
x
Progress

Galáxia


Results
Data Sets
Derived Values
Tables
Particle Trajectories (pt)
Export
Reports
Open Model and PDF
Open Model
Open PDF Document
Rotating Galaxy
This tutorial model shows how to implement user defined particle-particle interaction forces. A galaxy consisting of 1200 stars is initially rotating as a rigid body but the gravitational force between the stars causes the shape of the galaxy to change.



0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8

Exemplo: fluxo no cilindro

Solved with COMSOL Multiphysics 4.3b

Flow Past a Cylinder

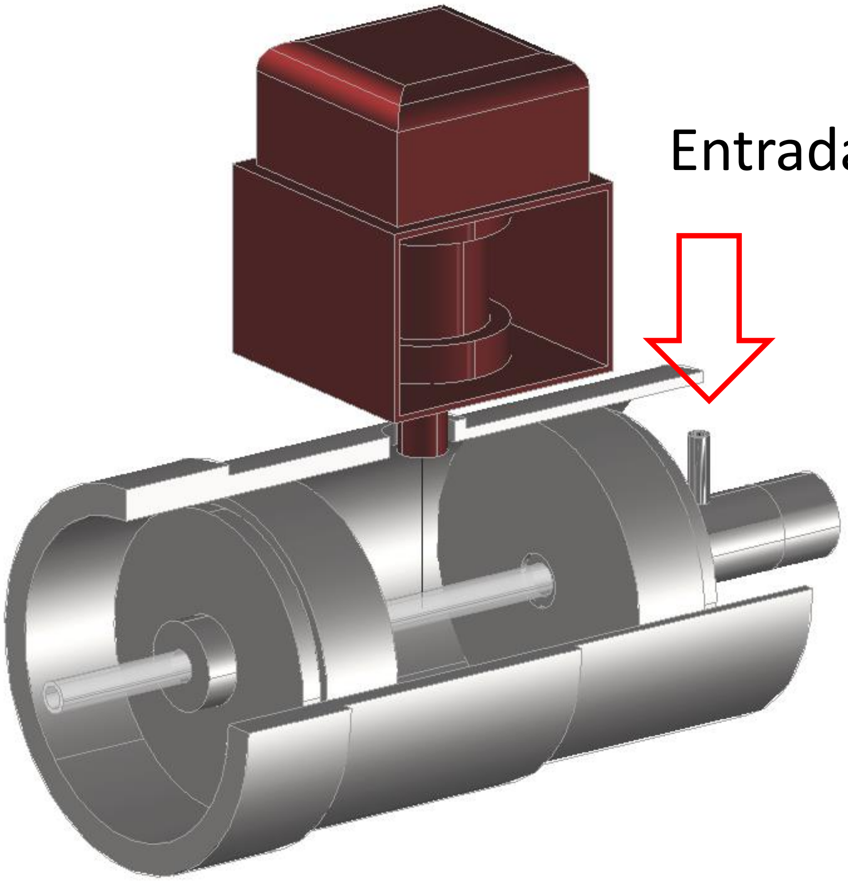
Introduction

The flow of fluid behind a blunt body such as an automobile is difficult to compute due to the unsteady flows. The wake behind such a body consists of unordered eddies of all sizes that create large drag on the body. In contrast, the turbulence in the thin boundary layers next to the streamlined bodies of aircraft and fish create only weak disturbances of flow.

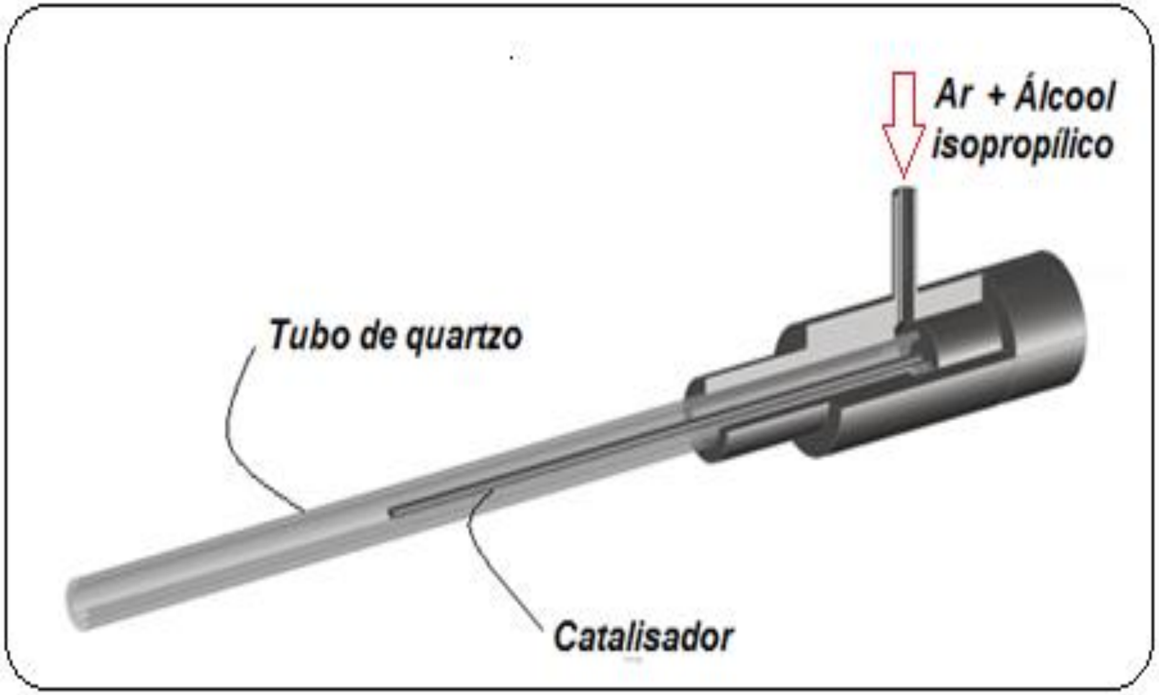
An exception to this occurs when you place a slender body at right angles to a slow flow because the eddies organize. A von Kármán vortex street appears with a predictable frequency and involves the shedding of eddies from alternating sides. Everyday examples of this phenomenon include singing telephone wires and an automobile radio antenna vibrating in an air stream.

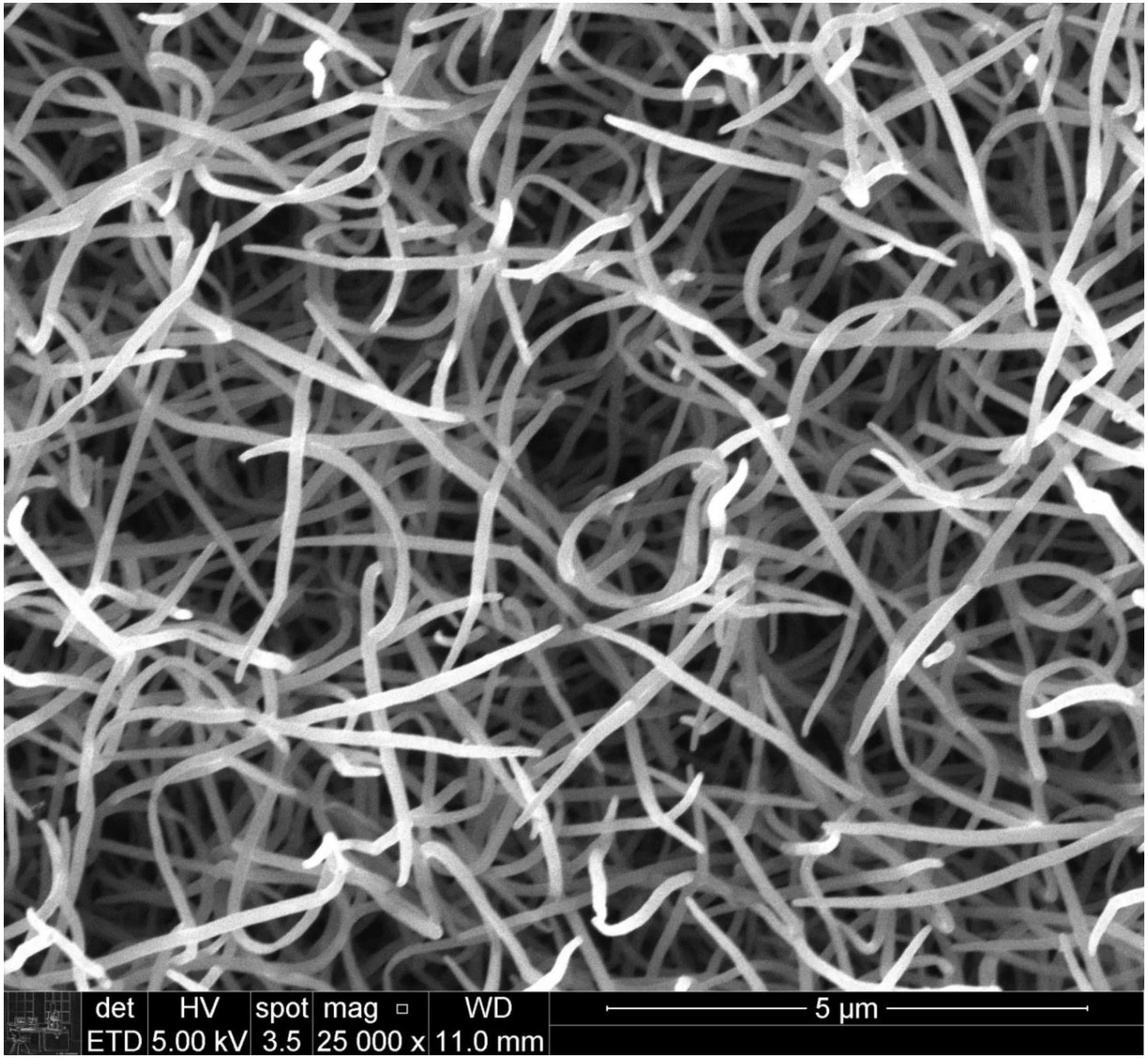
From an engineering standpoint, it is important to predict the frequency of vibrations at various fluid speeds and thereby avoid undesirable resonances between the vibrations of the solid structures and the vortex shedding. To help reduce such effects, plant engineers put a spiral on the upper part of high smokestacks; the resulting variation in shape prohibits the constructive interference of the vortex elements that the structure sheds from different positions.

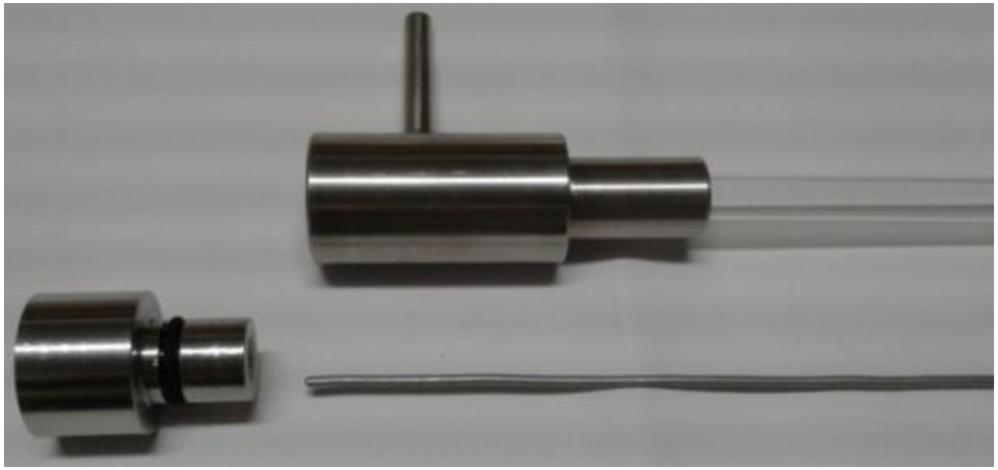
Cavidade ressonante



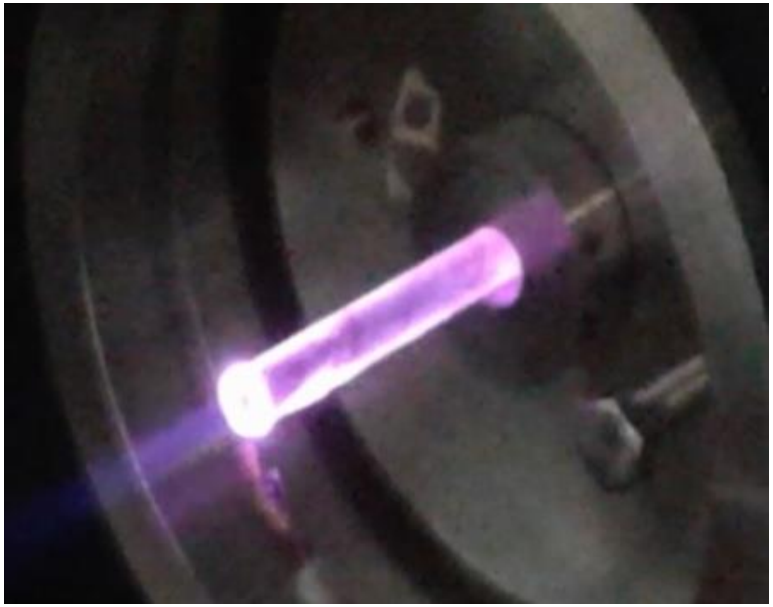
Sistema de injeção de Álcool Isopropílico



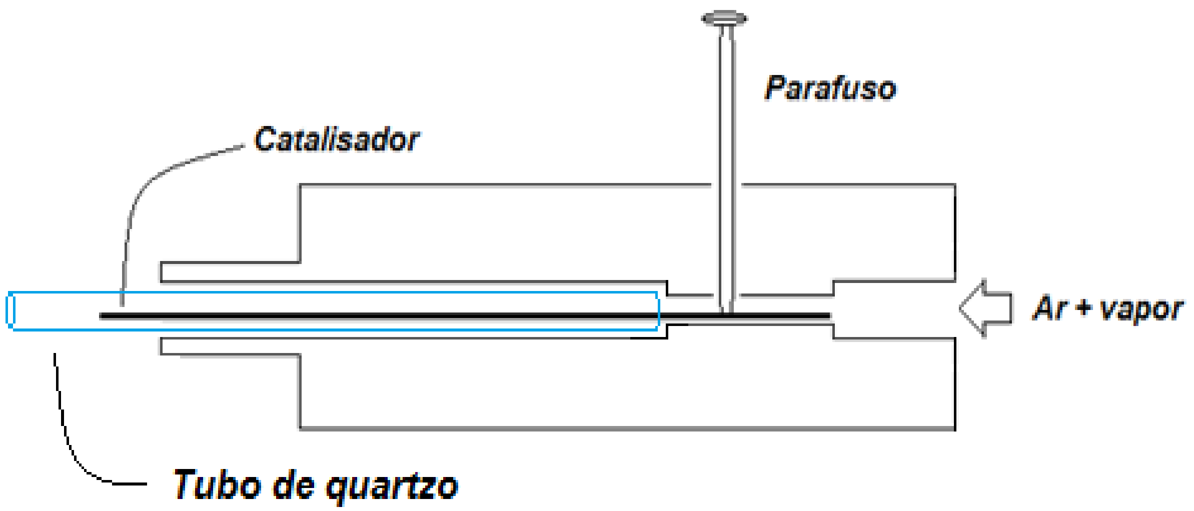

det
ETD
HV
5.00 kV
spot
3.5
mag
25 000 x
WD
11.0 mm
5 µm



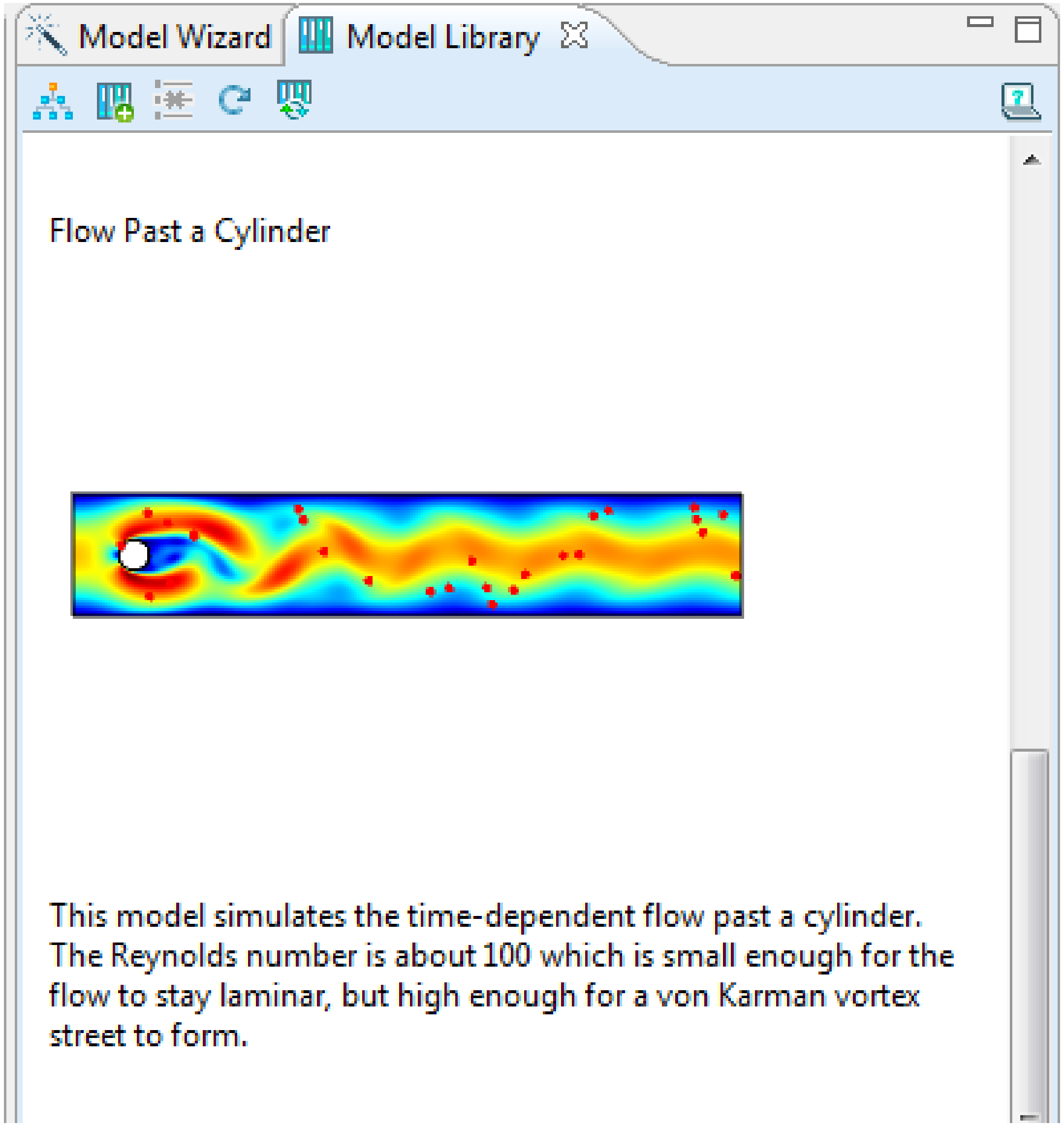
Plasma - com ajuste fino das tampas laterais



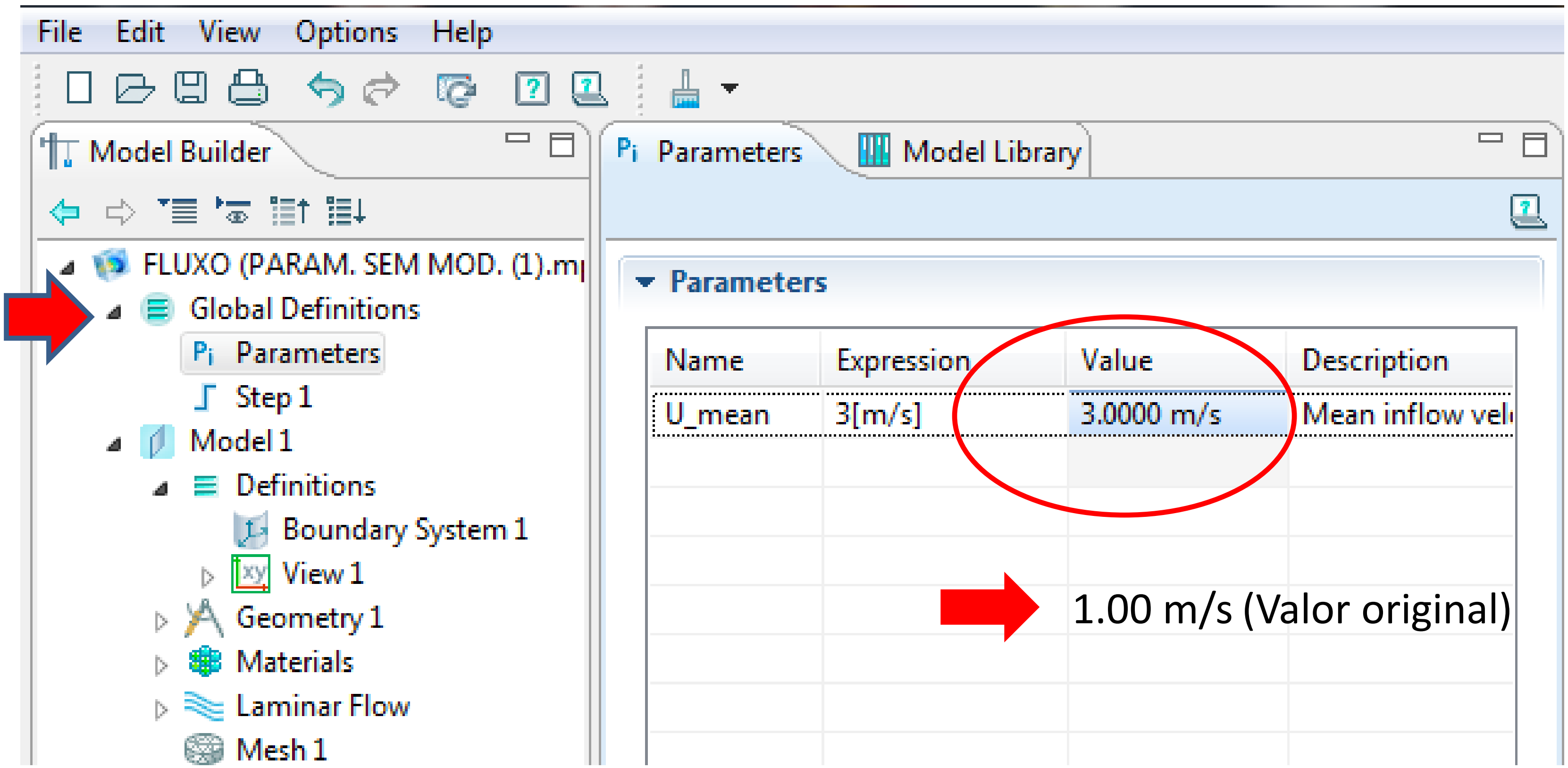
[redacted]


Parafuso
Catalisador
Ar + vapor
Tubo de quartzo

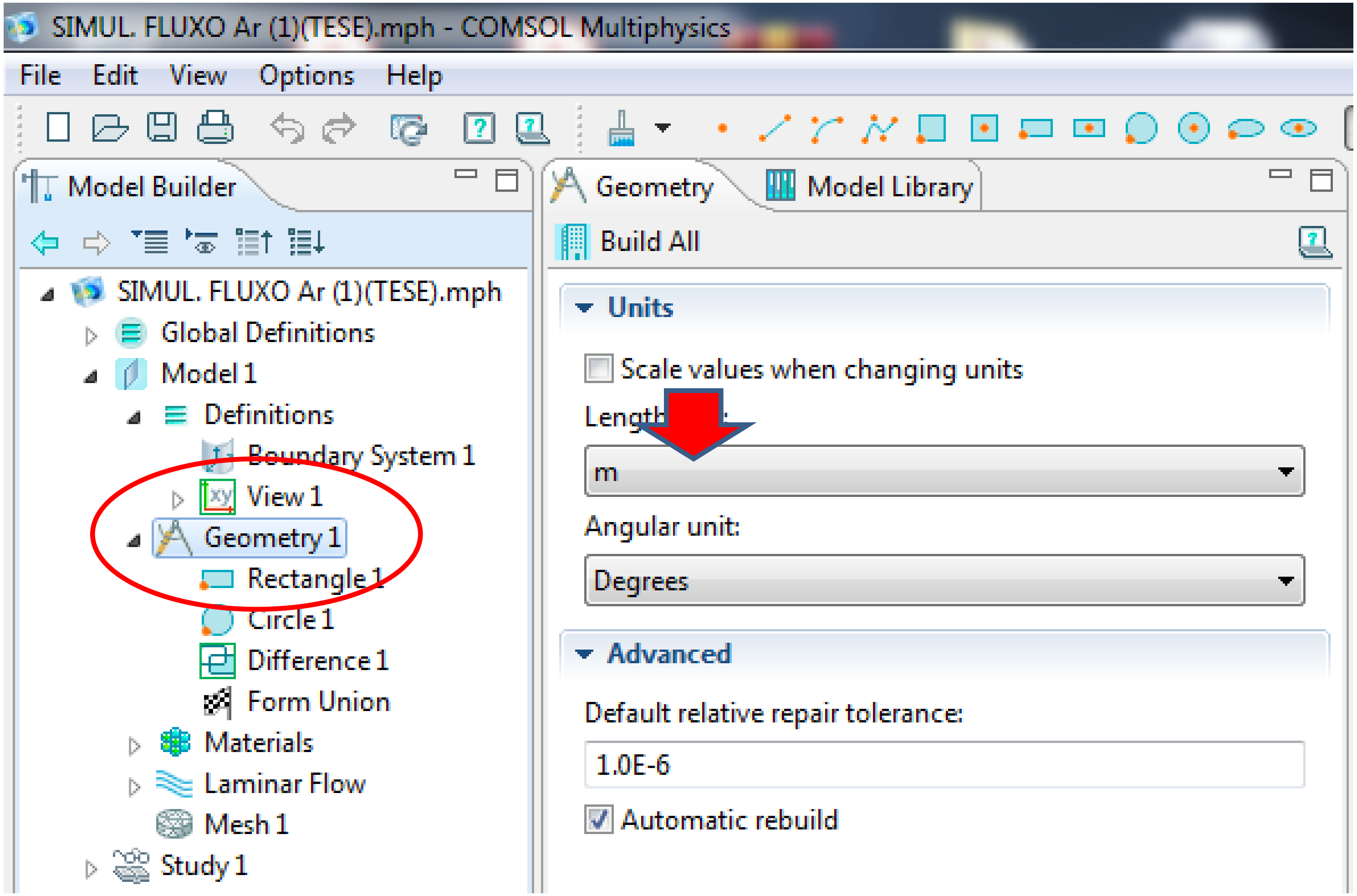
Modelo fornecido pelo COMSOL



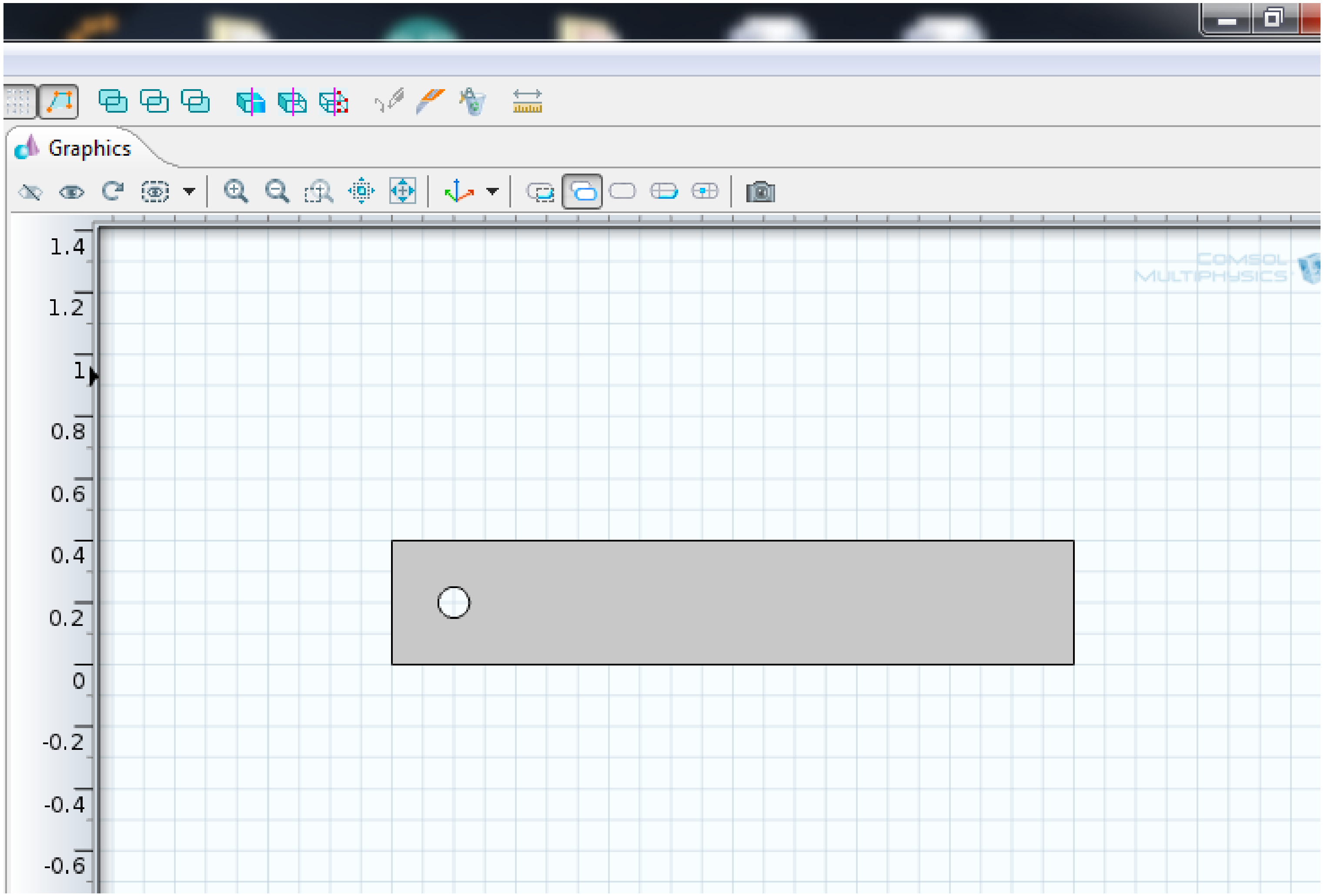
Alterando a velocidade inicial do fluxo



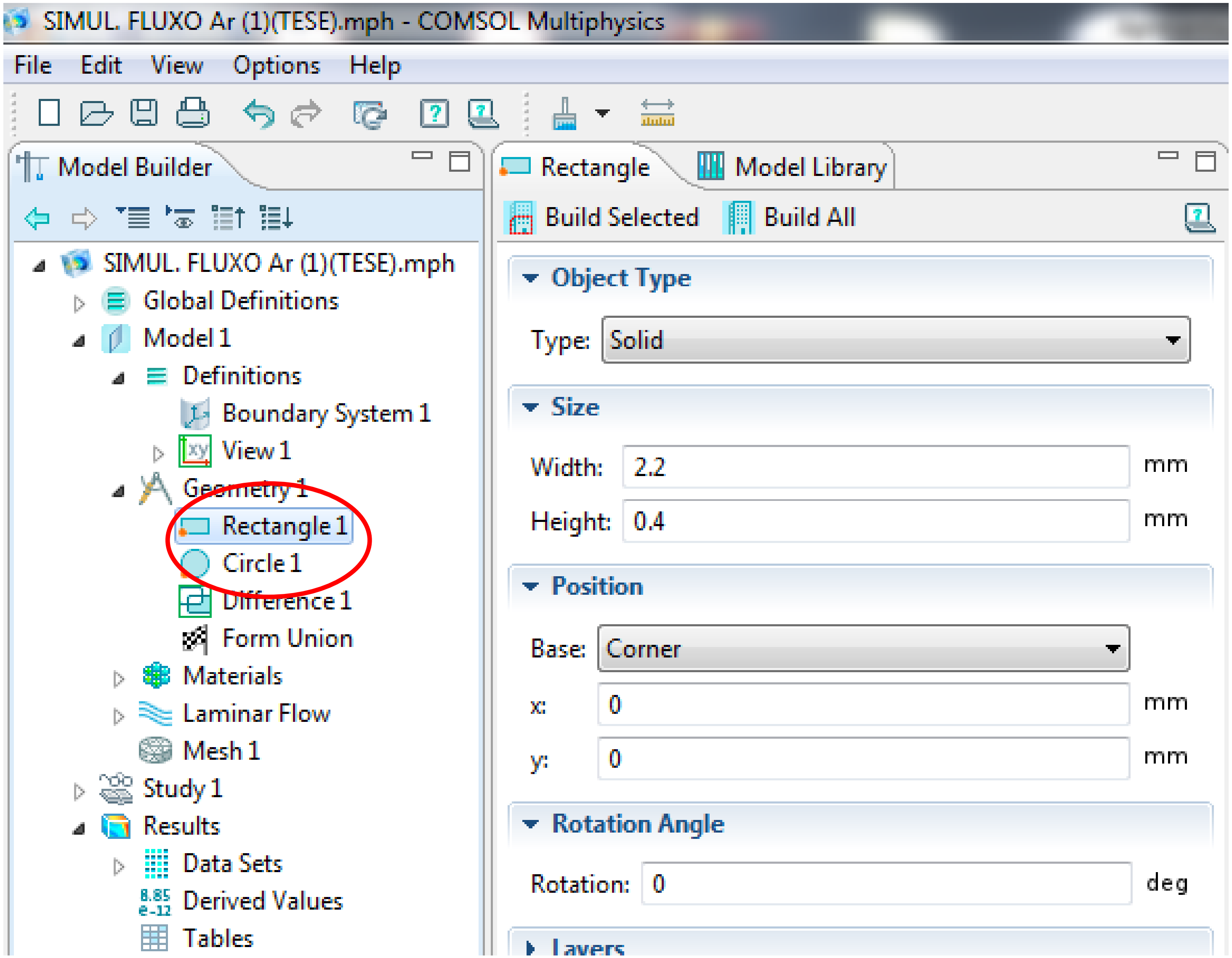
Geometria

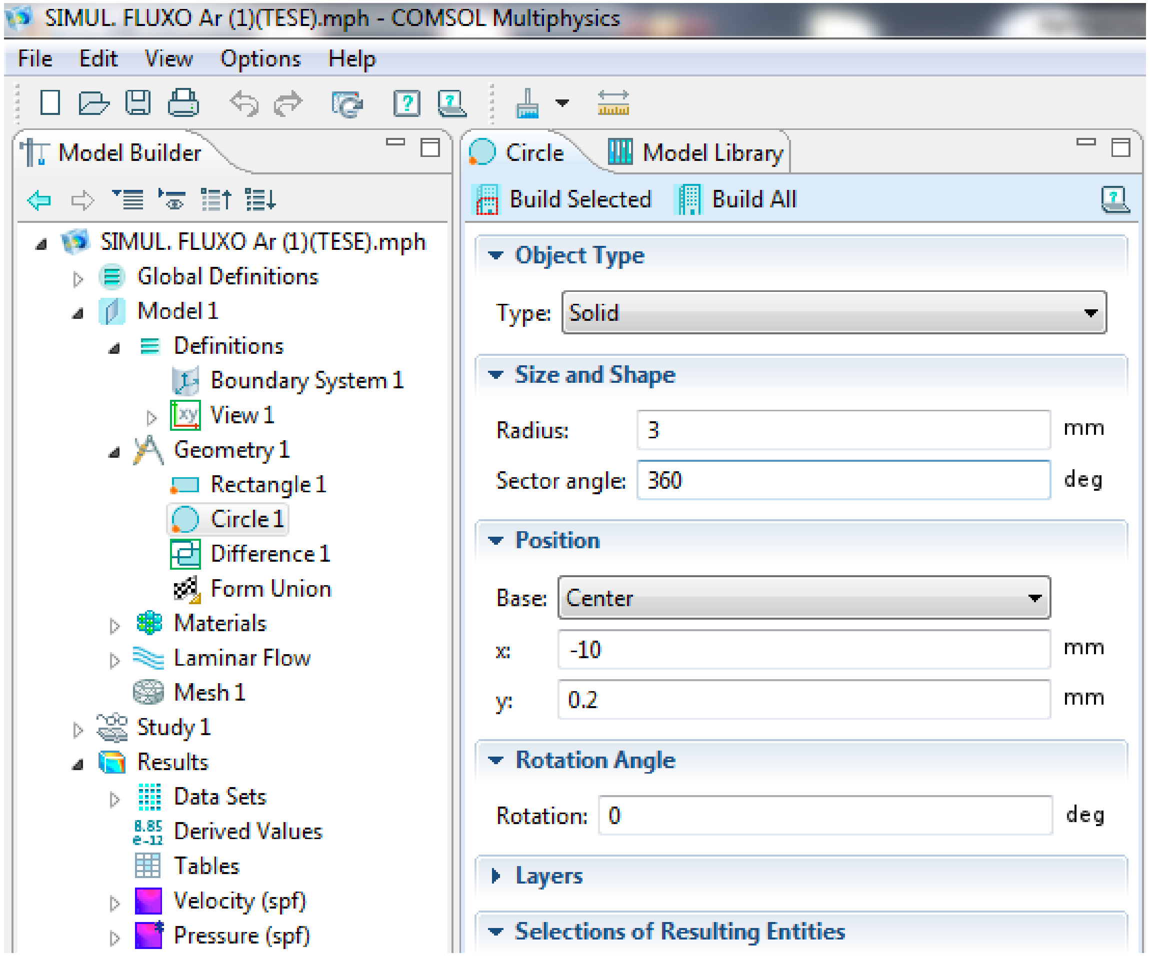

SIMUL. FLUXO Ar (1)(TESE).mph - COMSOL Multiphysics
File Edit View Options Help
Model Builder
SIMUL. FLUXO Ar (1)(TESE).mph
Global Definitions
Model 1
Definitions
Boundary System 1
View 1
Geometry 1
Rectangle 1
Circle 1
Difference 1
Form Union
Materials
Laminar Flow
Mesh 1
Study 1
Geometry
Model Library
Build All
Units
Scale values when changing units
Length unit:
m
Angular unit:
Degrees
Advanced
Default relative repair tolerance:
1.0E-6
Automatic rebuild

Estrutura fornecida pelo COMSOL

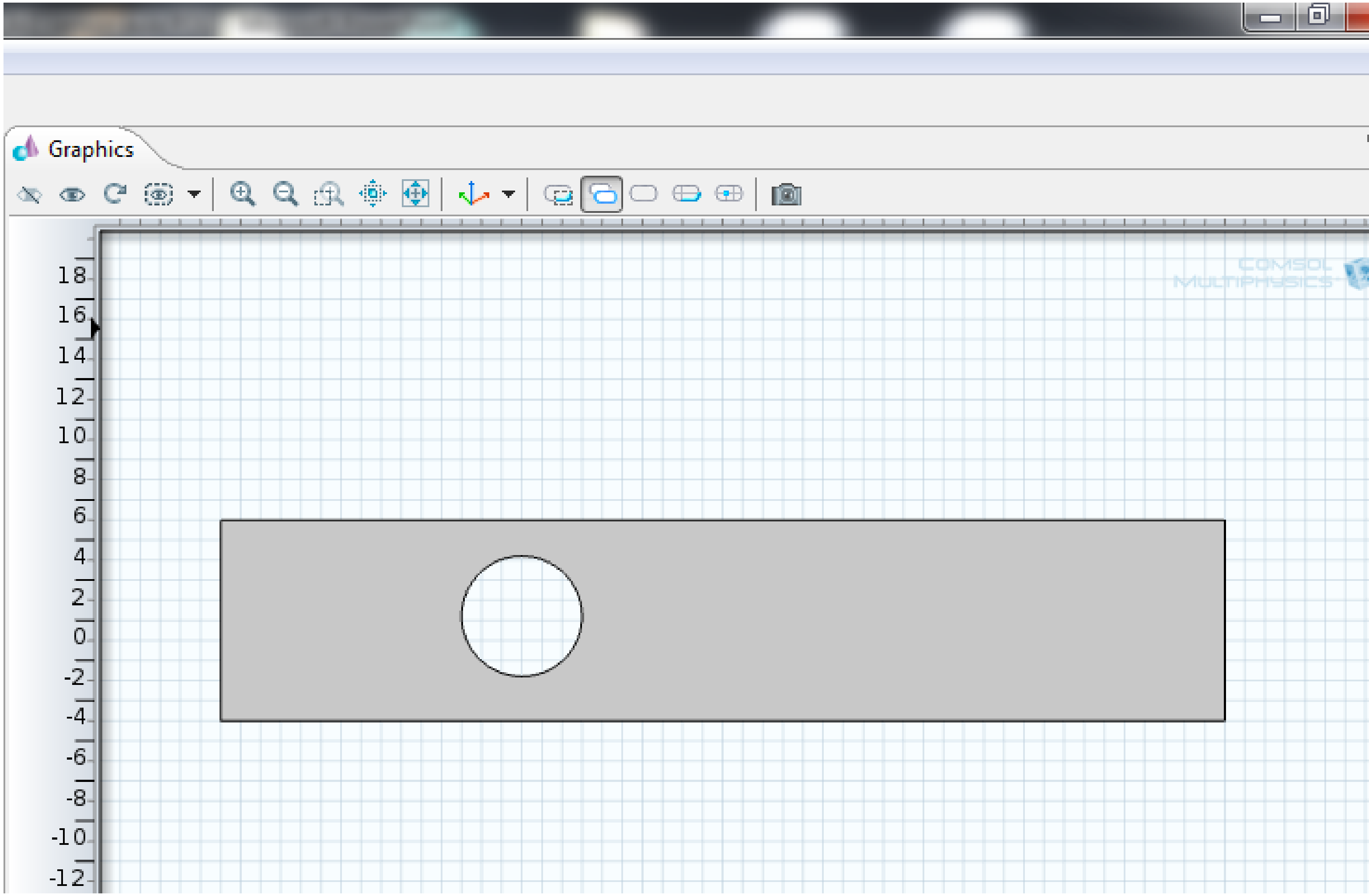


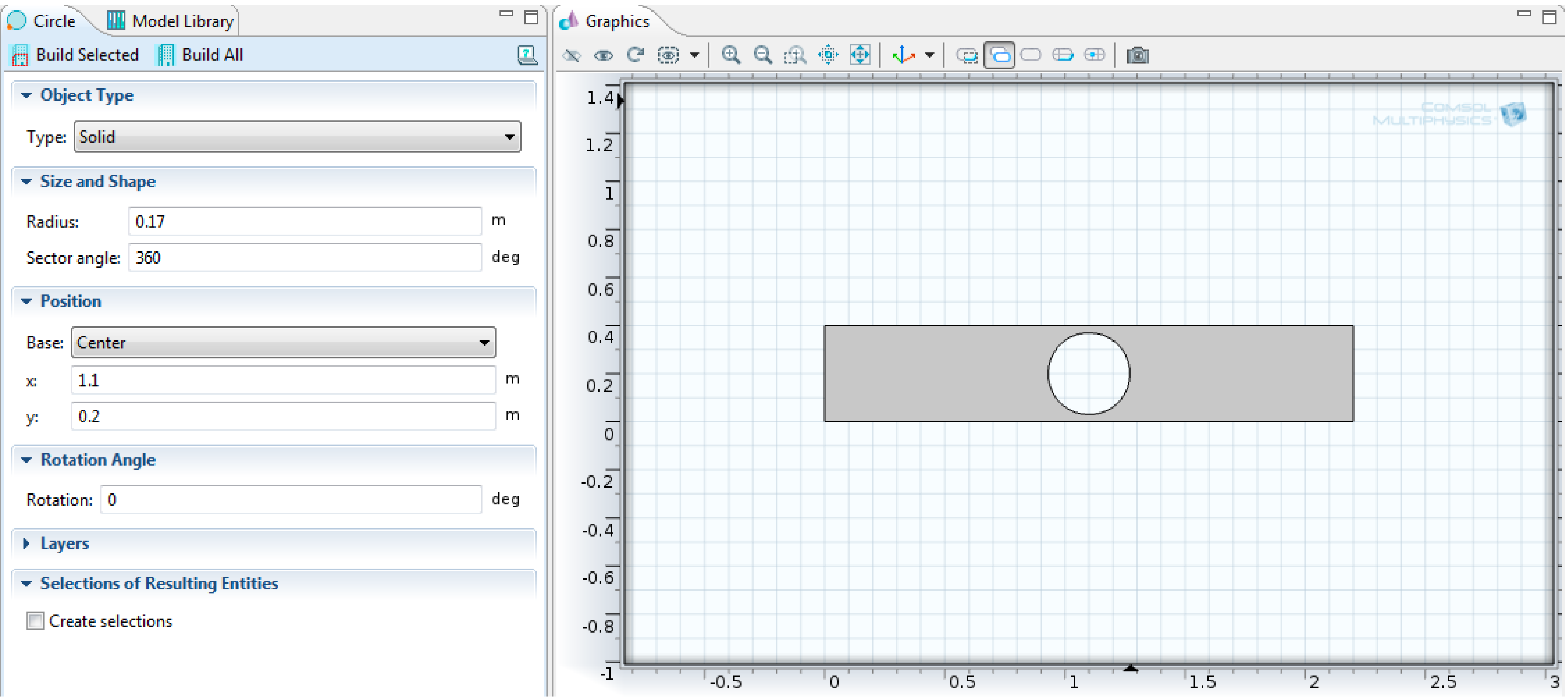
Alterando as dimensões



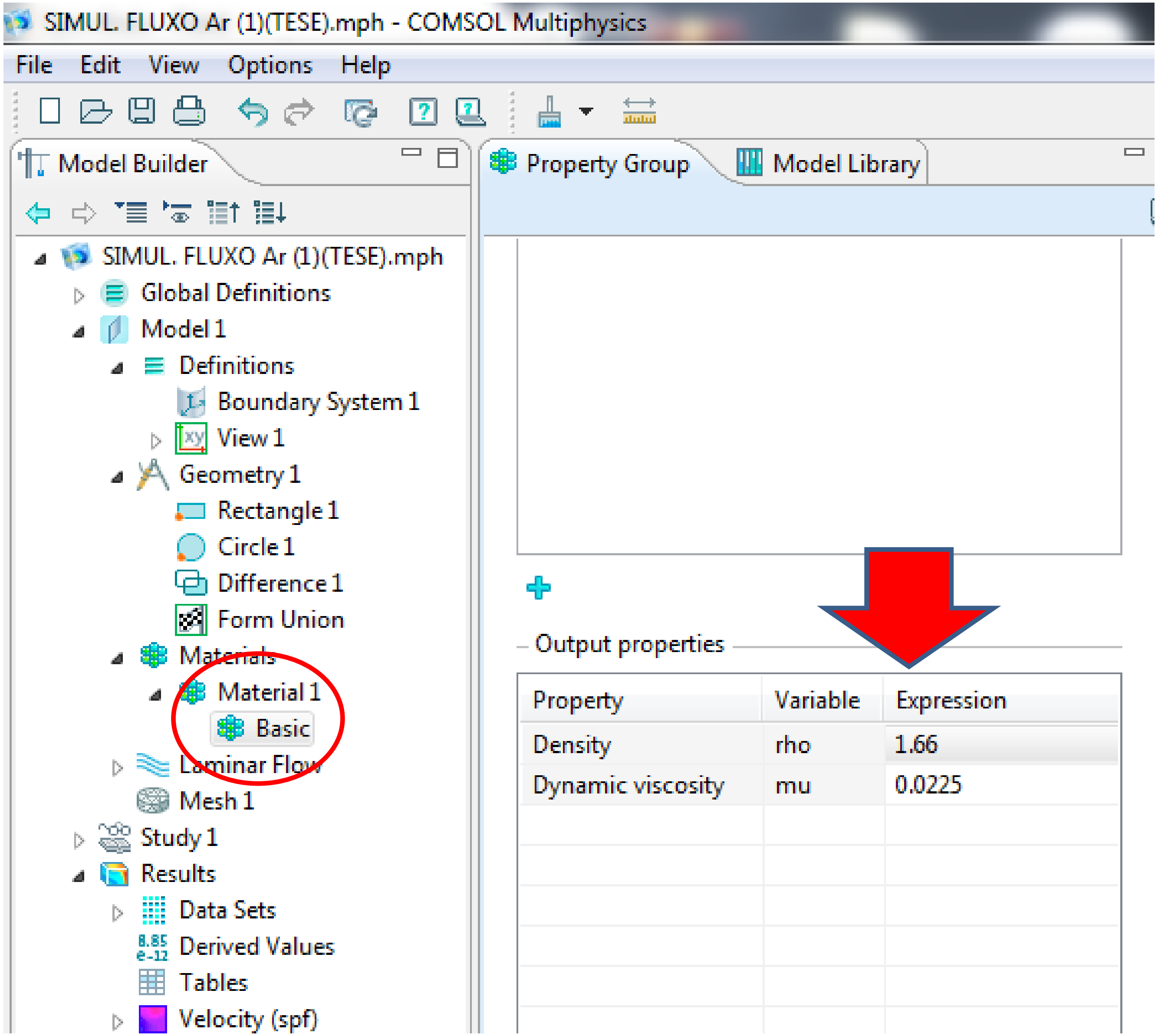

SIMUL. FLUXO Ar (1)(TESE).mph - COMSOL Multiphysics
File Edit View Options Help
Model Builder
SIMUL. FLUXO Ar (1)(TESE).mph
Global Definitions
Model 1
Definitions
Boundary System 1
View 1
Geometry 1
Rectangle 1
Circle 1
Difference 1
Form Union
Materials
Laminar Flow
Mesh 1
Study 1
Results
Data Sets
Derived Values
Tables
Velocity (spf)
Pressure (spf)
Circle
Model Library
Build Selected
Build All
Object Type
Type: Solid
Size and Shape
Radius: 3 mm
Sector angle: 360 deg
Position
Base: Center
x: -10 mm
y: 0.2 mm
Rotation Angle
Rotation: 0 deg
Layers
Selections of Resulting Entities

Dimensionando a estrutura

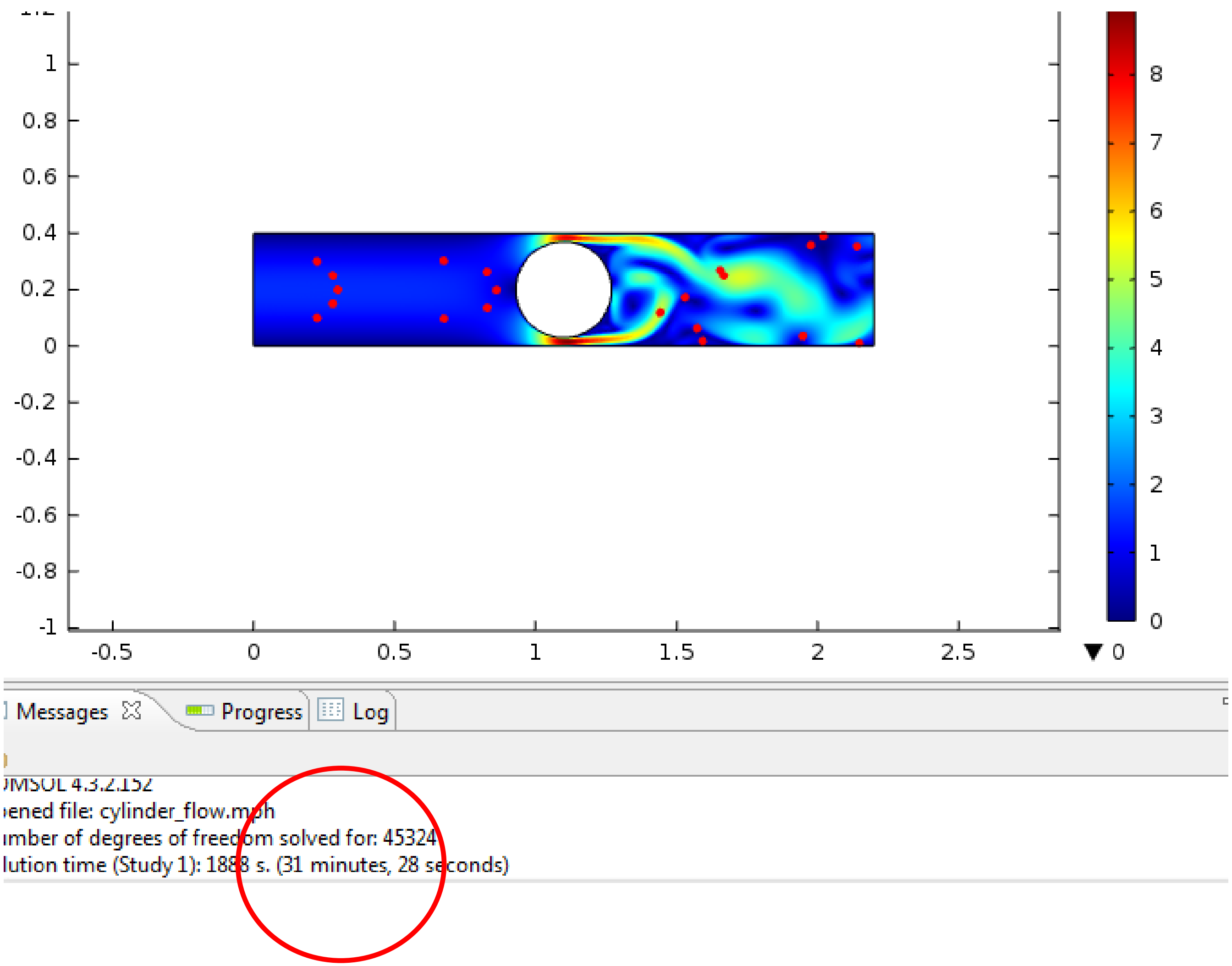



Circle
Model Library
Build Selected
Build All
Object Type
Type: Solid
Size and Shape
Radius: 0.17 m
Sector angle: 360 deg
Position
Base: Center
x: 1.1 m
y: 0.2 m
Rotation Angle
Rotation: 0 deg
Layers
Selections of Resulting Entities
Create selections
Graphics
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-0.5
0
0.5
1
1.5
2
2.5
3

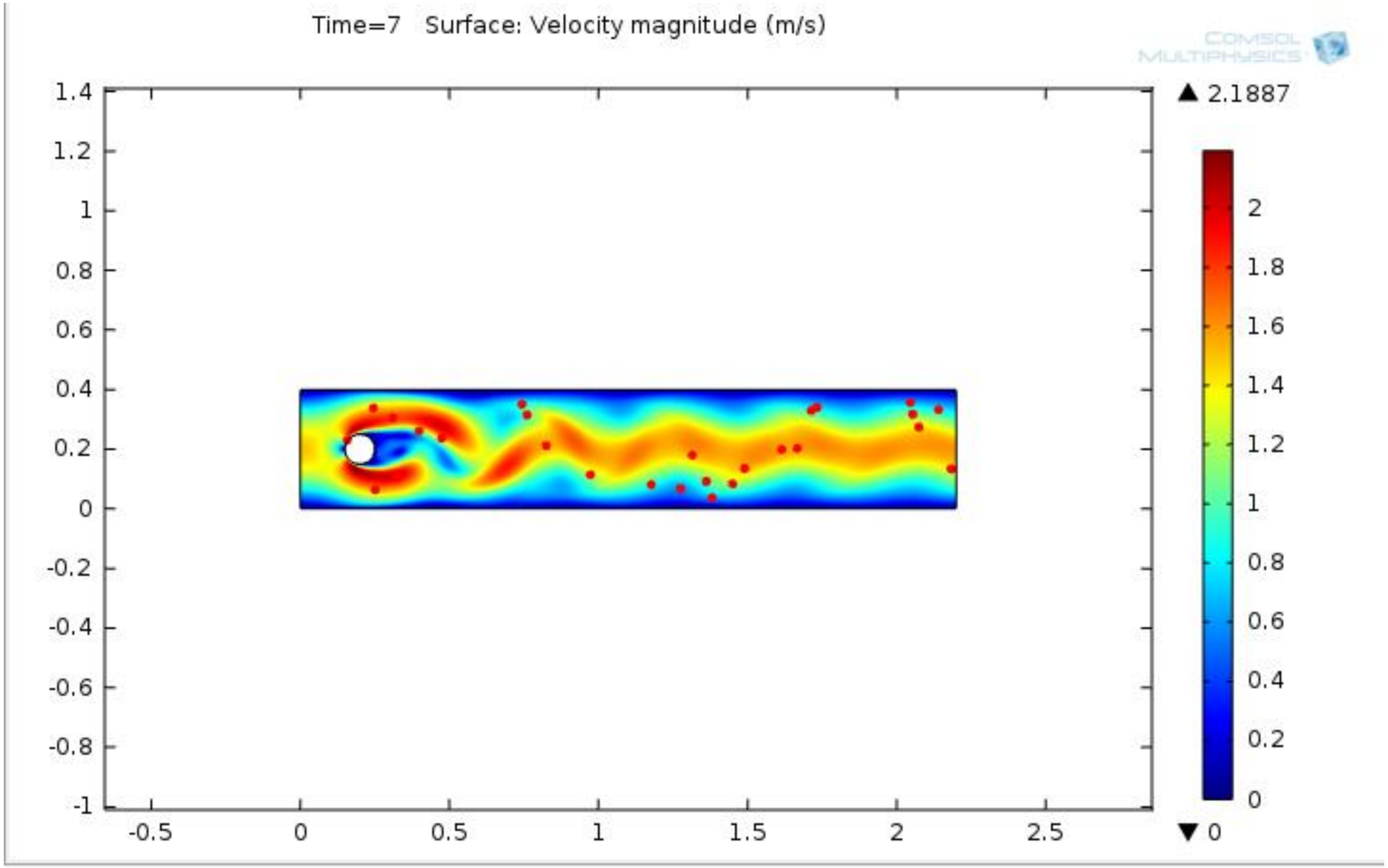
Material usado



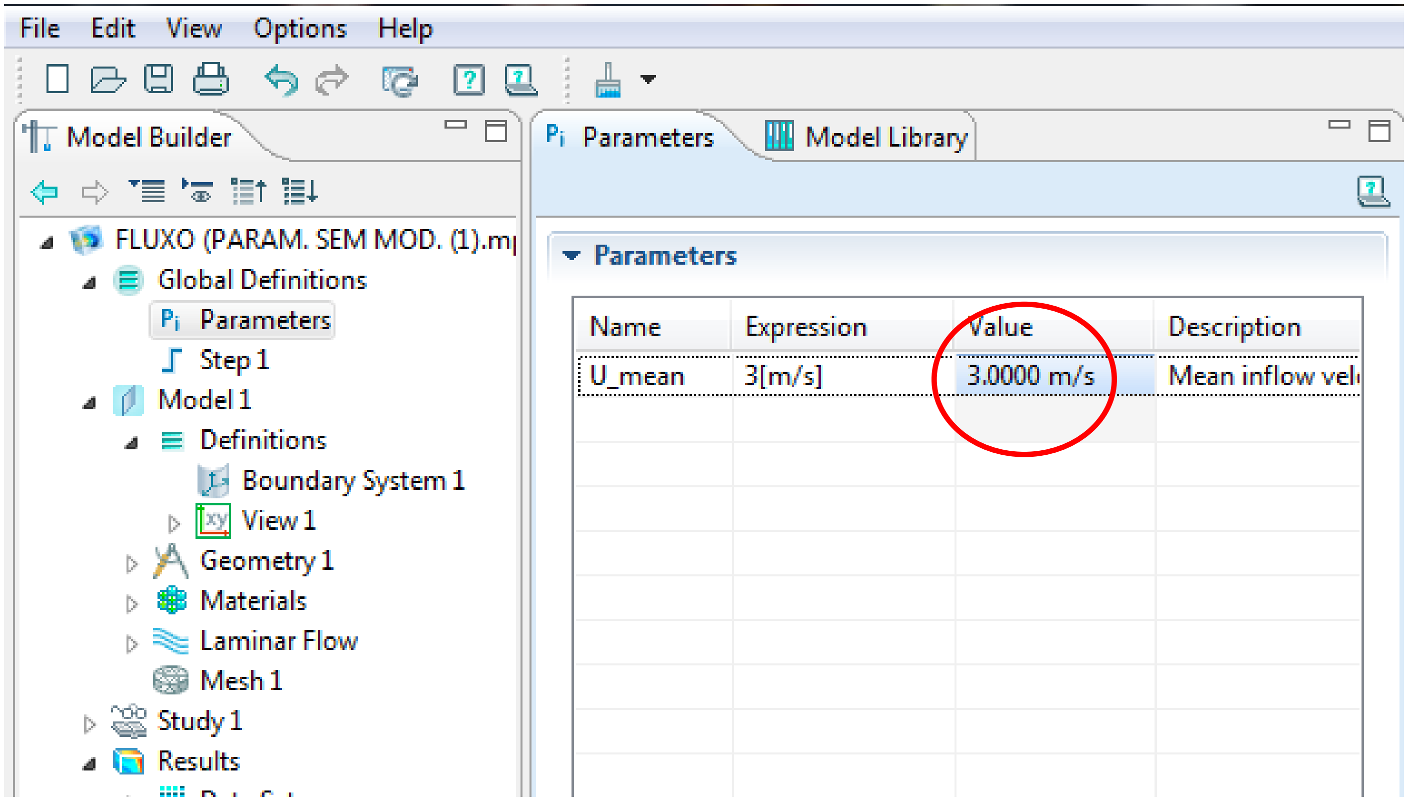
Tempo de simulação

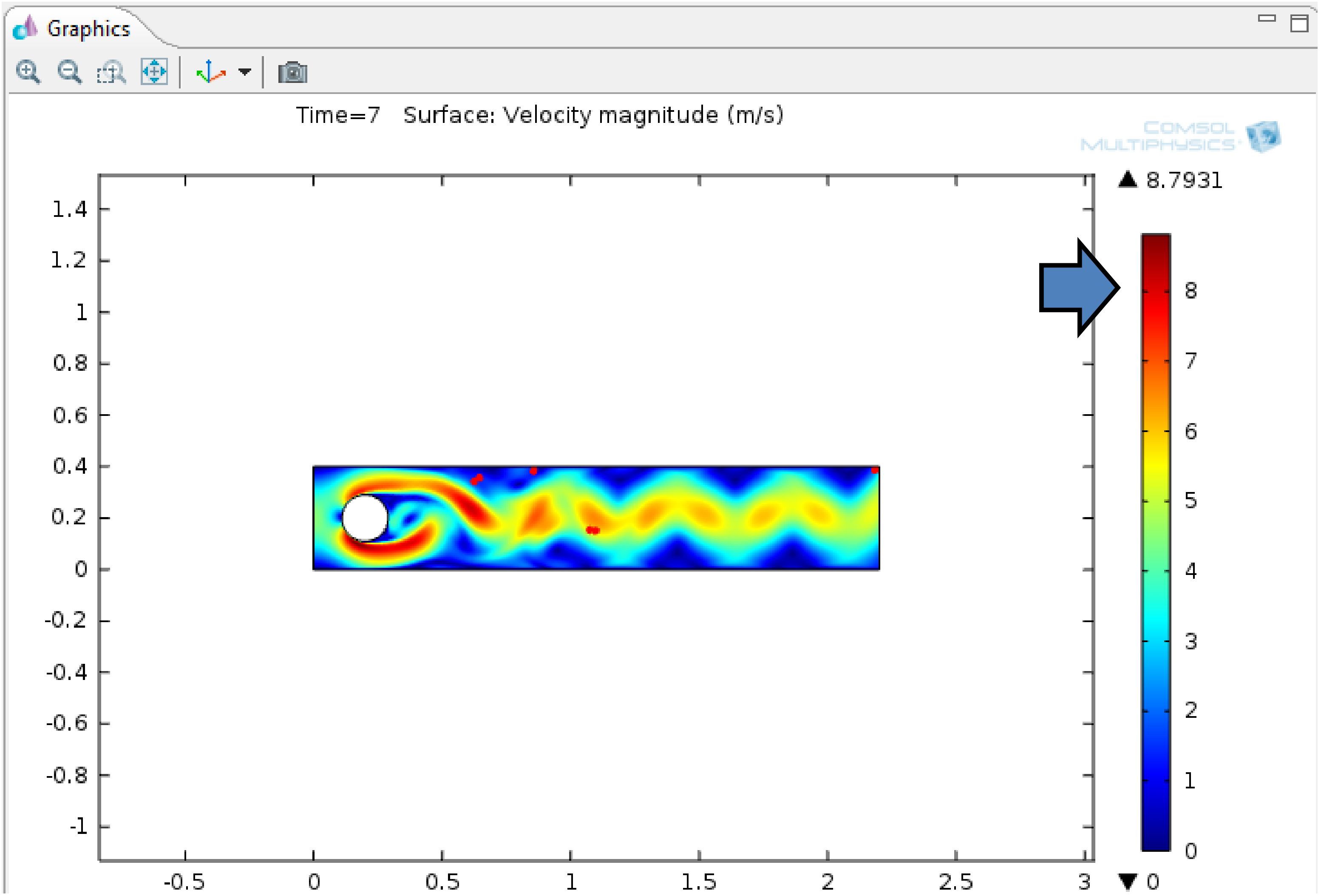


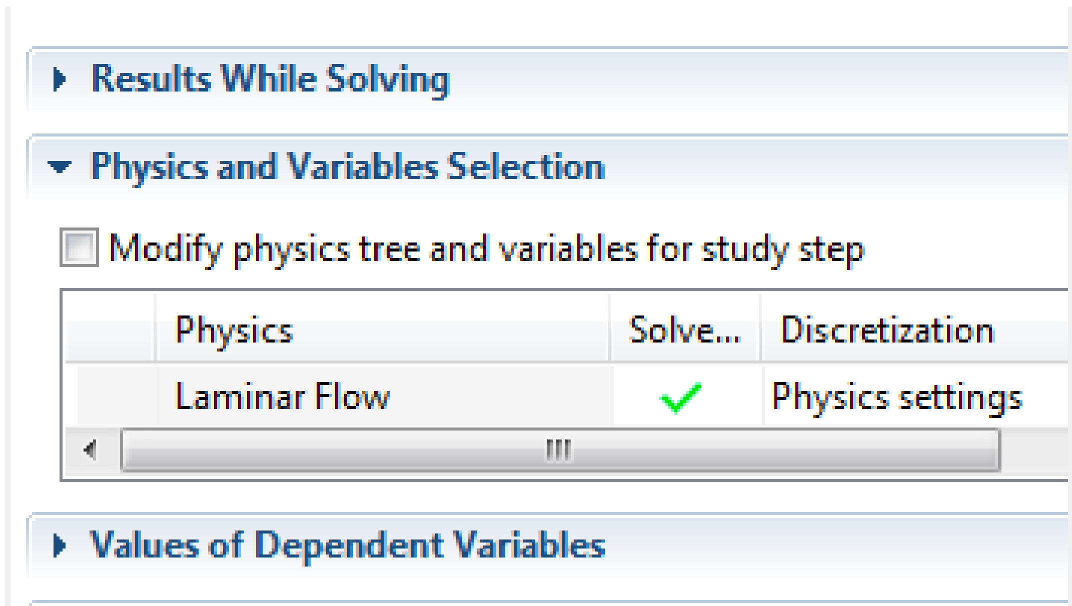
Sem modificação dos parâmetros



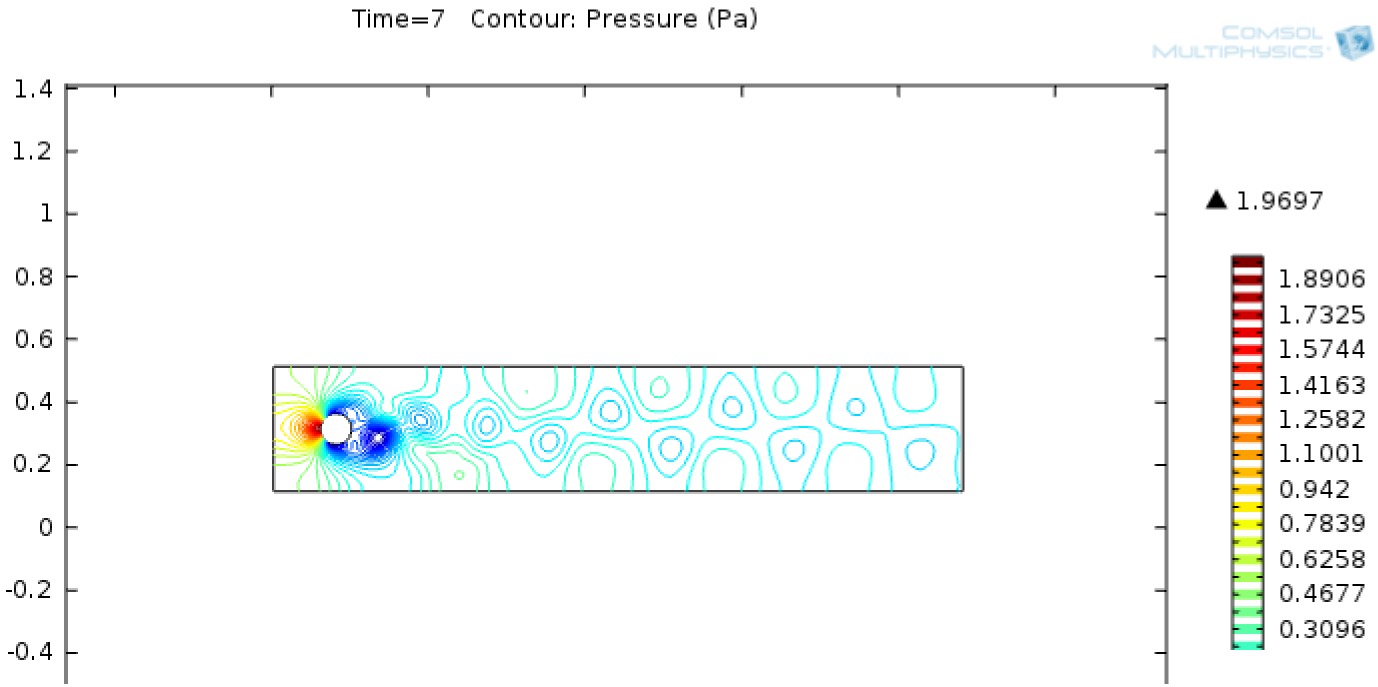
Alterando a velocidade inicial do fluxo



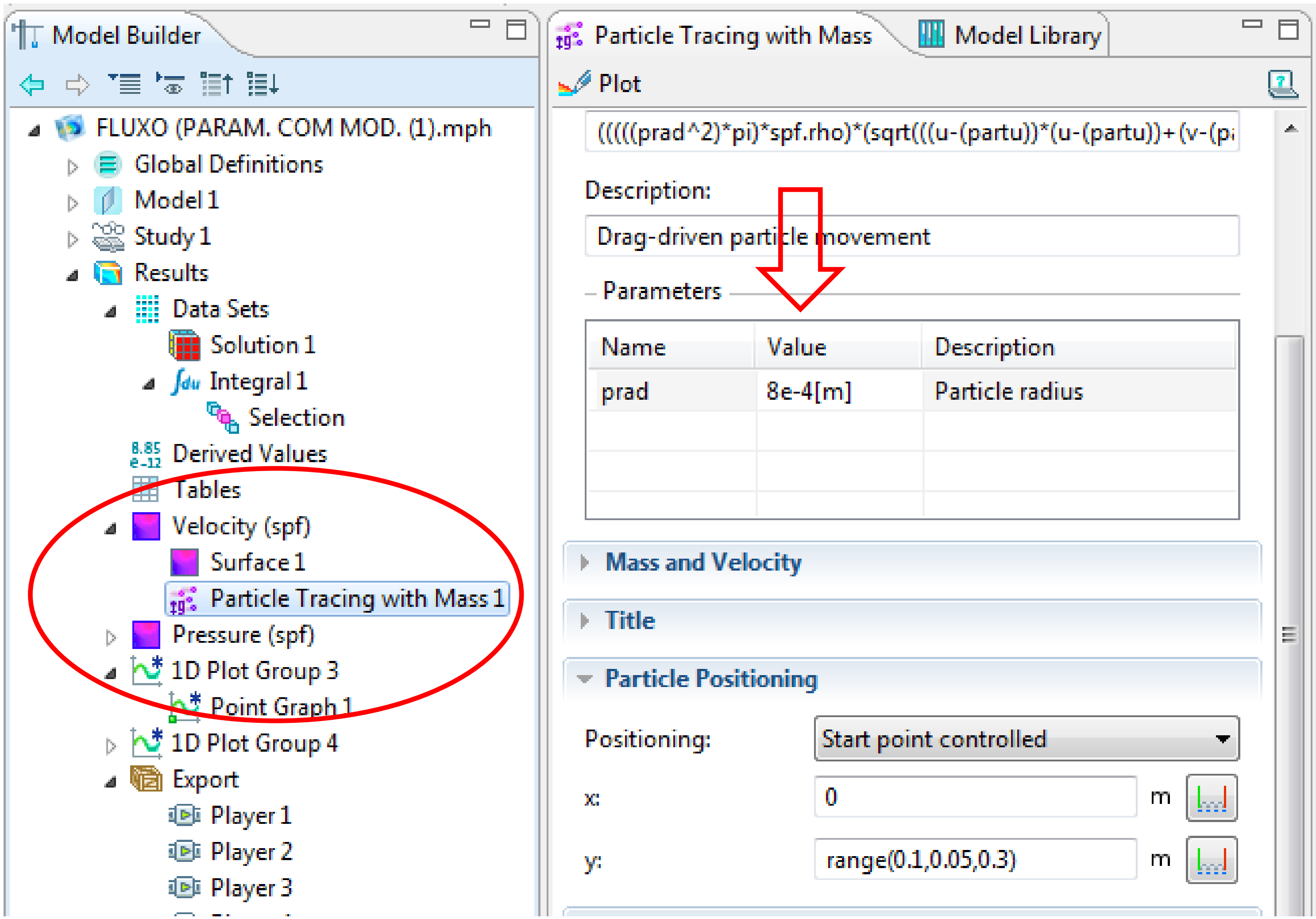

Graphics
Time=7 Surface: Velocity magnitude (m/s)
COMSOL MULTIPHYSICS
▲ 8.7931
▼ 0
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-0.5
0
0.5
1
1.5
2
2.5
3
8
7
6
5
4
3
2
1
0

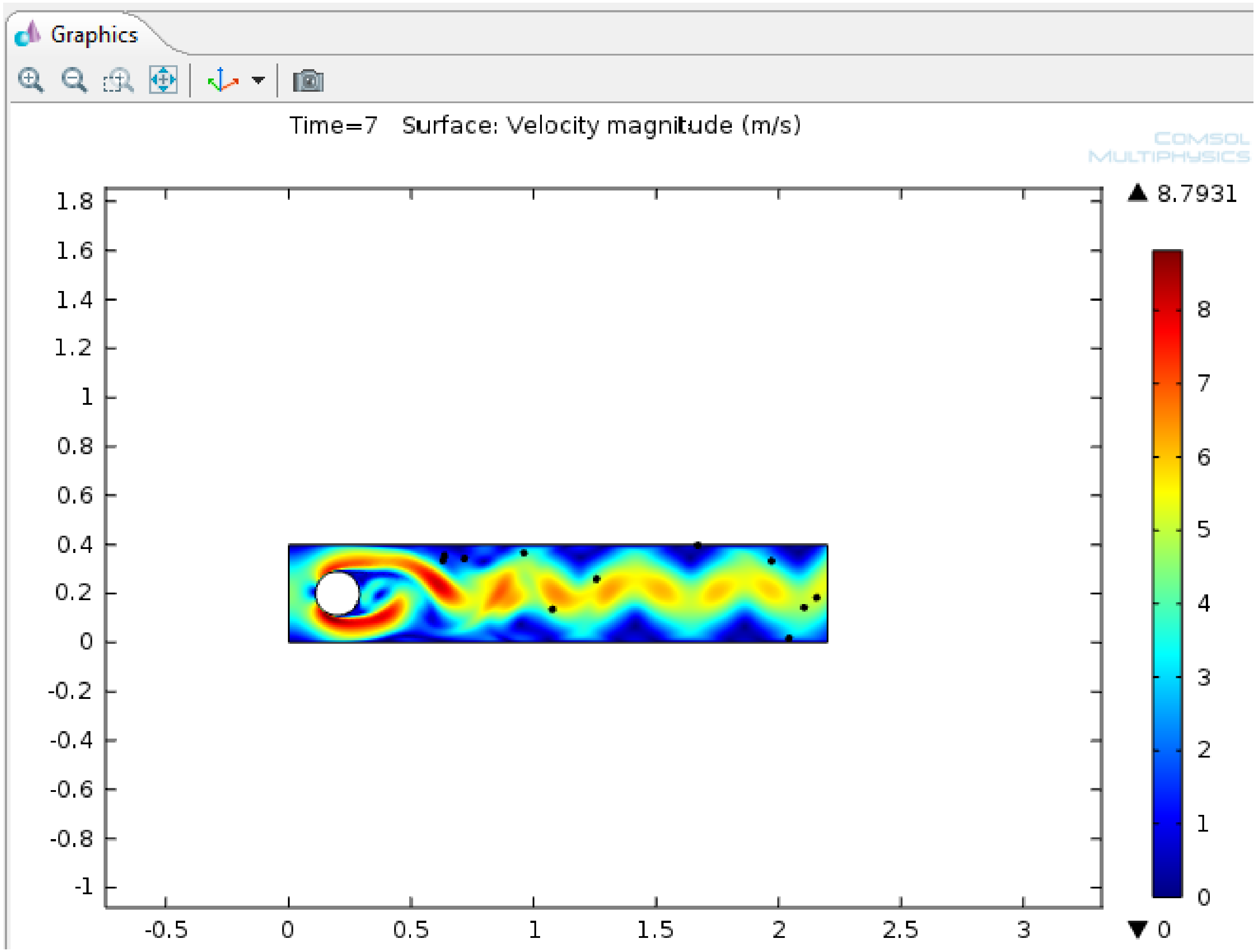

Results While Solving
Physics and Variables Selection
Modify physics tree and variables for study step
Physics
Solve...
Discretization
Laminar Flow
Physics settings
Values of Dependent Variables

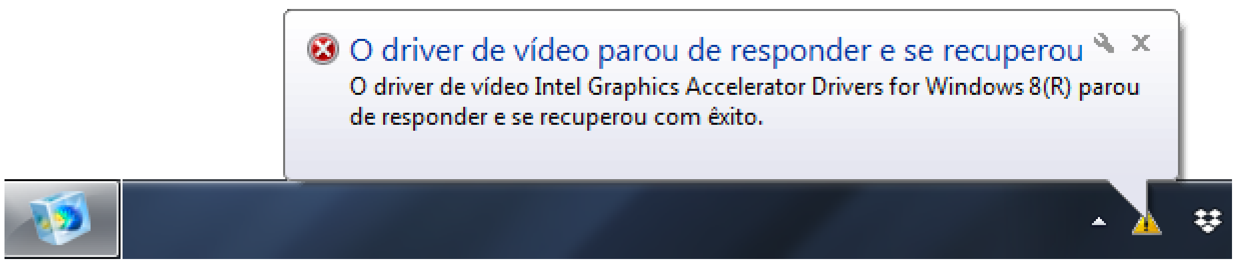
Resultados



Time=7 Contour: Pressure (Pa)
COMSOL MULTIPHYSICS
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
▲ 1.9697
1.8906
1.7325
1.5744
1.4163
1.2582
1.1001
0.942
0.7839
0.6258
0.4677
0.3096

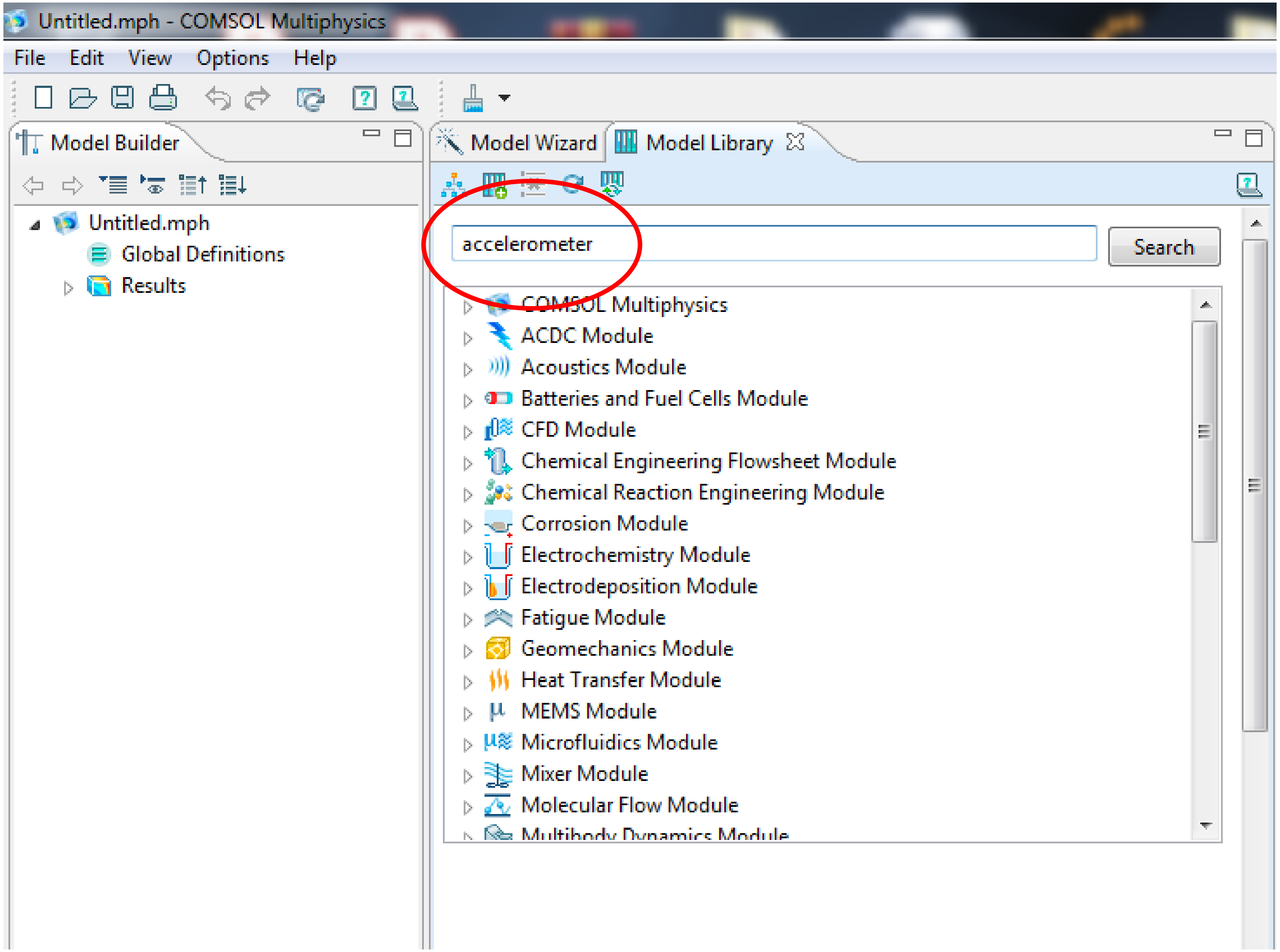

Model Builder
FLUXO (PARAM. COM MOD. (1).mph
Global Definitions
Model 1
Study 1
Results
Data Sets
Solution 1
Integral 1
Selection
Derived Values
Tables
Velocity (spf)
Surface 1
Particle Tracing with Mass 1
Pressure (spf)
1D Plot Group 3
Point Graph 1
1D Plot Group 4
Export
Player 1
Player 2
Player 3
Particle Tracing with Mass
Model Library
Plot
(((((prad^2)*pi)*spf.rho)*(sqrt(((u-(partu))*(u-(partu))+(v-(p
Description:
Drag-driven particle movement
Parameters
Name
Value
Description
prad
8e-4[m]
Particle radius
Mass and Velocity
Title
Particle Positioning
Positioning:
Start point controlled
x:
0
m
y:
range(0.1,0.05,0.3)
m

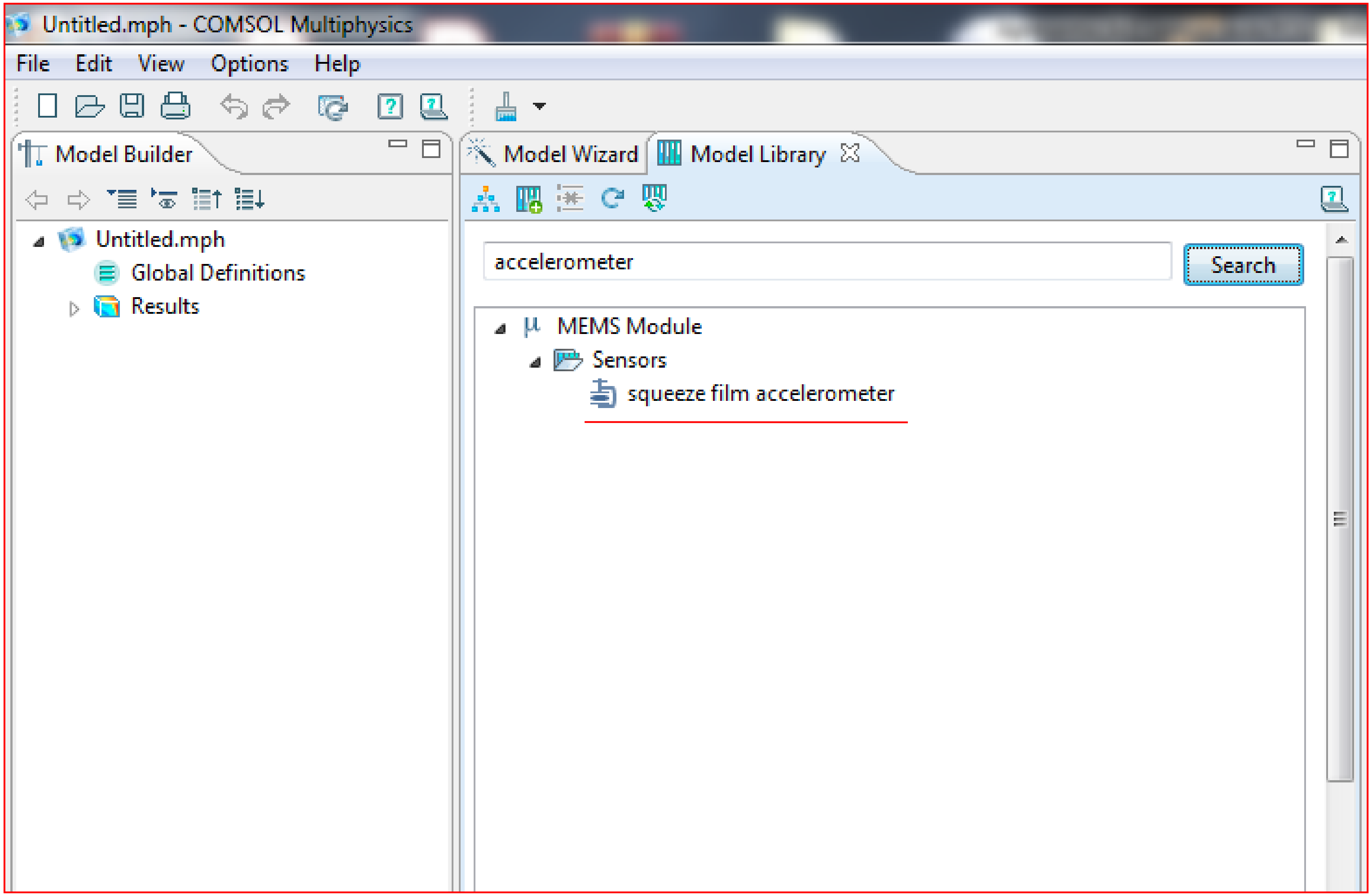

Graphics
Time=7 Surface: Velocity magnitude (m/s)
COMSOL MULTIPHYSICS
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-0.5
0
0.5
1
1.5
2
2.5
3
▲ 8.7931
8
7
6
5
4
3
2
1
0
▼ 0


O driver de vídeo parou de responder e se recuperou
O driver de vídeo Intel Graphics Accelerator Drivers for Windows 8(R) parou de responder e se recuperou com êxito.

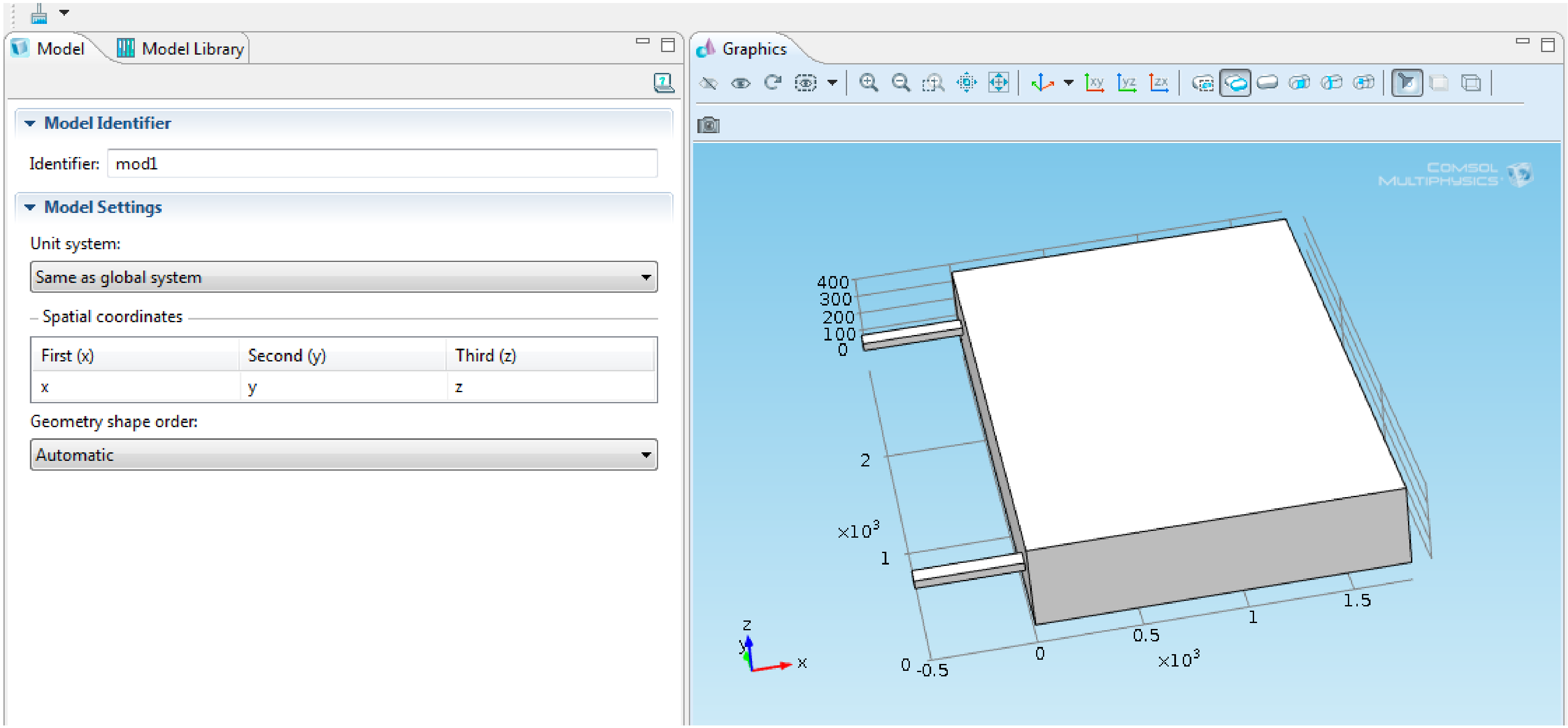
Acelerômetro

Modelos combinados em 3D e 2D mostram como o amortecimento de um filme comprimido no amortecimento de um gás pode ser acoplado aos deslocamentos mecânicos em um acelerômetro.

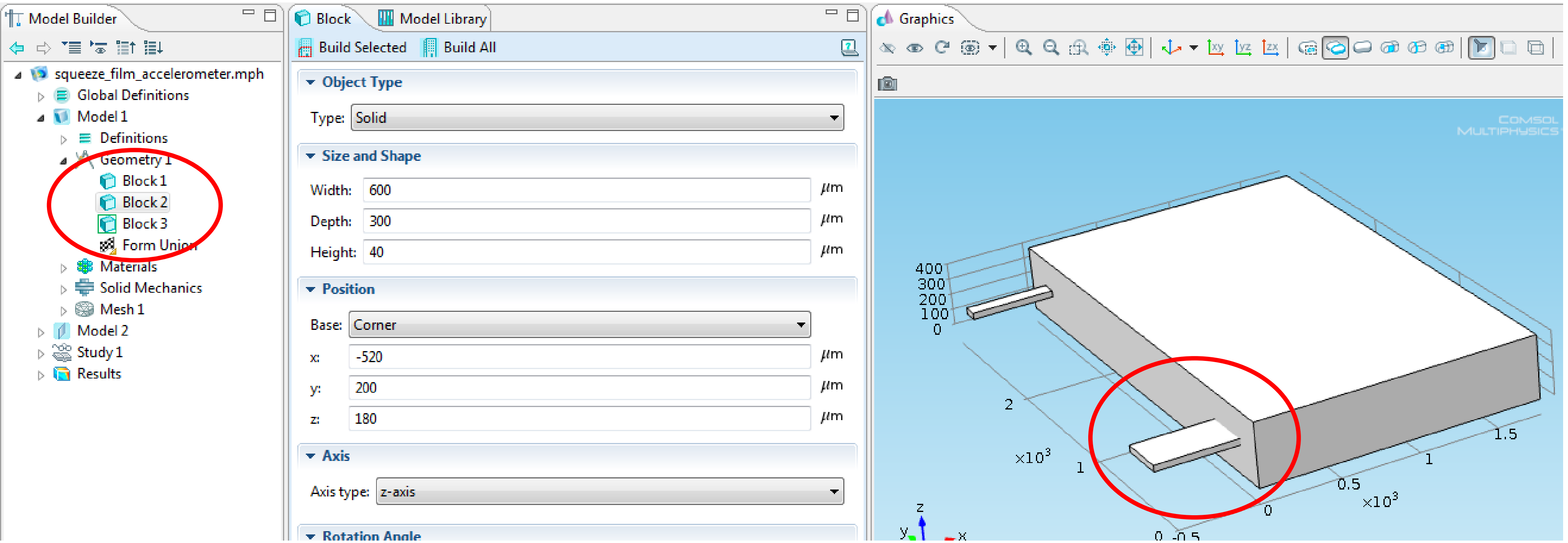

Untitled.mph - COMSOL Multiphysics
File
Edit
View
Options
Help
Model Builder
Untitled.mph
Global Definitions
Results
Model Wizard
Model Library
accelerometer
Search
COMSOL Multiphysics
ACDC Module
Acoustics Module
Batteries and Fuel Cells Module
CFD Module
Chemical Engineering Flowsheet Module
Chemical Reaction Engineering Module
Corrosion Module
Electrochemistry Module
Electrodeposition Module
Fatigue Module
Geomechanics Module
Heat Transfer Module
MEMS Module
Microfluidics Module
Mixer Module
Molecular Flow Module


Untitled.mph - COMSOL Multiphysics
File
Edit
View
Options
Help
Model Builder
Untitled.mph
Global Definitions
Results
Model Wizard
Model Library
accelerometer
Search
MEMS Module
Sensors
squeeze film accelerometer

Modelo 3D-COMSOL



Configurando a geometria

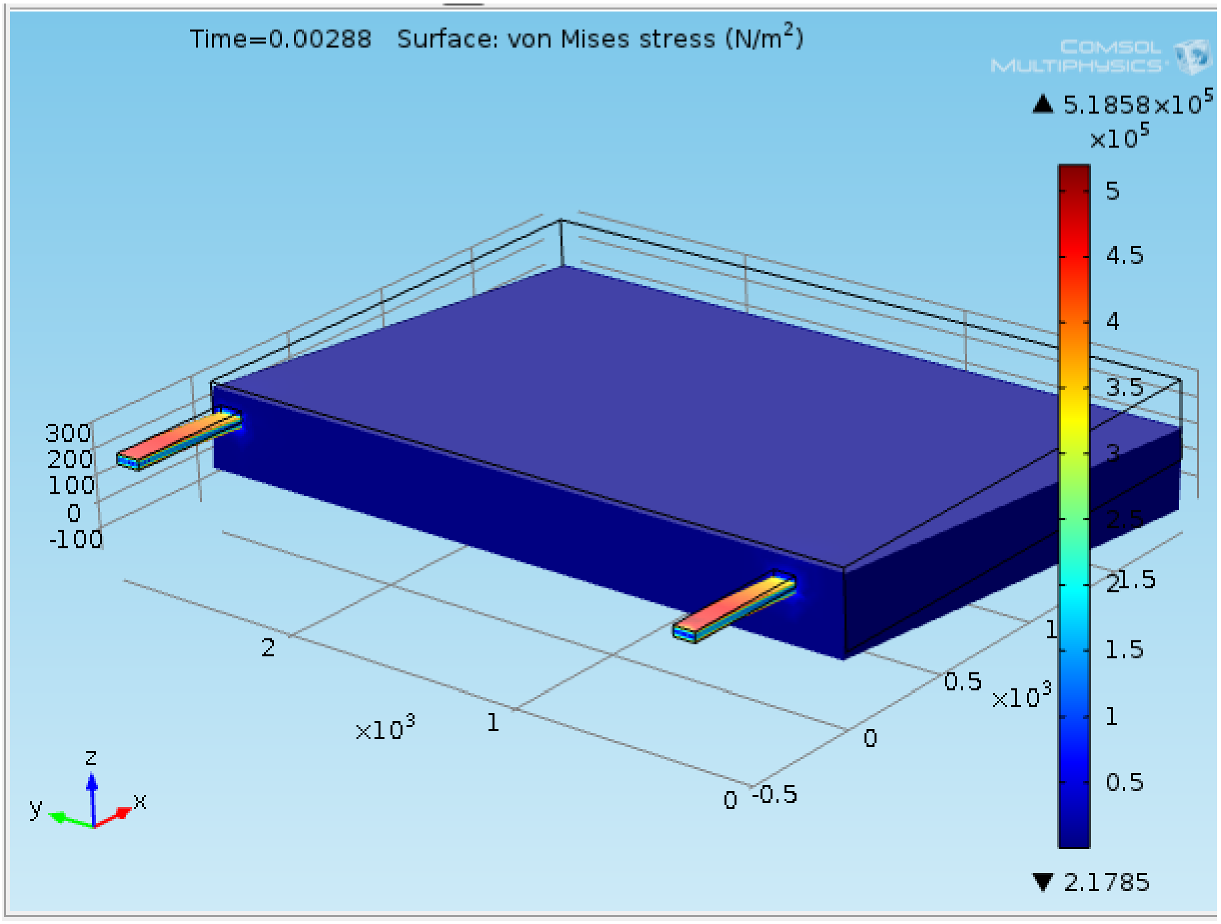


Este exemplo modela as partes móveis sólidas do acelerômetro usando o *Solid Interface* em 3D ; modelo restringe a pressão do filme (pf) a 0 nas bordas. (condição de contorno)

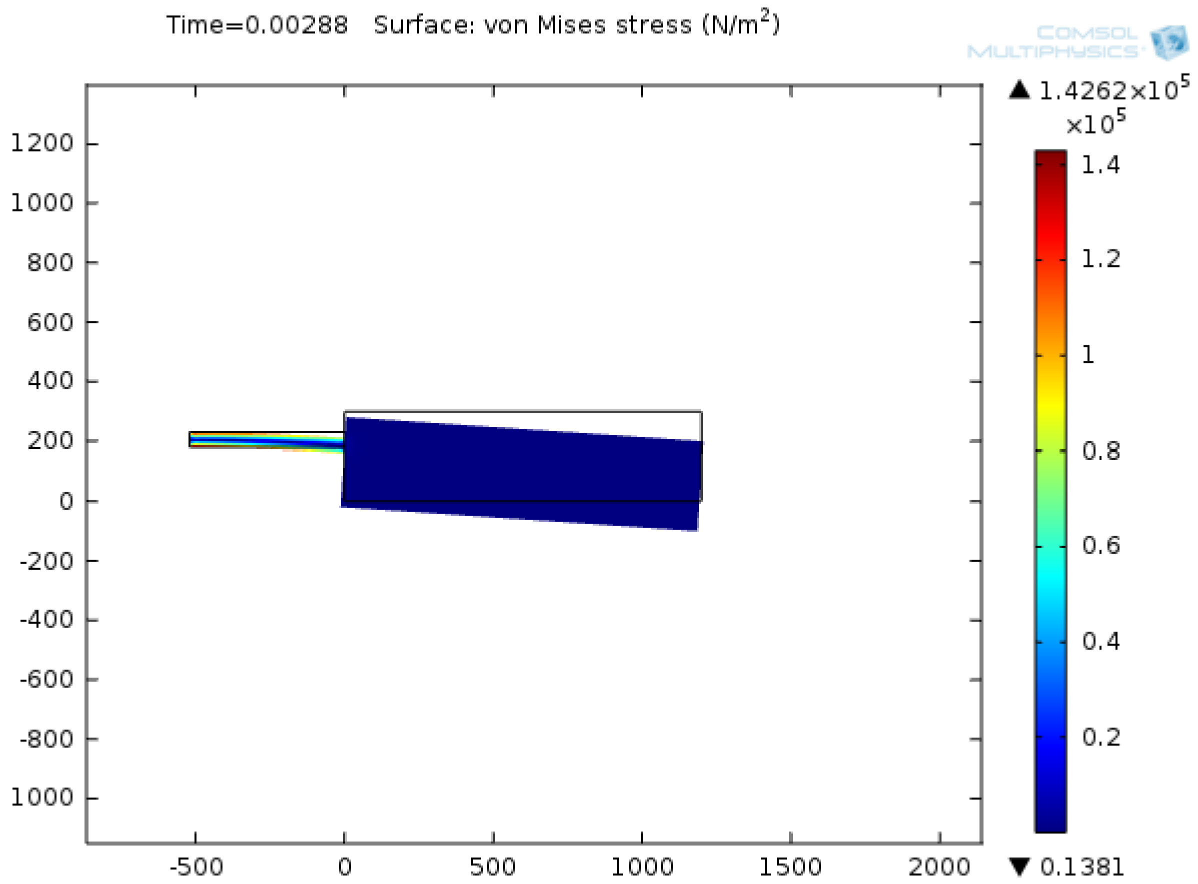
As duas figuras a seguir mostram a geometria do acelerômetro em 3D e em 2D. O modelo consiste em duas finas vigas (cantilever) de silício e uma massa de prova. O cantilever é fixado na estrutura circundante em uma das extremidades. A massa de prova reage à forças inerciais e deforma o cantilever. A aceleração externa (a), atua na direção z e causa uma força de volume

$F_z = \rho.\text{sólido}$.

3 D


Time=0.00288 Surface: von Mises stress (N/m²)
COMSOL MULTIPHYSICS
▲ 5.1858×10⁵
×10⁵
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
▼ 2.1785
300
200
100
0
-100
2
1
0
×10³
1
0.5
0
-0.5
×10³
z
y
x

2 D



Time=0.00288 Surface: von Mises stress (N/m²)
COMSOL MULTIPHYSICS
▲ 1.4262×10⁵
×10⁵
1.4
1.2
1
0.8
0.6
0.4
0.2
▼ 0.1381
1200
1000
800
600
400
200
0
-200
-400
-600
-800
1000
-500
0
500
1000
1500
2000

Exemplos fornecidos pelo COMSOL

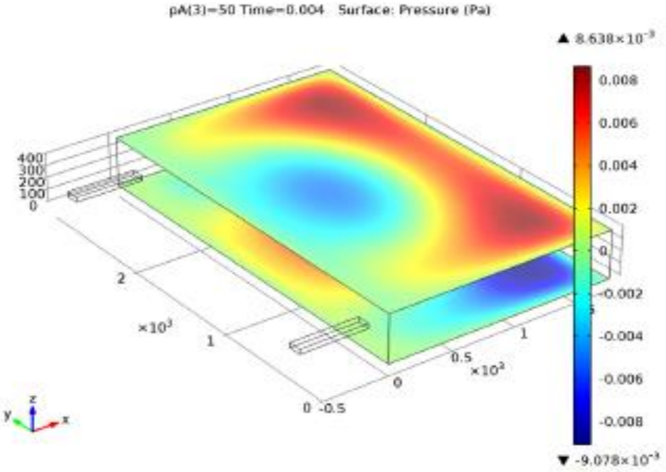


Figure 3: A load on the face of the proof mass in the z direction leads to a deformation.

Figure 4: The z displacement of the proof mass tip at ambient pressures of 3 Pa, 30 Pa, and

Sequência apresentada pelo COMSOL para simulação

- **Model Library path: MEMS_Module/Sensors/squeeze_film_accelerometer**
- **MODEL WIZARD**
-
- **GEOMETRY**
- **1** *Modeling Instructions* **1** Go to the **Model Wizard** window.
- **2** Click **Next**.
- **3** In the **Add physics** tree, select **Structural Mechanics>Solid Mechanics (solid)**.
- **4** Click **Next**.
- **5** Find the **Studies** subsection. In the tree, select **Preset Studies>Time Dependent**.
- **6** Click **Finish**.

- **1** In the **Model Builder** window, under **Model 1 (mod1)** click **Geometry 1**.
- **2** In the **Geometry** settings window, locate the **Units** section.
- **3** From the **Length unit** list, choose **µm**. *Block 1 (blk1)*
- **1** Right-click **Model 1 (mod1)>Geometry 1** and choose **Block**.
- **2** In the **Block** settings window, locate the **Size and Shape** section.
- **3** In the **Width** edit field, type 1780.
-
-
-
- **4** In the **Depth** edit field, type 2960.
- **5** In the **Height** edit field, type 400.
- *Block 2 (blk2)*
- **1** In the **Model Builder** window, right-click **Geometry 1** and choose **Block**. **2** In the **Block** settings window, locate the **Size and Shape** section. **3** In the **Width** edit field, type 520. **4** In the **Depth** edit field, type 100. **5** In the **Height** edit field, type 40.
- **6** Locate the **Position** section. In the **x** edit field, type -520.
- **7** In the **y** edit field, type 200.
- **8** In the **z** edit field, type 180.

STUDY 1

- Add a parametric sweep over the ambient pressure.
- **1** In the **Model Builder** window, expand the **Study 1** node. *Parametric Sweep* **1** Right-click **Study 1** and choose **Parametric Sweep**. **2** In the **Parametric Sweep** settings window, locate the **Study Settings** section. **3** Click **Add**. **4** In the table, enter the following settings:
- *Step 1: Time Dependent* **1** In the **Model Builder** window, under **Study 1** click **Step 1: Time Dependent**. **2** In the **Time Dependent** settings window, locate the **Study Settings** section. **3** In the **Times** edit field, type range(0,4e-5,4e-3). If you want smoother plots you can use a time step of 2e-5 (20 µs) or 1e-5 (10 µs) instead. The time step 40 µs gives reasonably smooth plots while keeping the MPH-file size down. **4** Select the **Relative**

Referências

- 1. J.B. Starr, "Squeeze-film Damping in Solid-state Accelerometers," *Technical Digest IEEE Solid-State Sensor and Actuator Workshop*, p. 47, 1990.
- 2. T. Veijola, H. Kuisma, J. Lahdenperä, and T. Ryhänen, "Equivalent-circuit Model of the Squeezed Gas Film in a Silicon Accelerometer," *Sensors and Actuators*, A 48, pp. 239–248, 1995.
- 3. M. Bao, H. Yang, Y. Sun, and P.J. French, "Modified Reynolds' Equation and Analytical Analysis of Squeeze-film Air Damping of Perforated Structures," *J. Micromech. Microeng.*, vol. 13, pp. 795–800, 2003.