On The Simulation of Electromagnetic Forming Process of Tube Using Multiphysics Software

Presented by

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Outline of Paper

- Aim of paper.
- High Velocity Forming(HVF).
- Electromagnetic forming(EMF).
- Simulation.
- Results and Conclusion.

Aim of Paper

- Demonstrating that Electromagnetic process can be simulated with a relatively simple model that has good correspondence to experimental data.

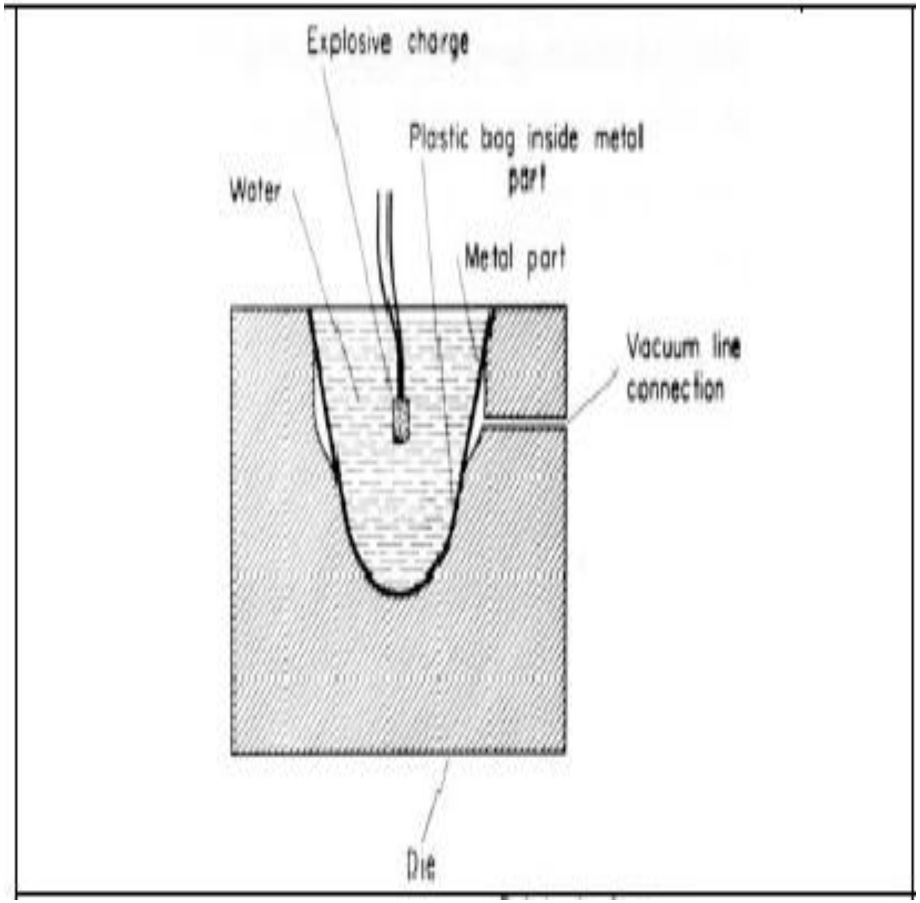
- Also, the validated model should be able to predict deformation at energy levels that cannot be achieved within safe operating limits of the equipment used presently, but can serve as a guide for next generation equipment.

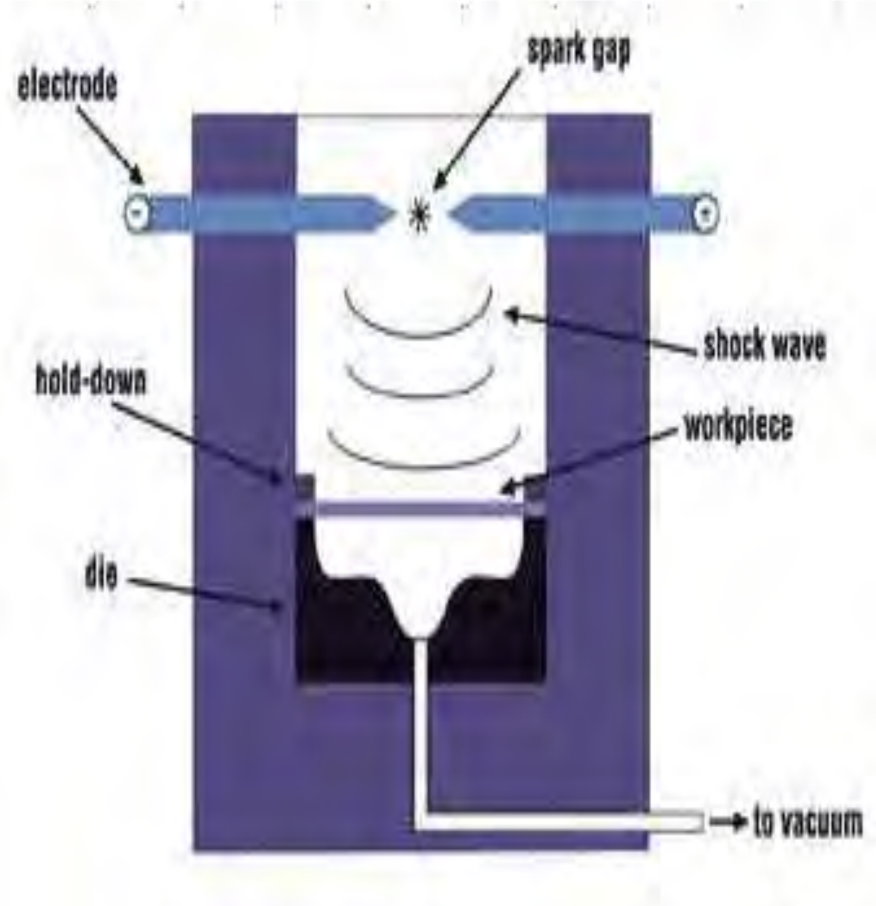
What Is High Velocity Forming

- High velocity forming (HVF) is the shaping of materials by rapidly conveying energy to them during short time durations.
- It is also known as a **HERF/HVF** process.
- The HVF forming velocity of workpiece reaches up to 100m/sec in less than 0.1 ms .
- The HERF processes are:

  (i)Explosive, (ii)Electro-Hydraulic, and

  (iii) Electromagnetic Forming.
- EMF is the most widely used HERF process in industries

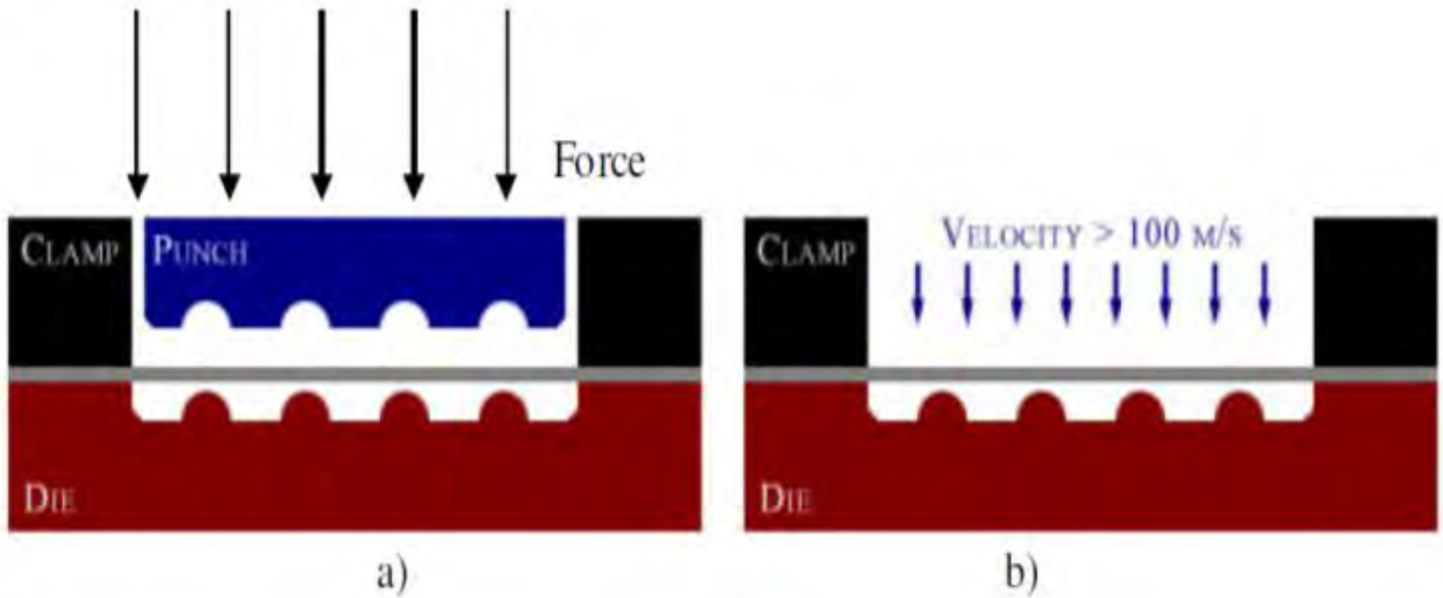




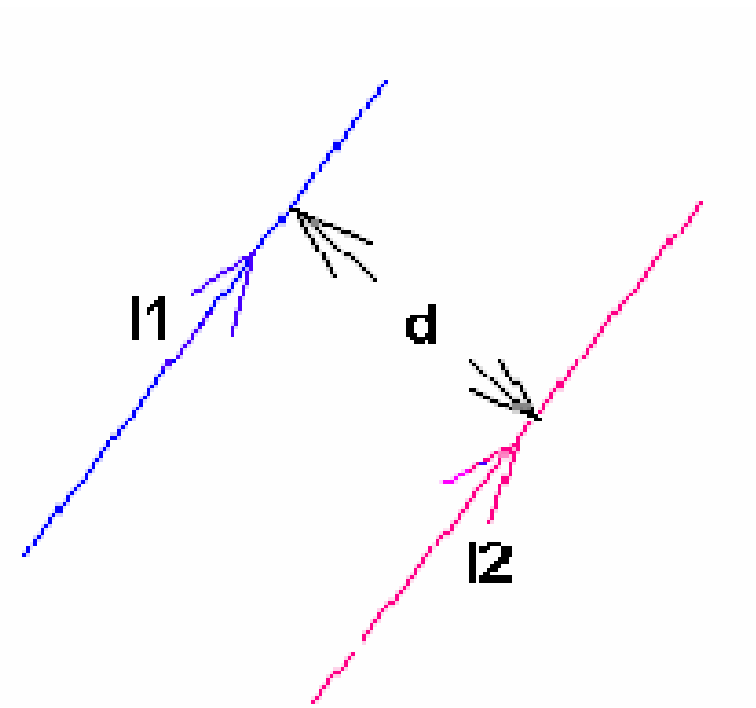
Explosive[1]

Electro-Hydraulic[1]

Traditional & Electromagnetic Forming[1]



Principle of EM Forming



$$F = \frac{\mu_0}{2\pi d} I_1 I_2$$

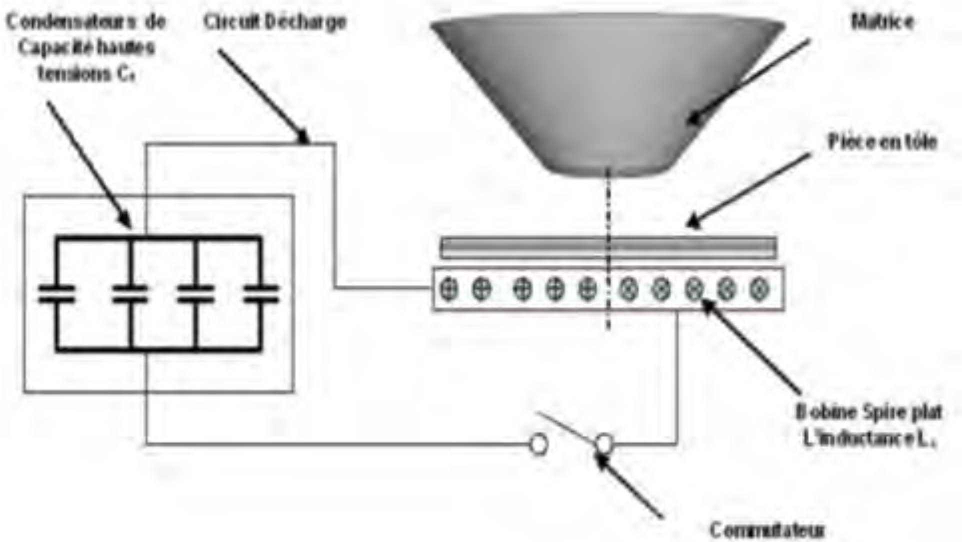
F **= Force; N/m,**

I1, *I*2 = Current; A

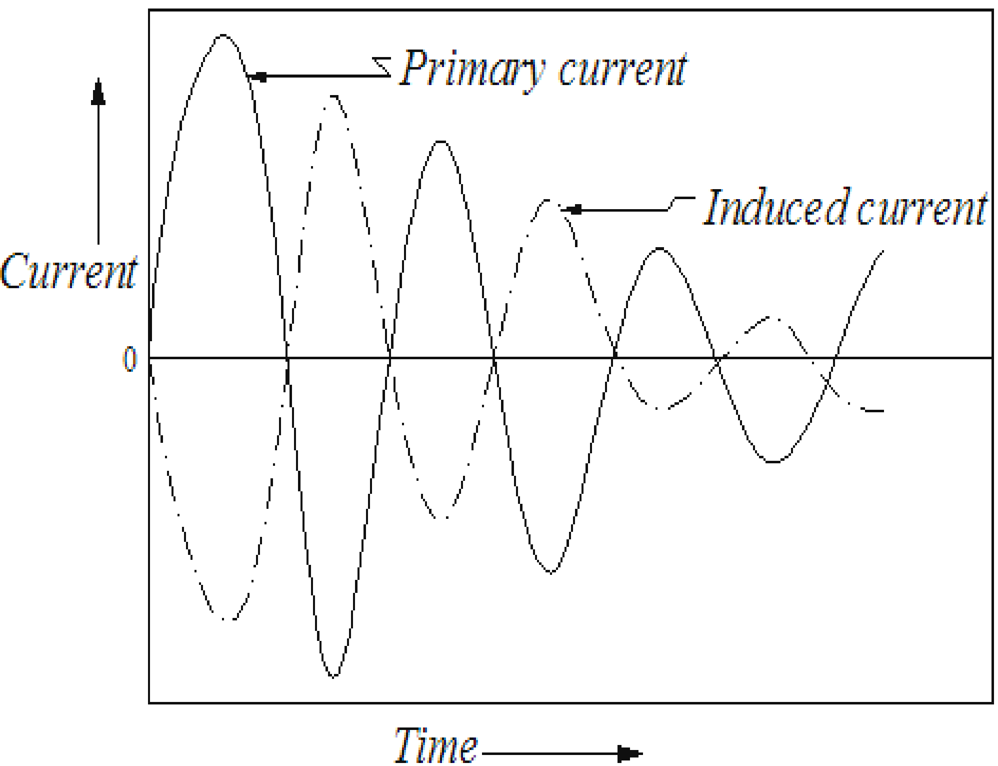
d = Spacing between conductors

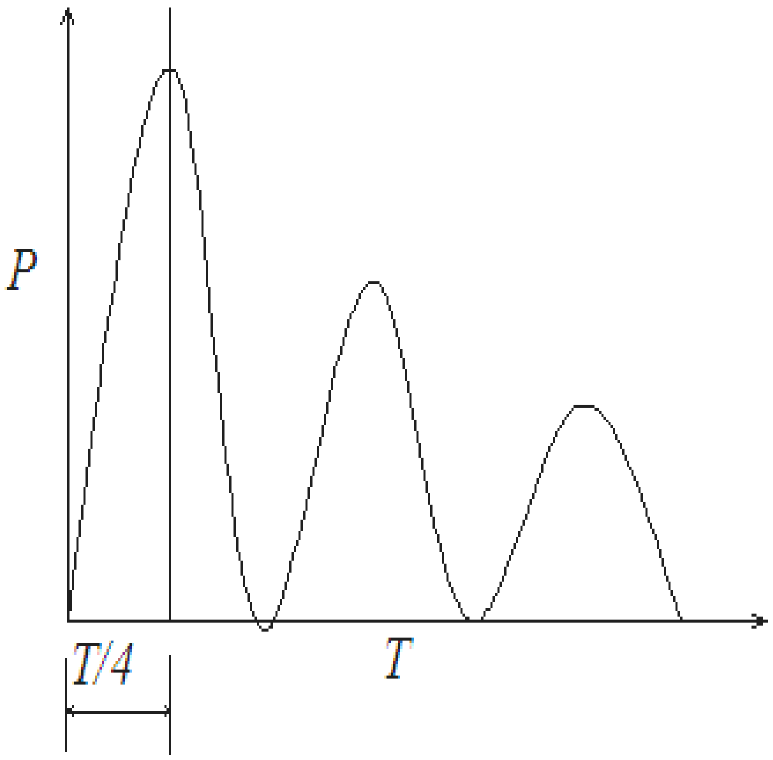
μ_0=permeability of free space; H/m

Electromagnetic Forming



Current and pressure in EMF Process



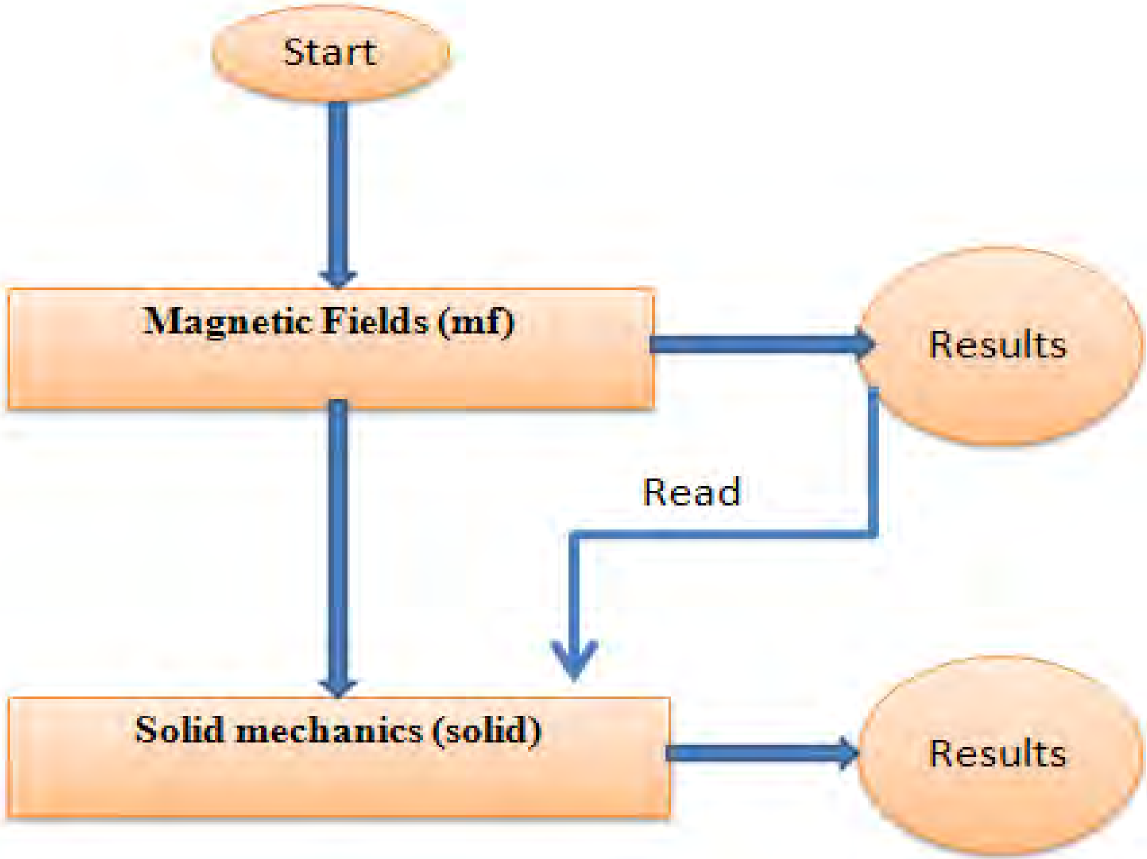


$$I(t) = \frac{V_0}{\omega L}\, e^{\frac{-R_S t}{2L}}\, \sin(\omega t)$$

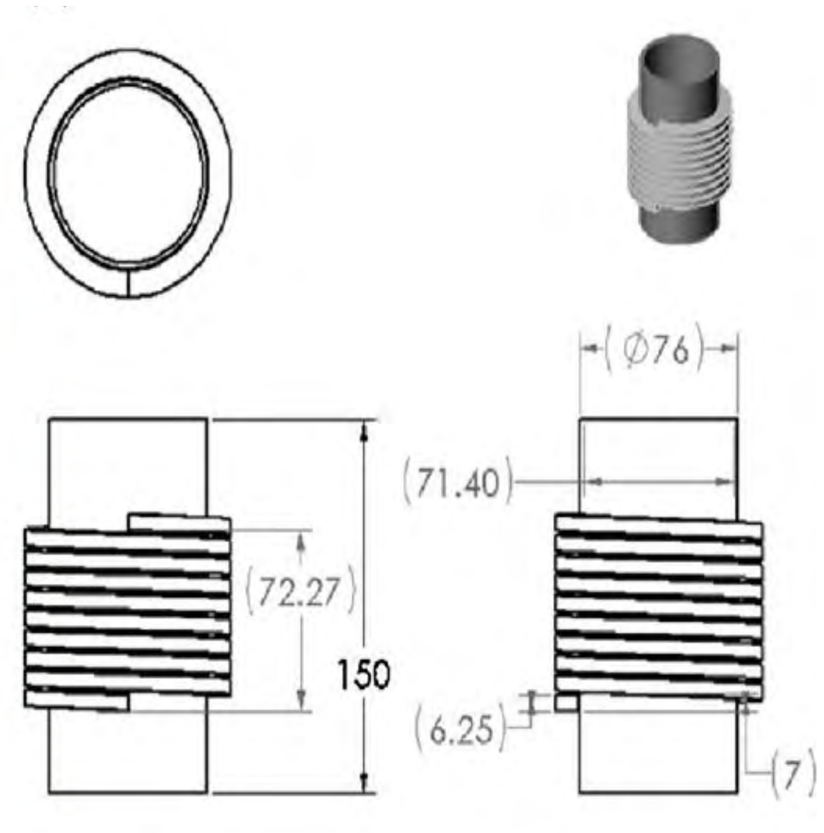
Application

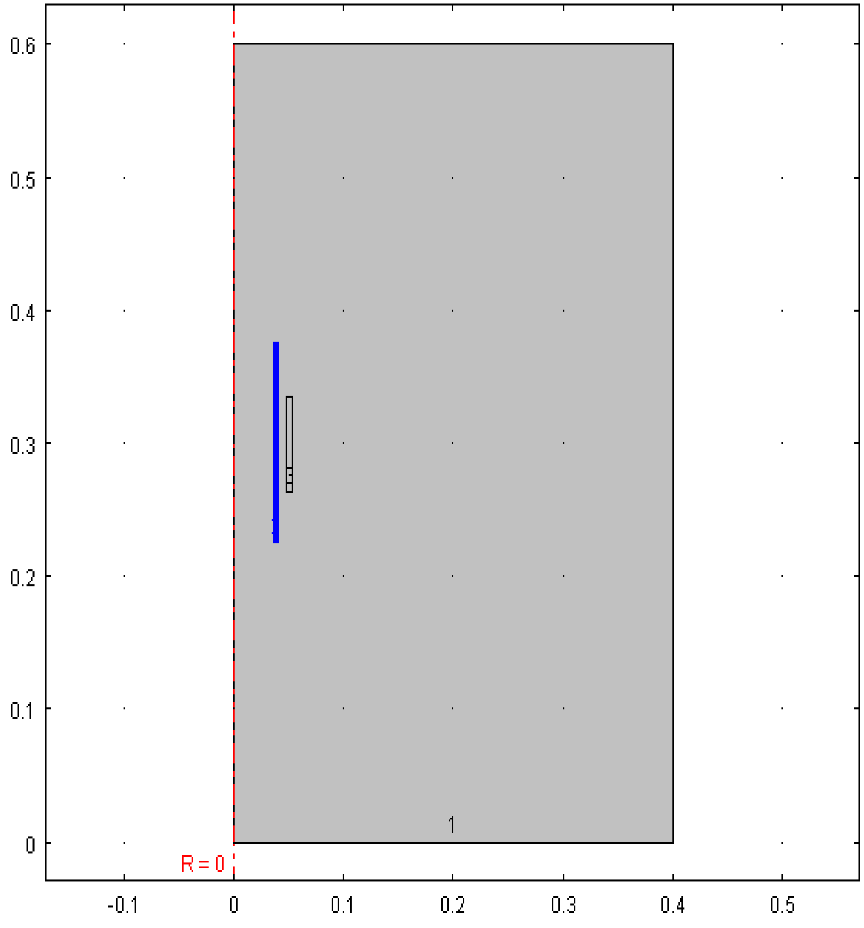
Application

Simulation Flow Chart



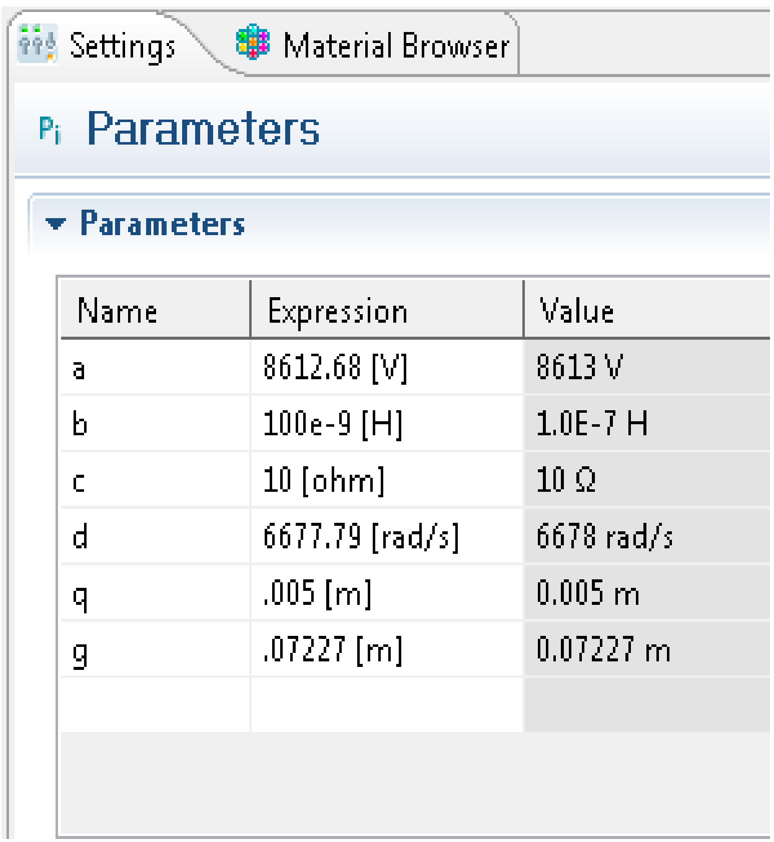
Modeling of EMF system



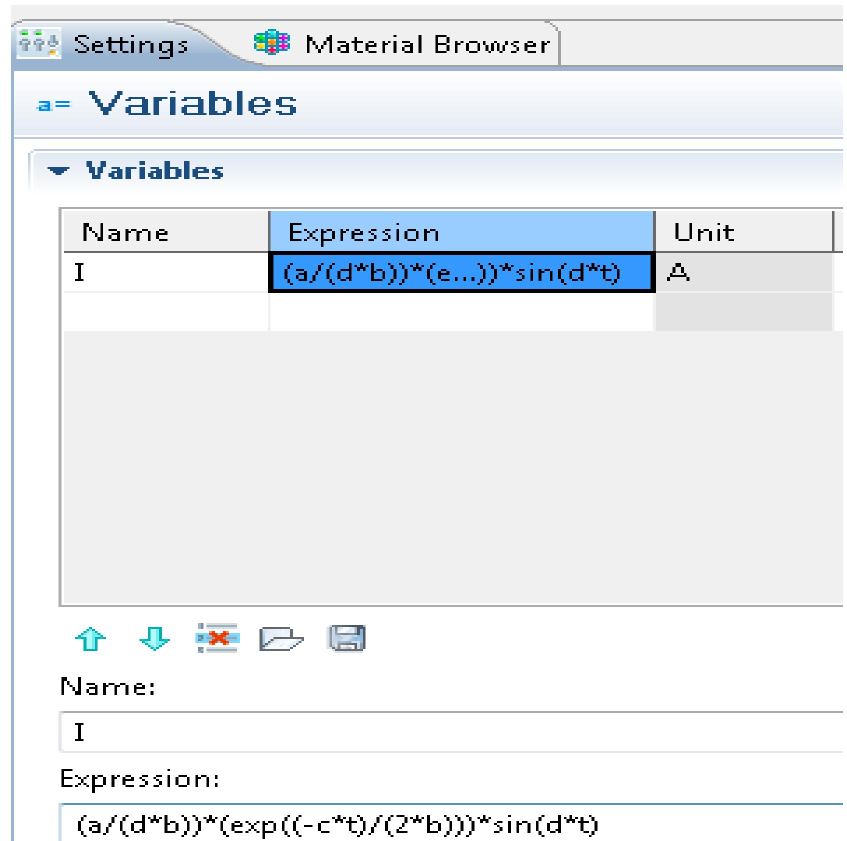


Global Parameters and Variables.

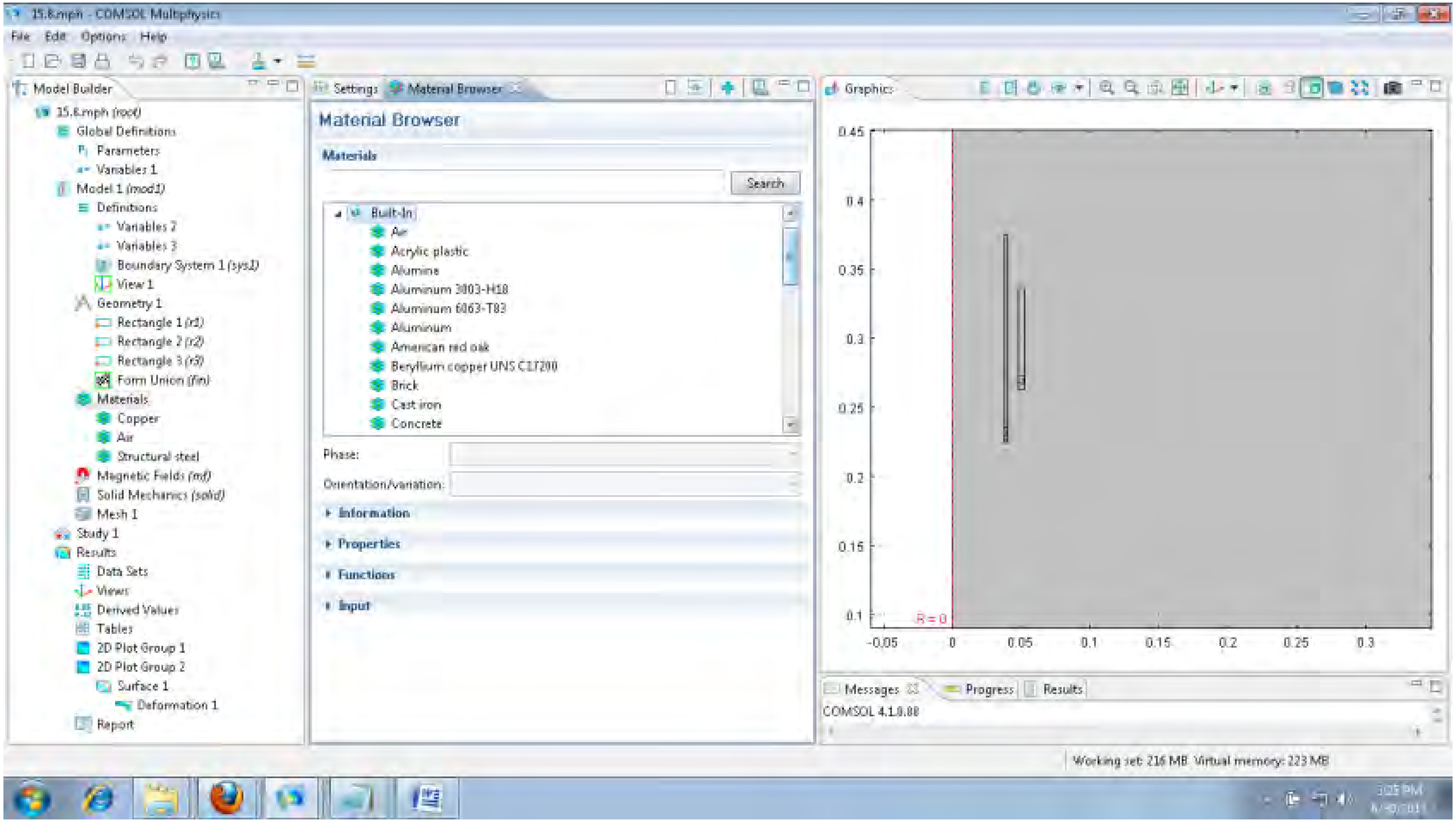
$$I(t) = \frac{V_0}{\omega L}\, e^{\frac{-R_S t}{2L}}\, \sin(\omega t)$$



Name	Expression	Value
a	8612.68 [V]	8613 V
b	100e-9 [H]	1.0E-7 H
c	10 [ohm]	10 Ω
d	6677.79 [rad/s]	6678 rad/s
q	.005 [m]	0.005 m
g	.07227 [m]	0.07227 m

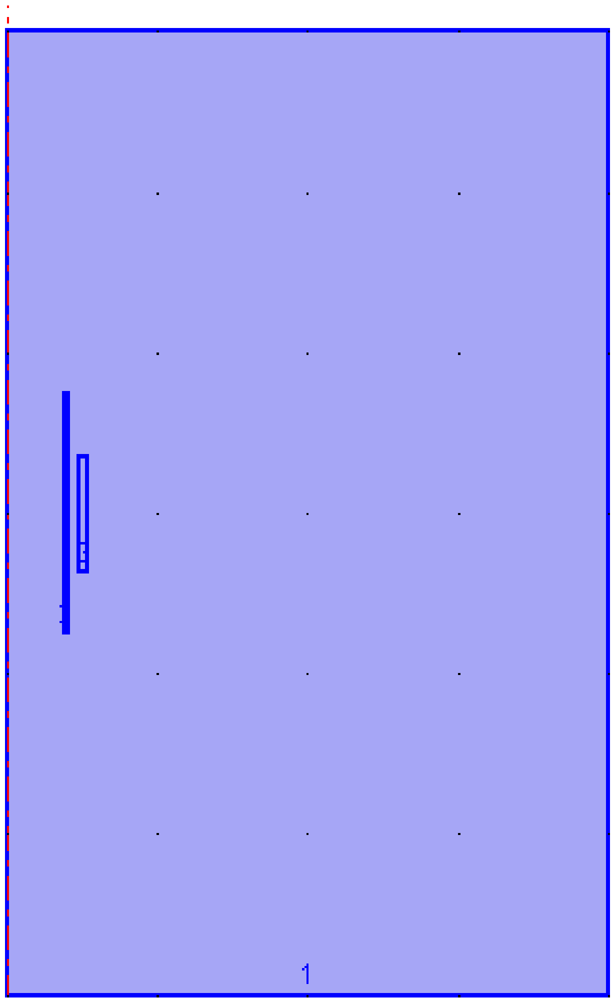


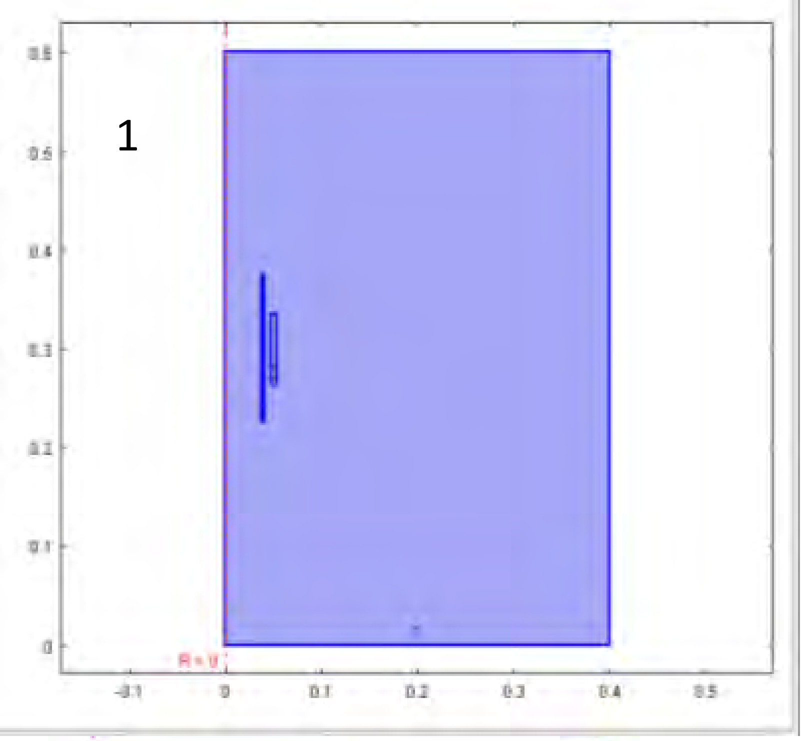
Define Material



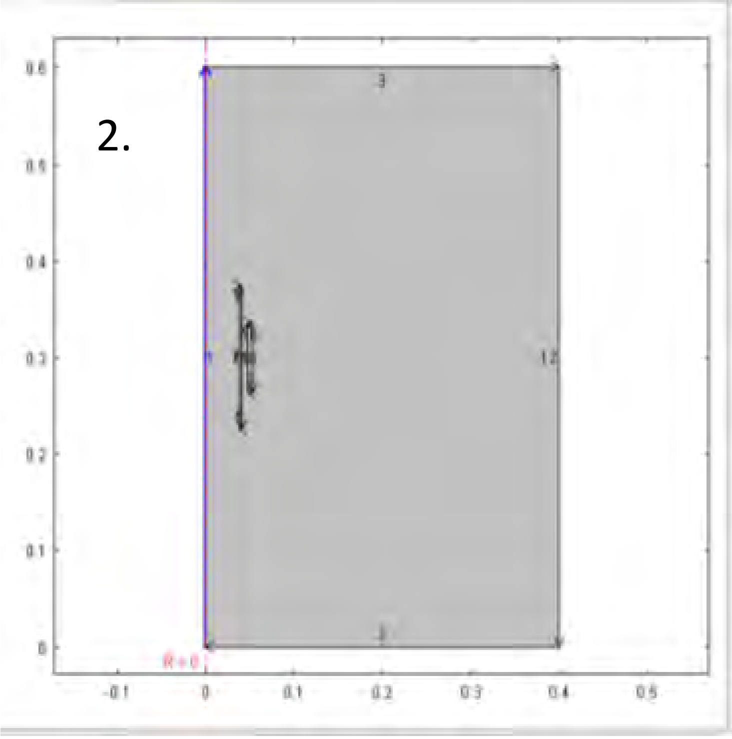
Magnetic Field Boundary Condition

Magnetic field physics is applied to all domain



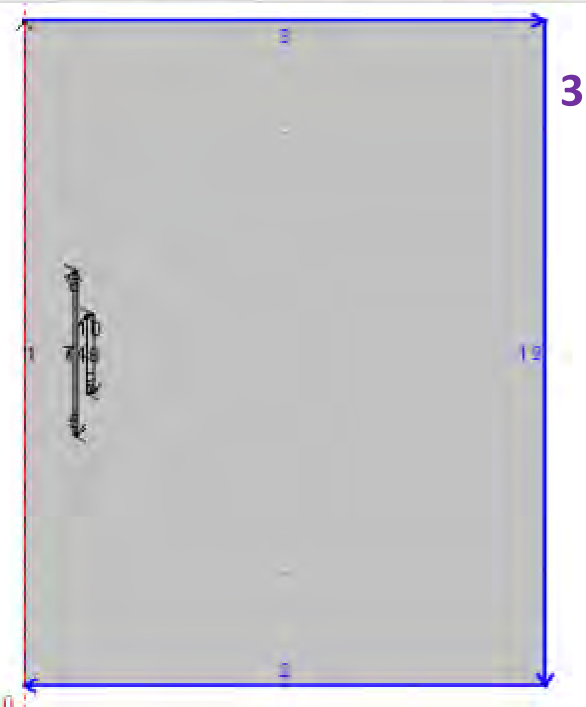


1.Ampere's Law



2.Axial Symmetry

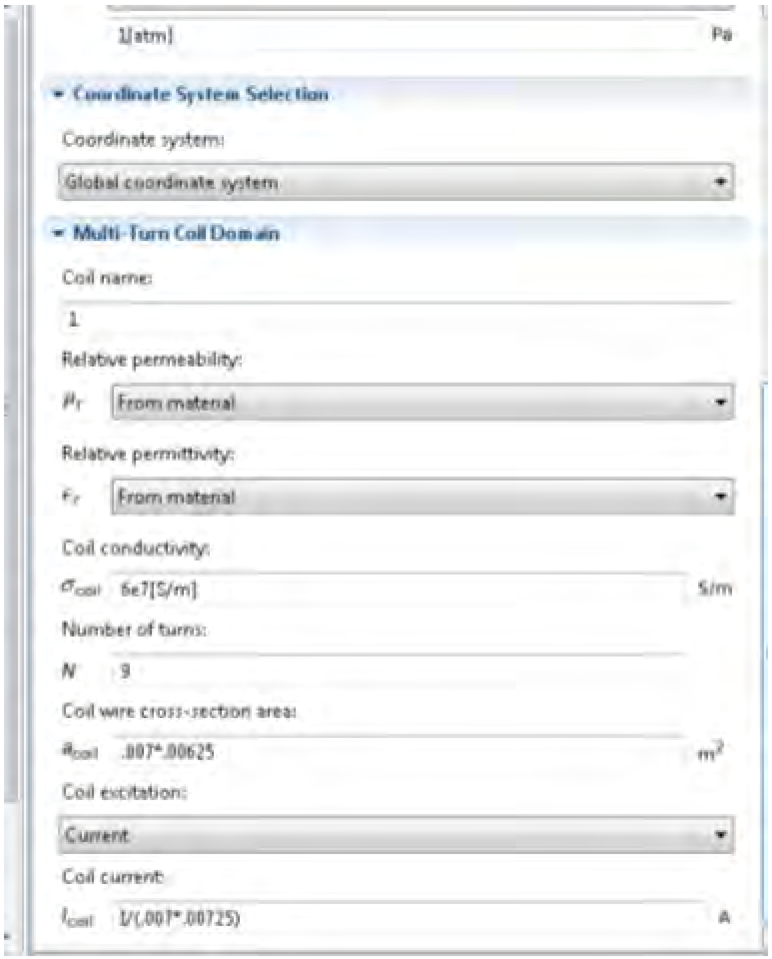
3

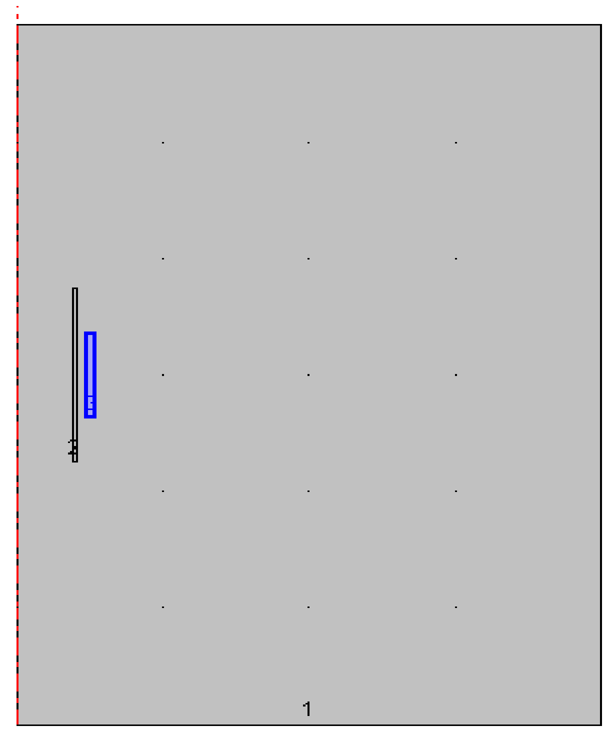


3.Magnetic Insulation

4

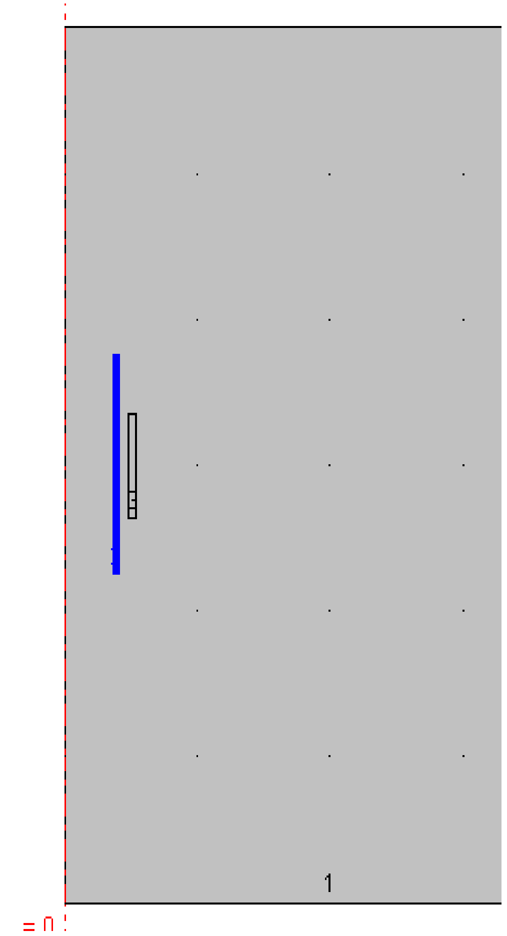
4.Initial value



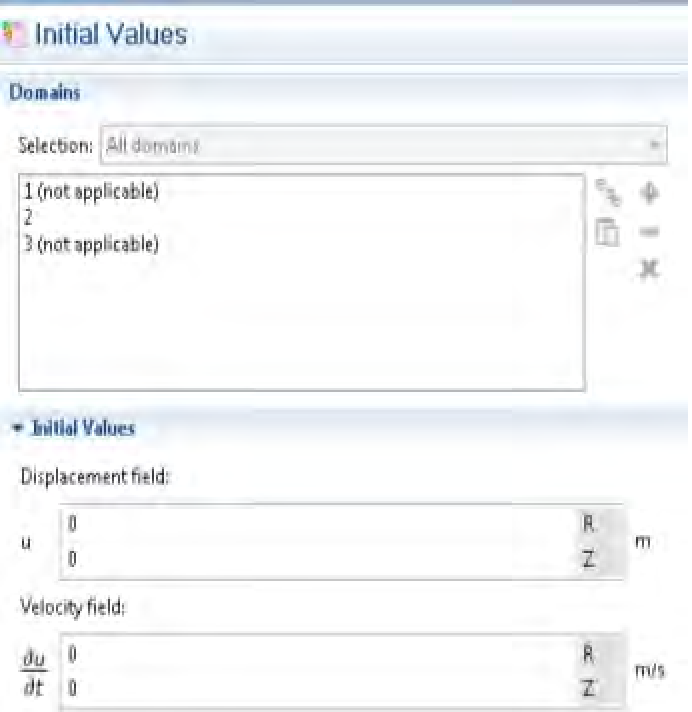


5.Multi-Turn Coil Domain

Solid Mechanics Boundary Condition



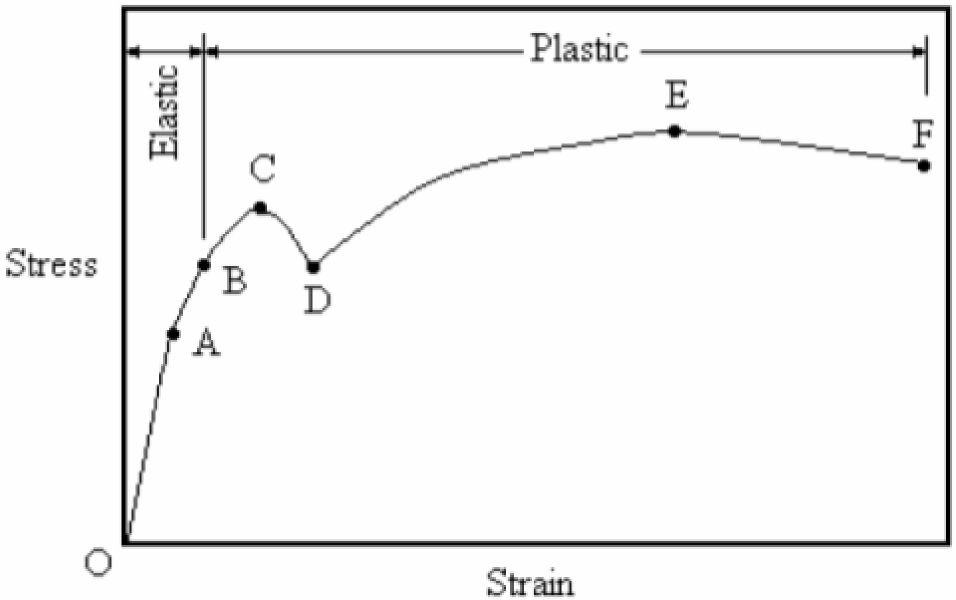
Solid Mechanics is applied to domain 2

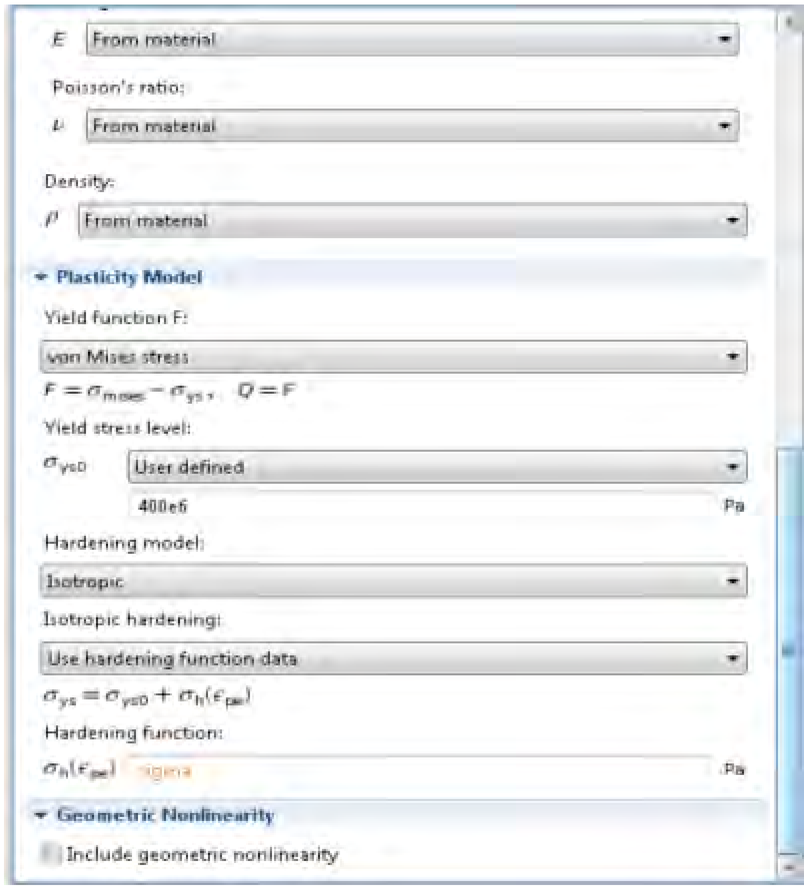


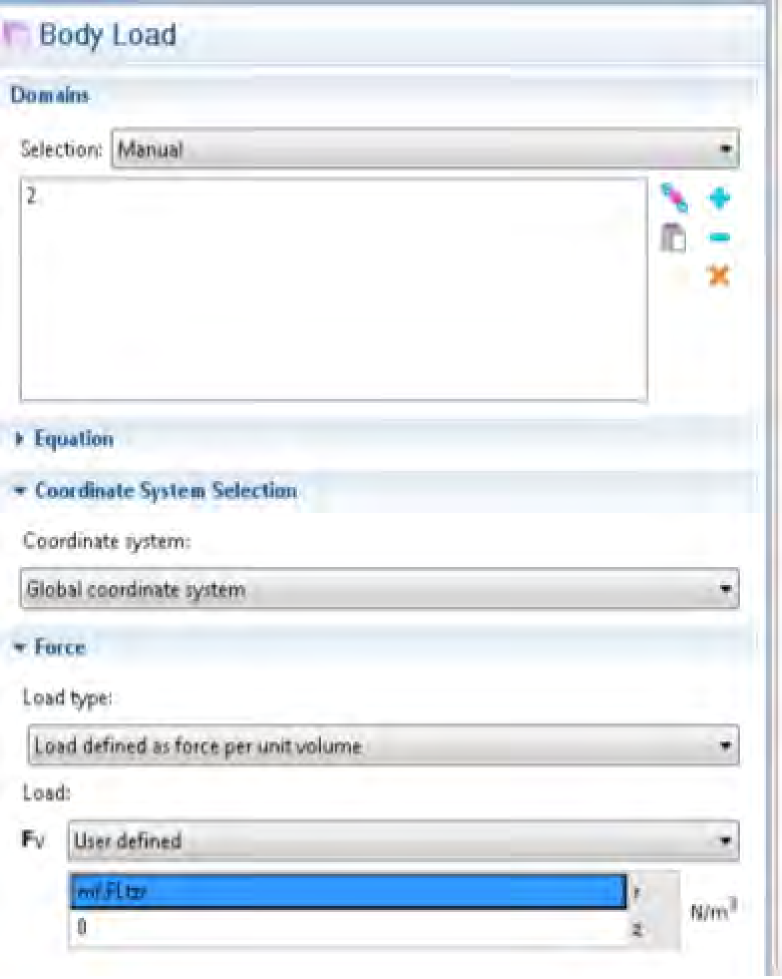
1.Initial Values

$$\sigma_{\mathrm{hard}} = \sigma_{\mathrm{y}}\left[1 + \left(\frac{\dot{\varepsilon}}{\mathrm{P}}\right)^{\mathrm{m}}\right] - \sigma_{\mathrm{yield}}$$

2.Elastoplastic Material

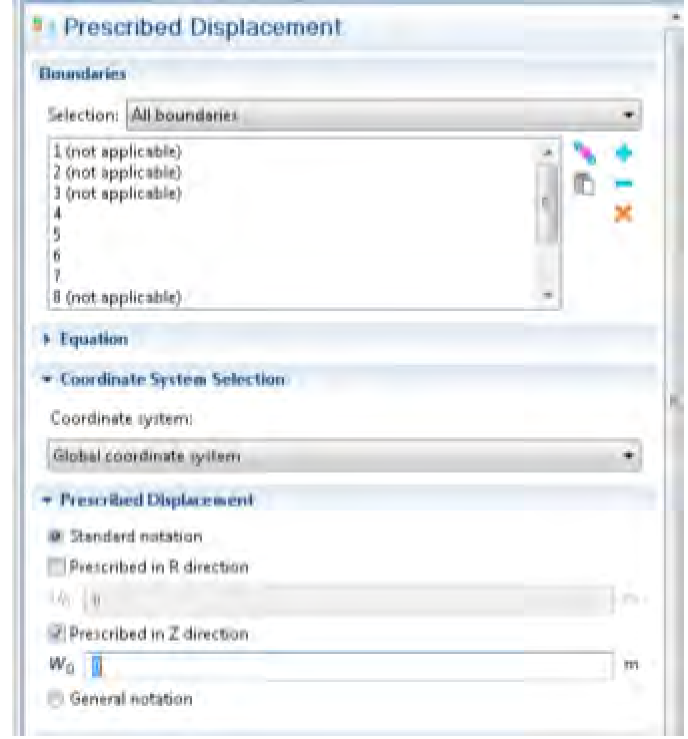




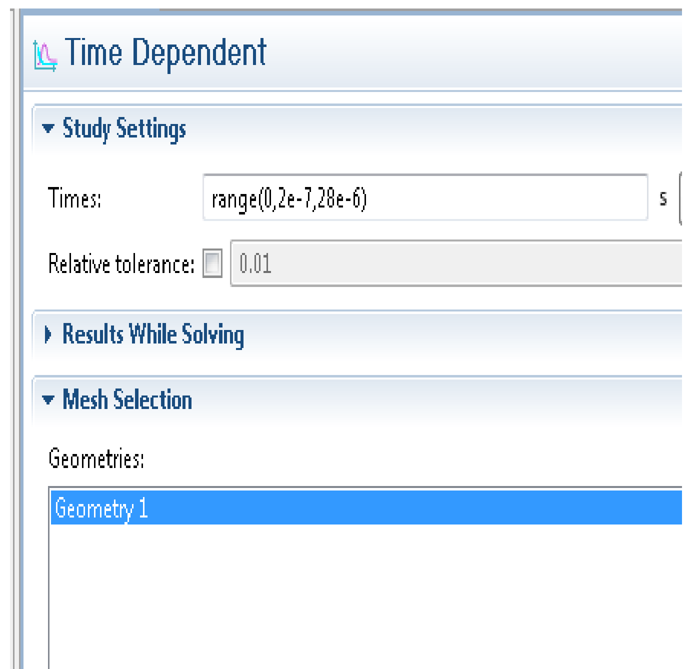


3.Coupling Body Load

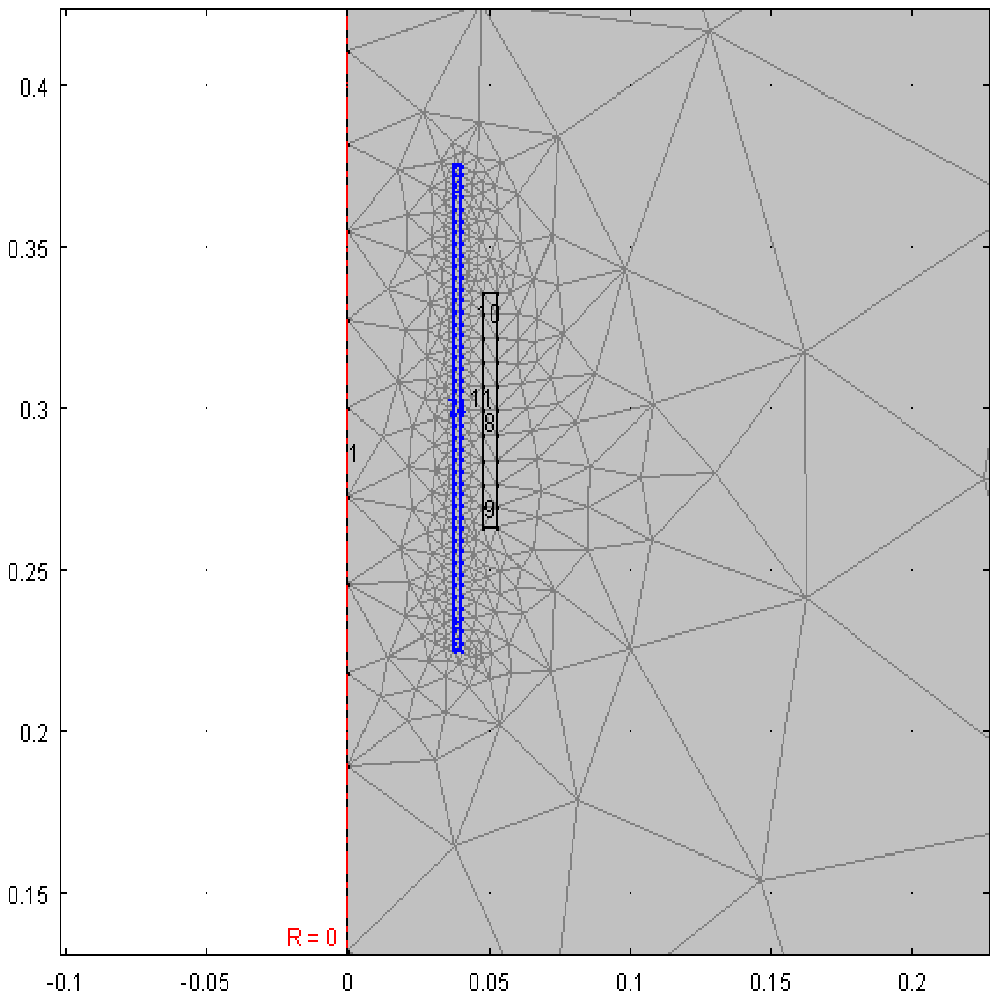
4.Prescribed Displacement



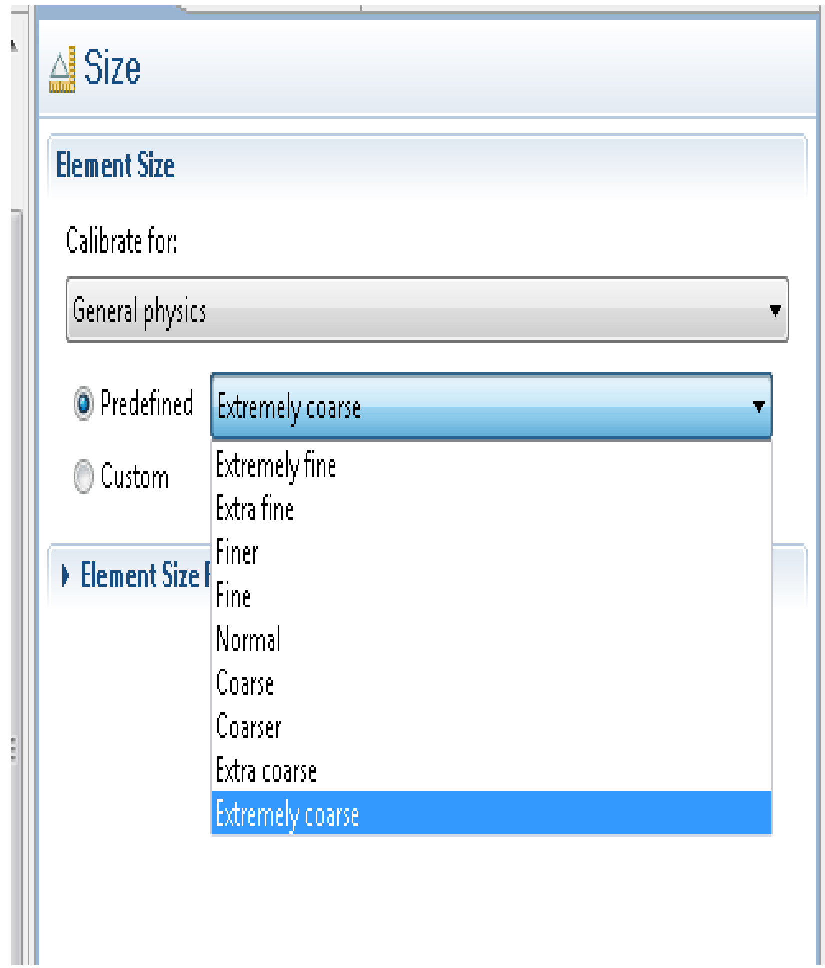
5.Study-
Time Dependant



Meshing

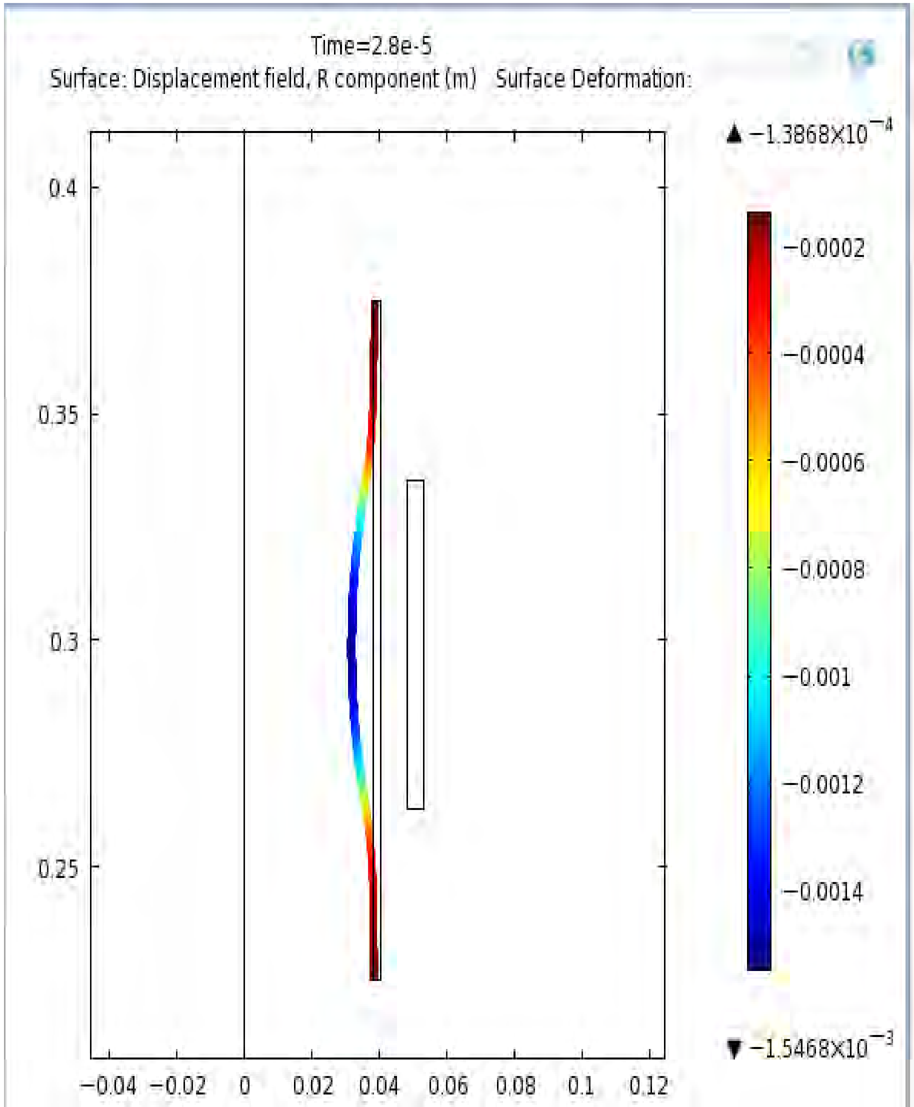


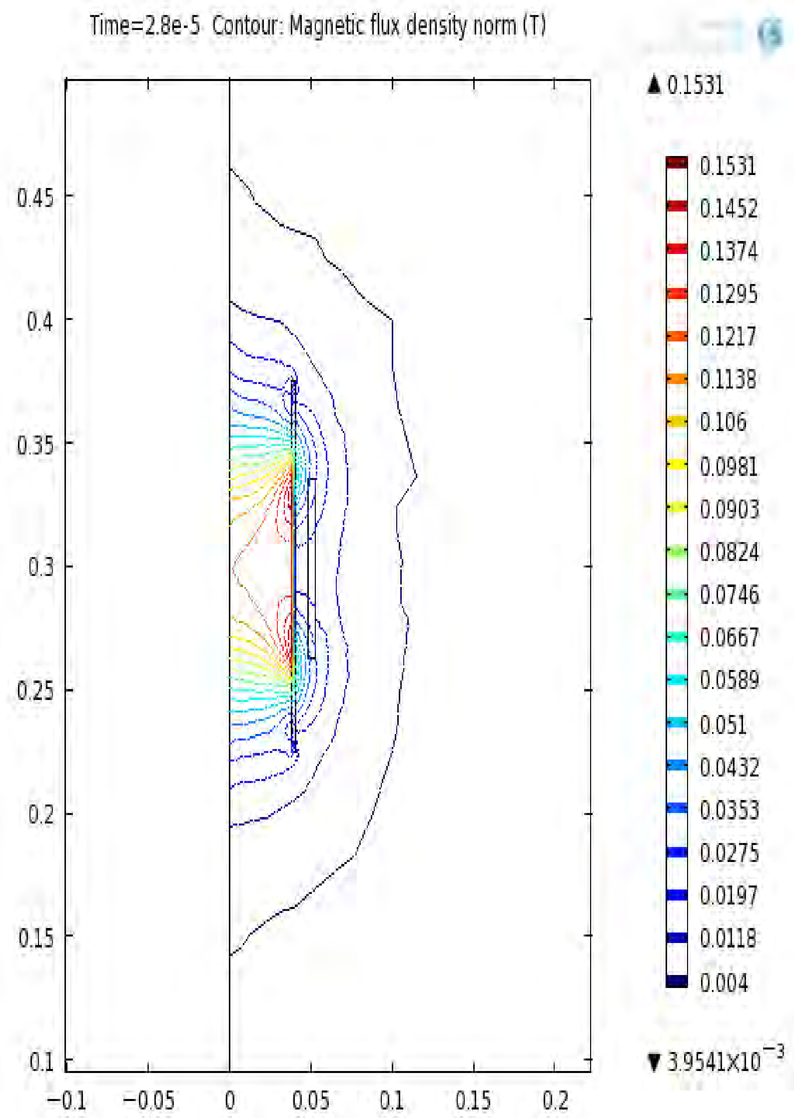
0.4
0.35
0.3
0.25
0.2
0.15
-0.1
-0.05
0
0.05
0.1
0.15
0.2
R = 0



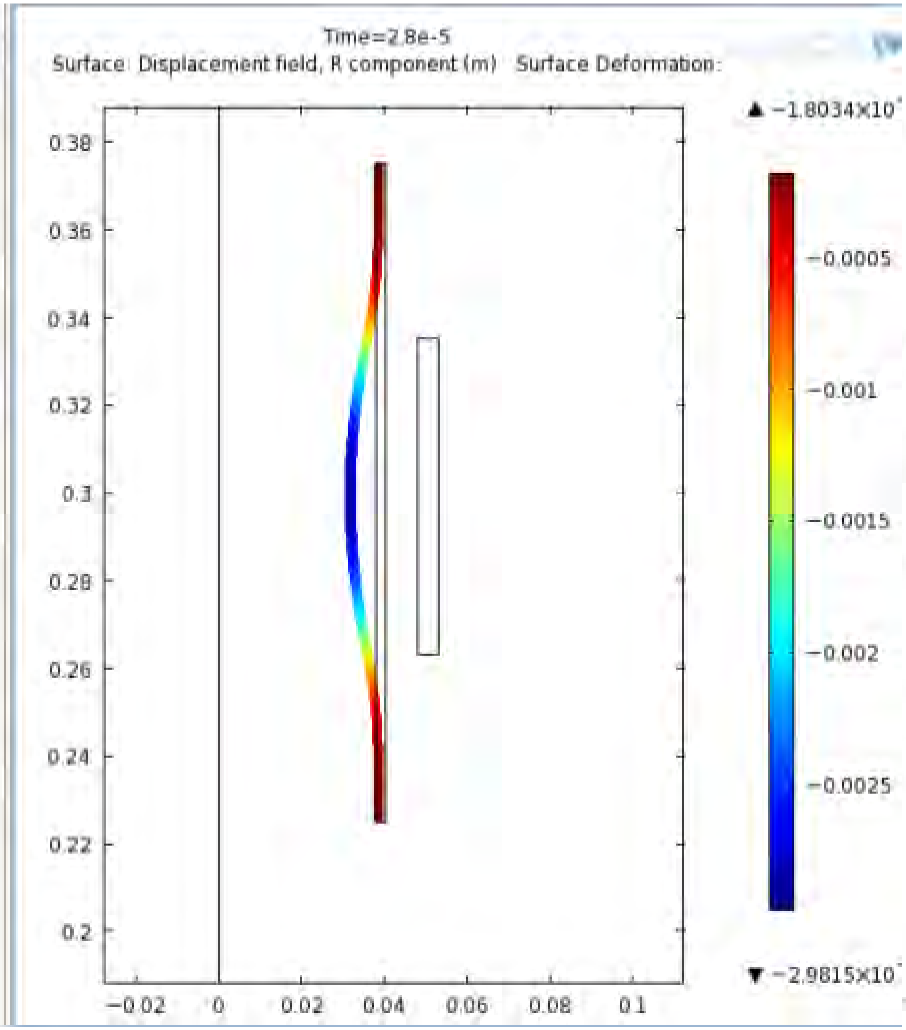
Size
Element Size
Calibrate for:
General physics
Predefined
Extremely coarse
Custom
Extremely fine
Extra fine
Finer
Fine
Normal
Coarse
Coarser
Extra coarse
Extremely coarse

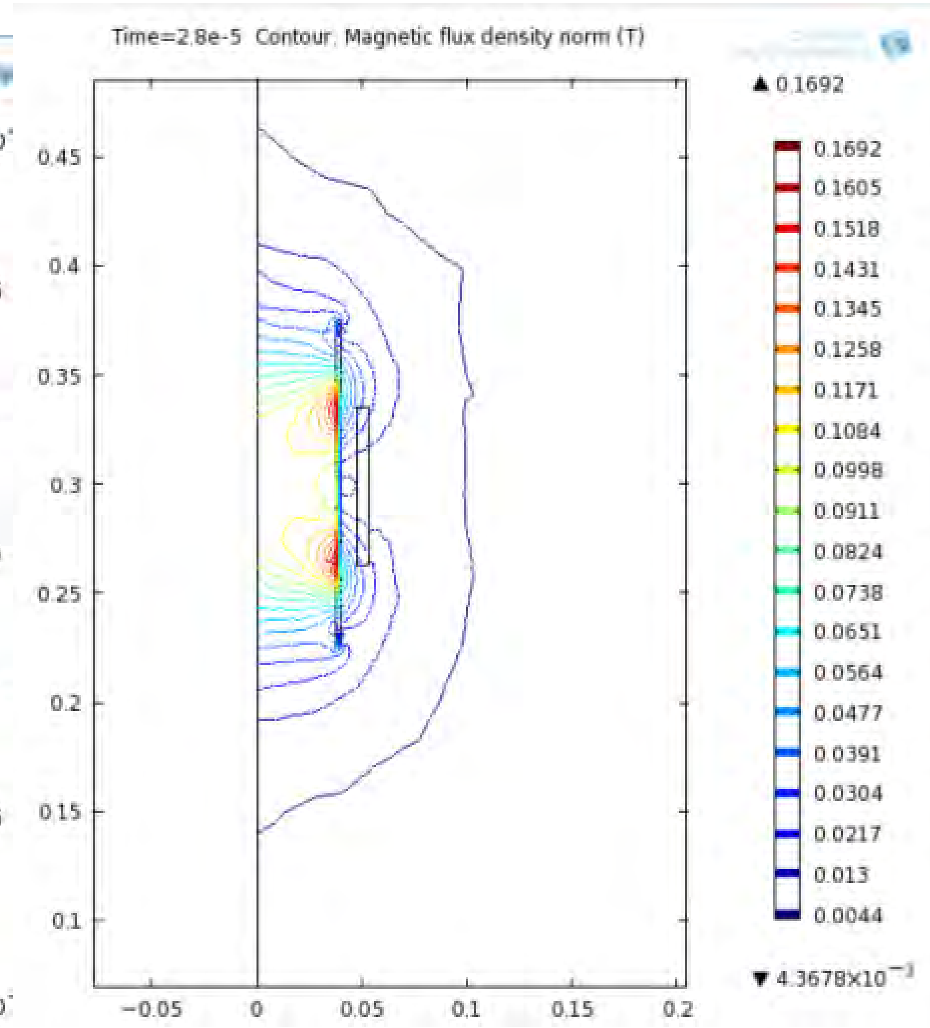
Displacement and Magnetic Flux Density for 8kJ



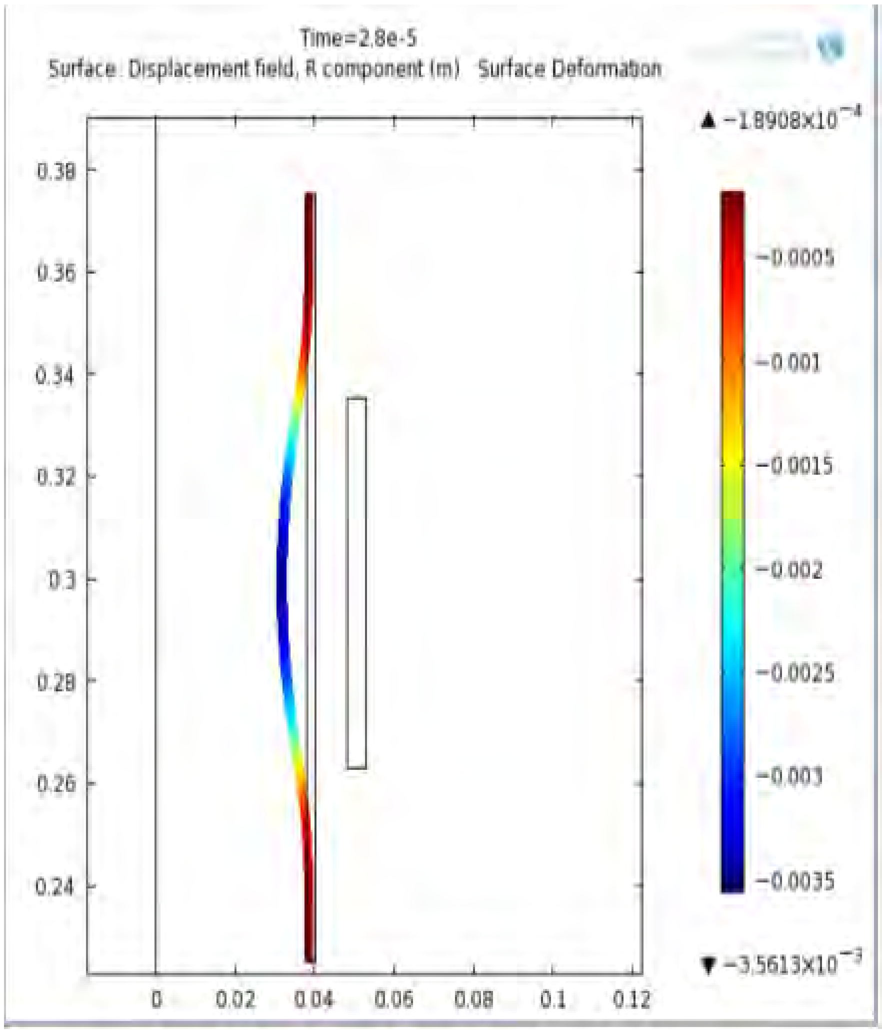


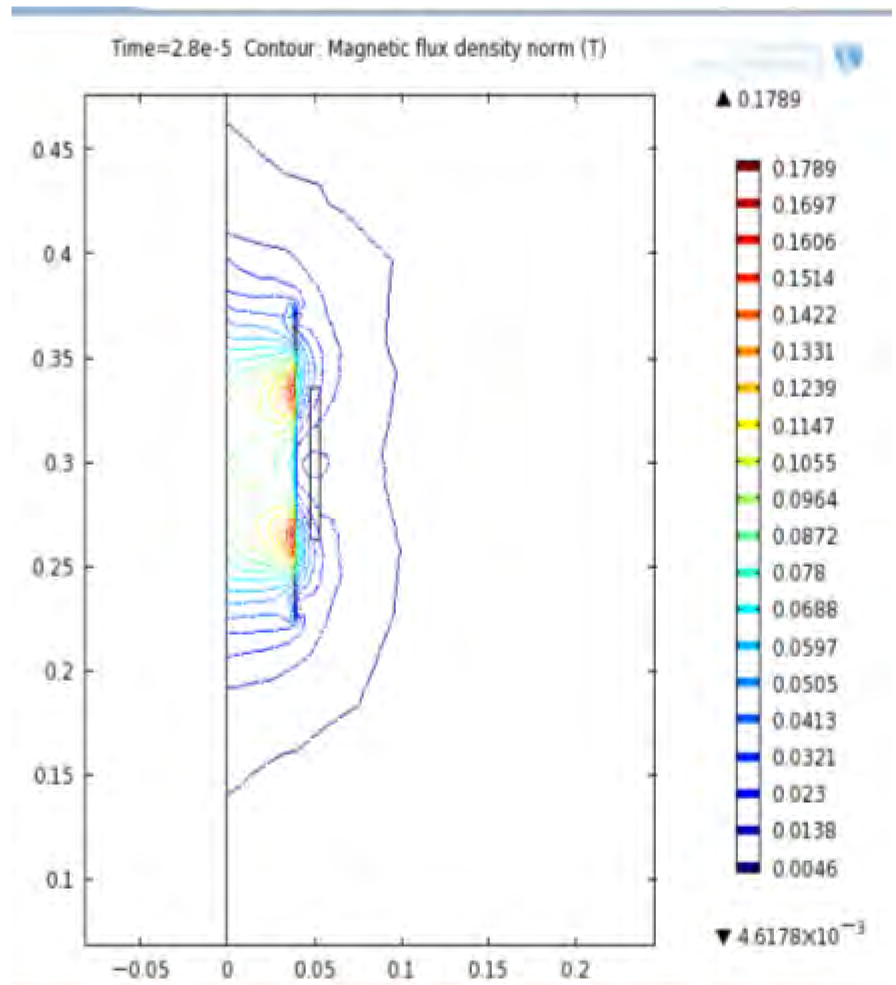
Displacement and Magnetic Flux Density for 15.8 kJ



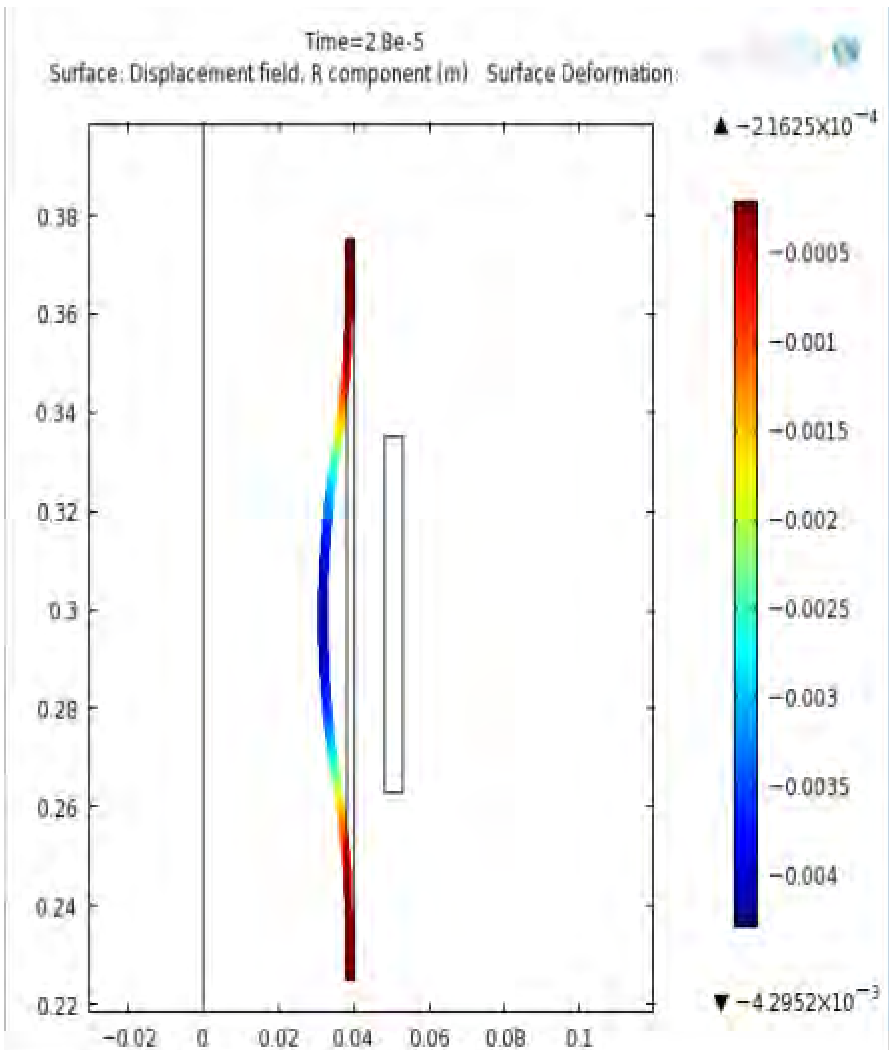


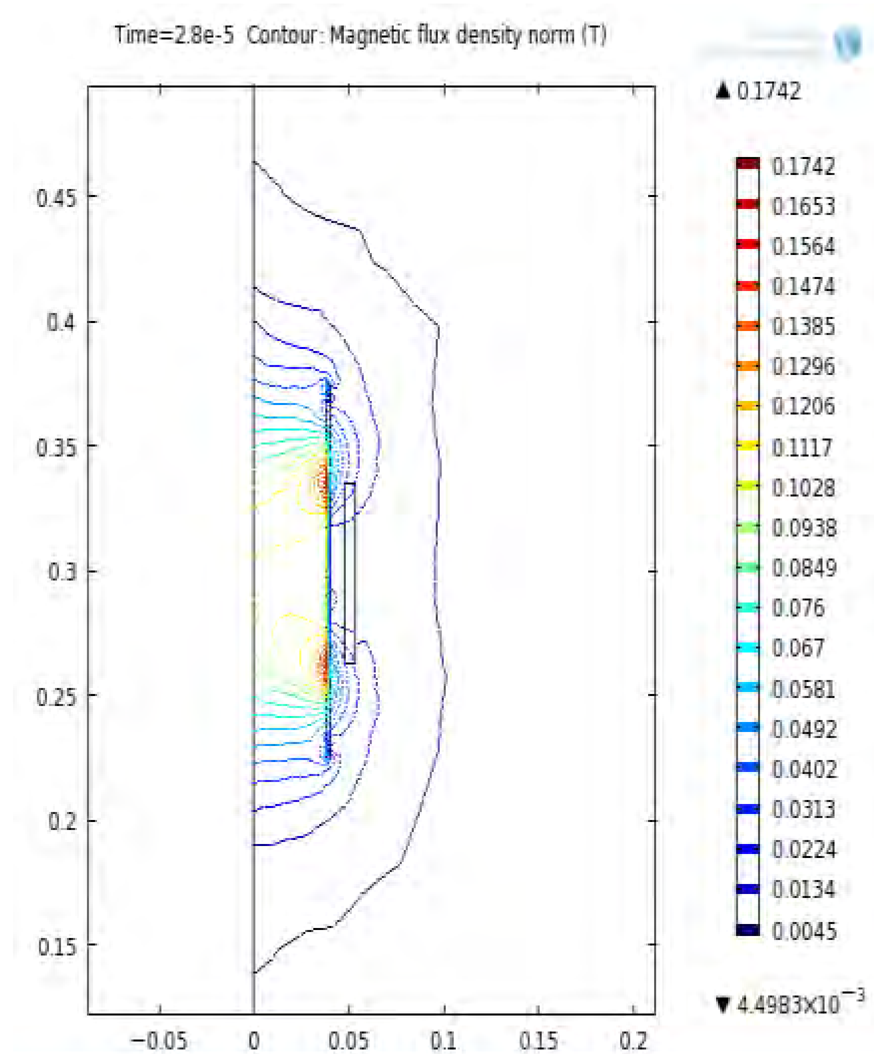
Displacement and Magnetic Flux Density for 18 kJ



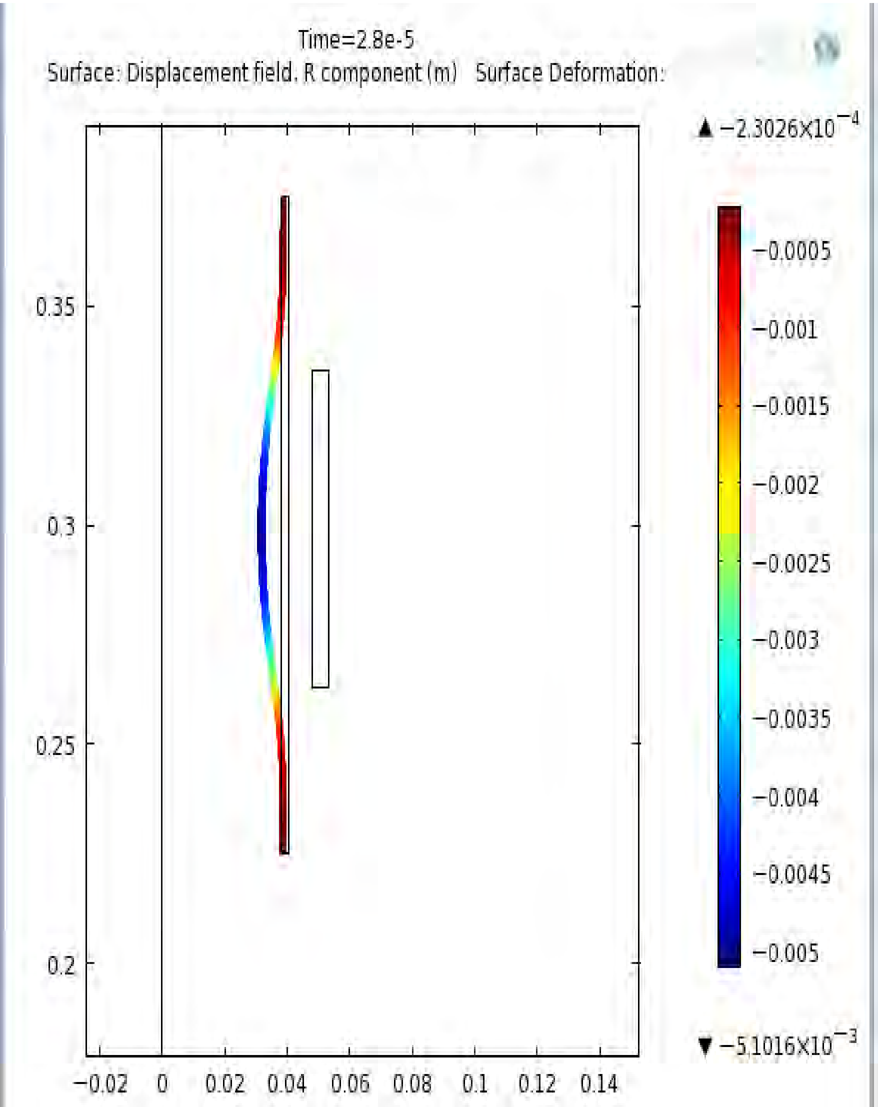


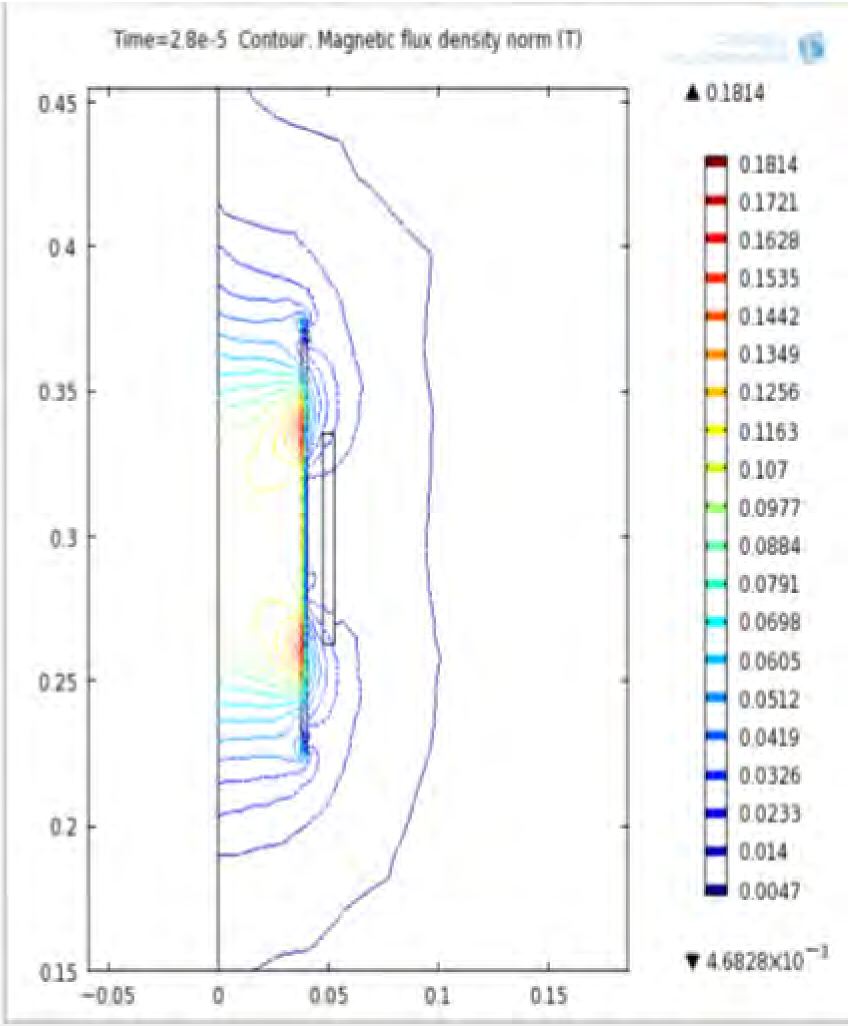
Displacement and Magnetic Flux Density for 21 kJ





Displacement and Magnetic Flux Density for 24 kJ

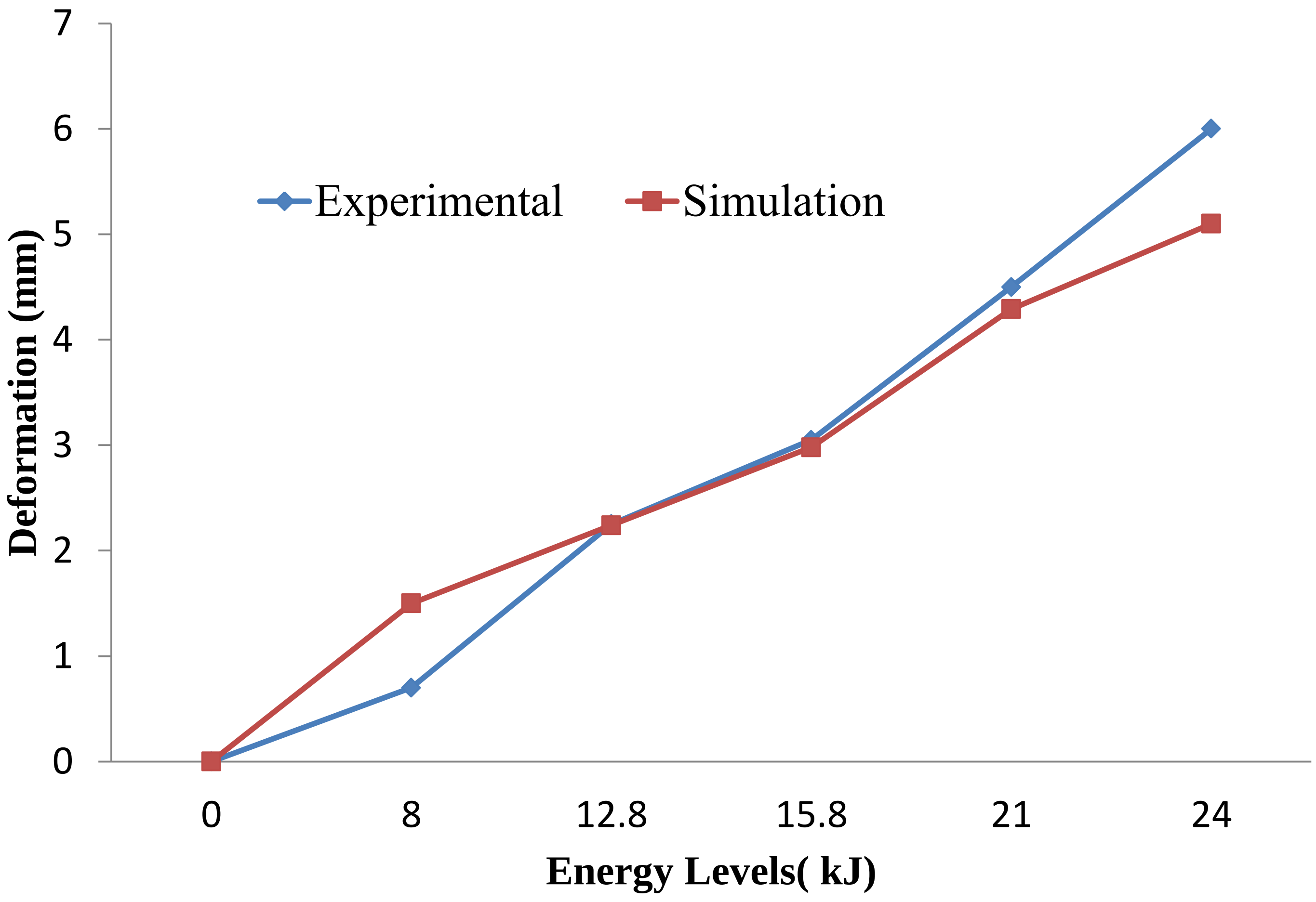




Results

Energy (KJ)	Rise time (μS)	Final deformation Expt.(mm)	Final deformation simulation (mm)	% reduction	Predicted % reduction
8	28	0.7	1.5	1.8	3.4
12.8	28	2.25	2.24	5.9	5.87
15.8	28	3.05	2.98	8.0	7.9
18	28	3.15	3.5	8.1	9.1
21	28	4.5	4.29	11.8	11.25
24	28	6	5.1	15.9	13.4

Graph of Deformation (mm) against Energy Levels (kJ)



Conclusion.

- Simulations were carried out on the electromagnetic compression of high strength (440MPatensile strength) 76.2mmdiameter, 2.3mm wall thickness tubes.
- Significant final deformations over a length of about 75mm were obtained with a fixed 9-turn helical compression coil.
- About 8% and 15% reductions in diameter were developed with 16 kJ and 24 kJ discharges from separate commercial capacitor banks.
- Comparisons between simulations and experimental data from litrature gave confidence that a simple numerical model can reliably predict system performance.
- COMSOL Multiphysics is very user friendly software , easy to operate and gives good simulation results.

References

- Kristin E. Banik, Factors Effecting Electromagnetic Flat Sheet Forming Using the Uniform Pressure Coil, MS thesis, Graduate School of the Ohio State University.
- A. Vivek, K.-H. Kim, G.S. Daehn, Simulation and instrumentation of electromagnetic compression of steel tubes, Journal of Materials Processing Technology 211 (2011) 840–850
- S d kore, p.p. date, s.v. kulkari, Electromagnetic Welding of Flat Sheets, PhD thesis, IIT Bombay,2007
- Moon FC. Magneto Solid Mechanics. John Willey & Sons Inc; 1984.

- Moon FC. Magneto Solid Mechanics. John Willey & Sons Inc; 1984.

- S.S. Prakash Alapati, S.V. Kulkarni, Coupled Magnetic-Structural Finite Element Analysis, Excerpt from the Proceedings of the COMSOL Conference 2009 Bangalore

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