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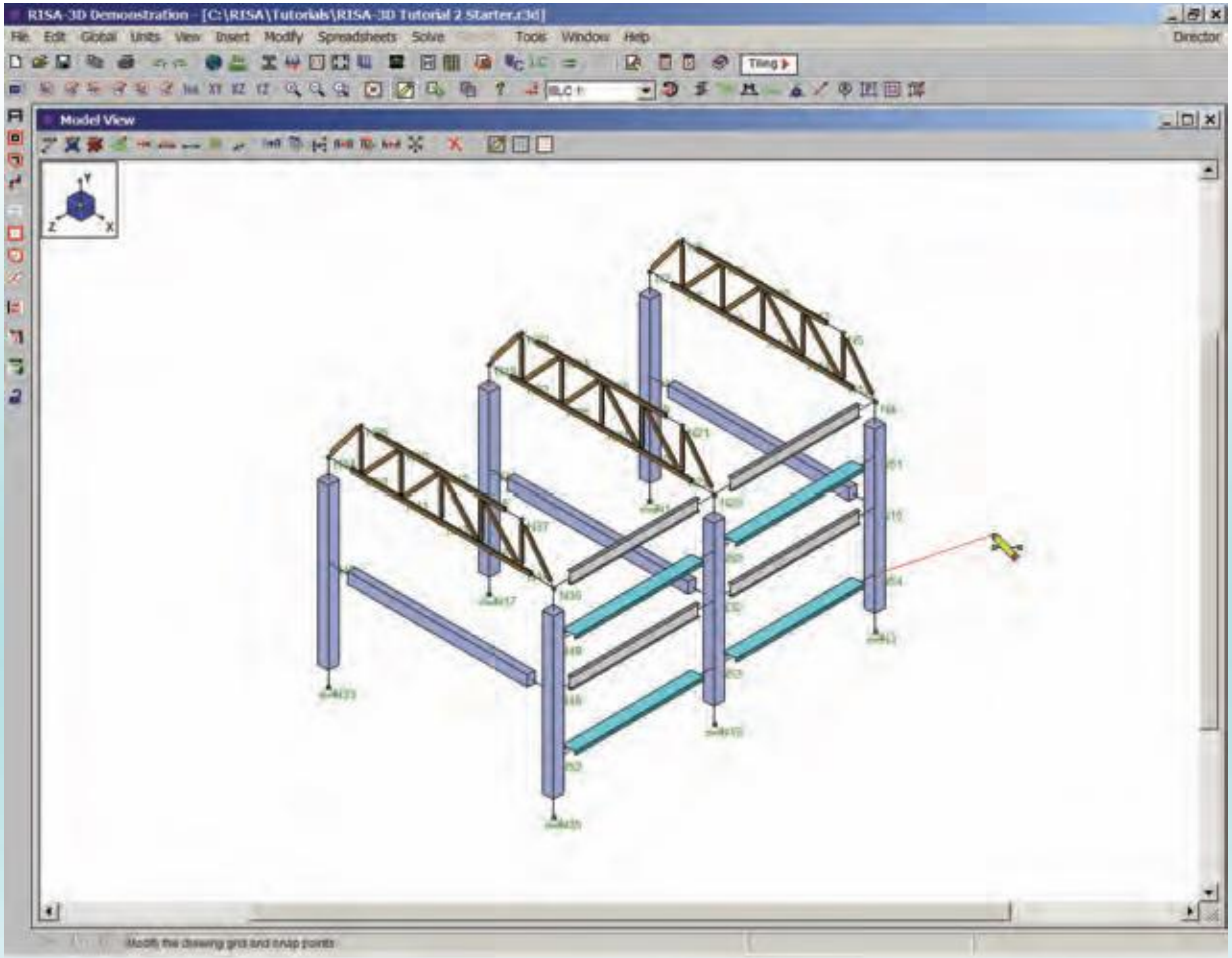
SENSITIVITY ANALYSIS OF TRUSS AND FRAME STRUCTURES WITH UNCERTAIN GEOMETRY

Truss structures

Frame structures



Civil engineering codes

ACI Code (USA)

Eurocode (Europe)

DIN (Germany)

Etc.

Example application:
FEM analysis and design of reinforced concrete slabs **according to Eurocode 2**.

Shape optimization

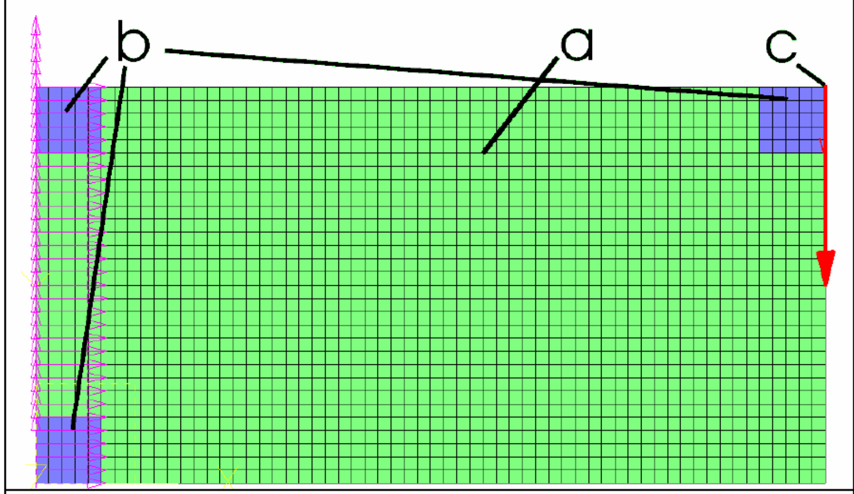


Figure 1 – Defined design space

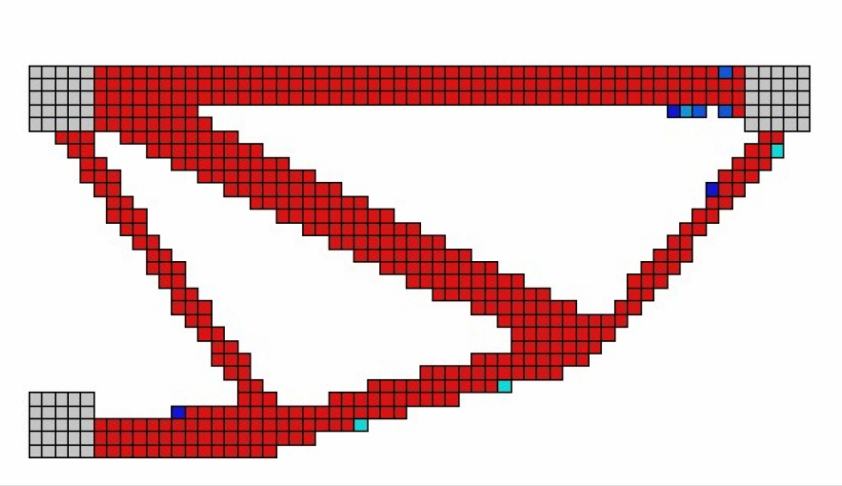
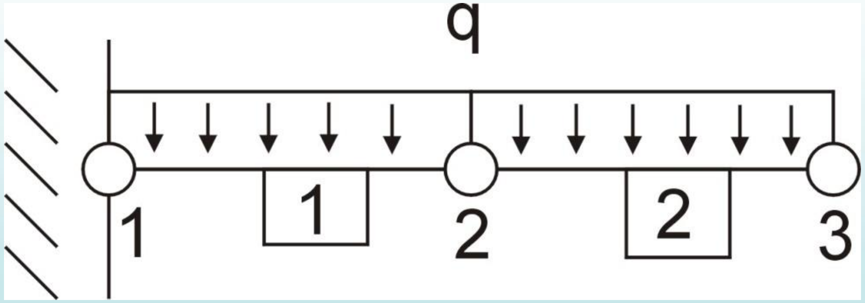


Figure 2 – Result of the topology optimization

Sensitivity analysis

analysis_type linear_static_functional_derivative

parameter 1 [210E9,212E9] sensitivity # E
parameter 2 [0.1,0.3] sensitivity # A
parameter 3 [8E-6,8.2E-6] sensitivity # J
parameter 4 [1,3] sensitivity # q
parameter 5 [1,3] sensitivity # q



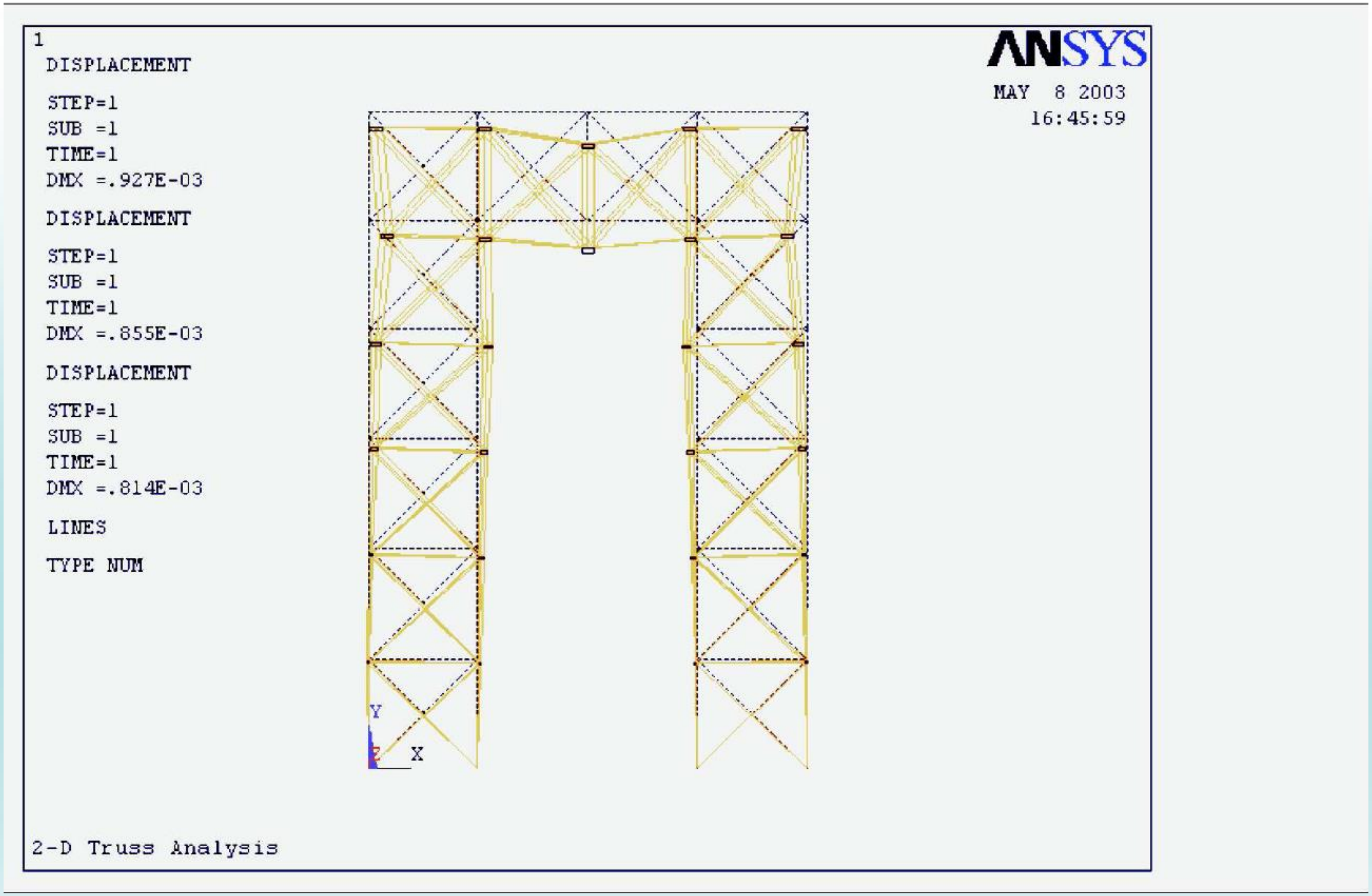
point 1 x 0.0 y 0
point 2 x 0.5 y 0
point 3 x 1.0 y 0

line 1 points 1 2 parameters 1 2 3
line 2 points 2 3 parameters 1 2 3

load constant_load_on_line_in_y_local_direction line 1 qy 4
load constant_load_on_line_in_y_local_direction line 2 qy 5

boundary_condition fixed point 1 ux
boundary_condition fixed point 1 uy
boundary_condition fixed point 1 rotz

Uncertain truss structures in ANSYS



Sensitivity analysis

$$\frac{\partial f}{\partial p_i} \geq 0$$

$$\underline{f} = f(\ldots, \underline{p}_i, \ldots)$$

$$\overline{f} = f(\ldots, \overline{p}_i, \ldots)$$

Sensitivity analysis

$$\frac{\partial f}{\partial p_i} \leq 0$$

$$\underline{f} = f(\ldots, \overline{p}_i, \ldots)$$

$$\overline{f} = f(\ldots, \underline{p}_i, \ldots)$$

Finite difference approximation

$$\frac{\partial f}{\partial p_i} \approx \frac{f(\ldots, p_i + \Delta p_i, \ldots) - f(\ldots, p_i, \ldots)}{\Delta p_i}$$

$$\frac{\partial^2 f}{\partial p_i^2} \approx \frac{f(\ldots, p_i + \Delta p_i, \ldots) - 2f(\ldots, p_i, \ldots) + f(\ldots, p_i - \Delta p_i, \ldots)}{\Delta p_i^2}$$

Monotonicity tests

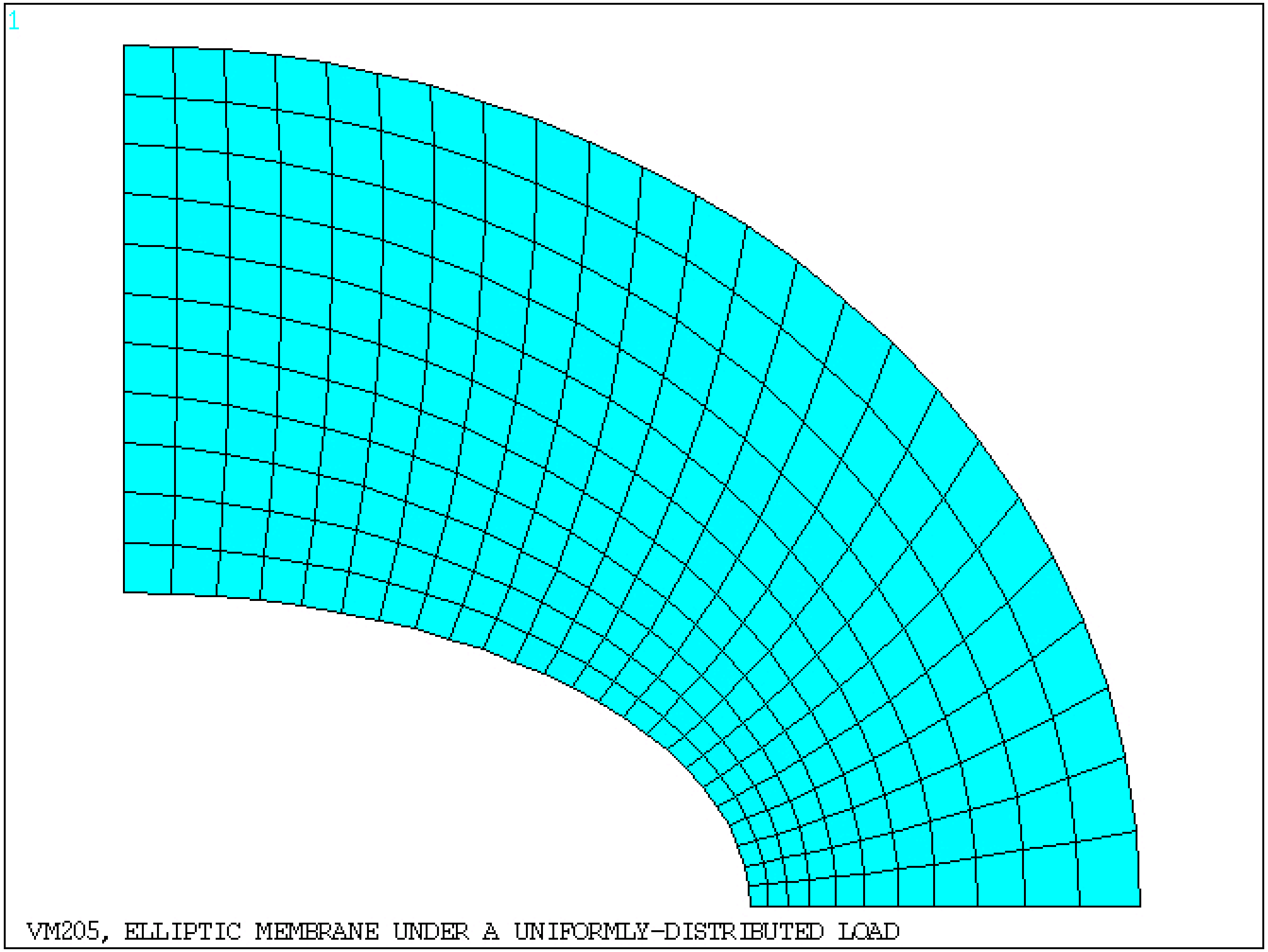
$$\frac{\partial u}{\partial p_i} \approx \frac{\partial u}{\partial p_i} + \sum_j \frac{\partial^2 u}{\partial p_i \partial p_j}\left(p_j - p_{j0}\right)$$

$$\left(\frac{\partial u}{\partial p_i}\right)^- \approx \frac{\partial u}{\partial p_i} - \sum_j \left|\frac{\partial^2 u}{\partial p_i \partial p_j}\right| \Delta p_j$$

$$\left(\frac{\partial u}{\partial p_i}\right)^+ \approx \frac{\partial u}{\partial p_i} + \sum_j \left|\frac{\partial^2 u}{\partial p_i \partial p_j}\right| \Delta p_j$$

VM205
Adaptive Analysis of an Elliptic Membrane

Figure 205.2 Final PLANE42 Mesh (SEPC = 5.5)



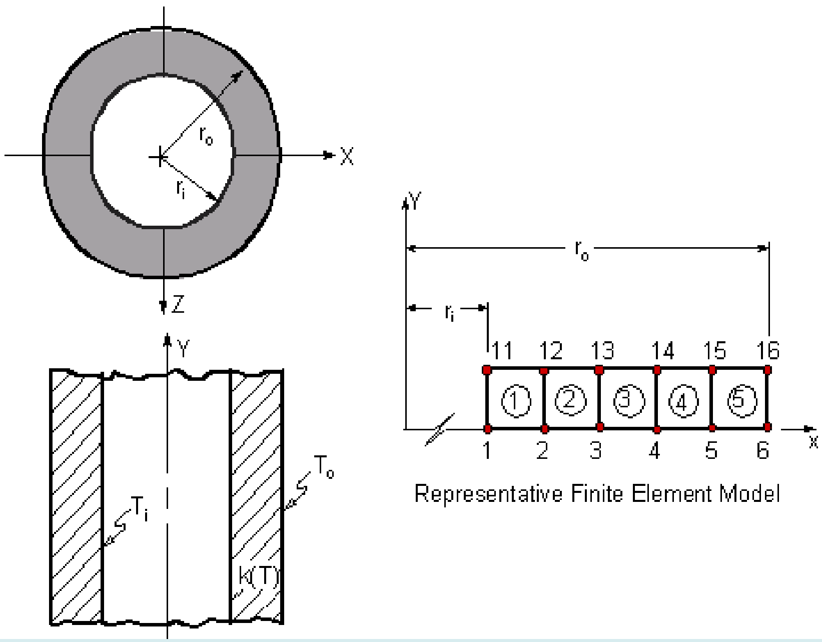
VM102
Cylinder with Temperature Dependent Conductivity

Test Case

A long hollow cylinder is maintained at temperature T_i along its inner surface and T_o along its outer surface. The thermal conductivity of the cylinder material is known to vary with temperature according to the linear function $k(T) = C_0 + C_1 T$. Determine the temperature distribution in the cylinder for two cases:

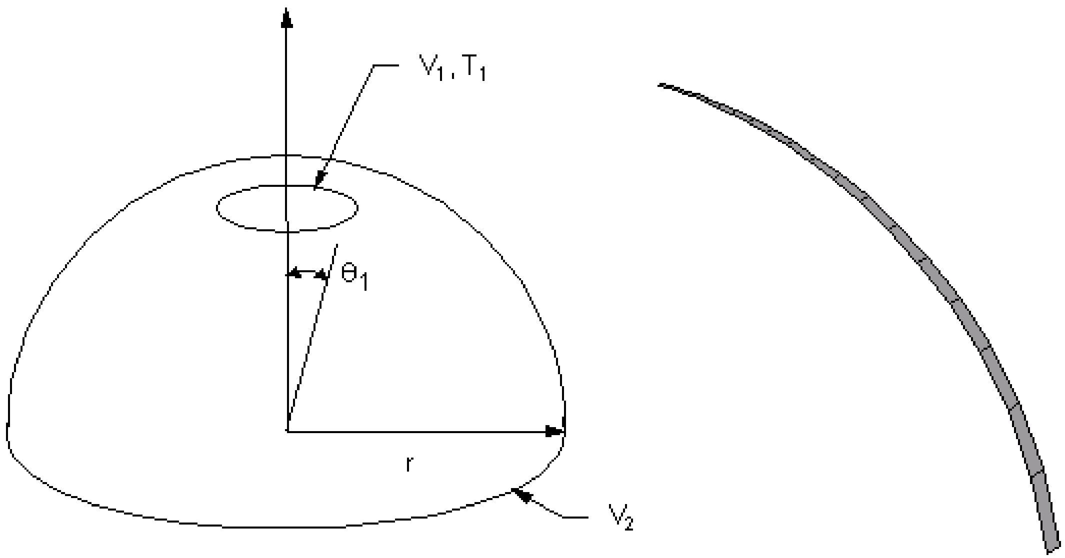
- $k = \text{constant}$, (i.e. $C_1 = 0$)
- $k = k(T)$.

Figure 102.1 Cylinder Problem Sketch



VM215
Thermal-Electric Hemispherical Shell with Hole

Figure 215.1 Hemispherical Shell Problem Sketch



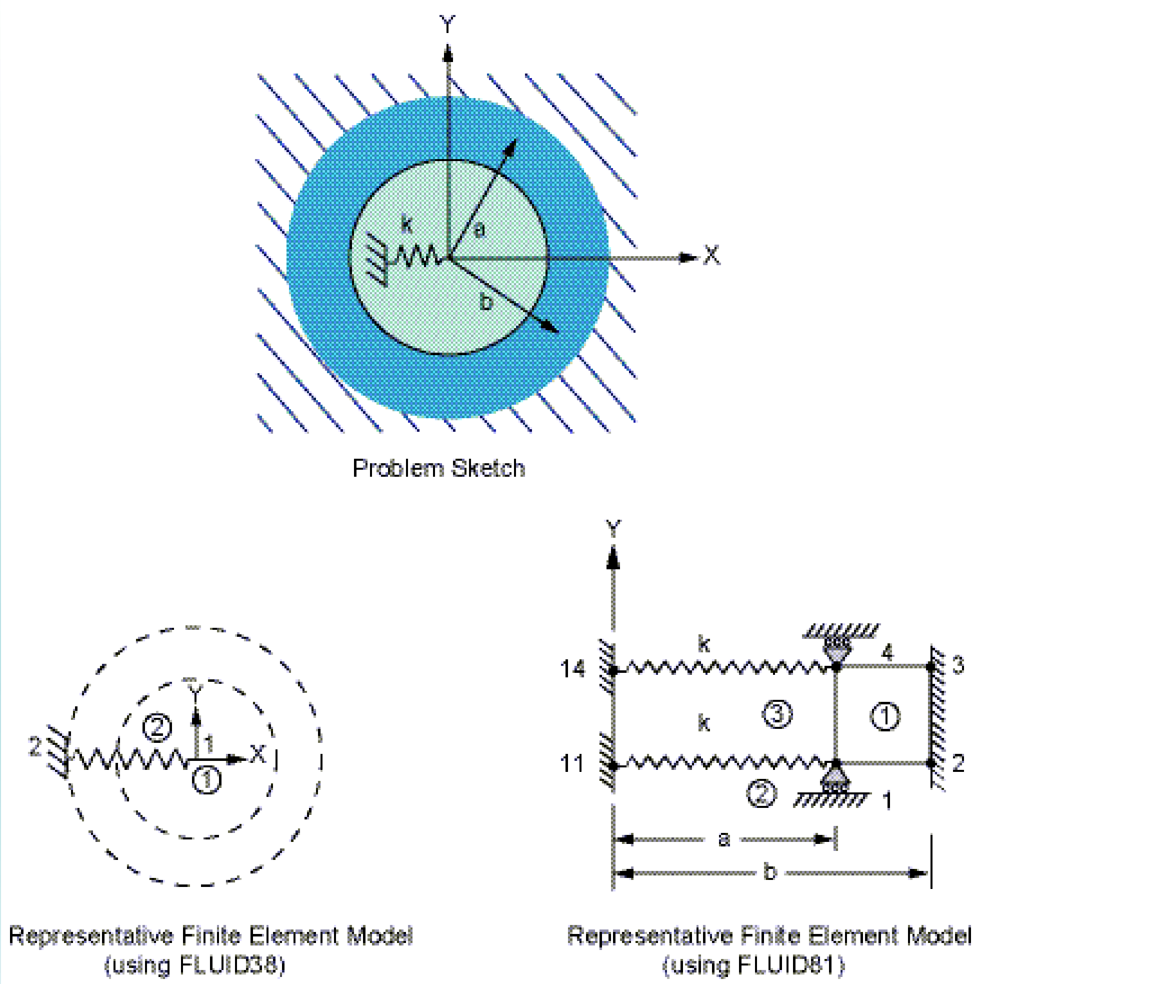
Problem Sketch

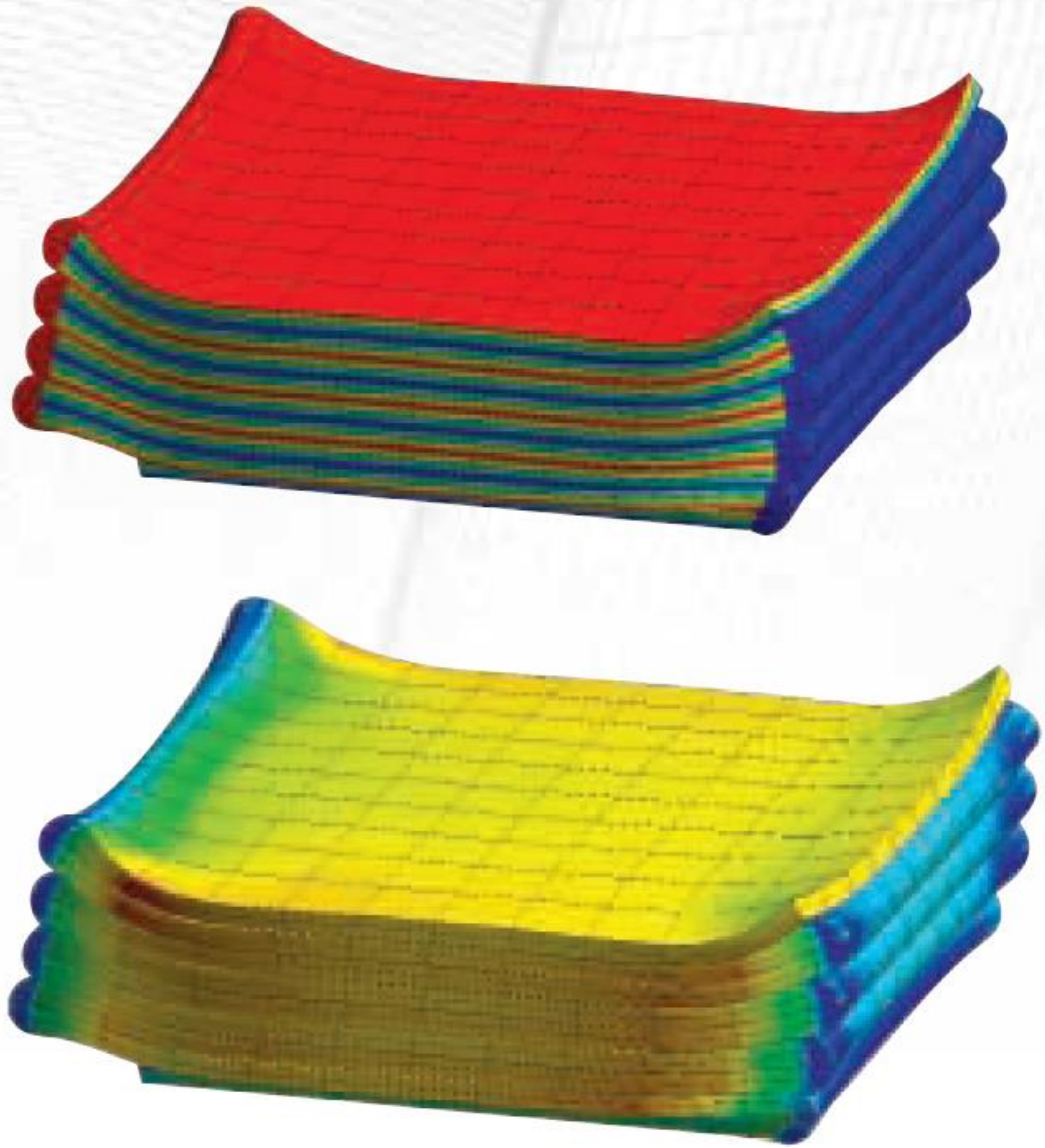
Representative Finite Element Model

Material Properties	Geometric Properties	Loading
$\rho = 7$ ohm-m	$t = 0.2$ m	$V_1 = 0$ volts
$K = 3$ W/m-K	$r = 10$ m	$V_2 = 100$ volts
	$\Theta_1 = 10°$	$T_1 = 0°C$
	$\Phi = 3°$	

VM154
Vibration of a Fluid Coupling

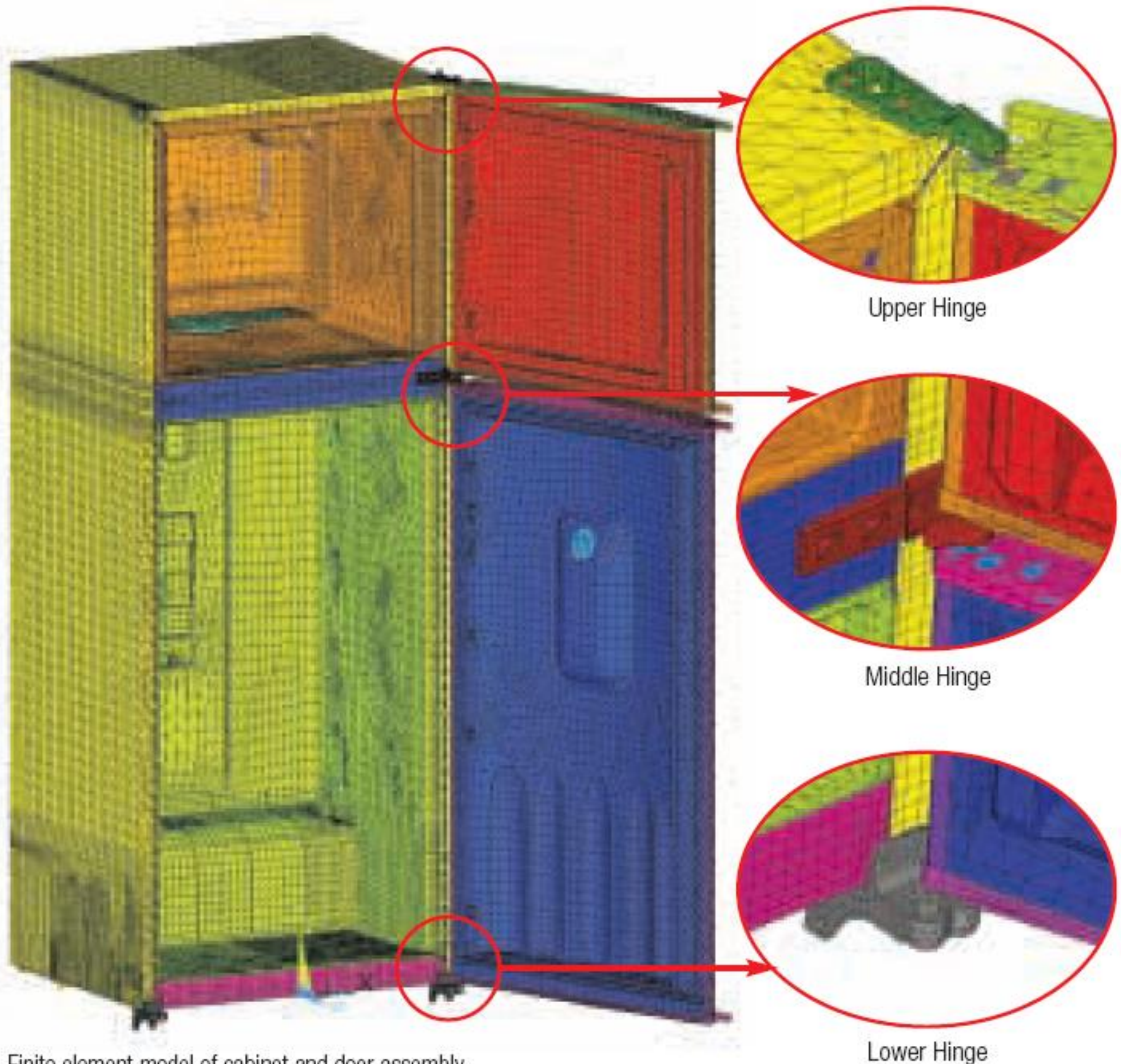
Figure 154.1 Fluid Coupling Problem Sketch



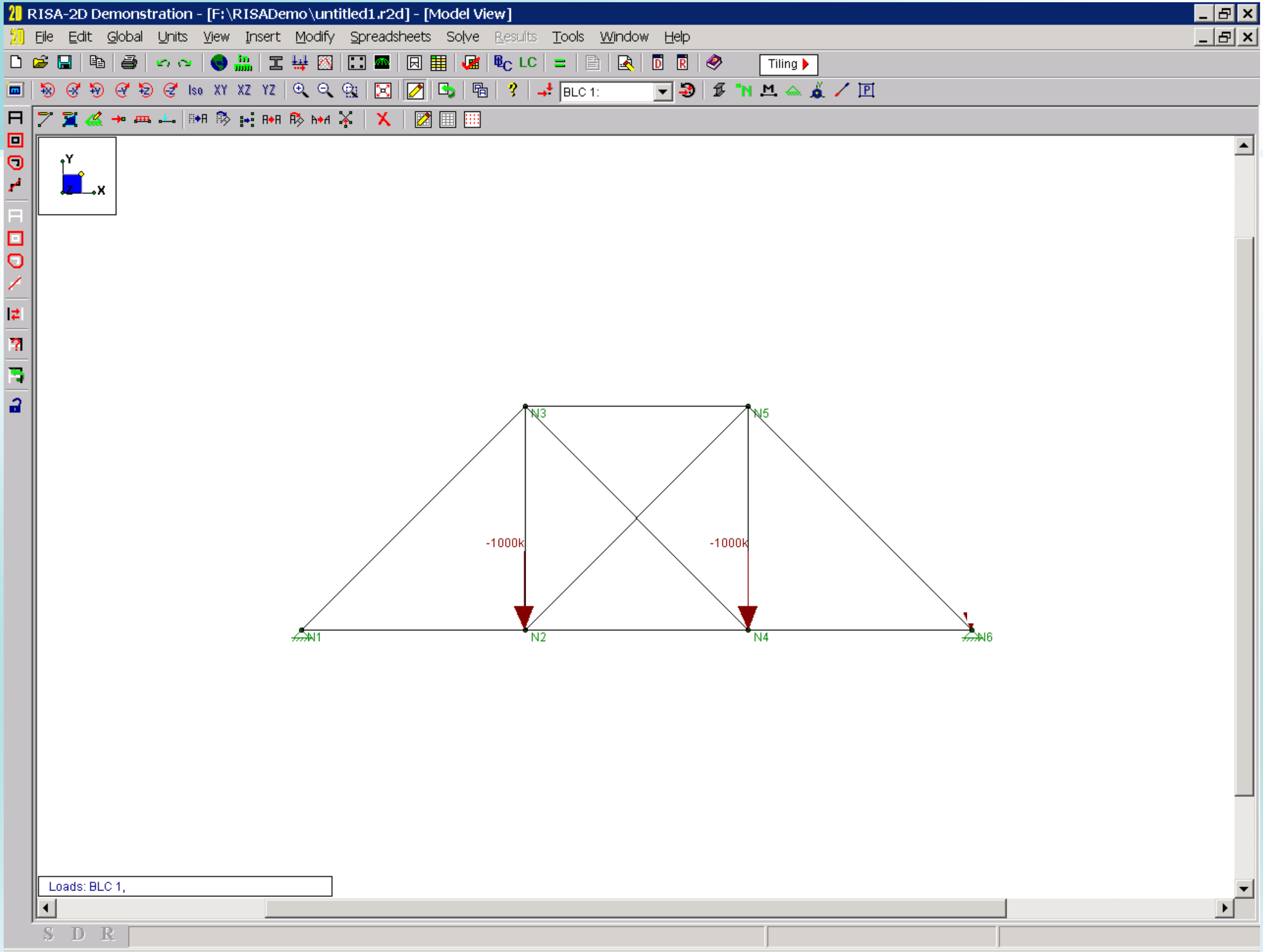


Electric potential (top) and equivalent stress (bottom) simulation results for a folded dielectric elastomer actuator

Original design of the Whirlpool refrigerator model used in the cabinet optimization analysis



Finite element model of cabinet and door assembly with close-ups of critical hinges

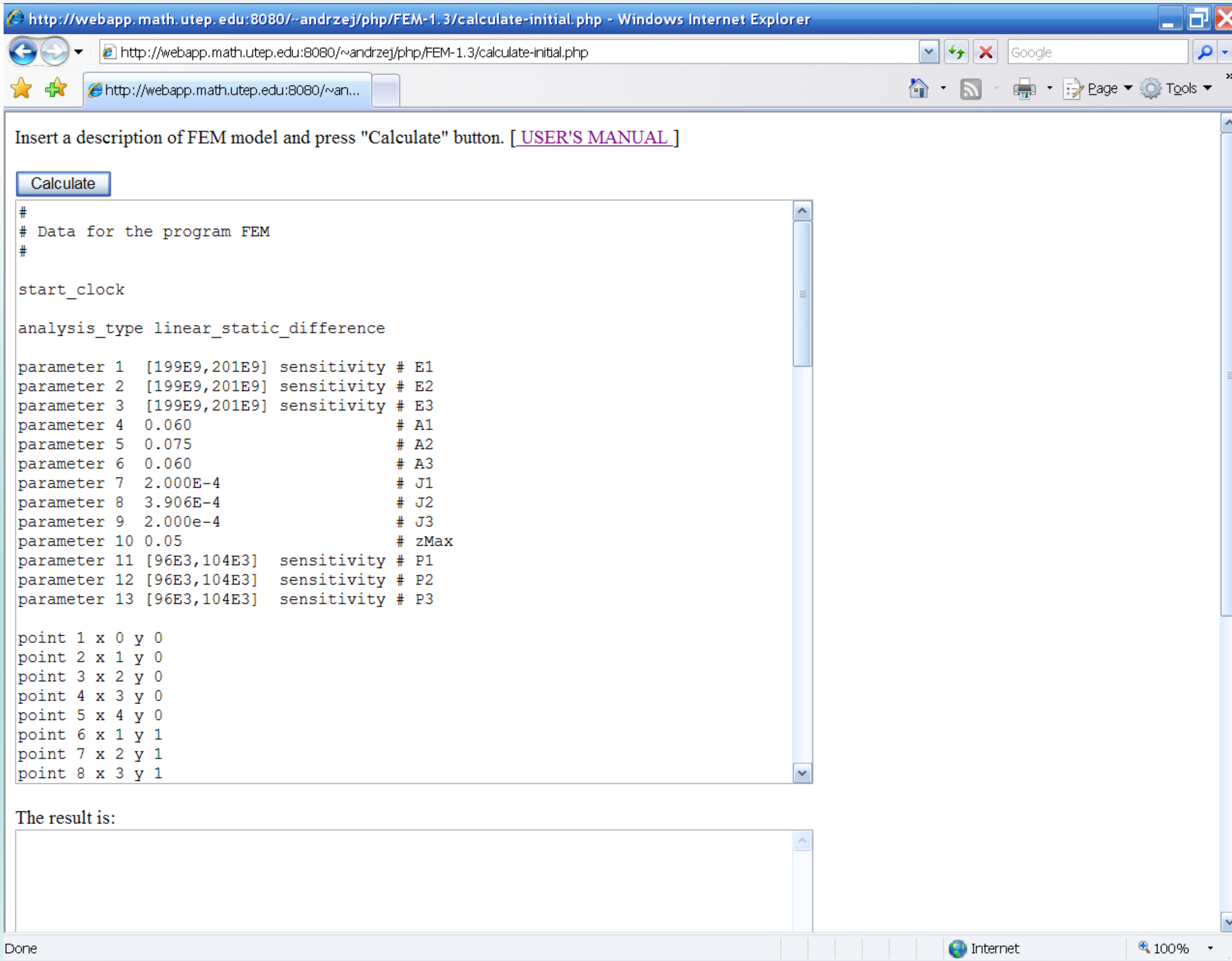


RISA-2D Demonstration - [F:\RISADemo\untitled1.r2d] - [Model View]
File Edit Global Units View Insert Modify Spreadsheets Solve Results Tools Window Help
Tiling
BLC 1:
N1
N2
N3
N4
N5
N6
-1000k
-1000k
Loads: BLC 1,

Sensitivity of the axial forces with respect to the position of nodes

Number of member	N0	N2x	dN2x	N2y	dN2y	N3x	dN3x
1	-1.41E+03	-1.49E+03	-7.24E+01	-1.35E+03	6.27E+01	-1.37E+03	4.71E+01
2	1.00E+03	1.10E+03	1.00E+02	9.09E+02	-9.09E+01	9.67E+02	-3.33E+01
3	7.93E+02	7.80E+02	-1.32E+01	8.39E+02	4.57E+01	7.62E+02	-3.08E+01
4	-1.21E+03	-1.22E+03	-1.71E+01	-1.17E+03	3.99E+01	-1.25E+03	-4.38E+01
5	2.93E+02	3.02E+02	8.71E+00	3.75E+02	8.23E+01	2.95E+02	1.80E+00
6	2.93E+02	3.17E+02	2.41E+01	2.28E+02	-6.46E+01	3.25E+02	3.23E+01
7	7.93E+02	7.98E+02	5.35E+00	7.48E+02	-4.53E+01	8.25E+02	3.21E+01
8	7.93E+02	7.76E+02	-1.71E+01	7.22E+02	-7.05E+01	7.92E+02	-1.27E+00
9	7.93E+02	1.00E+03	2.07E+02	1.00E+03	2.07E+02	1.03E+03	2.40E+02
10	-1.41E+03	-1.41E+03	0.00E+00	-1.41E+03	-3.56E-03	-1.46E+03	-4.71E+01

Web application



Conclusions

- Using finite difference approach it is possible to solve very complicated problems of computational mechanics with uncertain parameters.
- Finite difference approach allow us to use existing engineering software.
- Using presented approach it is possible to study uncertain solution only in selected regions. Not necessarly in the whole structure.