

Numerical simulation of surface ship hull beam whipping response due to submitted underwater explosion

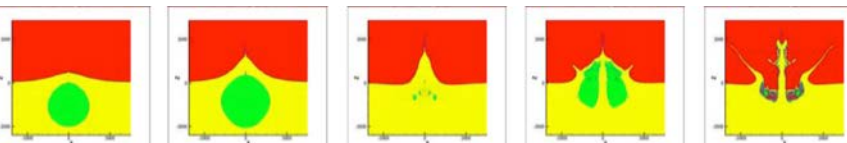
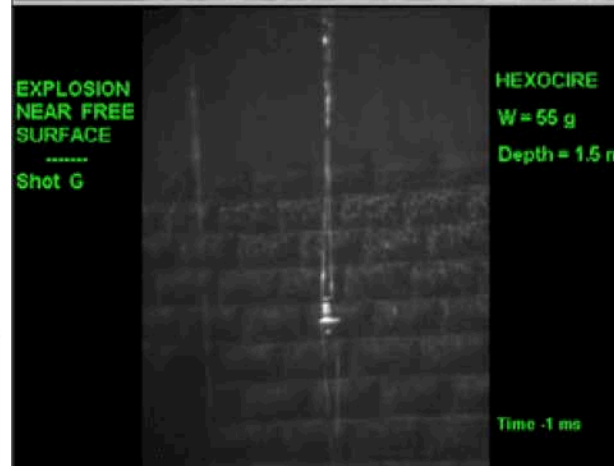
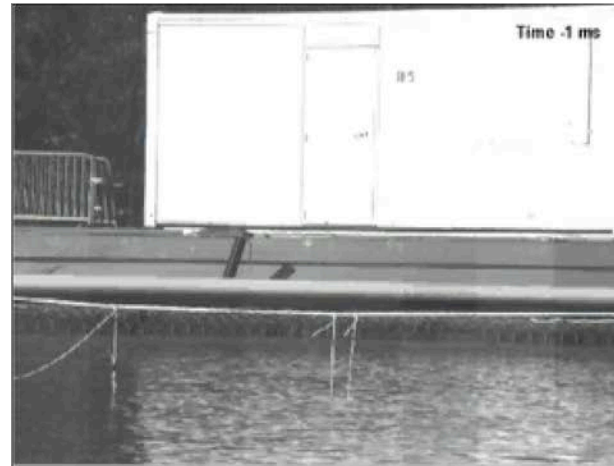
Presenter / Ssu-Chieh Tsai

Supervisor / Pr. Hervé Le Sourné

1 March 2017, Rostock



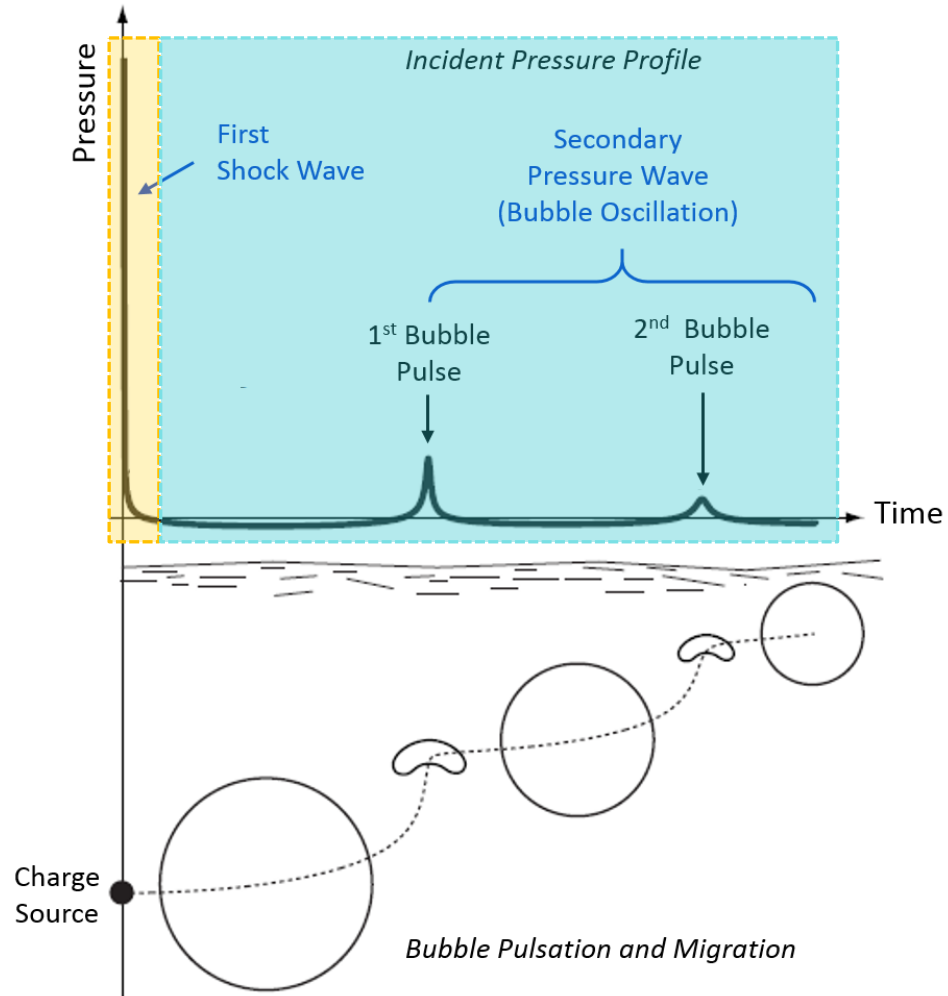
Motivation



Bubble Maximum Bubble Minimum Radial Plume Breakout

UNDEX Plume Above-Surface Effects

Background

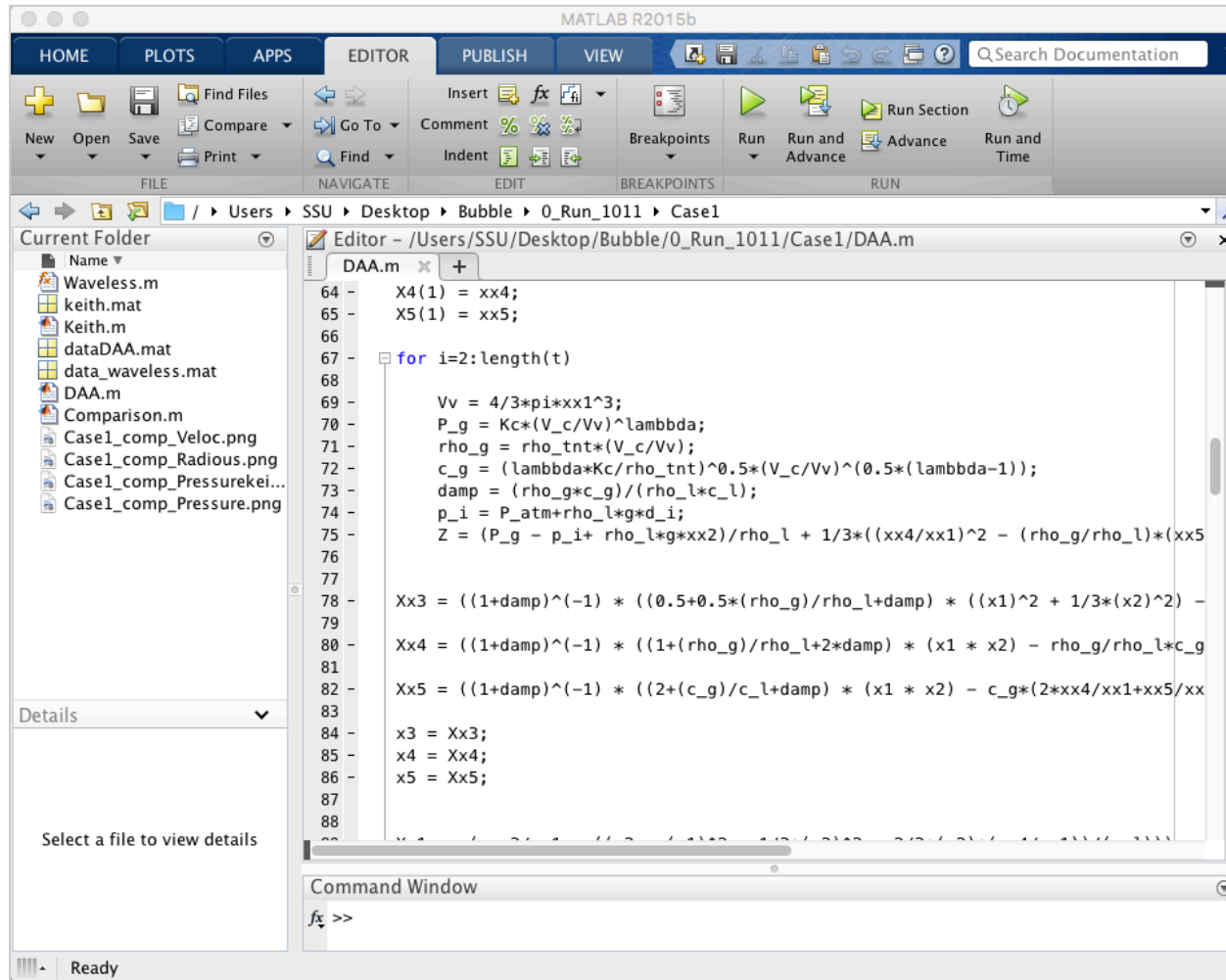


- Complete bubble migration process
- First shock wave (Mauricio,2015)
 - Exponential decay
 - Empirical approach
 - Very short time duration (ms)
- Bubble oscillation phase
 - Non-linear
 - Longer time duration
 - Motion of bubble migration
 - Radius and vertical displacement

Methodology – 3 models

- **Waveless model**
 - Consider as an ideal fluid
 - Without damping effect and the effect of gas bubble pressure inside bubble
- **DAA model** (*Doubly Asymptotic Approximation*)
 - Considering the interaction between the liquid and gas bubble
 - Including damping effect in the liquid
- **Empirical model**
 - Peak approximation method
 - Restricted to experienced coefficients, specific material cases

Development of Matlab programs



```

MATLAB R2015b
HOME PLOTS APPS EDITOR PUBLISH VIEW Search Documentation
New Open Save Find Files Compare Go To Comment Indent Breakpoints Run Run and Advance Run Section Run and Time
FILE NAVIGATE EDIT BREAKPOINTS RUN
/Users/SSU/Desktop/Bubble/0_Run_1011/Case1
Current Folder
Waveless.m keith.mat Keith.m dataDAA.mat data_waveless.mat DAA.m Comparison.m Case1_comp_Veloc.png Case1_comp_Radiou.png Case1_comp_Pressurekei... Case1_comp_Pressure.png
Editor - /Users/SSU/Desktop/Bubble/0_Run_1011/Case1/DAA.m
DAA.m
64 - X4(1) = xx4;
65 - X5(1) = xx5;
66
67 - for i=2:length(t)
68
69 -     Vv = 4/3*pi*xx1^3;
70 -     P_g = Kc*(V_c/Vv)^lambda;
71 -     rho_g = rho_tnt*(V_c/Vv);
72 -     c_g = (lambda*Kc/rho_tnt)^0.5*(V_c/Vv)^(0.5*(lambda-1));
73 -     damp = (rho_g*c_g)/(rho_l*c_l);
74 -     p_i = P_atm+rho_l*g*d_i;
75 -     Z = (P_g - p_i + rho_l*g*xx2)/rho_l + 1/3*((xx4/xx1)^2 - (rho_g/rho_l)*(xx5
76
77
78 -     Xx3 = ((1+damp)^(-1) * ((0.5+0.5*(rho_g)/rho_l+damp) * ((x1)^2 + 1/3*(x2)^2) -
79
80 -     Xx4 = ((1+damp)^(-1) * ((1+(rho_g)/rho_l+2*damp) * (x1 * x2) - rho_g/rho_l*c_g
81
82 -     Xx5 = ((1+damp)^(-1) * ((2+(c_g)/c_l+damp) * (x1 * x2) - c_g*(2*xx4/xx1+xx5/xx
83
84 -     x3 = Xx3;
85 -     x4 = Xx4;
86 -     x5 = Xx5;
87
88
Command Window
fx >>

```

- Developed code in Matlab
- Empirical and analytical models
- Calculate motion of bubble
- Pressure loads
- Test program by 3 charge cases

Comparison on 3 different UNDEX cases

- The 3 models are tested on:
 - ❖ Case 1: Barras Guillaume's Case
 - ❖ Case 2: Hunter & Geers' Case
 - ❖ Case 3: Keith G, Webster's Case

Case 1	Description
m_c	TNT charge mass, $m_c = 500$ kg
	Distance from charge to free surface, = 50 m
r	Distance from charge to standoff point, $r = 50$ m
	Density of charge, = 1600 kg/m ³

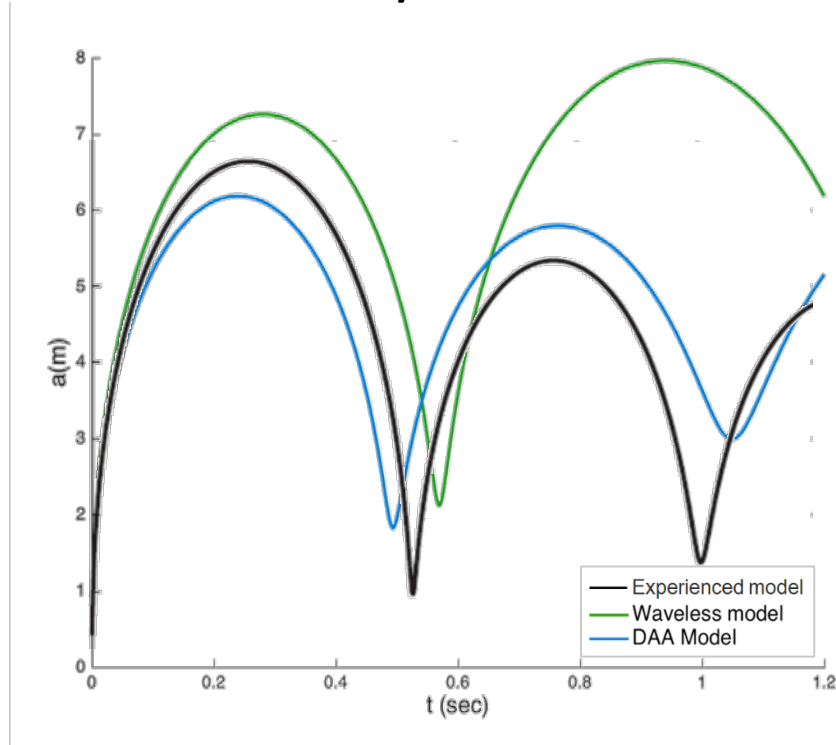
Case 2	Description
m_c	TNT charge mass, $m_c = 0.3$ kg
	Distance from charge to free surface, = 92 m
	Density of charge, = 1500 kg/m ³

Case 3	Description
m_c	TNT charge mass, $m_c = 1.45$ kg
	Distance from charge to free surface, = 178 m
	Density of charge, = 1500 kg/m ³
	Radial distance from charge,

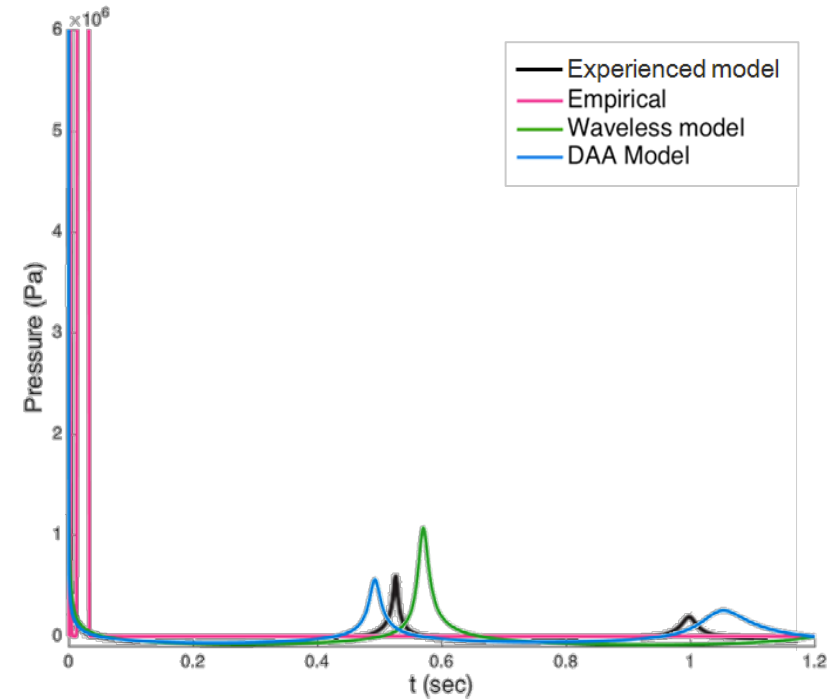
• Comparison with experience (Case 1)

Experience: Barras Guillaume, Numerical simulation of underwater explosions using an ALE method. The pulsating bubble phenomena. (2012)

Case 1 / Radius: a



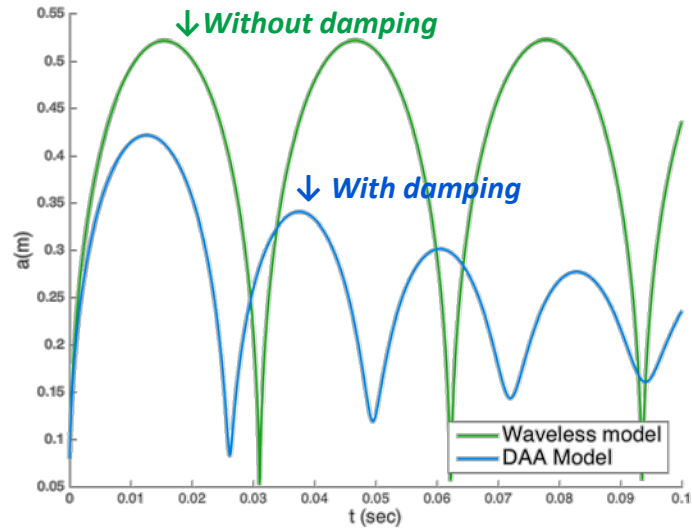
Case 1 / Pressure



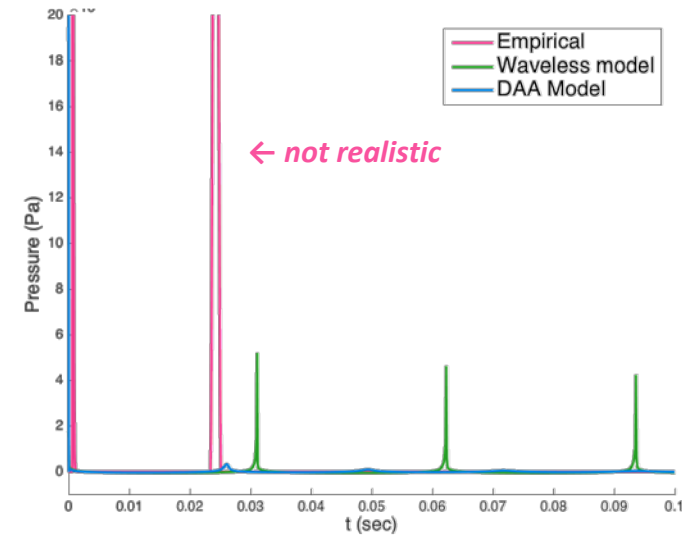
DAA model is close to Experience model !

Comparison 3 models for Case 2 & Case 3

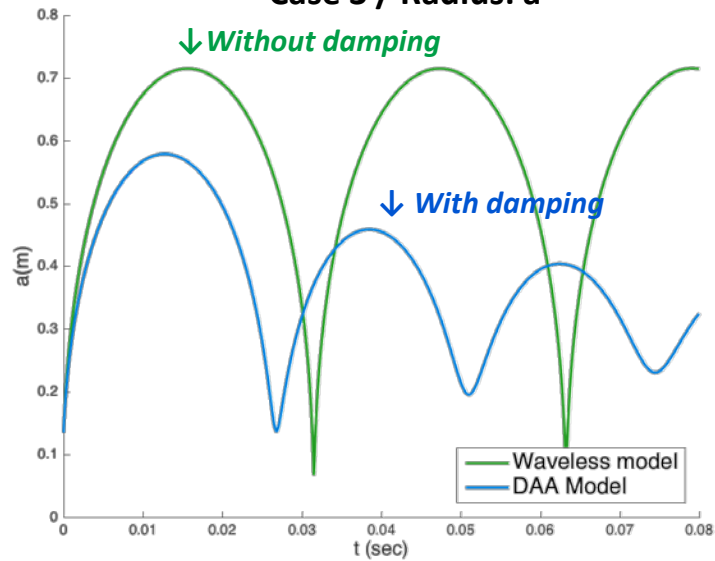
Case 2 / Radius: a



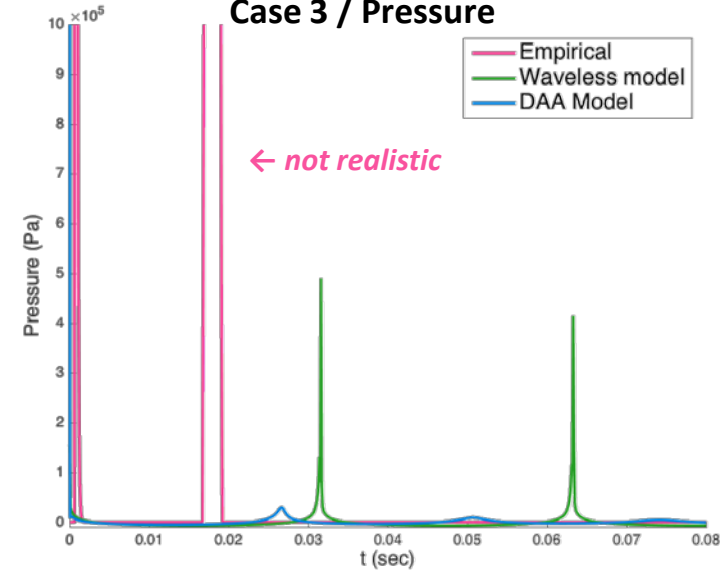
Case 2 / Pressure



Case 3 / Radius: a



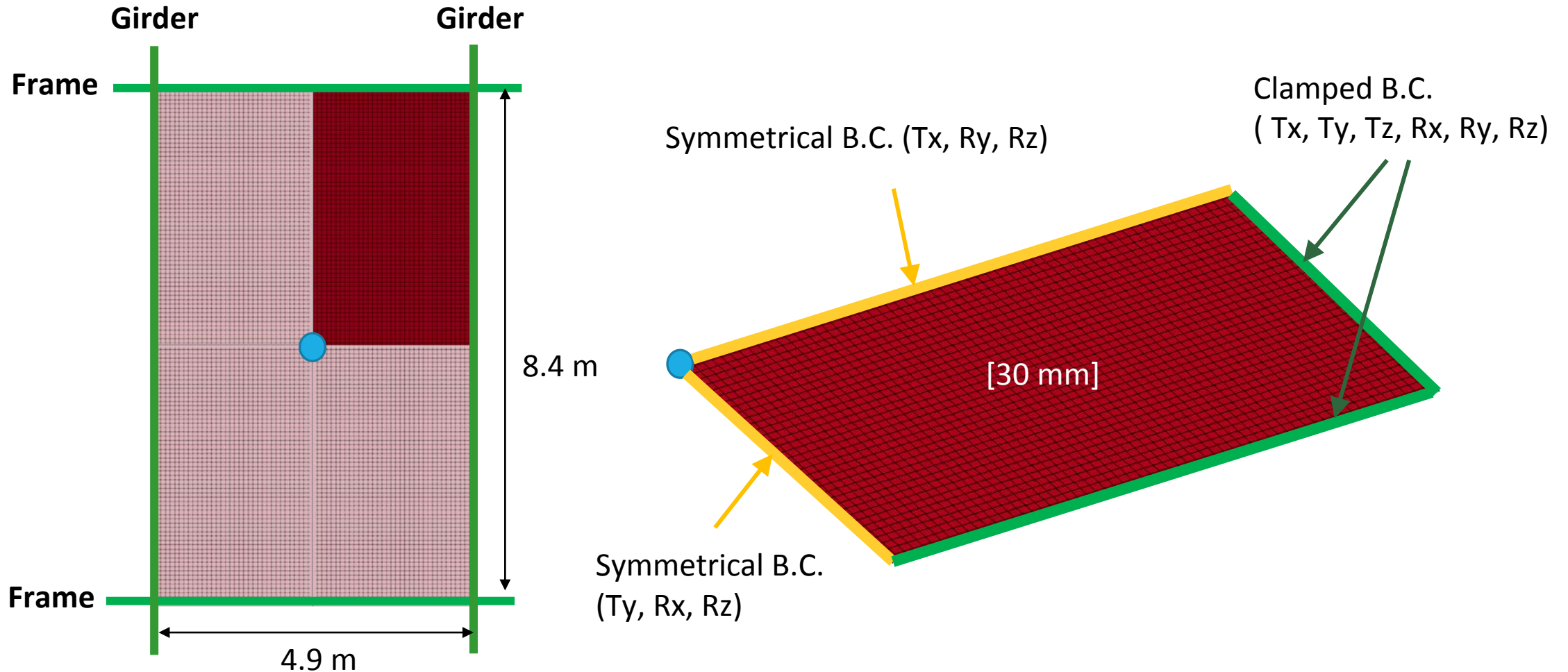
Case 3 / Pressure



Conclusions

- ✓ **Analytical models** can be used for various charge materials, mass and water depth
- ✓ **DAA model** is more representative of the reality than **waveless model**

Example 1 : Clamped plate model



Results of clamped plate

- Case 1: $m_c = 500 \text{ kg}$, $d_i = 50 \text{ m}$, $\rho_c = 1600 \text{ kg/m}^3$

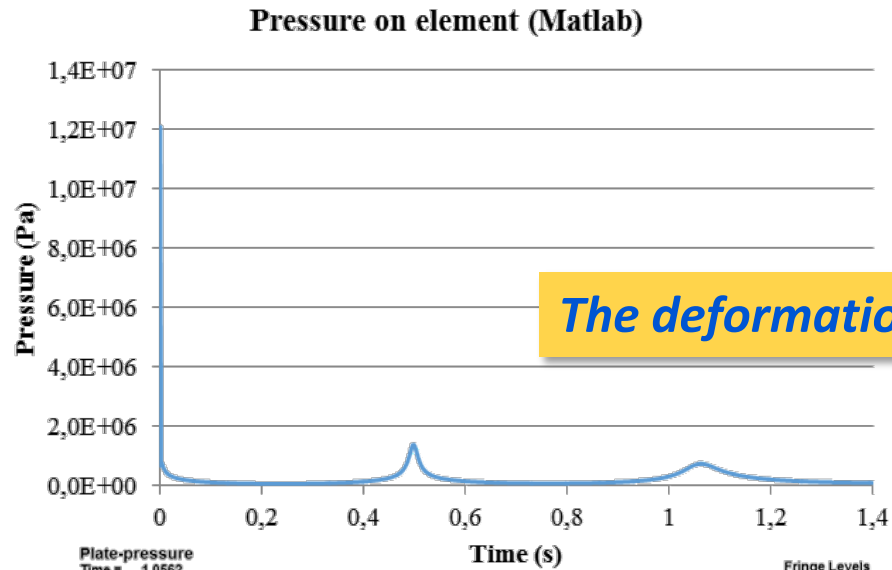
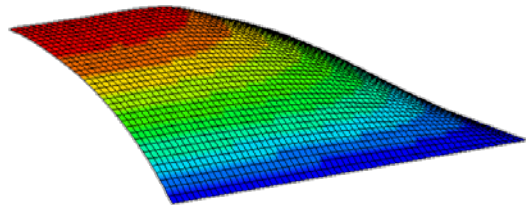


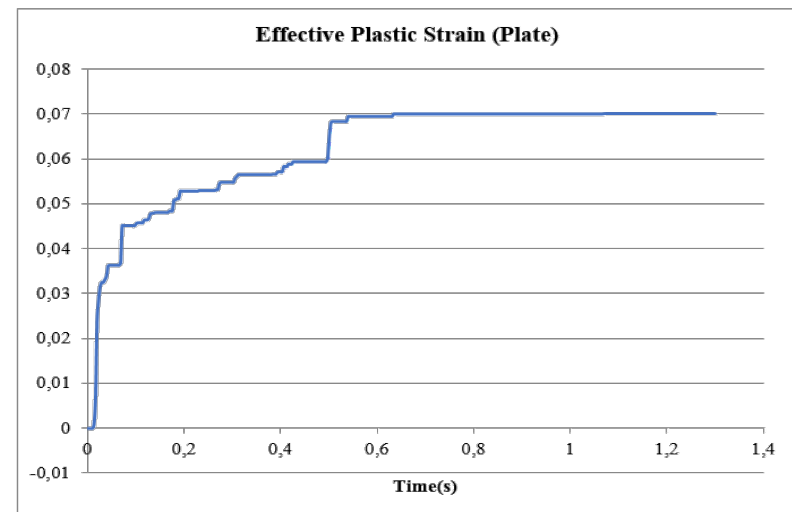
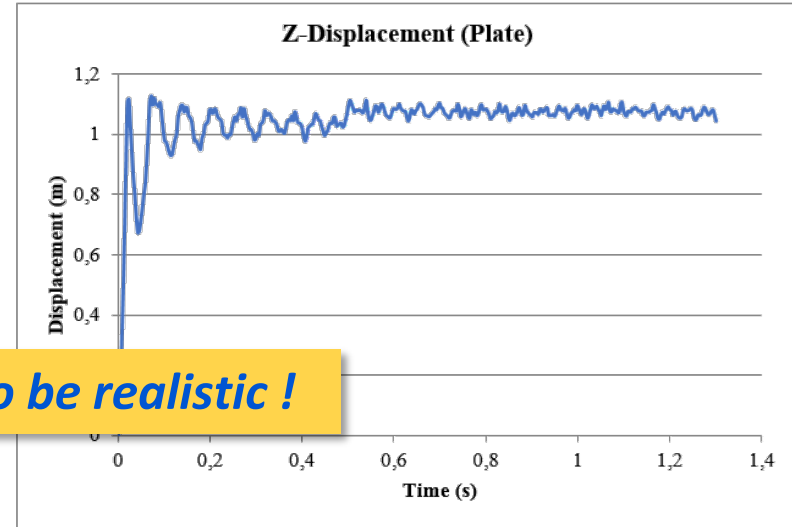
Plate-pressure
Time = 1.0562
Contours of Z-displacement
min=0, at node# 72
max=1.0958, at node# 1
max displacement factor=2

Fringe Levels

1.096e+00
9.862e-01
8.766e-01
7.671e-01
6.575e-01
5.479e-01
4.383e-01
3.287e-01
2.192e-01
1.096e-01
0.000e+00

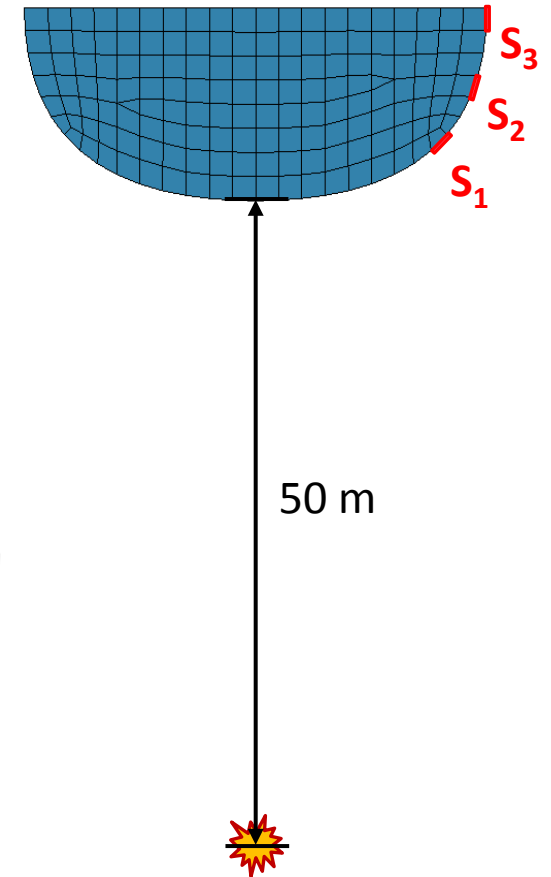
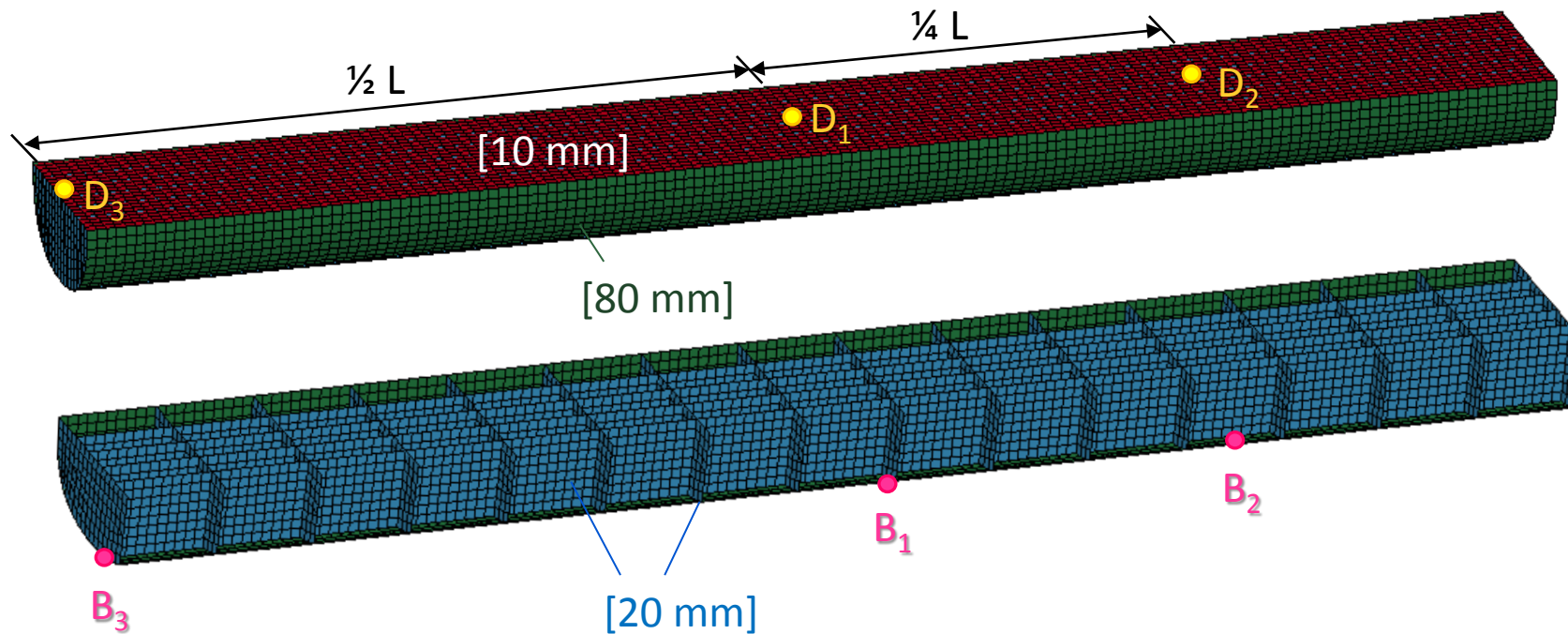


The deformation seems to be realistic !



Example 2 : Semi-cylinder model

- Charge Case 1: $m_c = 500 \text{ kg}$, $d_i = 50 \text{ m}$, $\rho_c = 1600 \text{ kg/m}^3$
- Length: 150 m, Breadth: 20m, Draft: 8 m

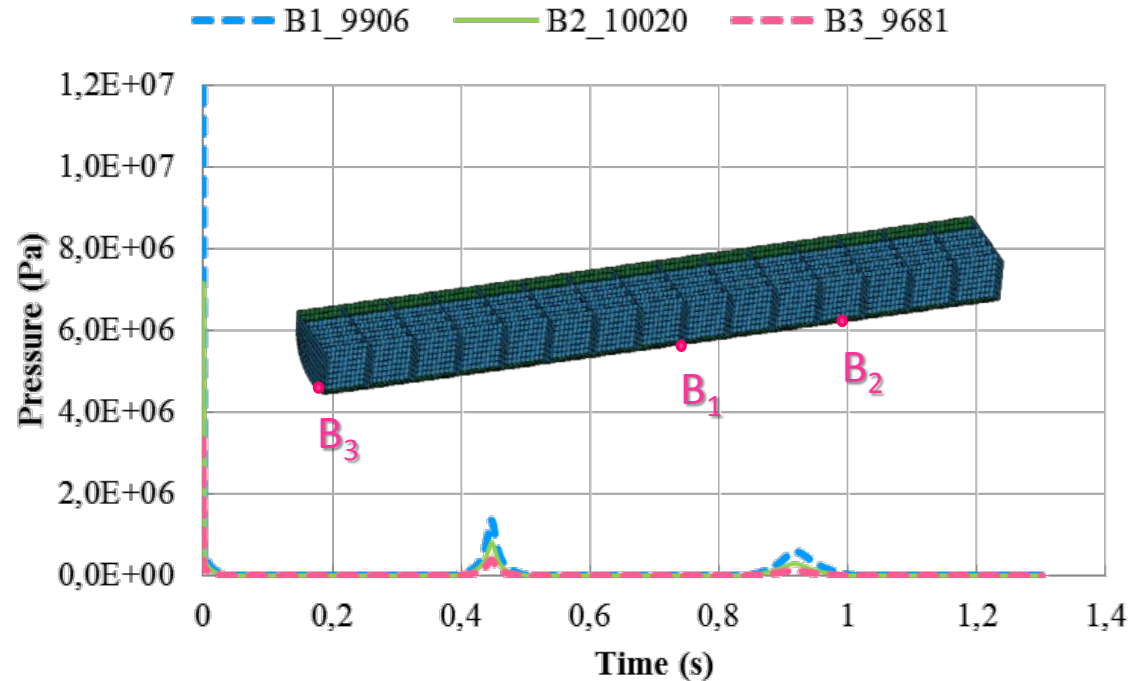




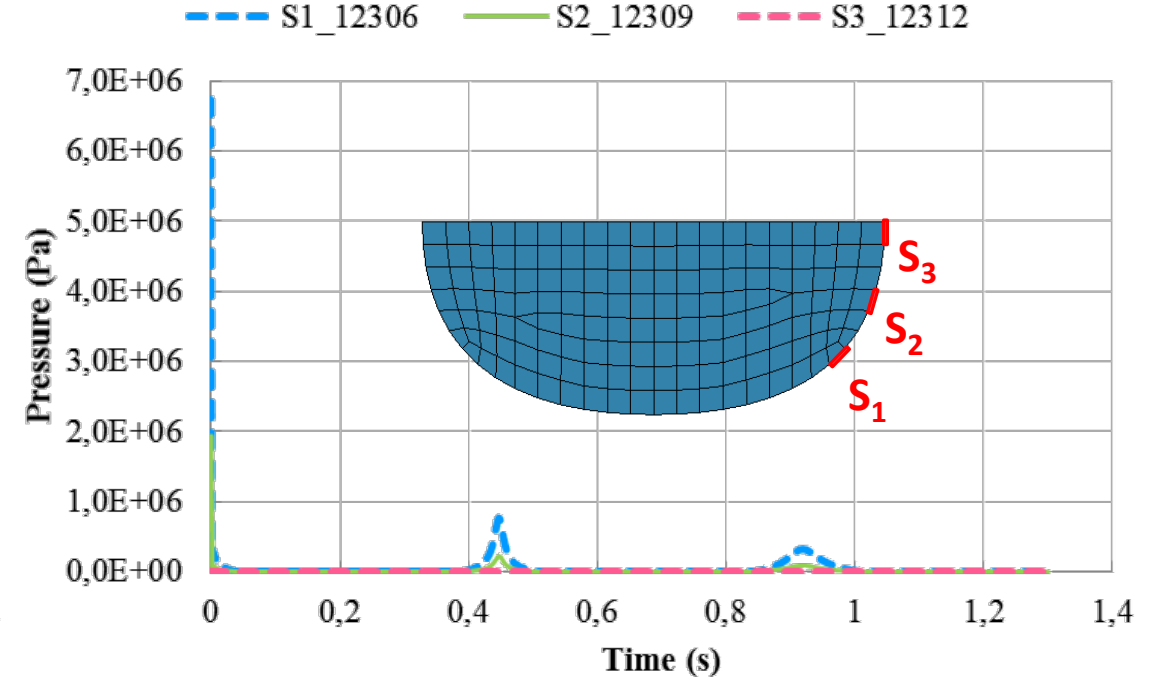
Pressure loads for semi-cylinder

- Charge Case 1: $m_c = 500 \text{ kg}$, $d_i = 50 \text{ m}$, $\rho_c = 1600 \text{ kg/m}^3$

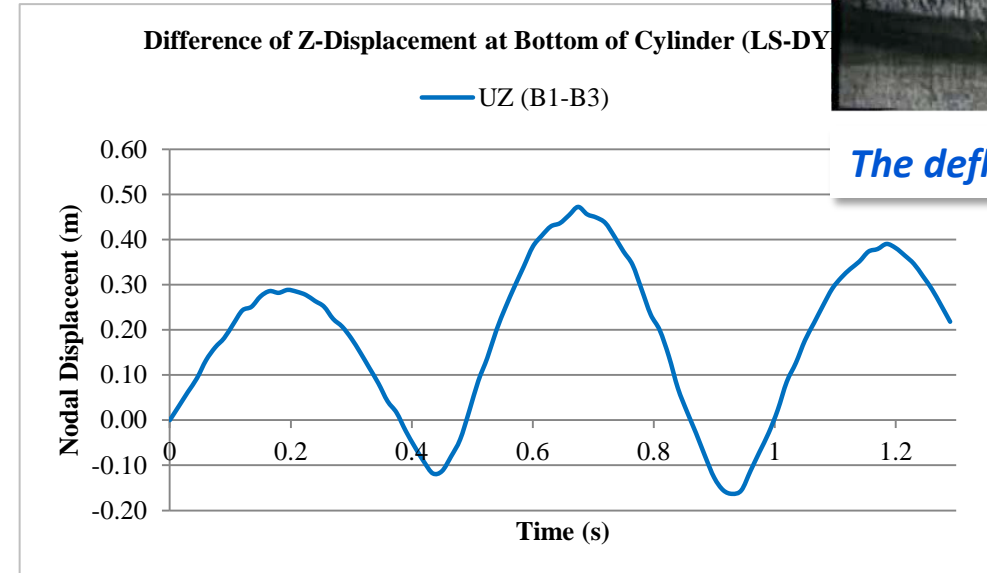
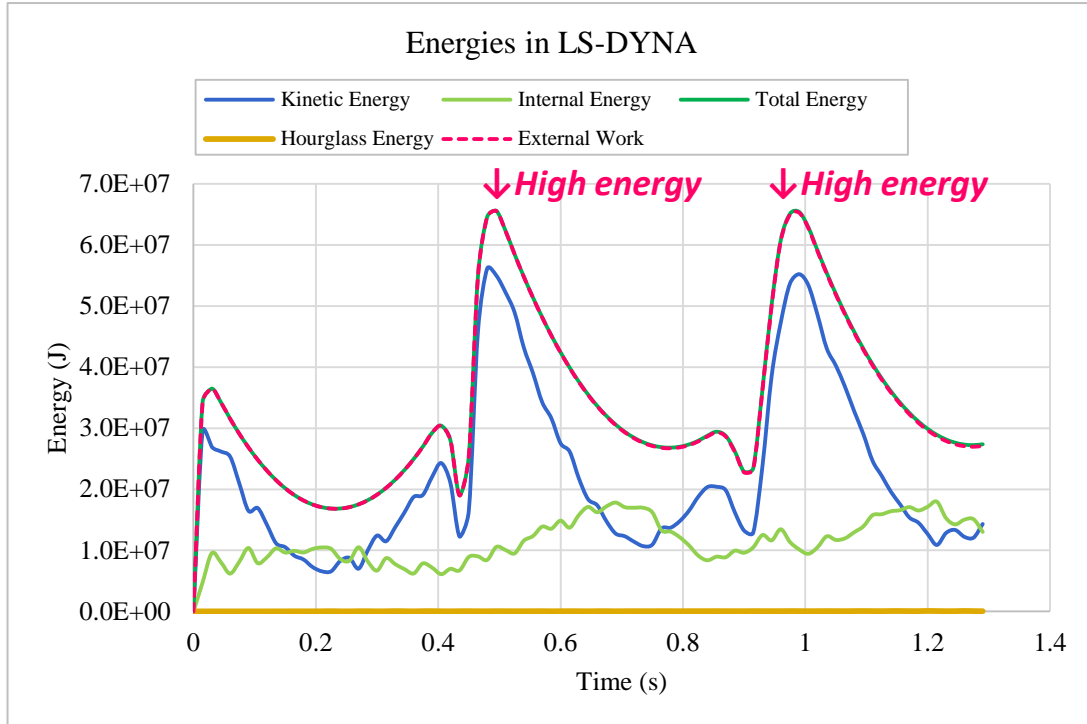
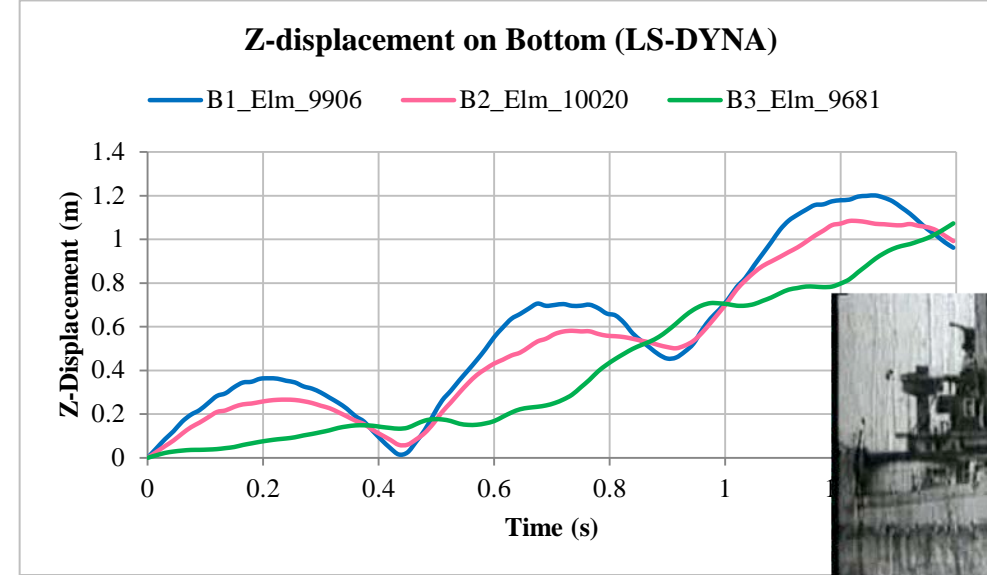
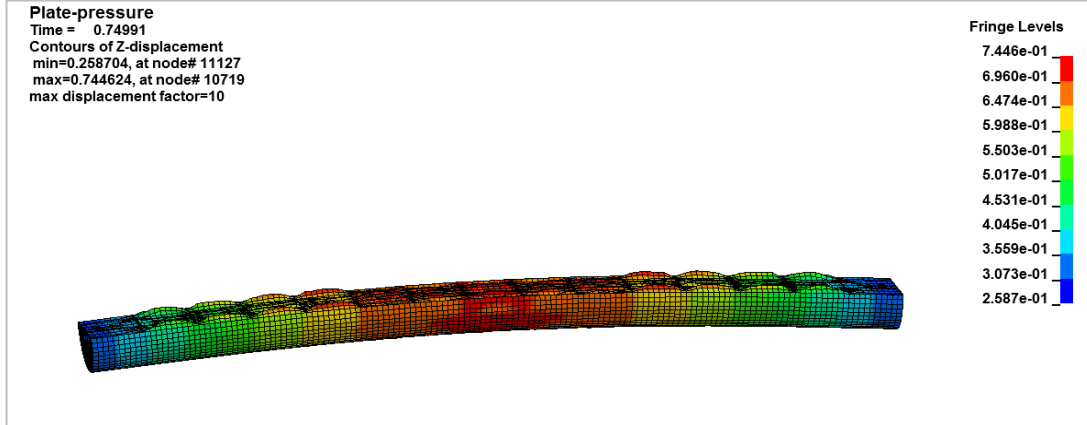
Final Pressure on Bottom (LS-DYNA)



Final Pressure on Side (LS-DYNA)



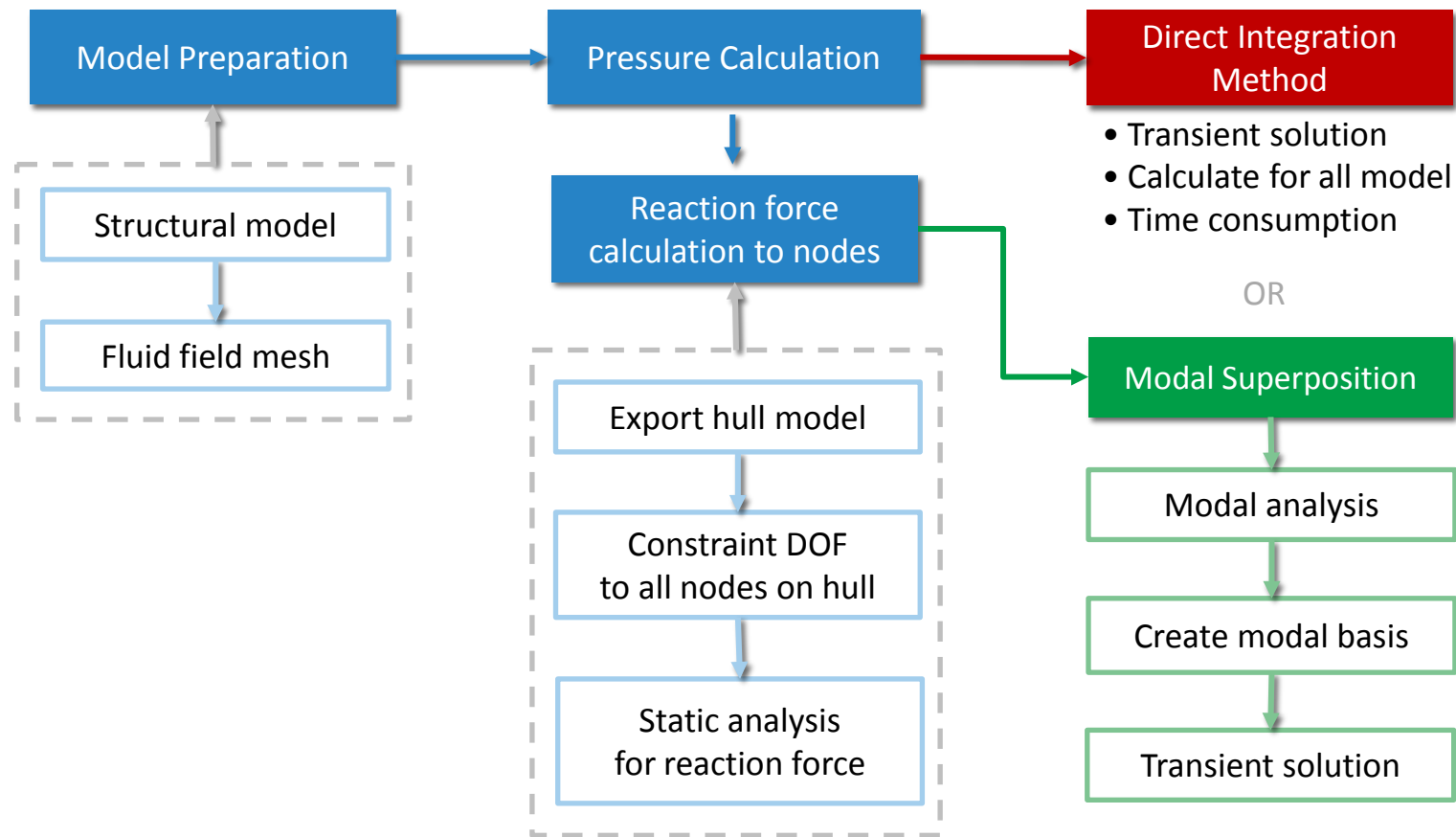
Results of semi-cylinder model



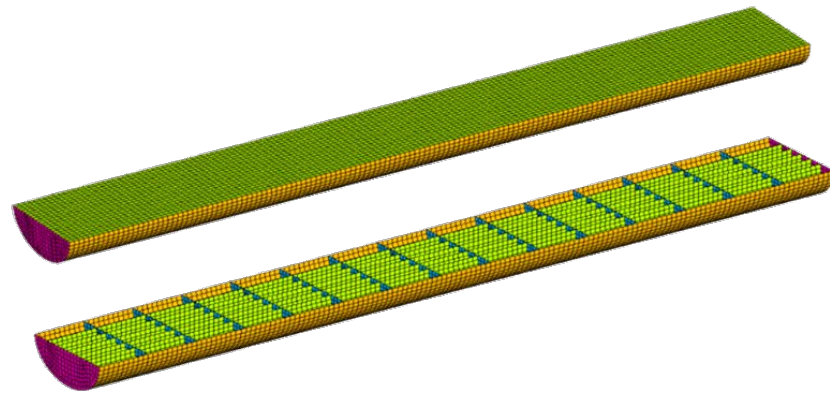
The deflection is realistic.

Analysis process for ANSYS

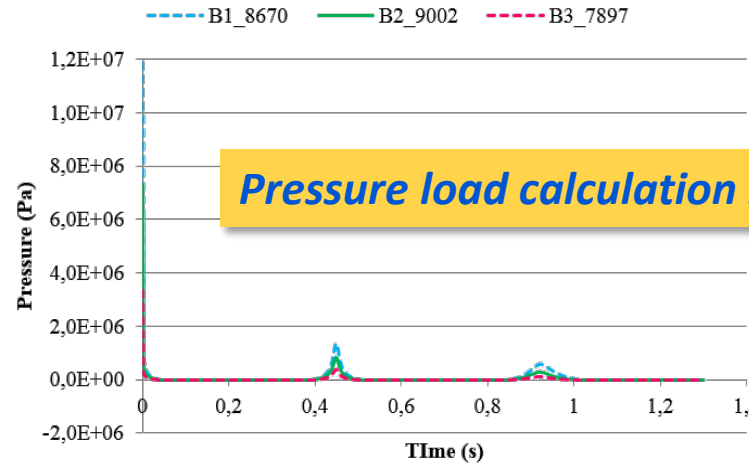
- Objective: Convert code from MATLAB to ANSYS language



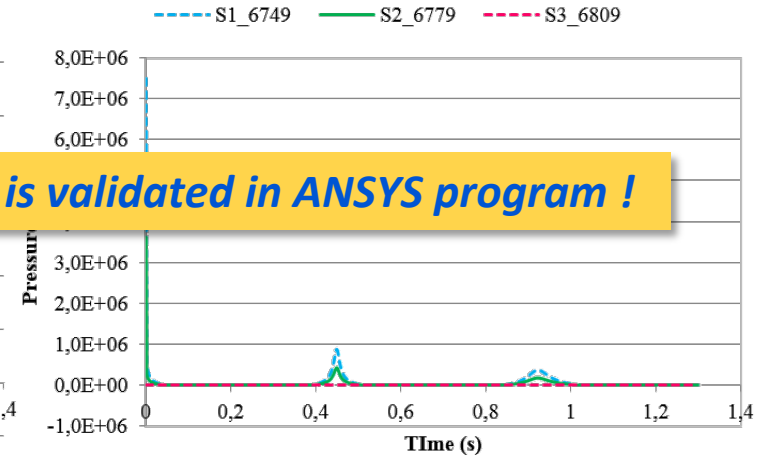
Example 2: Semi-cylinder model



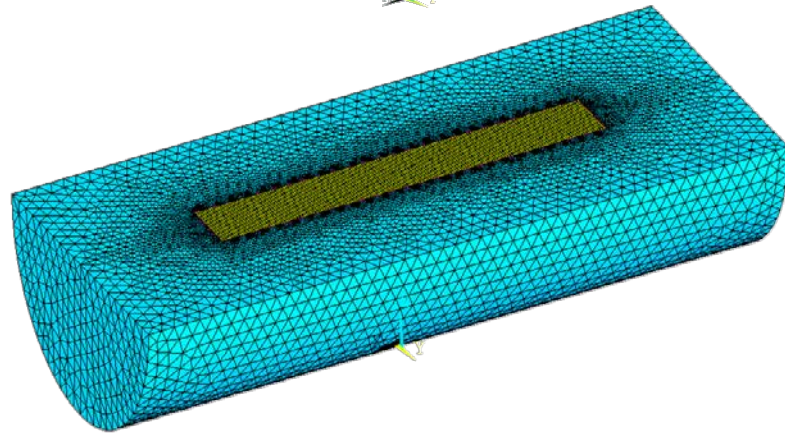
Pressure on Bottom (ANSYS)



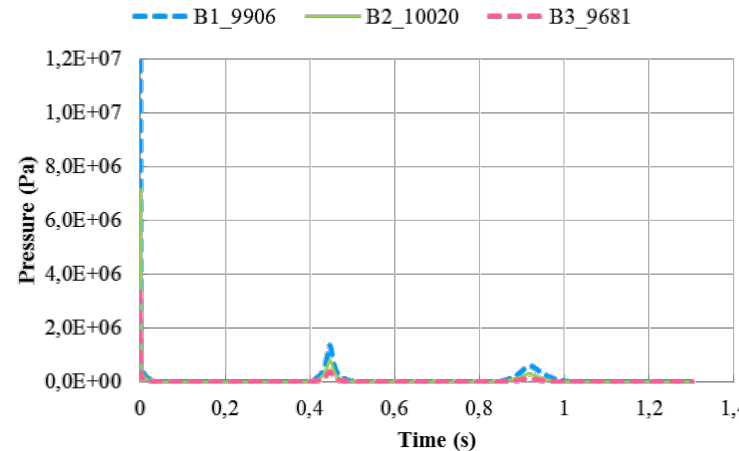
Pressure on Side (ANSYS)



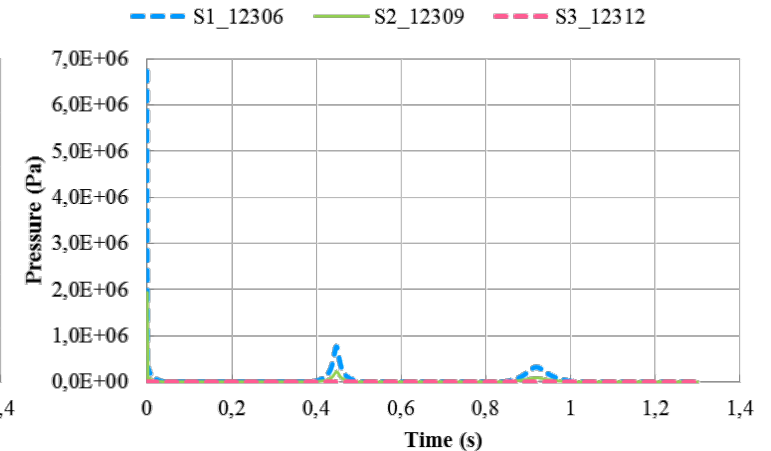
Pressure load calculation is validated in ANSYS program !



Final Pressure on Bottom (LS-DYNA)

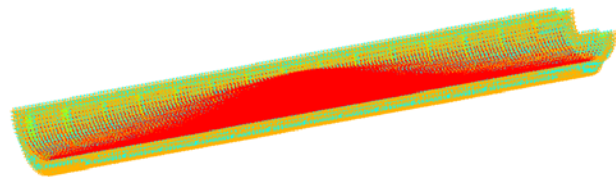


Final Pressure on Side (LS-DYNA)

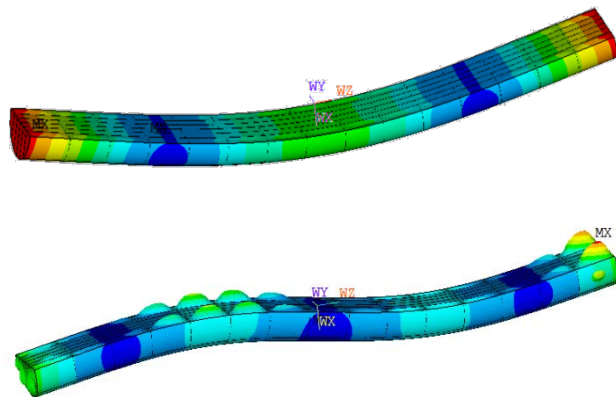


Results of semi-cylinder model

- Static analysis



- Modal analysis

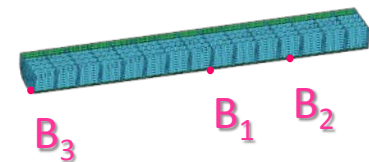
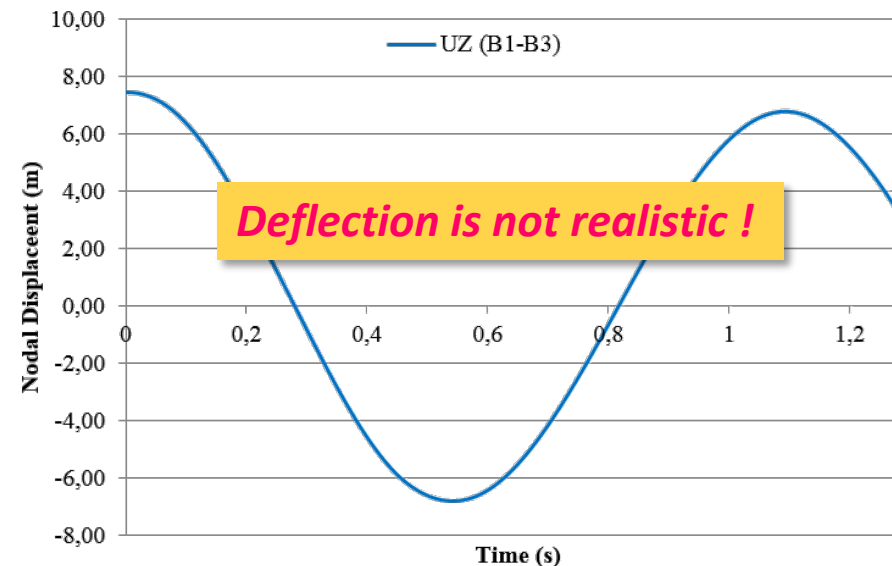


- Transient solution

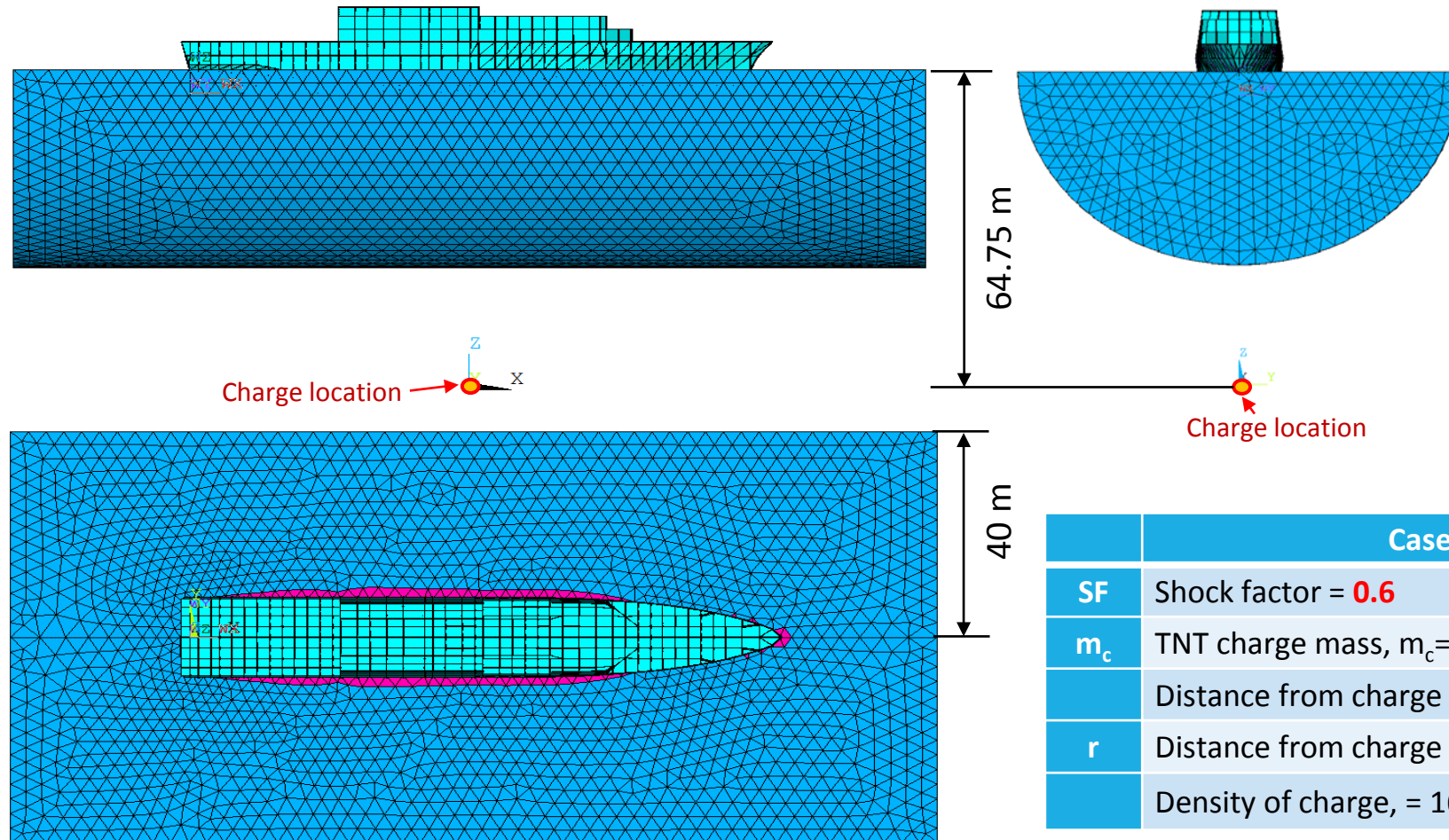
by model superposition

- Displacement should be zero at time 0
- Too high deflection > 14m !!!

Difference of Z-Displacement at Bottom of Cylinder (ANSYS)



Example 3 : Frigate ship model

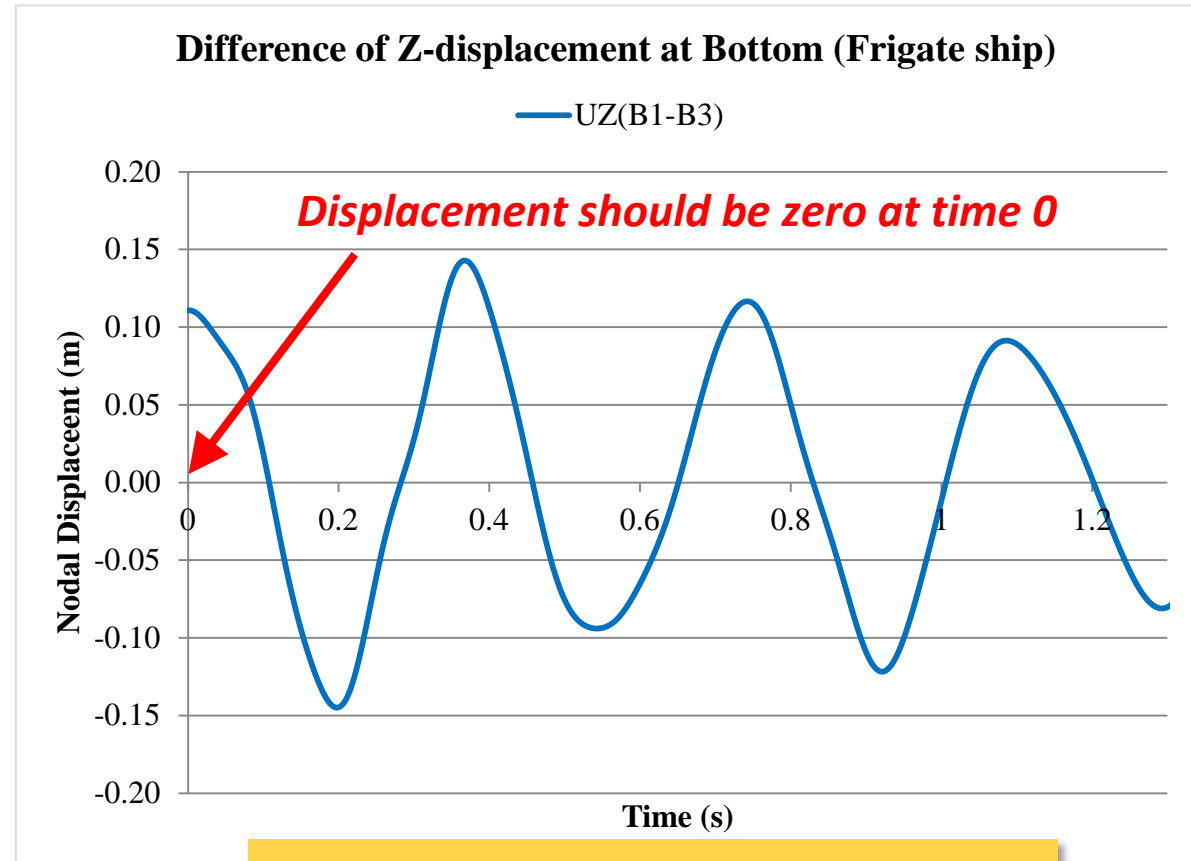


- Length of all: 95.0 m
- Breadth: 14.0 m
- Draught: 4.75 m

	Case Description
SF	Shock factor = 0.6
m_c	TNT charge mass, $m_c =$ 1296 kg
	Distance from charge to free surface, = 64.75 m
r	Distance from charge to standoff point, $r =$ 60 m
	Density of charge, = 1600 kg/m ³

Results of Example 3

- Transient solution by modal superposition



Conclusion

- DAA analytical model, representative of the reality, has been chosen
- Secondary bubble oscillation phase has significant influence on structure
- Model superposition method leads to unrealistic results
 - ➔ This method is suitable only for small displacements (it is not the case here)
- **Direct integration method**

Future work

- Perform shock response analysis for one or several embarked materials using Dynamic Design Analysis Method (DDAM)
- Examples : Shaft line or / and pipes line

