HEXAGON

Forced Response of Coupled Plate and Cavity

Actran Student Edition Tutorial

Workshop description

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Introduction

- This workshop demonstrates Actran capabilities to compute response of coupled plate / cavity system to mechanical excitation

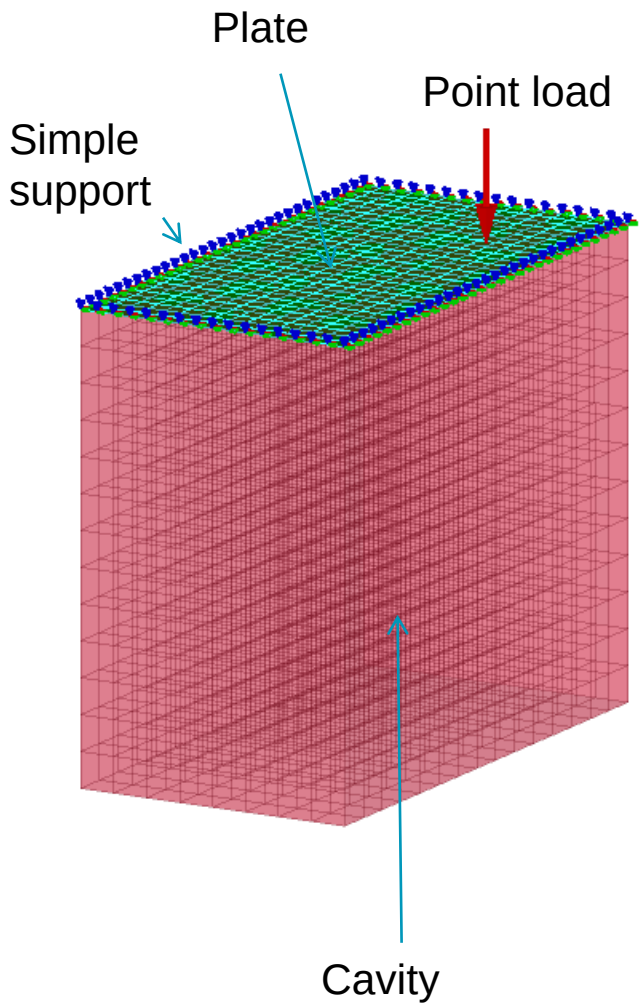
- The objectives of this workshop are the following:
  - Compute the structural and cavity responses to a point load excitation on the plate
  - Get introduced to incongruent meshing technique for structure/cavity coupling

- Software version:
  - Actran 2021.1 Student Edition

- **Pre-requisites** - before going through this presentation, the reader should have read and understood the following presentation:
  - Workshops : Plate modes, plate forced response
  - Workshops: Cavity modes, cavity forced response

Workshop description

- The plate has the same size, thickness and material as the one in the tutorials of “plate forced response” and “plate modes extraction”
- The air cavity has the same size as the one in tutorials “cavity forced response” and “cavity modes extraction”
- The excitation is modeled as an harmonic force applied on the plate



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Geometry description

- Let us consider a plate with the following properties:
  - Size: $L_x = 0.75\,m$, $L_y = 0.40\,m$, thickness $t = 0.003\,m$
  - Material properties: $E = 7 \cdot 10^{10}\,Pa$ with 1% damping, $\nu = 0.25$ and $\rho = 2400\,kg/m^3$
  - Plate simply supported along the four edges
  - Time-harmonic point load with unit amplitude at point $x = 0.2\,m$, $y = 0.1\,m$:

$$F(t) = R\left(Ae^{i\omega t}\right) \; where \; A = 1 \; and \; \omega = 2\pi f$$

Workshop pre-processing

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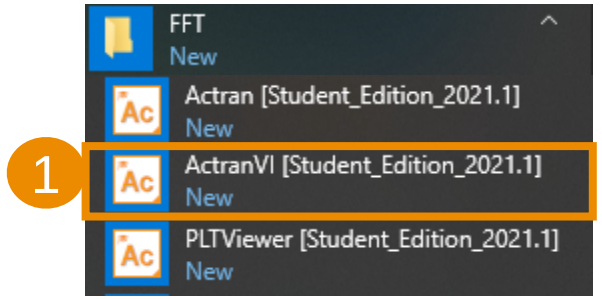
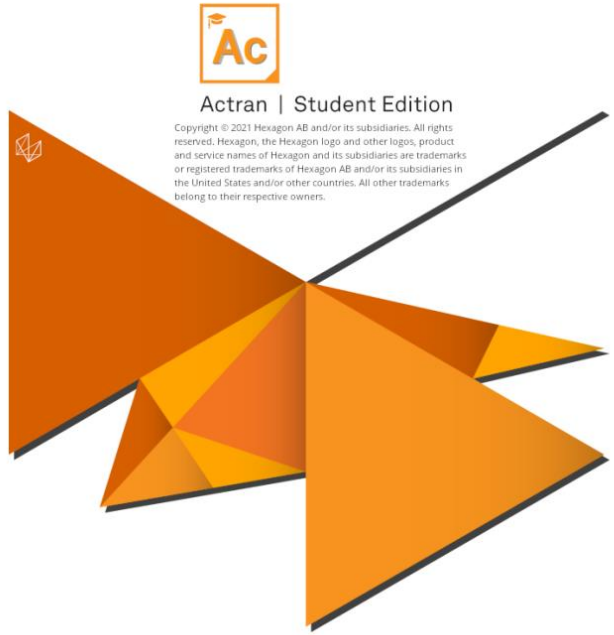
Start ActranVI

- Start ActranVI:
  - Shortcut is available through the Windows Start Menu



(Windows Start Menu)



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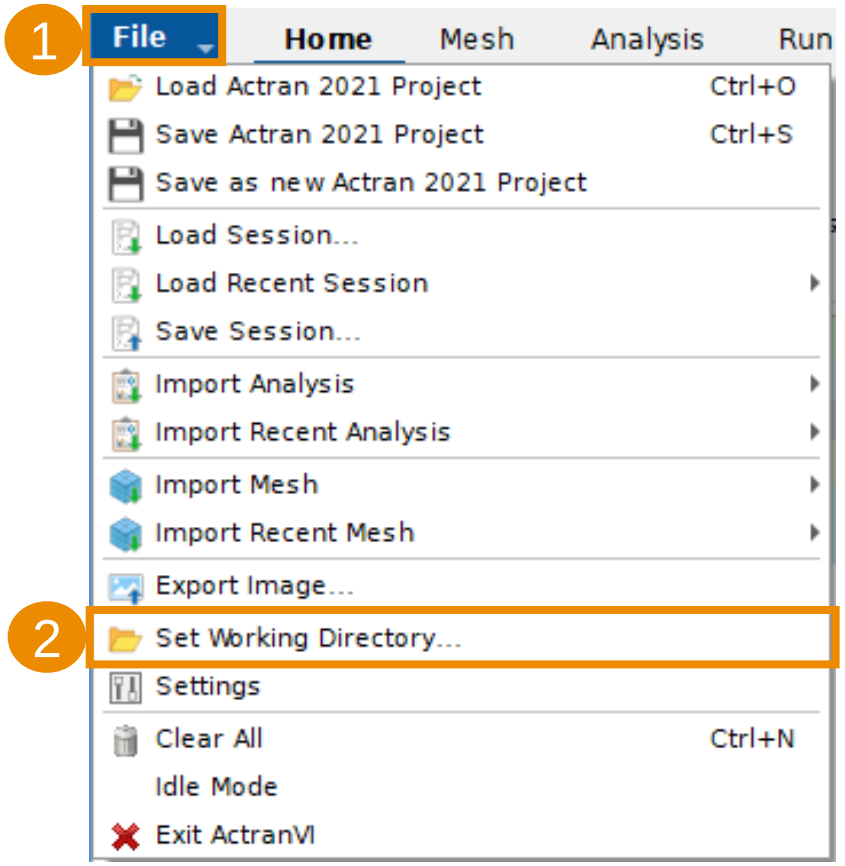
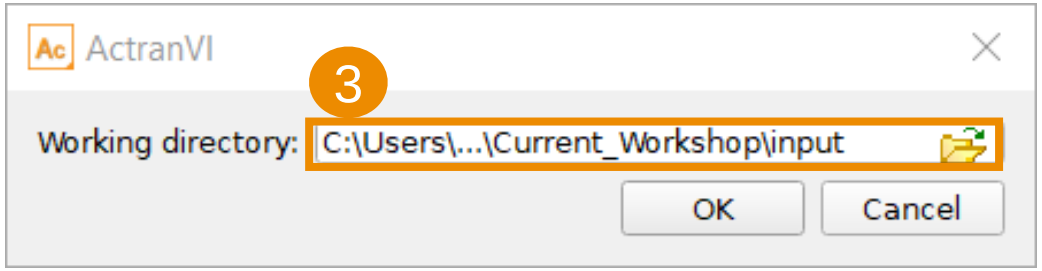
Set the working directory

Select the workshop input directory as the working directory

- The working directory is the project directory where all ActranVI related files are output

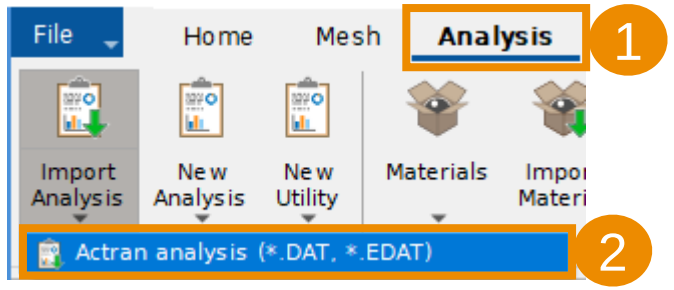


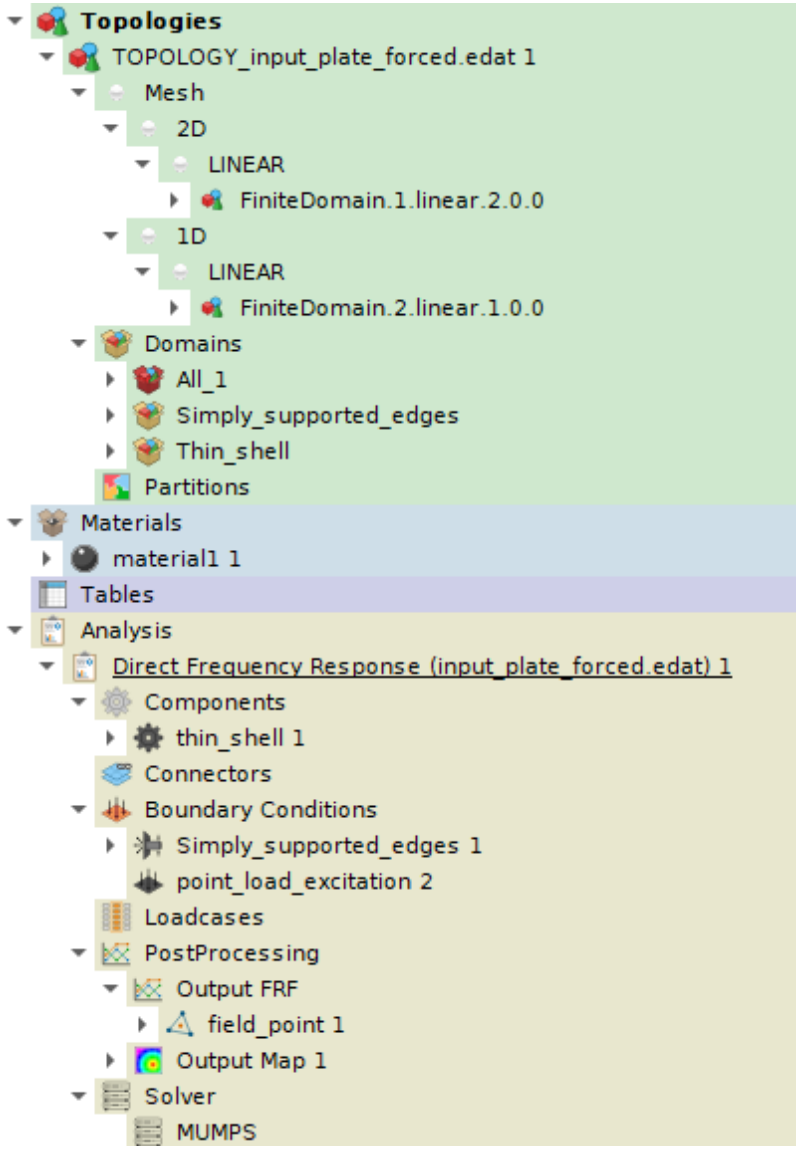


The working directory path should not contain any space or special character

Import the analysis of “Plate force response”

- Import the *input_plate_forced.edat* analysis





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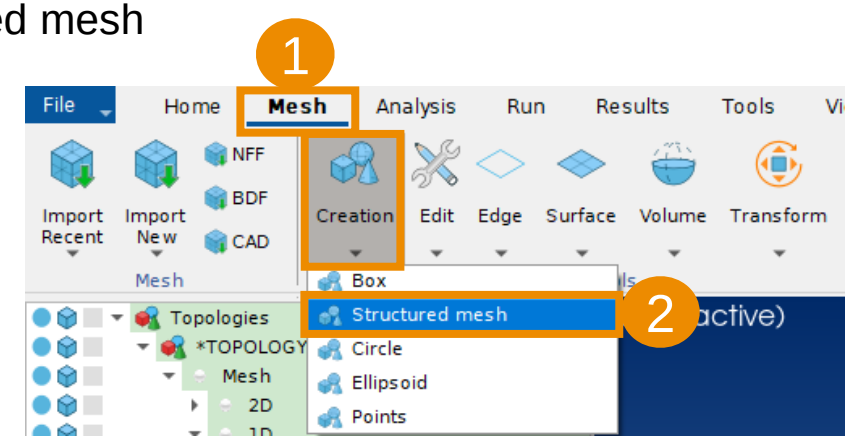
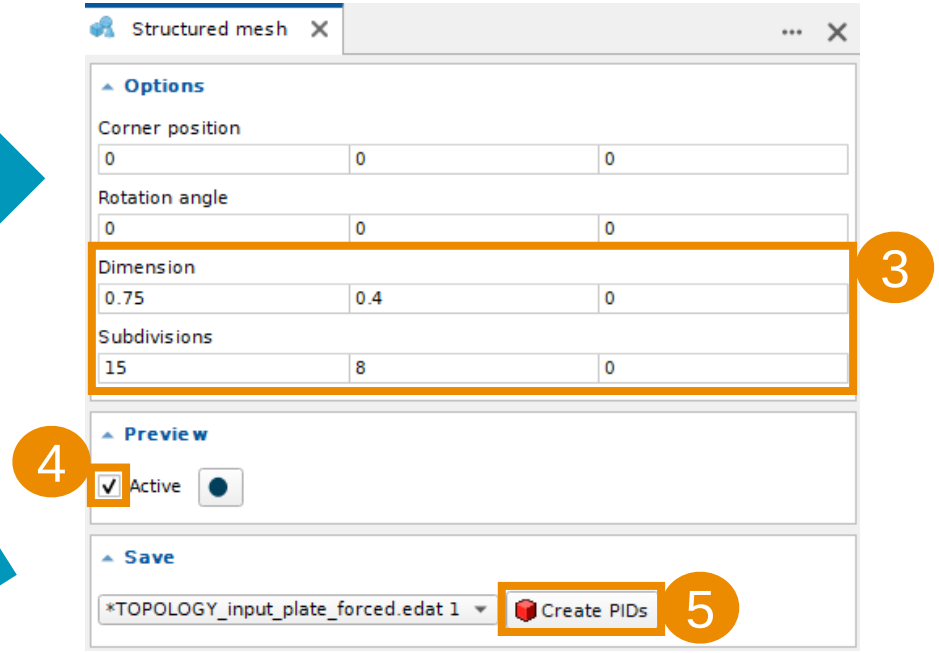
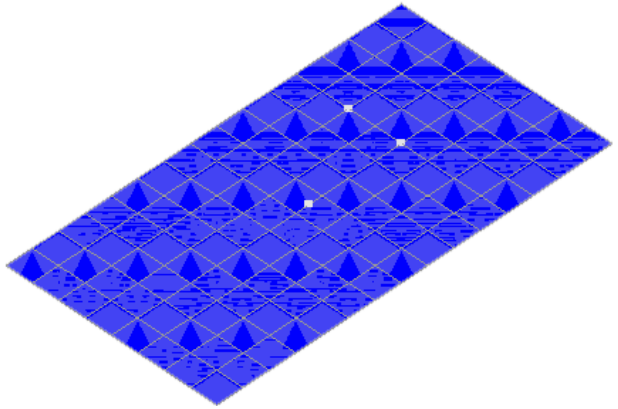
Create the cavity mesh (1)

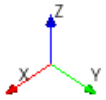
- Create a structured mesh





- Visualize it before creation





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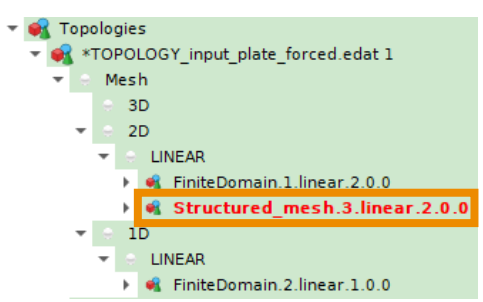
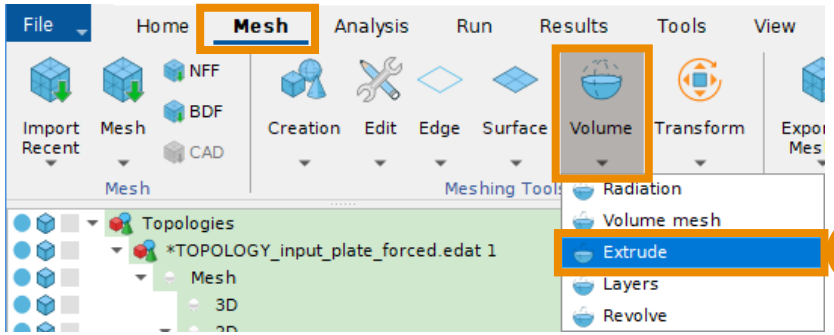
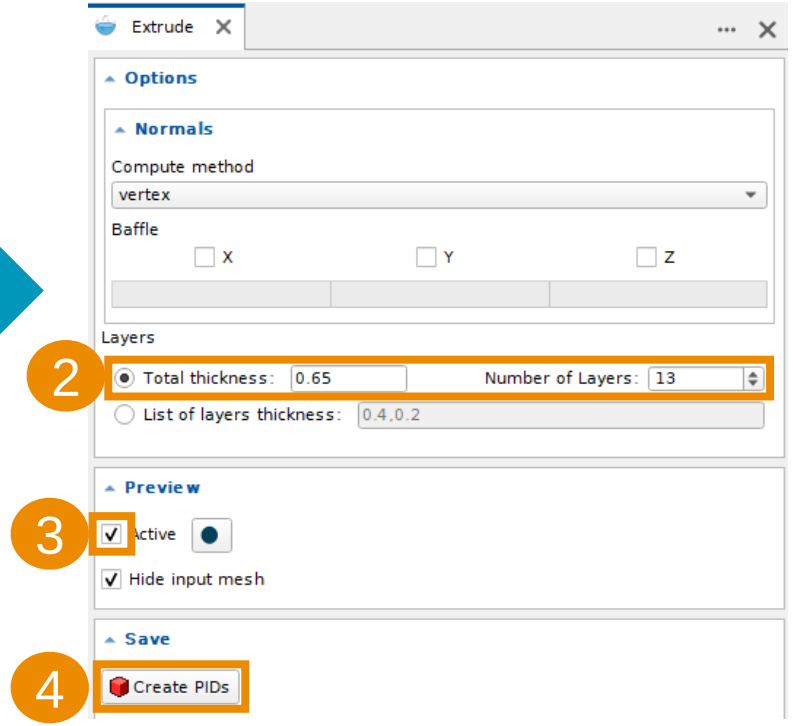
Create the cavity mesh (2)

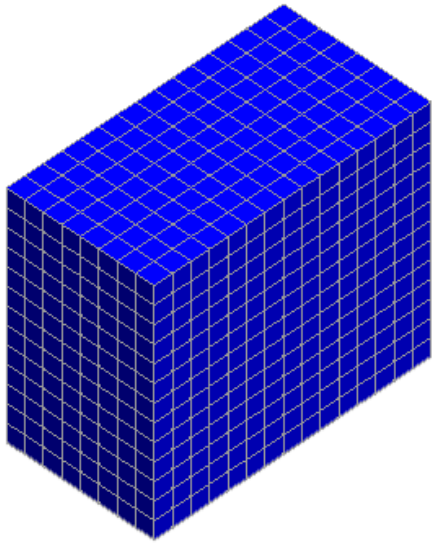
- Extrude the structured mesh

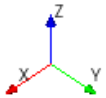






- Visualize it before creation





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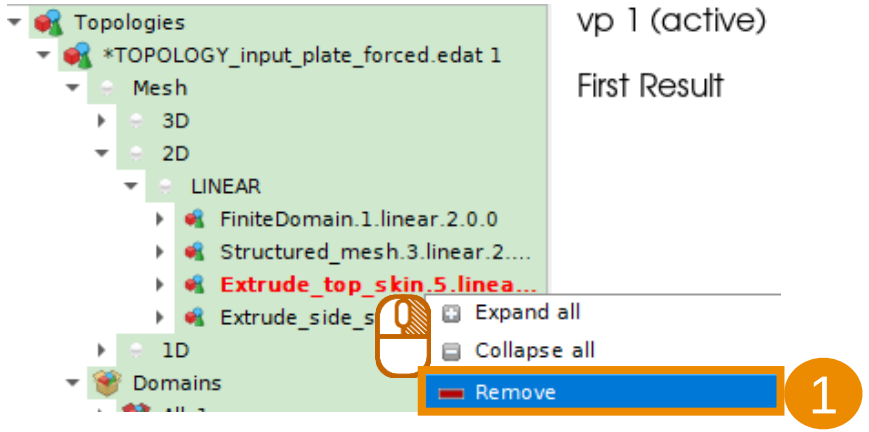
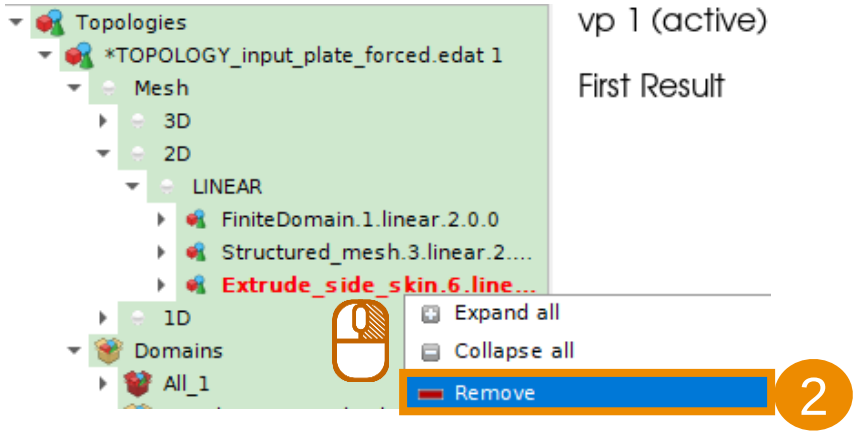
Create the cavity mesh

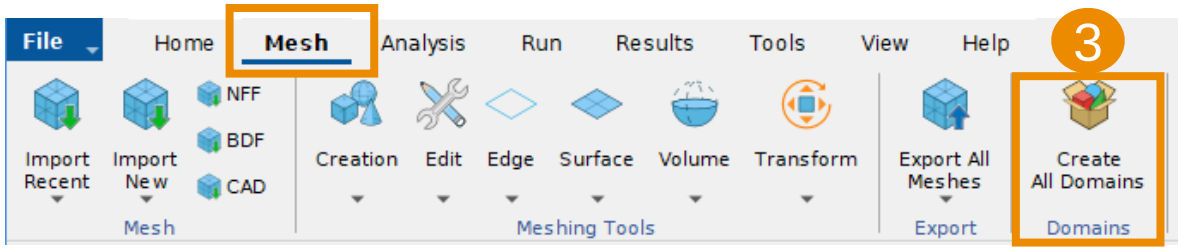
We won't need *Extrude_top_skin and Extrude_side_skin* for the analysis

Delete them

Auto-create domains







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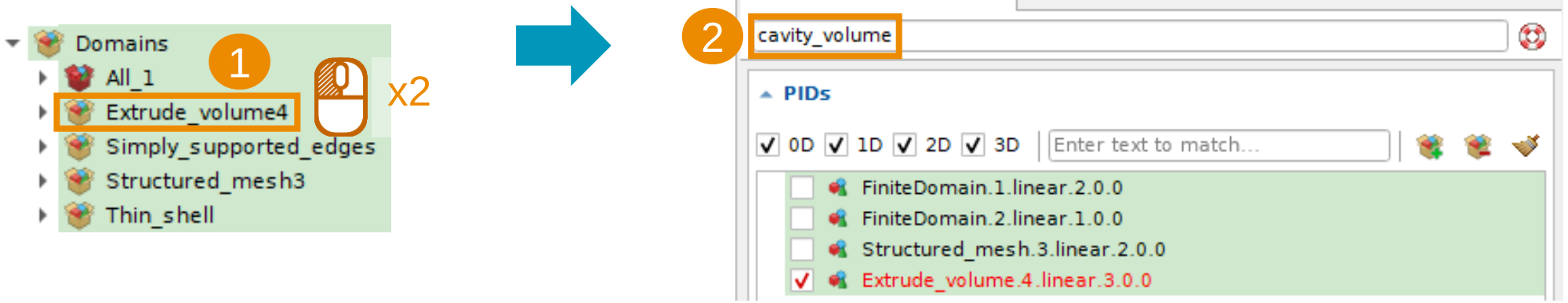
Create the cavity domain

- Rename the following domains
  - *Extrude_volume → cavity_volume*
  - *Structured_mesh → cavity_coupling_surface*



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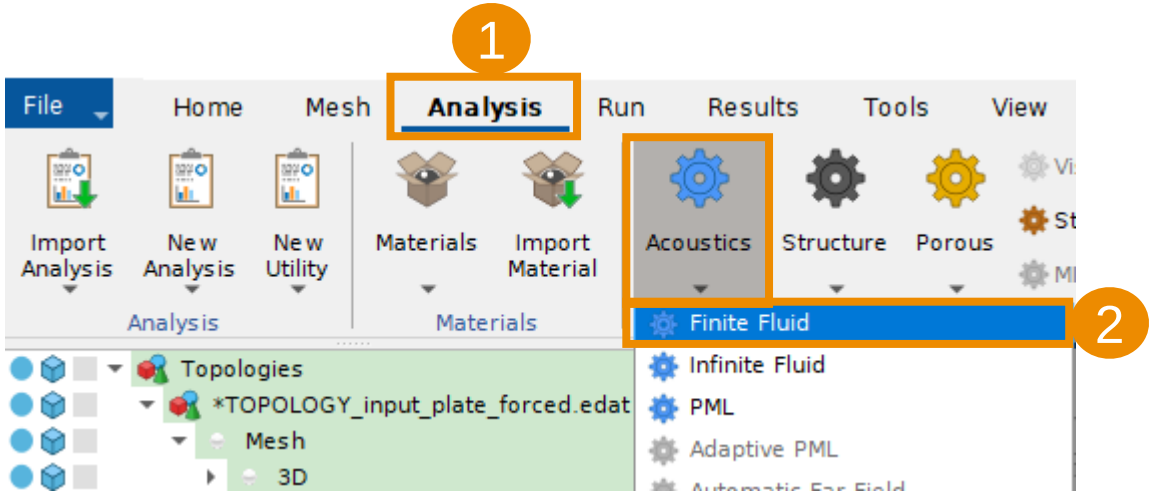
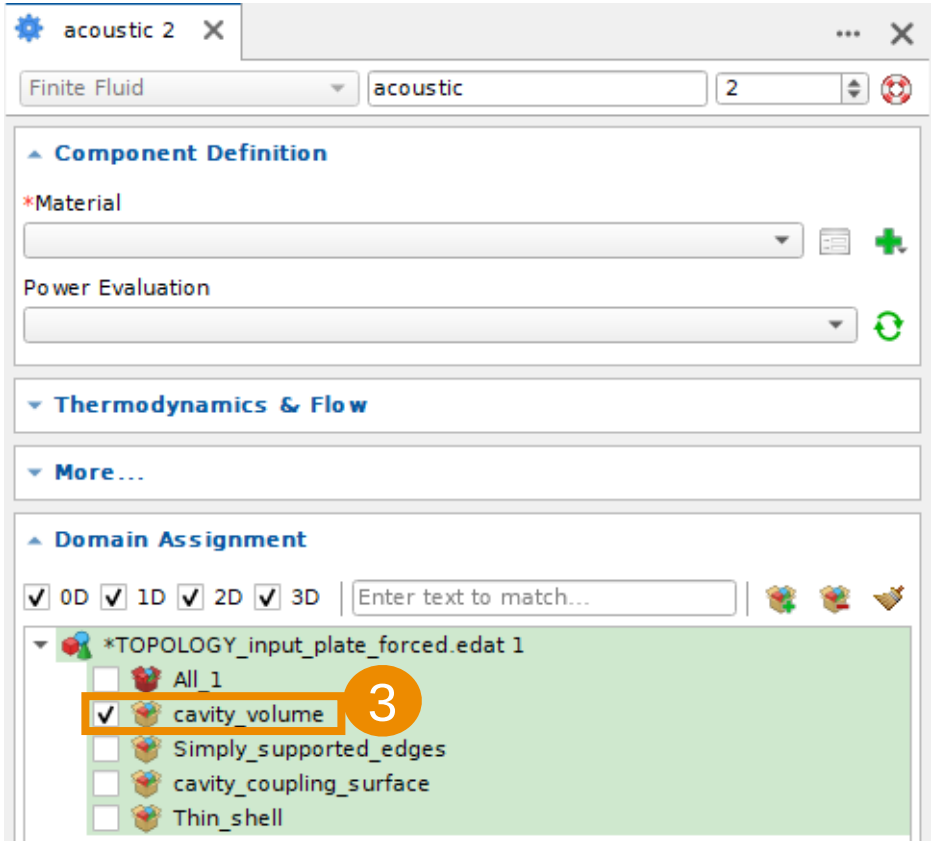
Create a Finite Fluid component for the cavity (1)



Add a *Finite Fluid component*

Set up the *Finite Fluid component* domain



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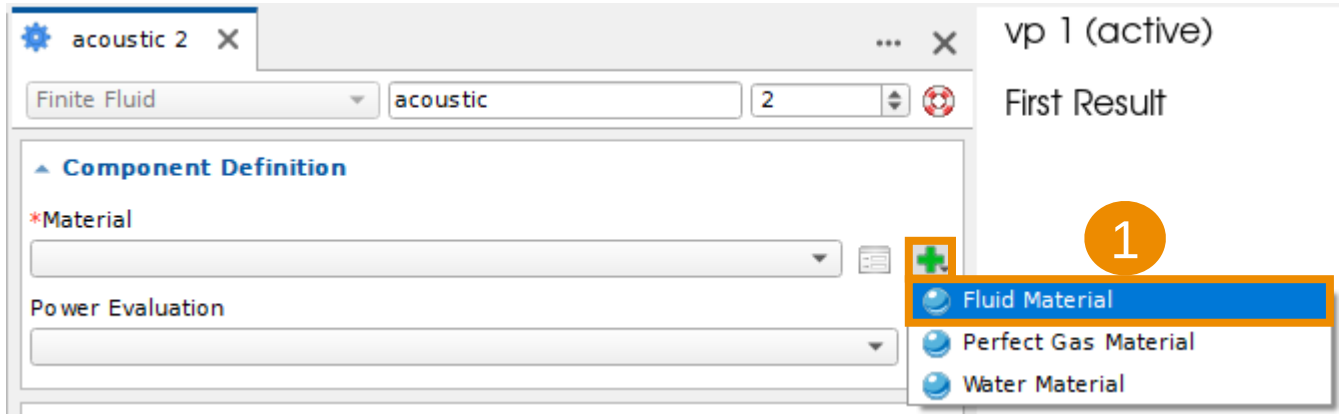
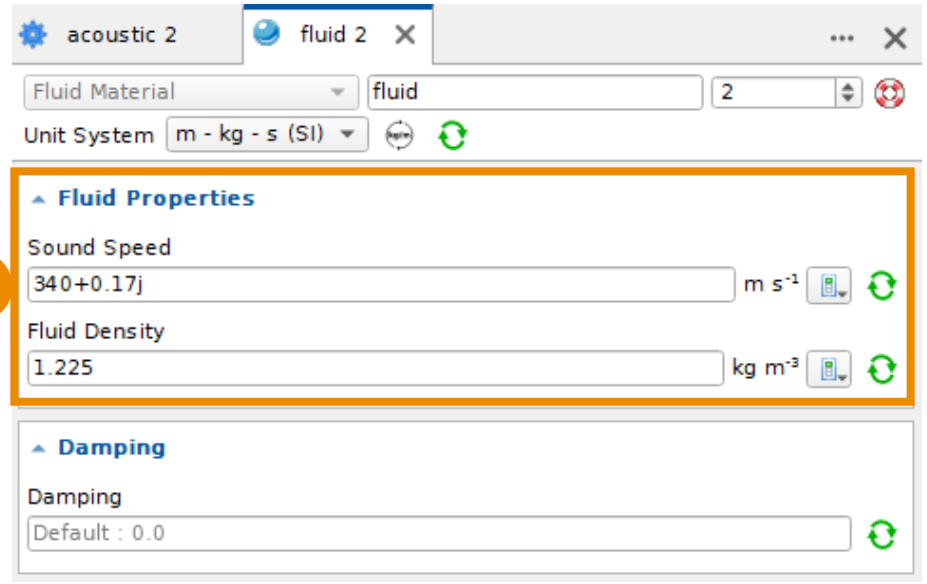
Create a Finite Fluid component for the cavity (2)





Define a material for air

- Add a Fluid Material
- Set the following properties:
  - $c = 340 + 0.17j\ m/s$ (see next slide)
  - $\rho = 1.225\ kg/m^3$

Close both property windows (material & component)

Internal losses in fluids (1)

- Air viscosity induces an exponential decrease of a wave's amplitude with distance
- The pressure distribution can be expressed as follows:

$$p = e^{-ikx} \cdot e^{-\alpha x} = e^{-i\tilde{k}x}$$

Where α is the attenuation coefficient

- The attenuation effect can be analyzed as an addition of an imaginary part to the wave number which becomes complex:

$$\tilde{k} = k - i\alpha = \frac{\omega - i\alpha c}{c} = \frac{\omega}{c}\left(1 - \frac{i\alpha c}{\omega}\right)$$

- Assuming

$$1 - \epsilon \simeq \frac{1}{1+\epsilon} \; for \; \epsilon \ll 1 \rightarrow \tilde{k} \simeq \frac{\omega}{c\left(1 + i\frac{\alpha c}{\omega}\right)}$$

Internal losses in fluids (2)

- This decrease can be carried by the speed of sound through the definition of a complex quantity:

$$\tilde{k} \simeq \frac{\omega}{\tilde{c}} \; with \; \tilde{c} = c\left(1 + i\frac{\alpha c}{\omega}\right) = c\left(1 + i\frac{\alpha}{k}\right)$$

- The internal loss factor is the ratio between the imaginary part and the real part of the speed of sound. An internal loss of 0.05% leads to a speed of sound of (340+0.17j) m/s

$$\tilde{p}(x) = e^{i\tilde{k}x} = e^{-i\frac{\omega}{\tilde{c}}x} = e^{-ix\left(\frac{\omega}{c\left(1+i\frac{\alpha c}{\omega}\right)}\right)} = e^{-ix\left(\frac{\omega - i\alpha c}{c}\right)} = e^{-ikx} \cdot e^{-\alpha x}$$

- For acoustic radiation in closed cavities, these viscous losses are often considered
- For exterior acoustic problem they have a very limited impact on results

Plate – Cavity coupling

- The plate and the cavity overlap, but do not share the same nodes. In this case, an Interface Component needs to be created for the plate / cavity incompatible coupling

- An Interface links two Coupling Surfaces
  - **Surface 1**: the shell mesh (surface)
  - **Surface 2**: the surface mesh of the cavity which is in contact with the plate

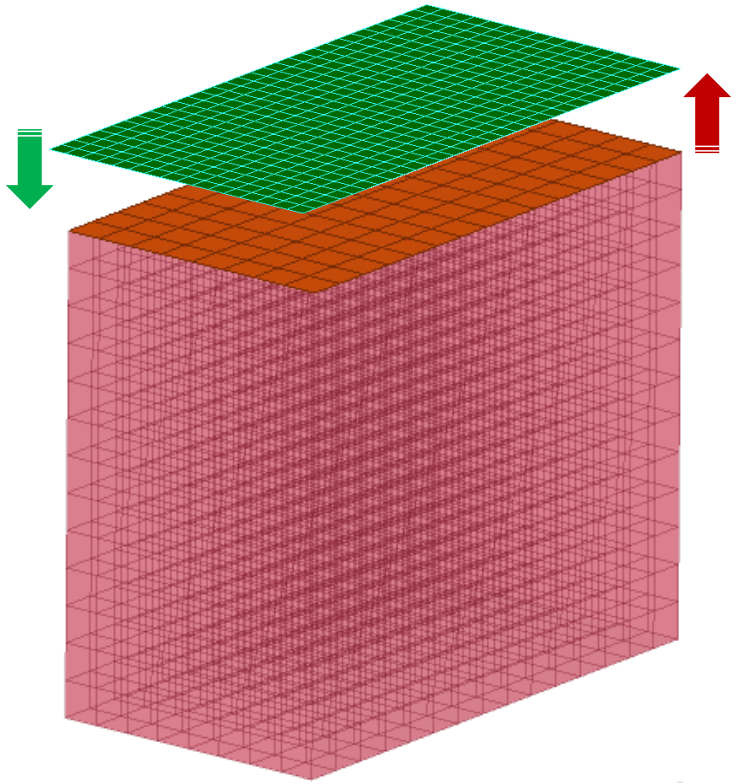


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Plate – Cavity coupling – Incompatible mesh

- Using incompatible mesh, a pair of coupling surfaces needs to be defined to specify which parts of the mesh needs to be coupled

- To obtain the best projection
  - Coupling surface 1: with smallest elements
  - Coupling surface 2: with largest elements

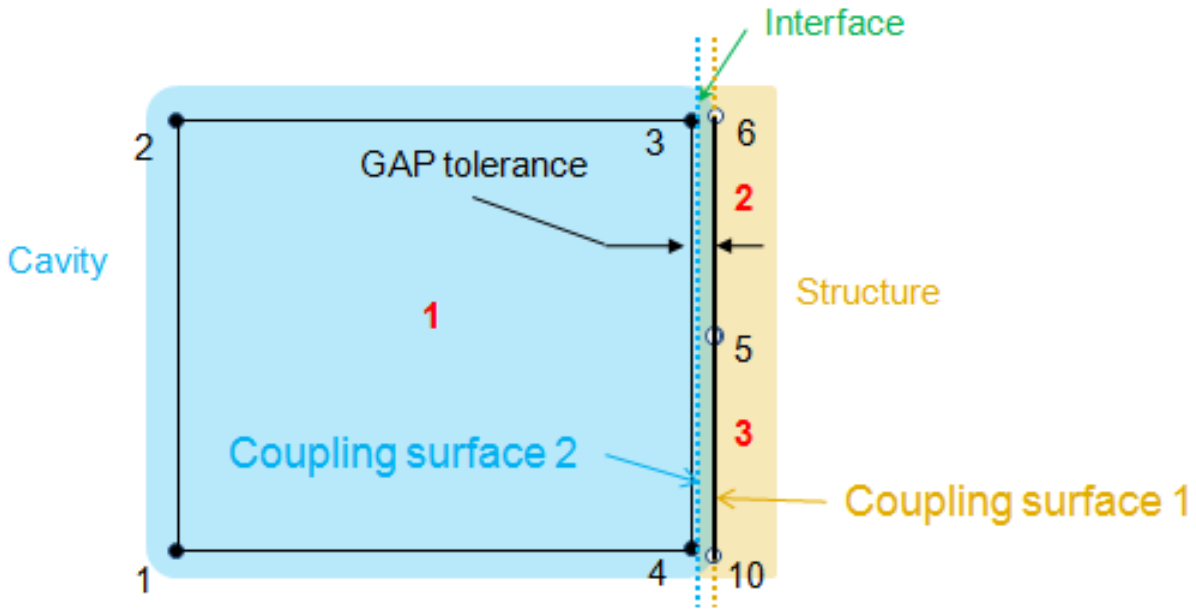

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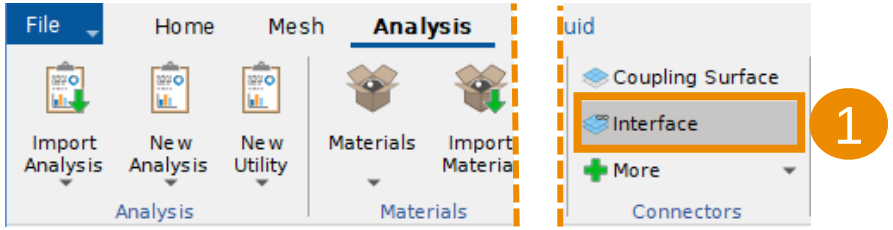
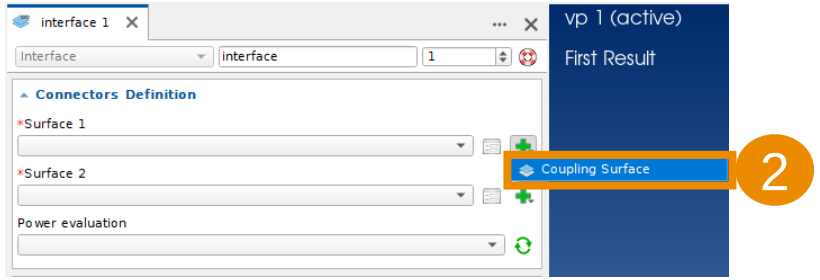
Plate – Cavity coupling – Interface

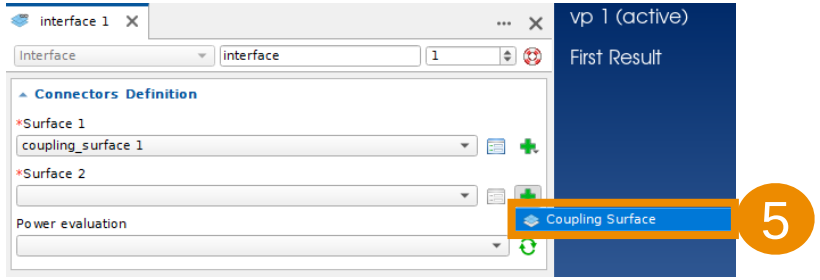
Add an *Interface*

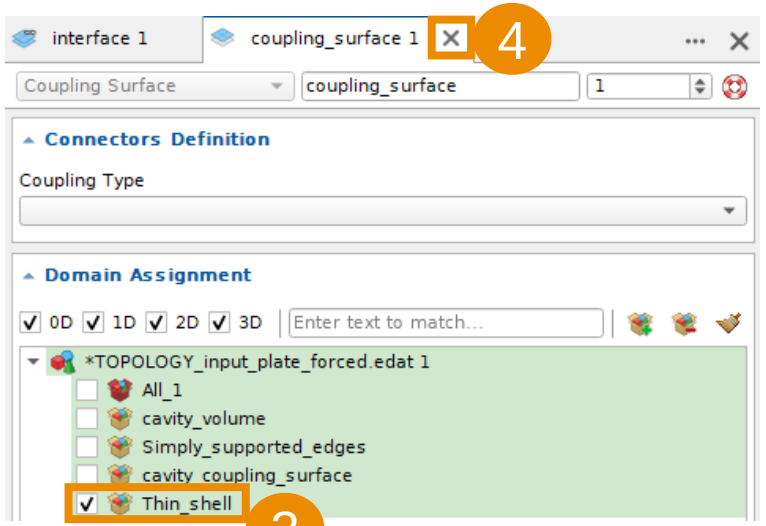
Add the the plate mesh as Surface 1

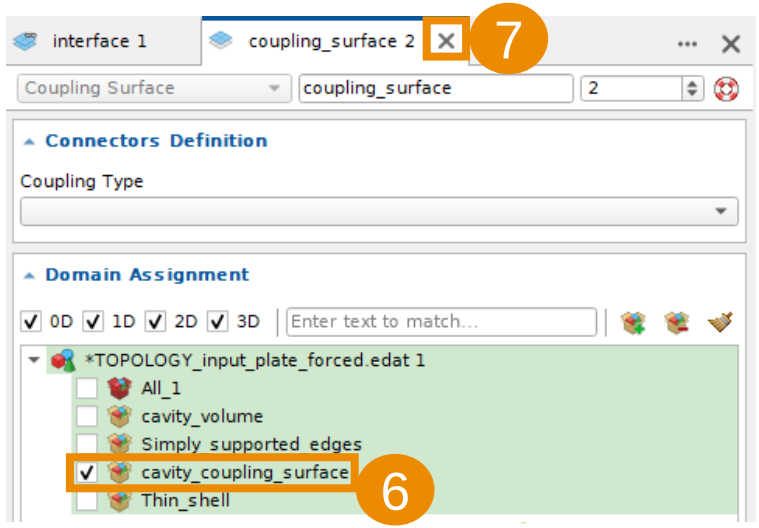
Add the cavity coupling surface mesh as Surface 2



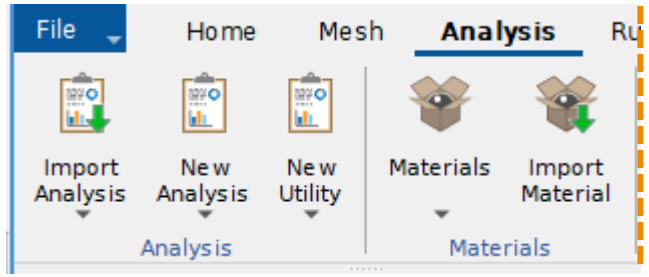


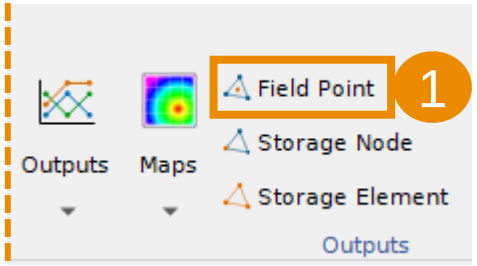






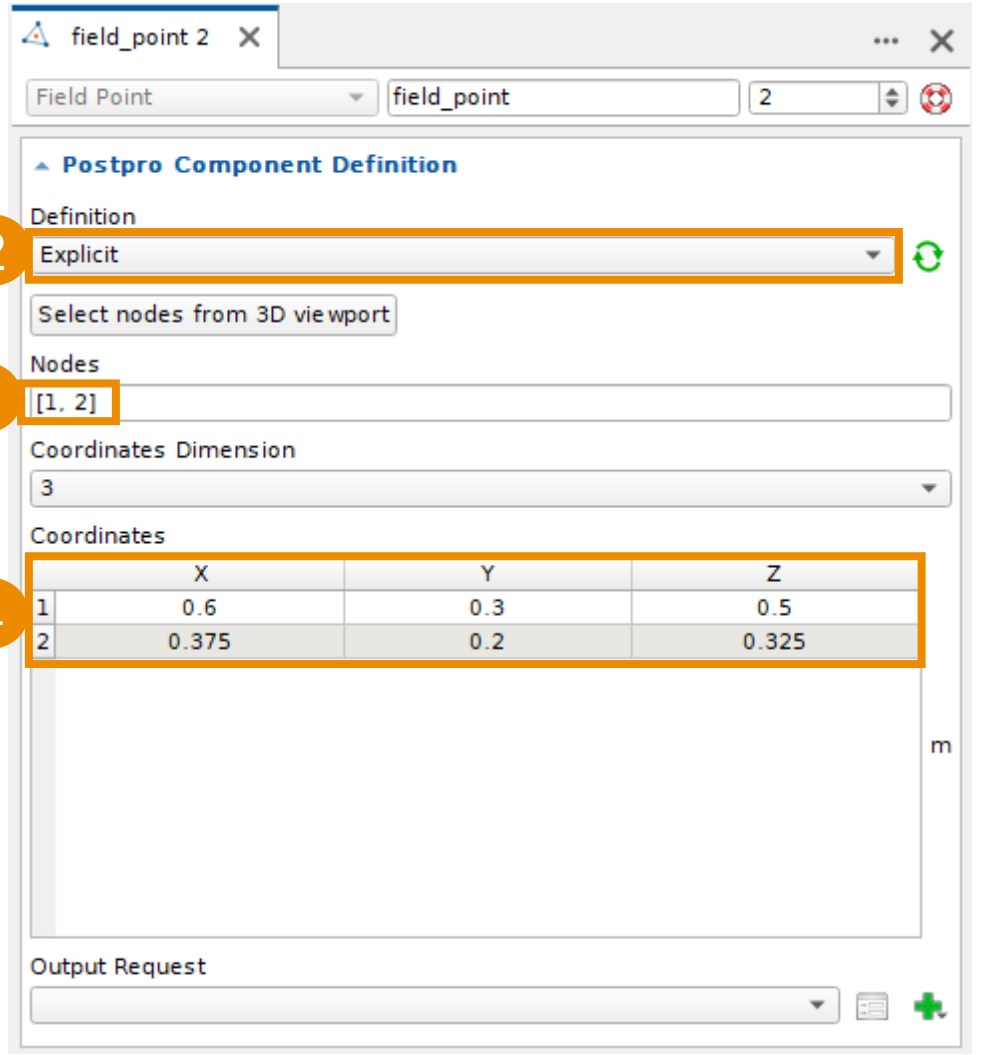
Add cavity Field Points in the FRF output





Add a *Field Point* to define 2 microphones

Set up the *Field Point* coordinates explicitly



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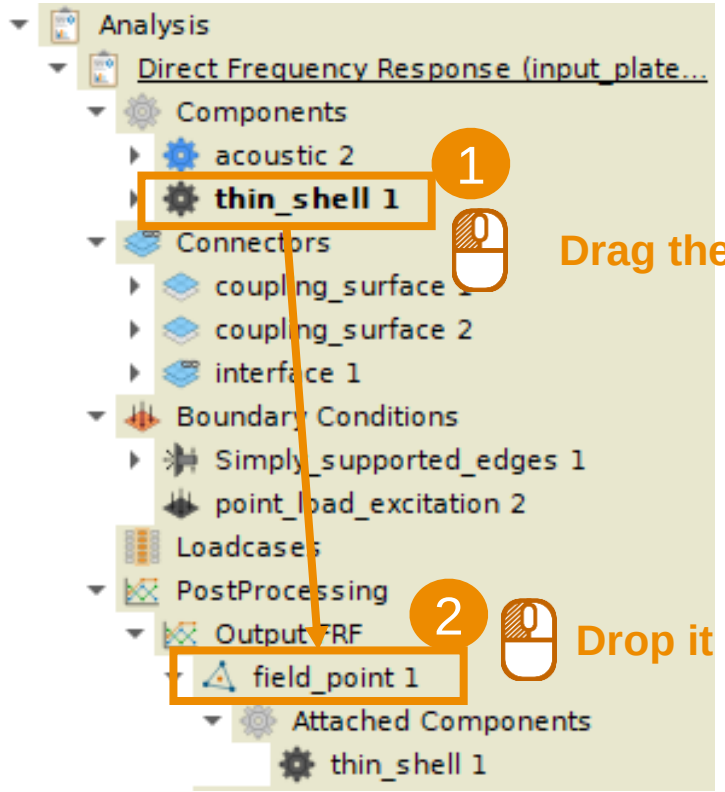
Attach Field Points located on the plate to the Shell component

- With the cavity volume added to the model, the three field points on the plate need to be attached explicitly to the shell components to ensure these field points are considered as “accelerometers” on the plate and not as “microphones” in the cavity



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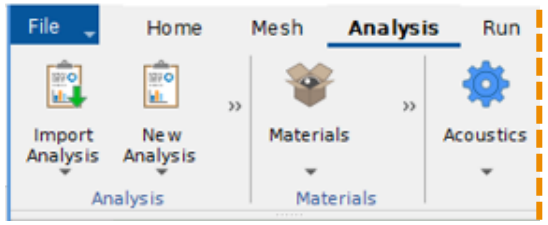
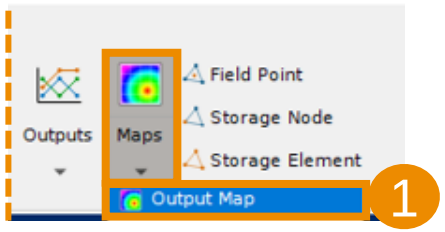
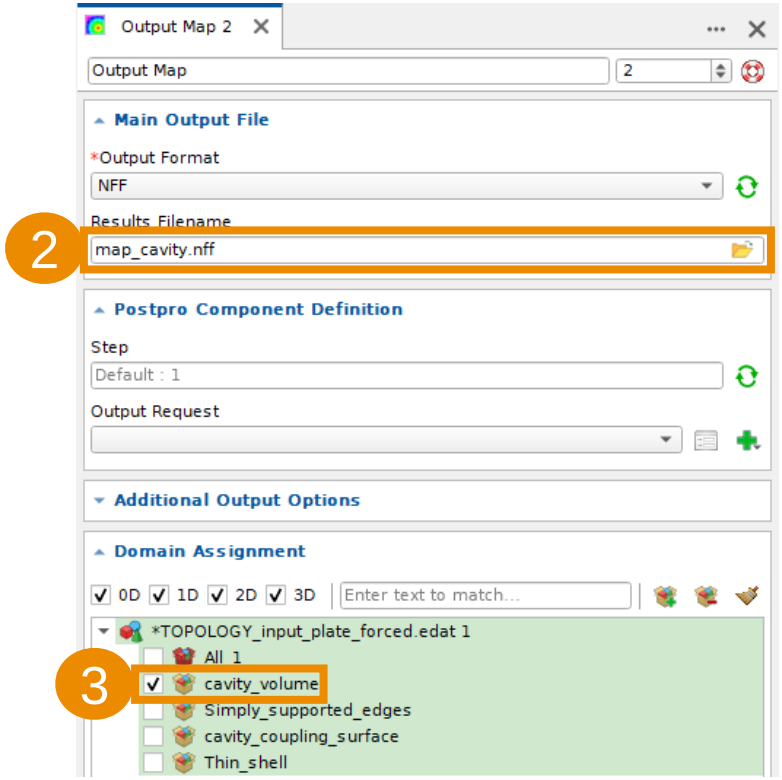
Post-processing parameters – Maps





Add an *Output Map post-processing parameter*

Specify a map in *.nff format to be saved in the whole mesh, at each frequency step



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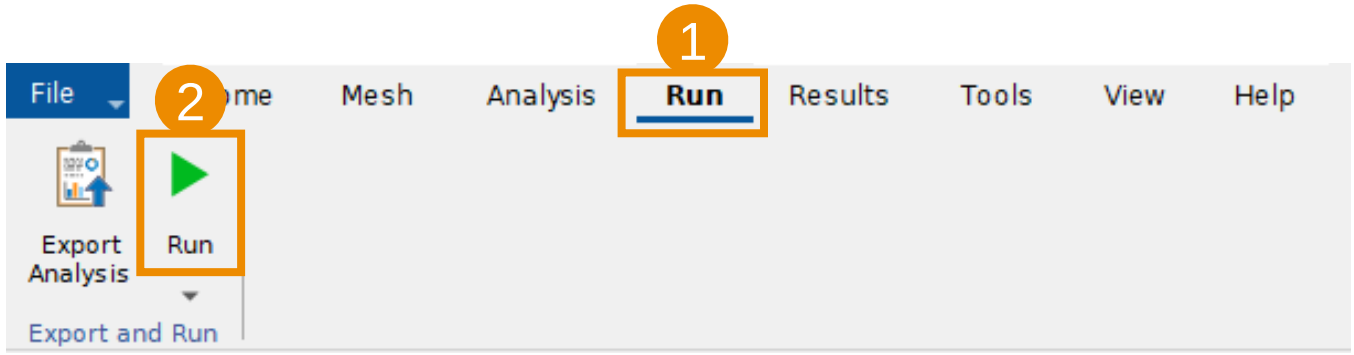
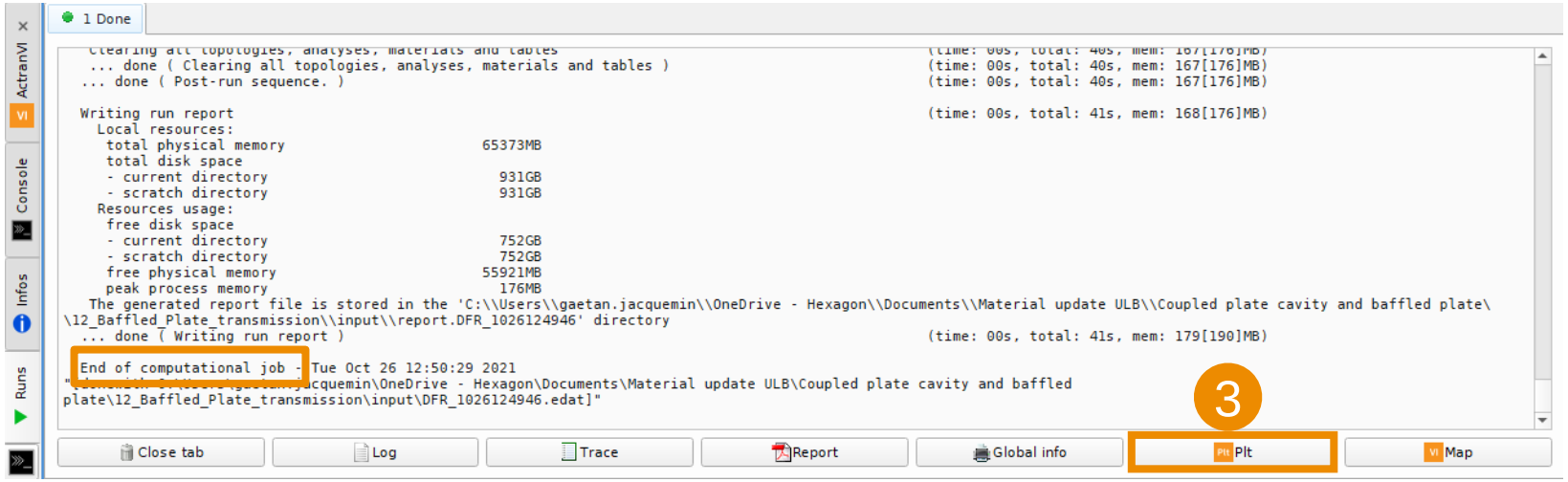
Launch the Actran analysis in ActranVI

Launch the computation

Check the log showing the computation progress

Import the *.plt computation result file





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Post-processing in the PLTViewer

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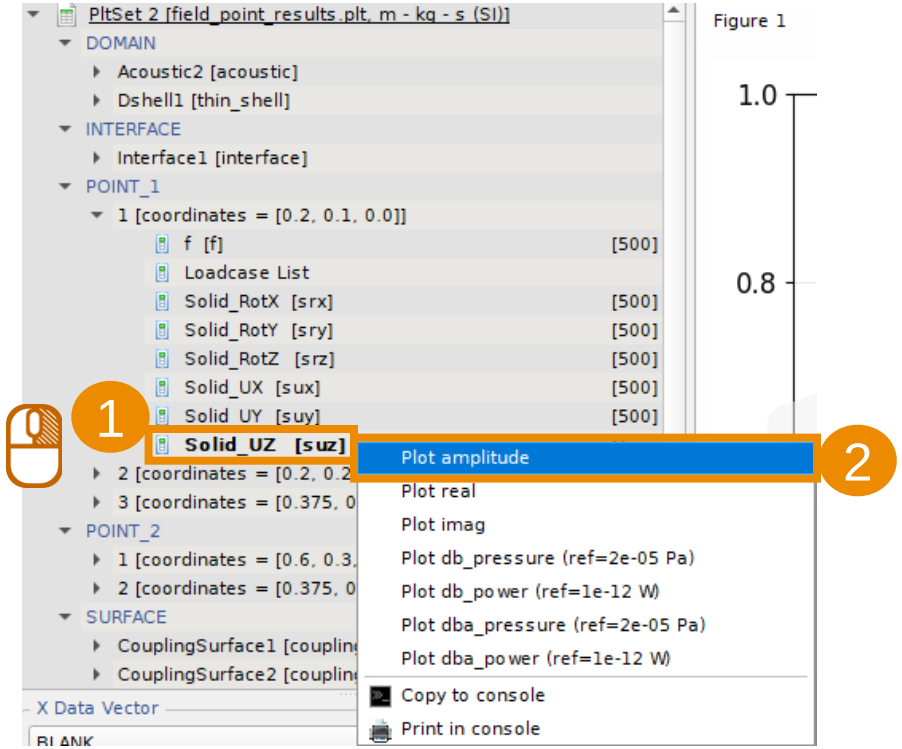
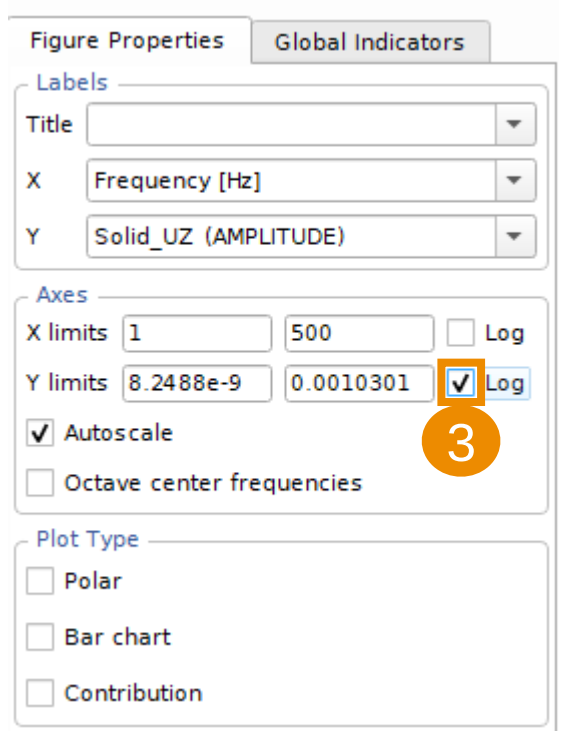
Evaluate the structural displacement

- The plate vibrates along the Z axis, the amplitude of structural displacement along the Z axis is plot **for each point**
- Visualize the plot using a logarithm scale for displacement amplitude





(For the 3 coordinates in *POINT_1*)

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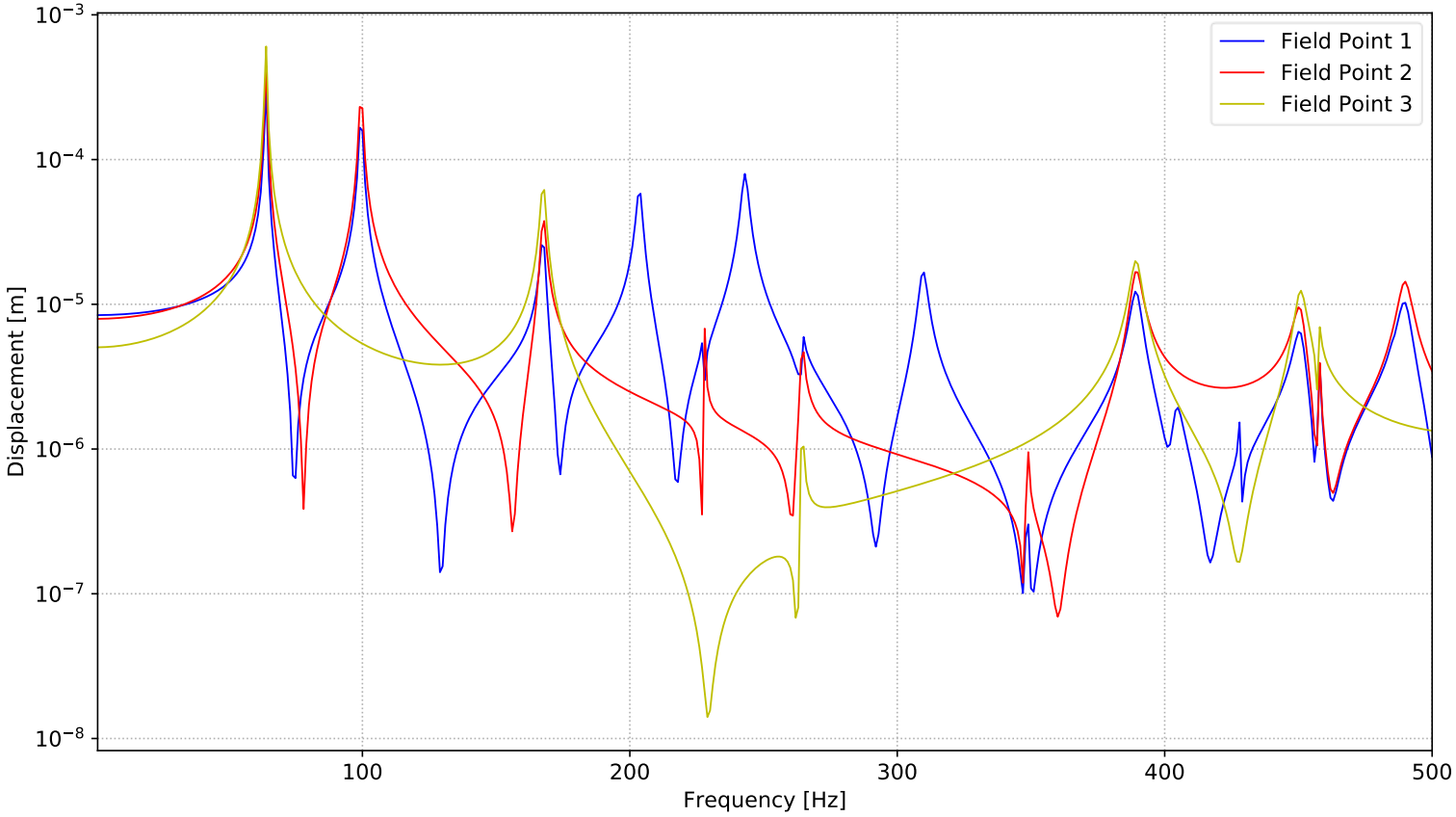
Structural displacement at each Field Point in the plate



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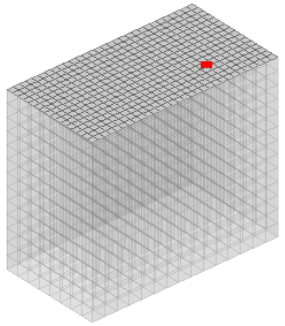
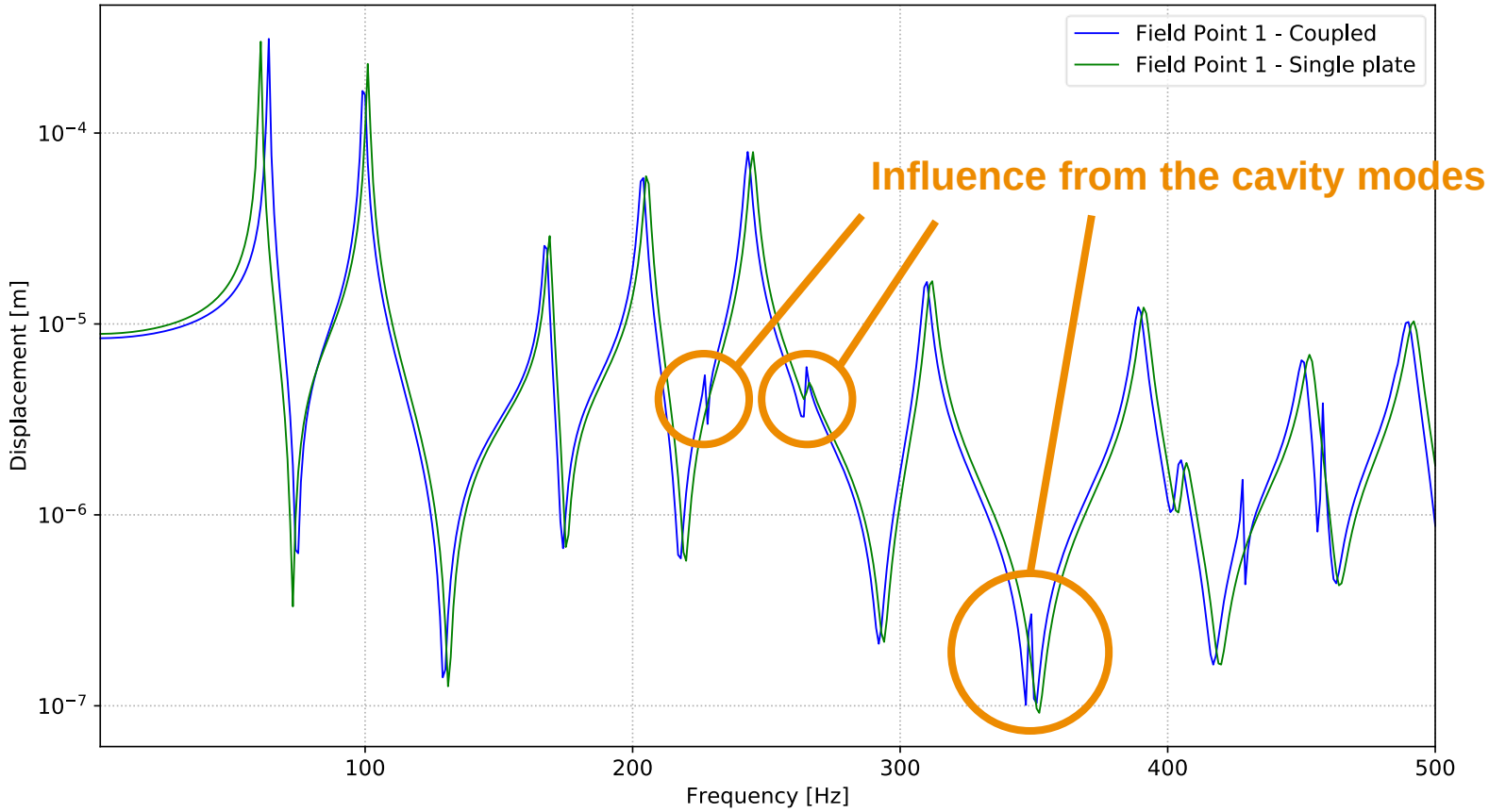
Structural Displacement

Comparison with Plate Forced Response Model

- Import the (provided) PLT results file *plate_only_forced_response.plt* and compare the structural displacement between two models
- The plate response is slightly altered by the coupled cavity
- Several cavity eigen frequencies appear on the curve of the coupled problem (see workshop of cavity modes)





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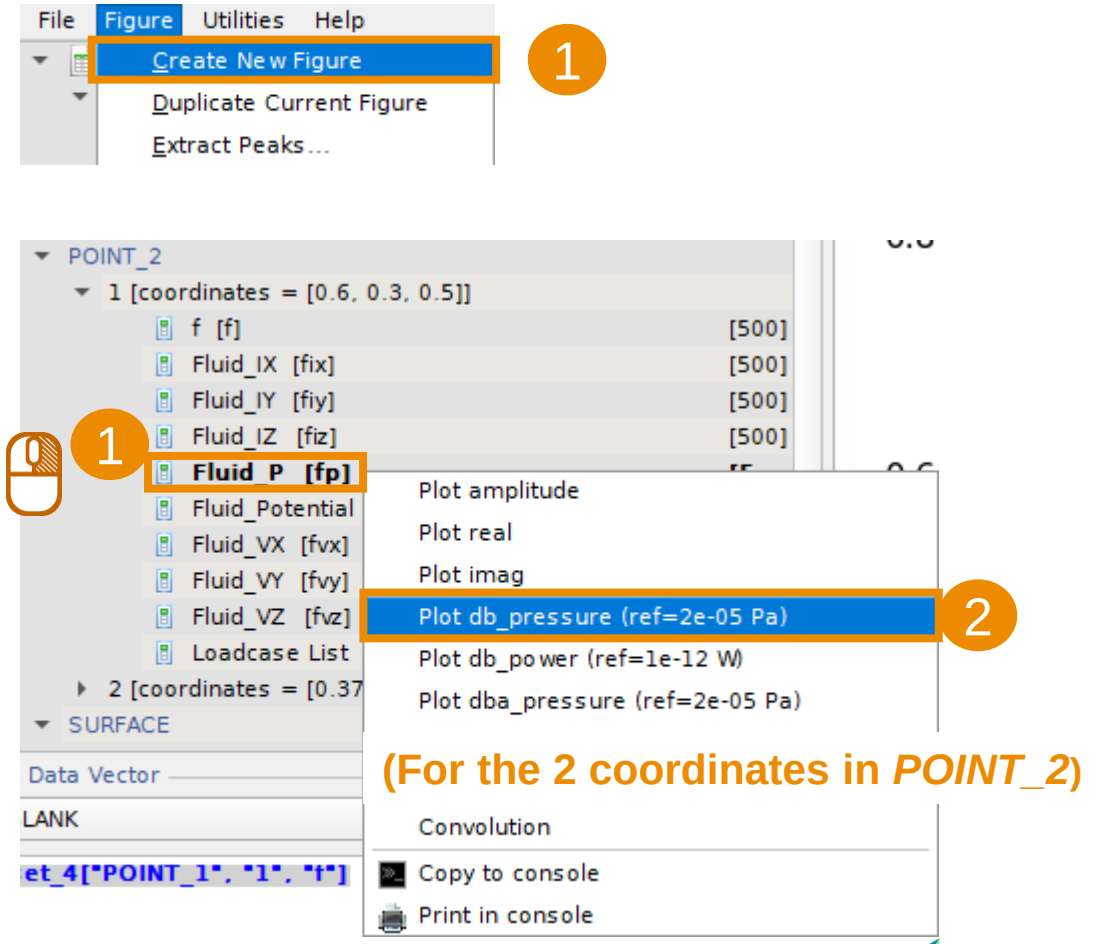
Evaluate the cavity acoustic pressure

- Create a new figure
- Plot the pressure of the field point 1 and field point 2 of cavity in dB (SPL)



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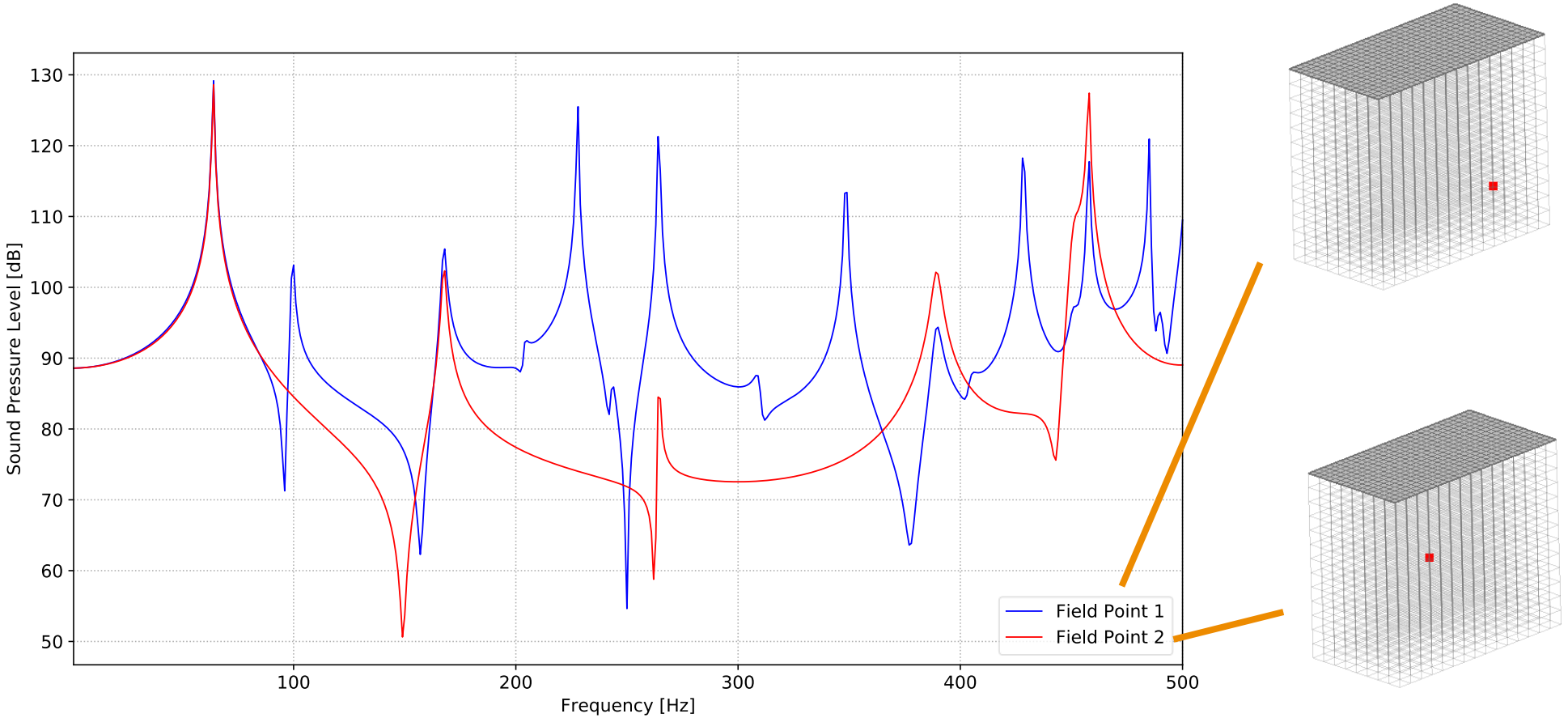
Evaluate the cavity acoustic pressure



- More peaks in pressure can be observed for the point at coordinates [0.6, 0.3, 0.5]

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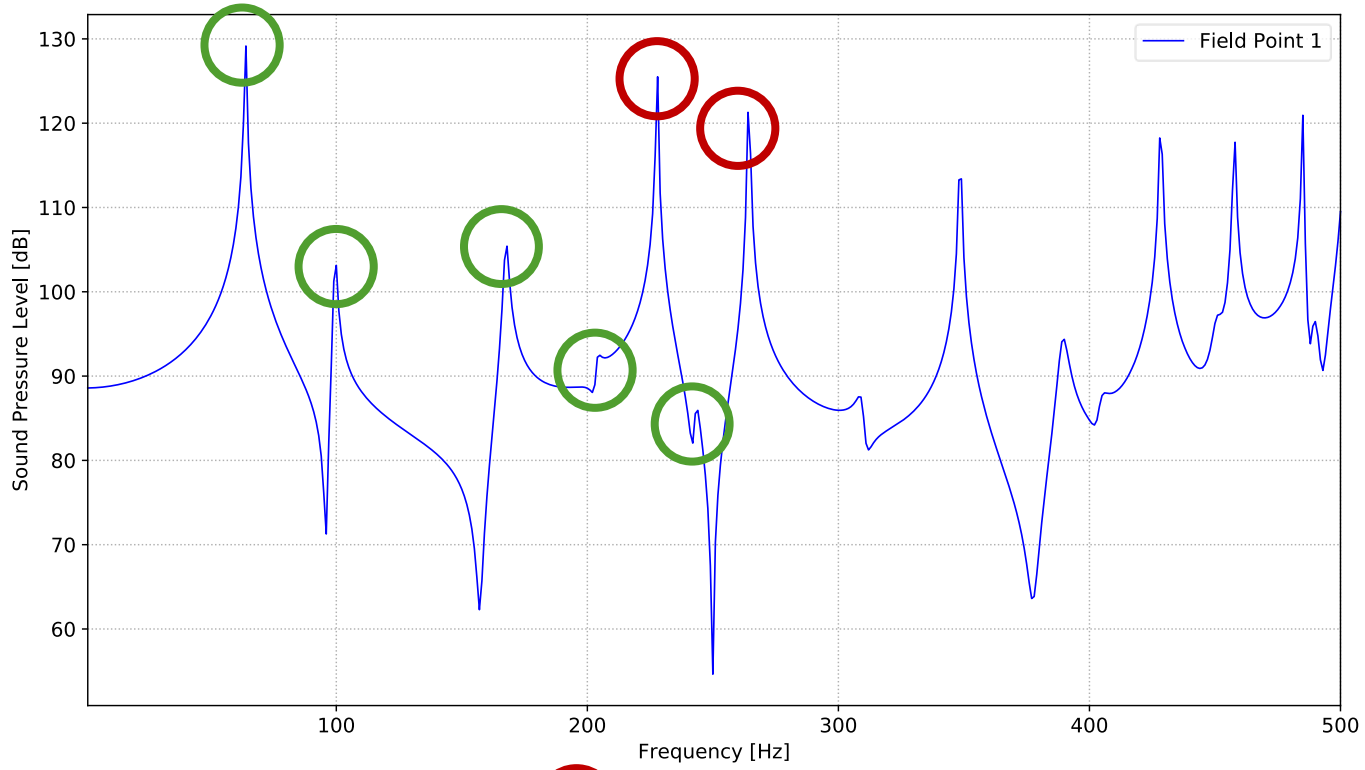
Evaluate the cavity acoustic pressure

- Different peaks on the FRF of cavity field points are due to different plate modes and cavity modes → see again the workshops of plates modes and cavity modes to find the eigen frequencies

- Take the cavity field point at [0.6, 0.3, 0.5]
  for example

- Peak frequencies [Hz]:

64	100	167	203	228	243	263	…



Peaks due to plate mode Peaks due to cavity mode

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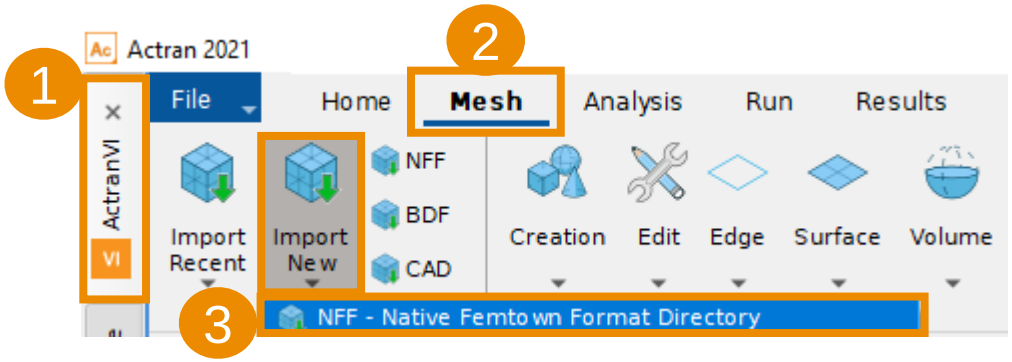
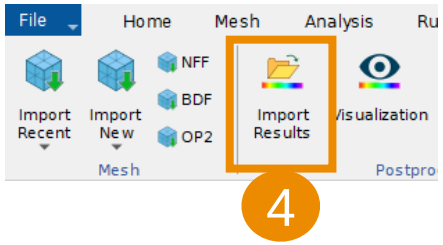
Import the displacement results mesh

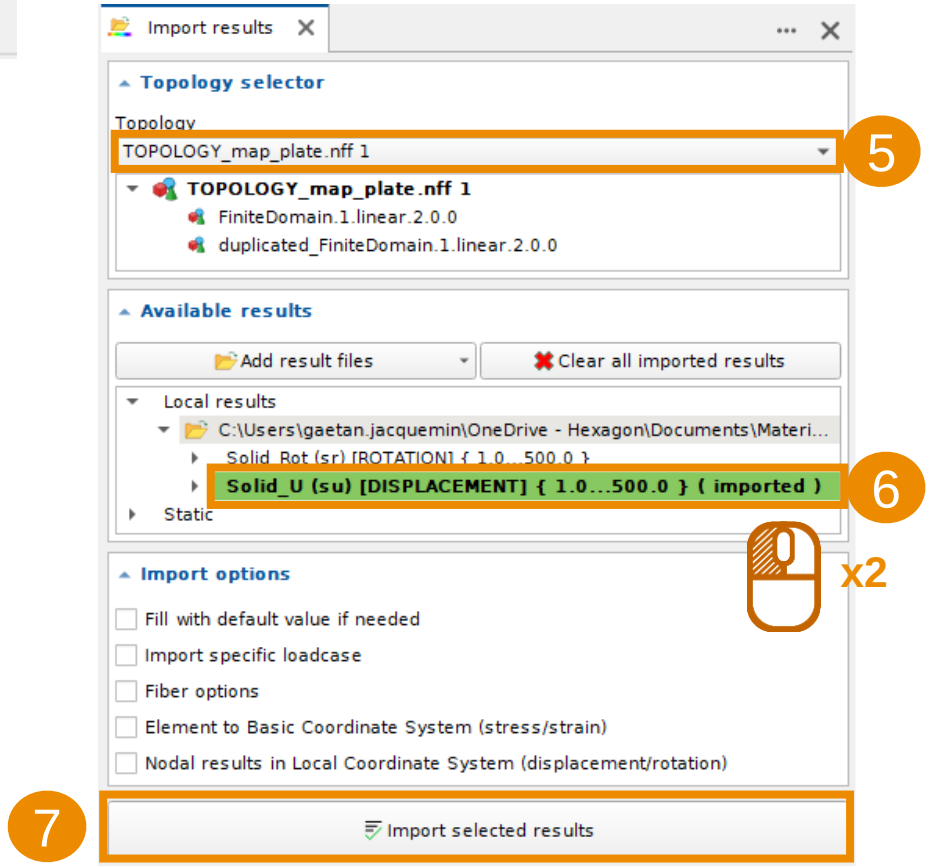
Go back to ActranVI



Load the output **map_plate**.nff file containing the maps

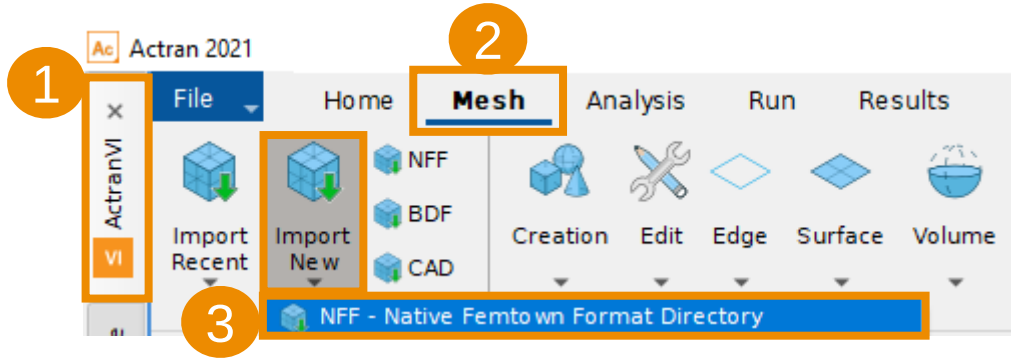
Import the displacement results





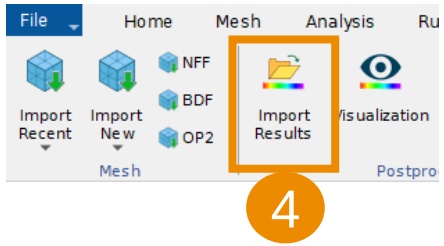
Import the pressure results mesh

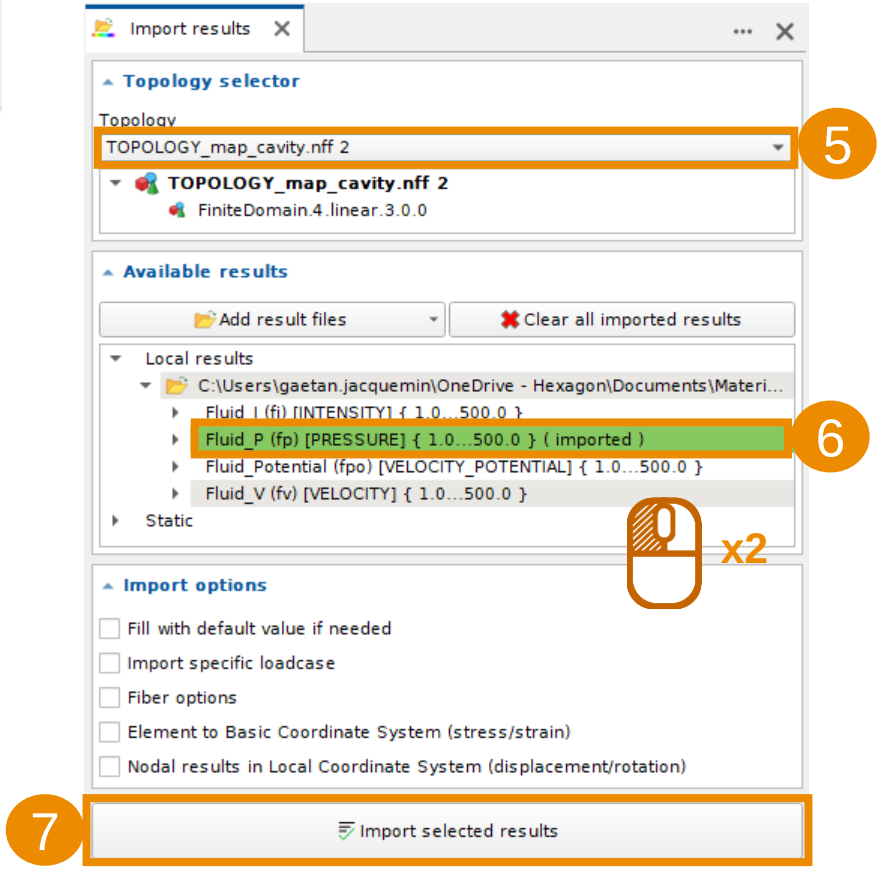
Go back to ActranVI



Load the output **map_cavity**.nff file containing the maps

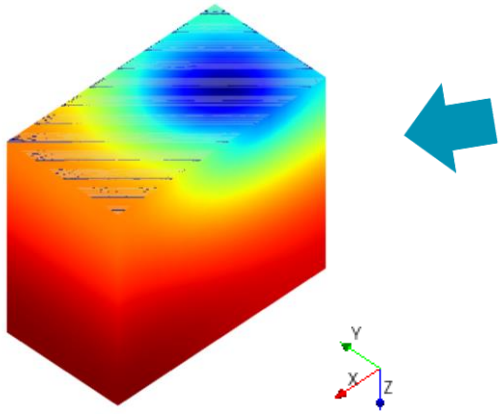
Import the displacement results

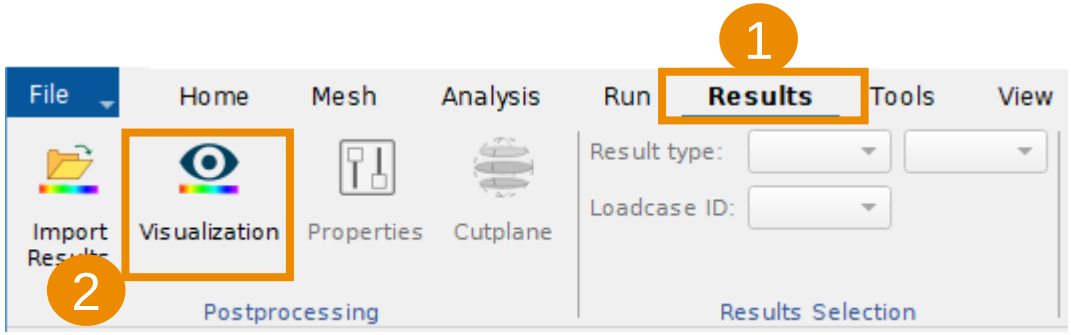


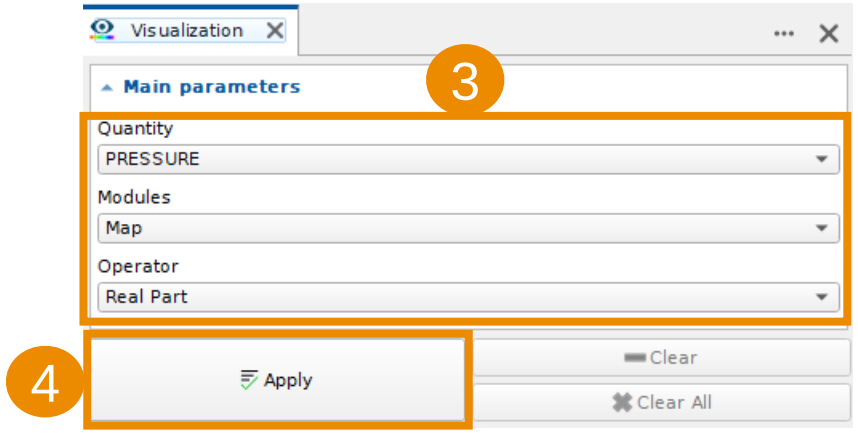


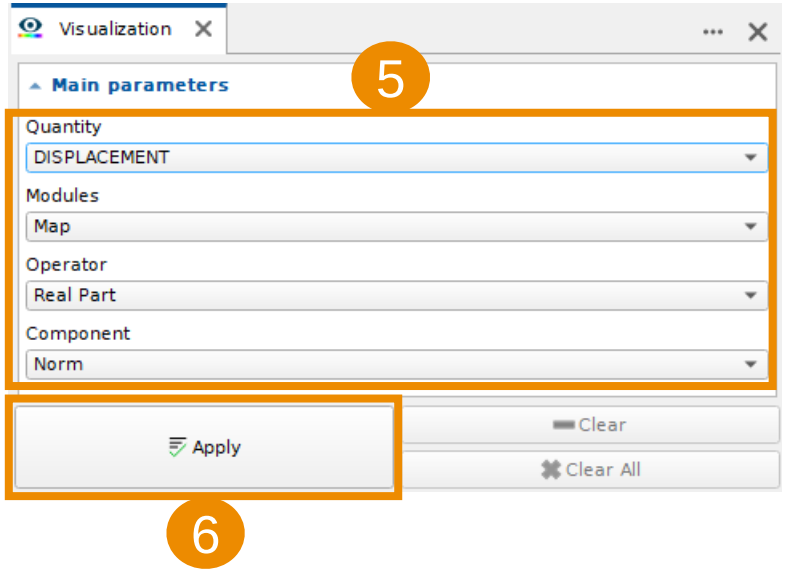
Visualize all results

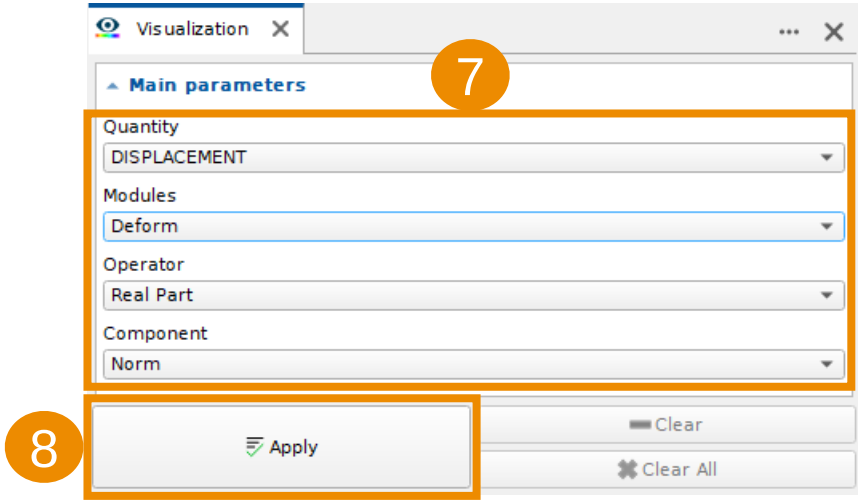
- Visualize
  - Pressure map real part
  - Displacement map real part
  - Displacement deformation of the mesh











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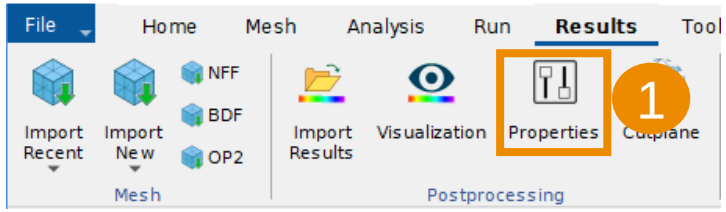
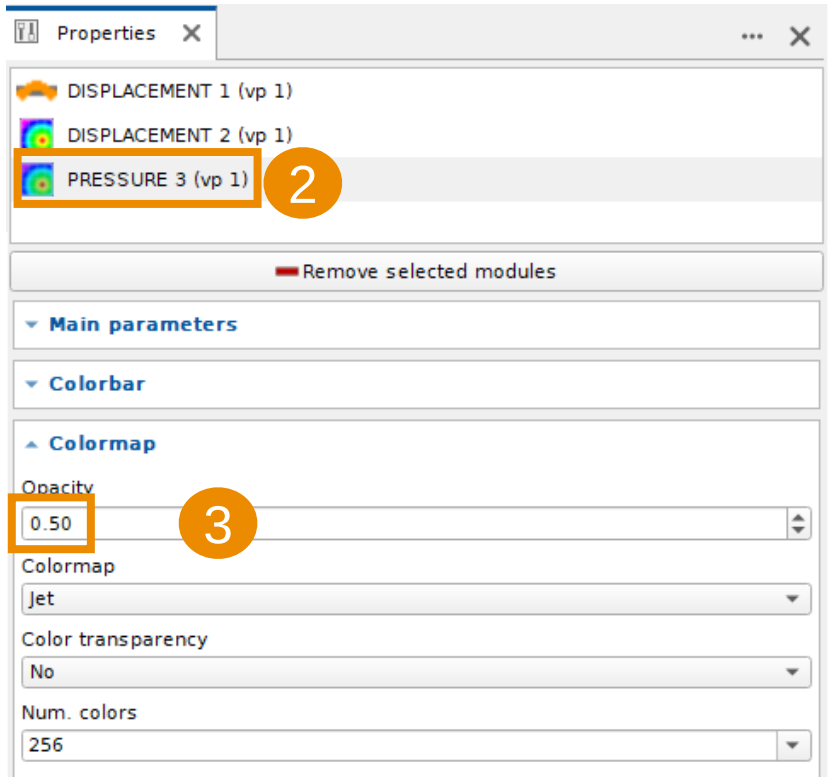
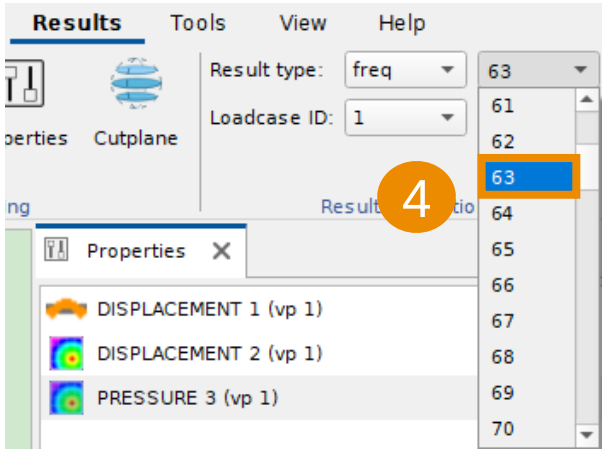
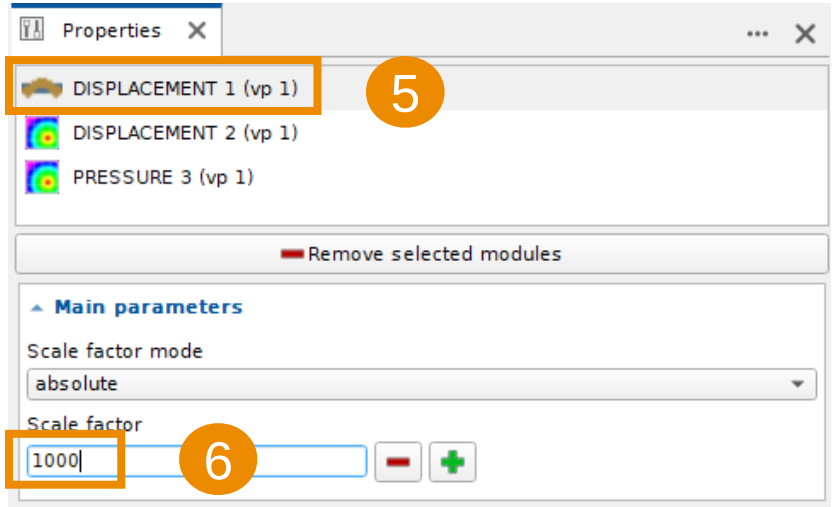
Visualize all results

- Adjust visualization parameters
  - Set pressure results opacity to 0.5
  - Display different frequencies
  - Adapt the deformation factor consequently









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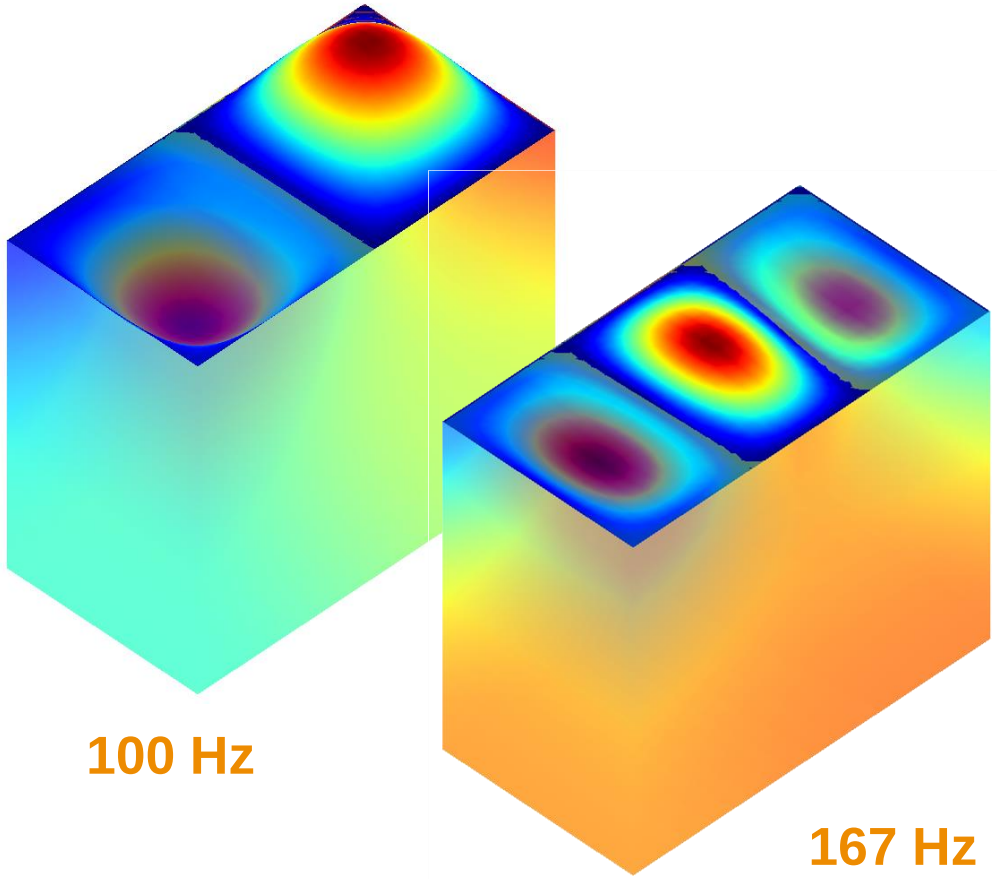
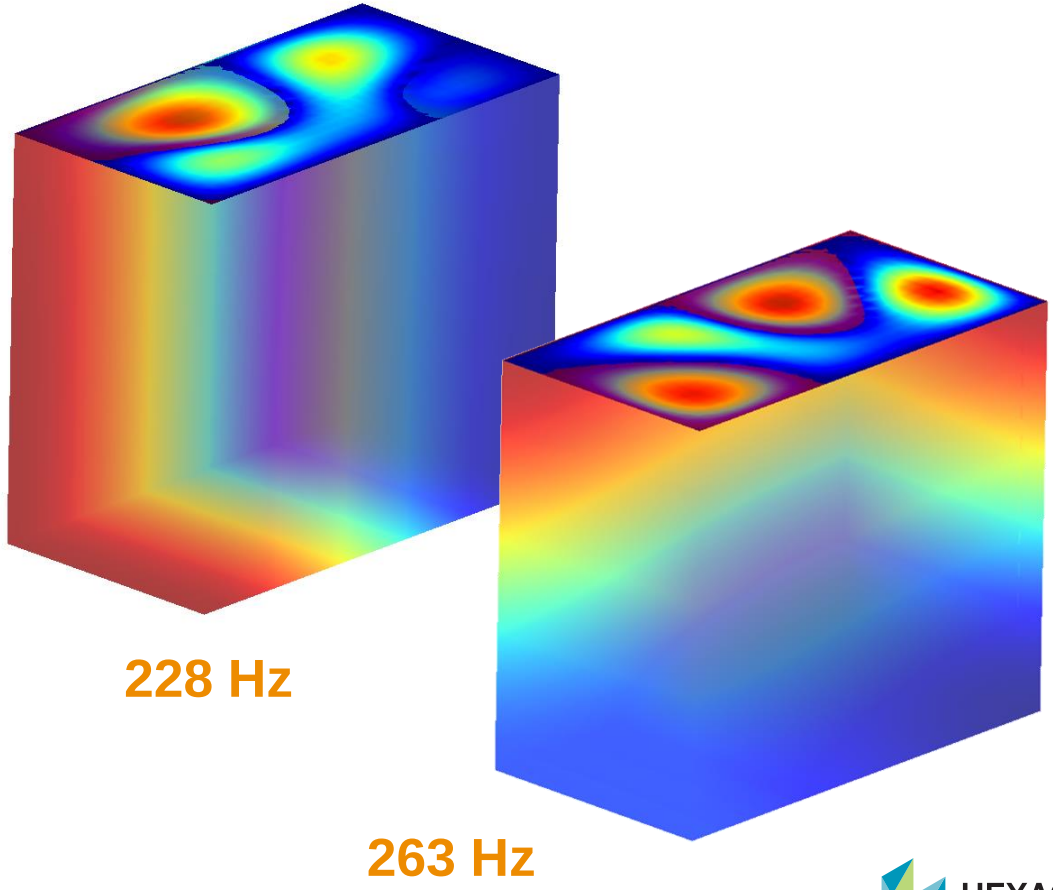
Visualize all results

Response driven by plate modes



Response driven by cavity modes



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