OpenPulse - Open source code for numerical modelling of low-frequency acoustically induced vibration in gas pipeline systems

User's guide: Acoustic gas pulsation module
V1.0

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1 Acoustic gas pulsation module: a user's guide approach

1.1 Running OpenPulse software

Once the OpenPulse's installation is done and the python interpreter is into the OpenPulse's folder location, is possible to initialize it by the following command in the python terminal:

```
C:\"OpenPulse's folder location"\OpenPulse>python pulse.py
```

After this, the OpenPulse's interface will be open as is shown in figure 1

On the LHS of Openpulse's interface there is a tree of options and in this section just the last three options will be used. These are, Acoustic model setup, Analysis and Result Viewer. On the top of the screen, there are some options related with the project, the geometry and the analysis process, all of these with their correspondents shortcuts.

1.2 Create project and import geometry

To start a new project the shortcut `ctrl+N` will help or clicking on the project option located on the top of the screen (Figure 2). OpenPulse is capable of read `.iges` format files (lines based geometry) or `.dat` format files from commercials FEM programs as *Ansys*.

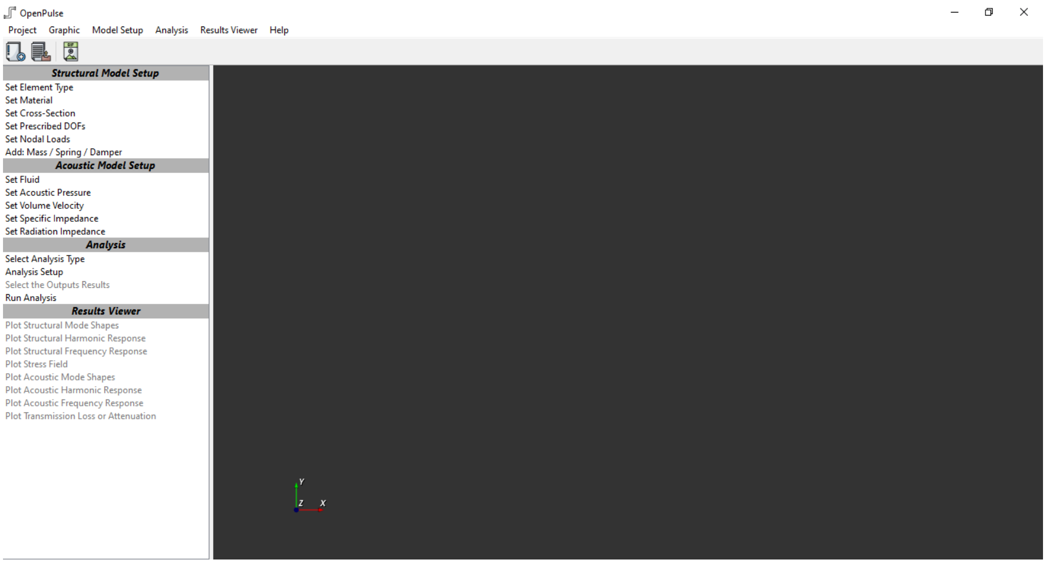


Figure 1: OpenPulses's interface

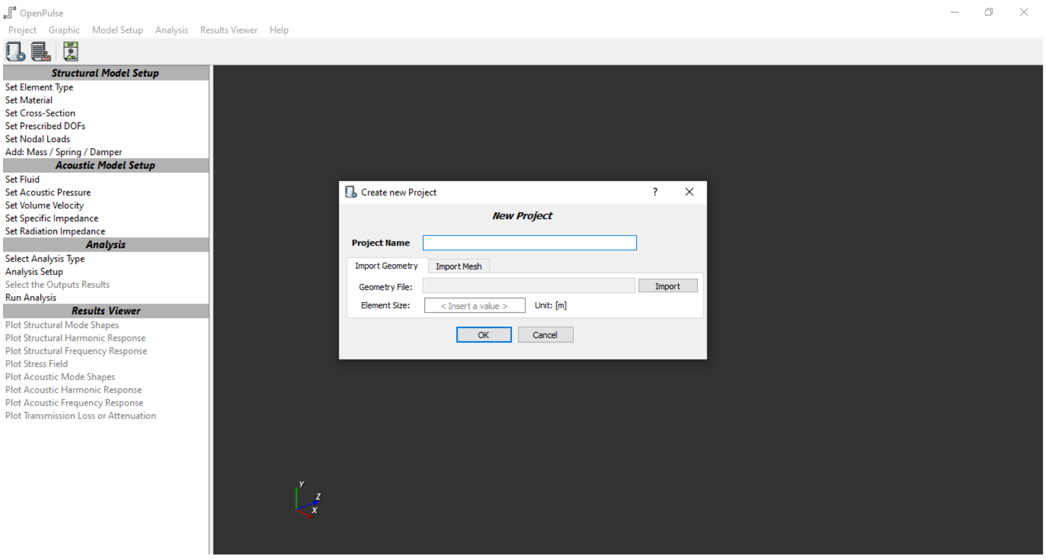


Figure 2: OpenPulses's interface: create project

Once the `.iges` geometry was imported, the element size (in meters) for discretization is required (in this case was used 0.01 m). The new project is created under the name indicated in the first field clicking on the `OK` button. The imported geometry will appear as is shown in Figure 3. Maintaining pressing the right mouse button is possible to rotate the geometry and moving the scroll mouse button up and down is possible to do zoom in and zoom out, respectively. Maintaining pressing the scroll button is possible to move the entire geometry inside the screen.

1.3 Setting material and cross sections

In this version of OpenPulse the acoustic module is not totally independent of the structural module. For this reason, if the user wants to do only a structural analysis, two options of the Structural model setup needs to be configured. These are, the material (Figure 4) and cross section options. These have direct influence on the acoustic analysis, the structural material is used to correct the speed of sound of a plane wave in a gas by the presence of rigid walls and the cross section options determine the volume of the acoustic fluid to analise.

For the example piping geometry an outer duct diameter of 0.05 m was set with a thickness of

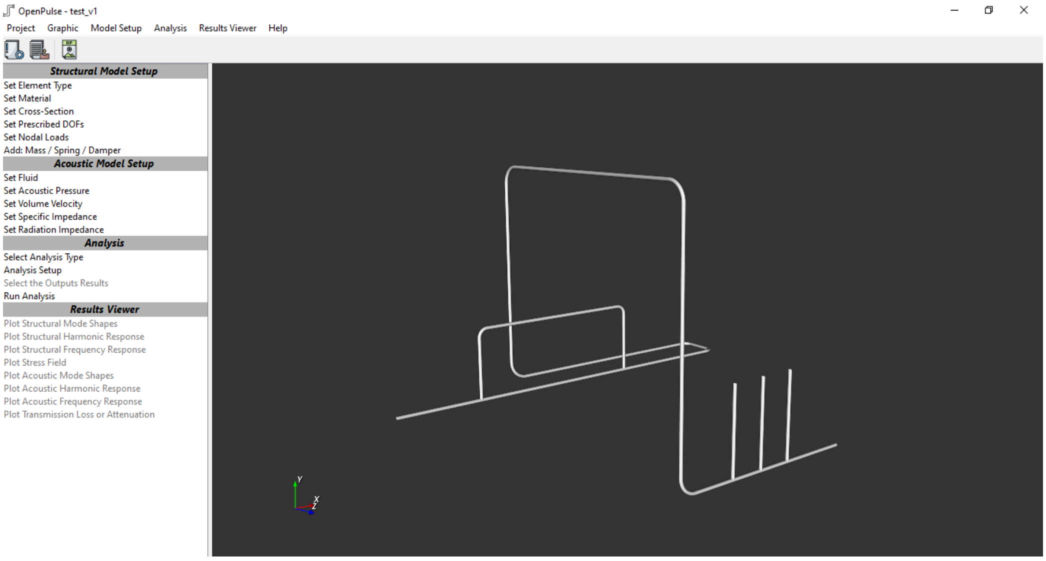


Figure 3: OpenPulses's interface: Imported geometry

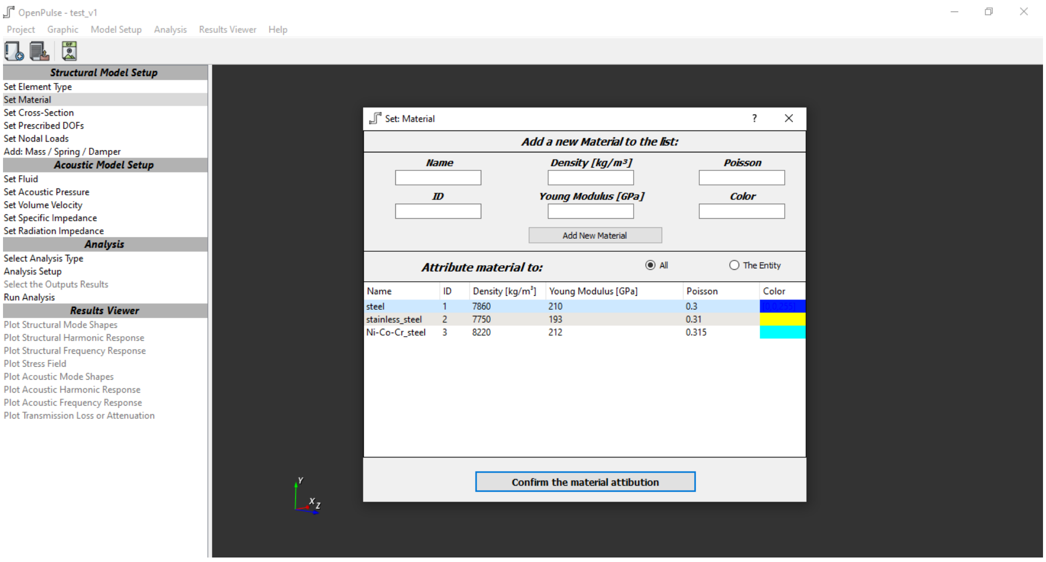


Figure 4: OpenPulses's interface: Configuration of structural material for all geometry elements.

0.008 m (Figure 5). It is possible to check if the cross section configuration was done successfully clicking on `Graphic > Entity with Cross-section`. This option allow us to see the elements with the configured cross section. Because this geometry has an expansion chamber, we need to set for this entity a different cross section. This is done clicking on the correspondent identity and setting again the element cross section as is shown in figures 6a and 6b. This process need to be repeated for each element that has a different main duct's cross section. Clicking again on the mouse's left button is possible to disable the selected entity.

1.4 Acoustic Modal Setup

1.4.1 Acoustic fluid

Once the geometry is well defined, is time to set the fluid properties. For this, `Acoustic modal Setup > Set Fluid` as is shown in figure 7. In the Set Fluid windows is possible to select an in build fluid property or create a new one and apply to all the entities or just to one of them.

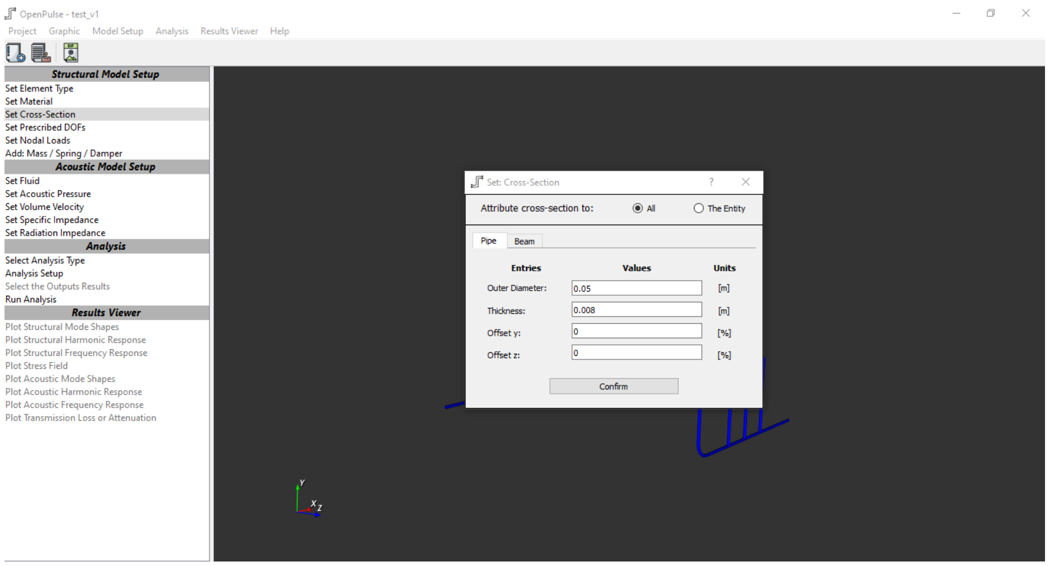
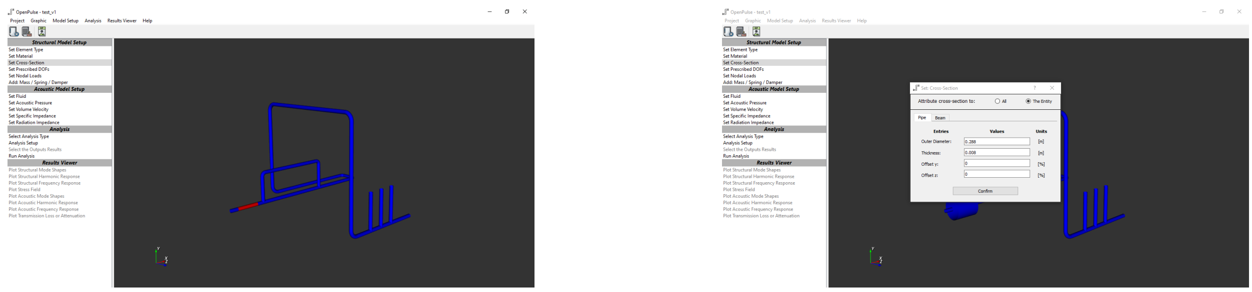


Figure 5: OpenPulses's interface: Cross section settings



(a) (b)

Figure 6: Selection of an entity (6a) and configuration of its cross-section (6b)

1.4.2 Boundary Conditions

In this version of Openpulse the available BC's are: pressure, volume velocity, specific impedance and specific radiation impedance. In the pressure boundary condition is possible to insert a table with a frequency dependant pressure excitation. In a near future this function will be available for the others BC's. As is shown in figure 9, the first element (Node ID: 10) was selected to set a constant 1 Pa pressure wave excitation. To select a desired element and also knows which is its `Node ID` value, is recommended to set the geometry's view as points `Graphics > Points` because the `Node ID` value will be displayed on the screen. As was done for the cross section of a particular entity, to set a pressure in a particular element first click on the point (element) desired an then click on the option `Set Acoustic Pressure` on the RHS tree option.

The same process needs to be done for the other BC's. In this example an anechoic impedance was set for the piping's out (Node ID: 1047) clicking on the `Set Specific Impedance` tree option. The default value for the air is 413 $kg/m^2\,s$. For more details on BC's see the Acoustic's module theory reference.

1.5 Analysis

After define the geometry and the BC's, the last step before see the results of the time-harmonic acoustic analysis, an analysis setup needs to be done. On the RHS `Analysis` tree option , the `Analysis Type > Harmonic Analysis - Acoustic > Analysis Type > Direct Method` was choice because FETM is conveniently solved, by nature, with a direct method (Figure 10).

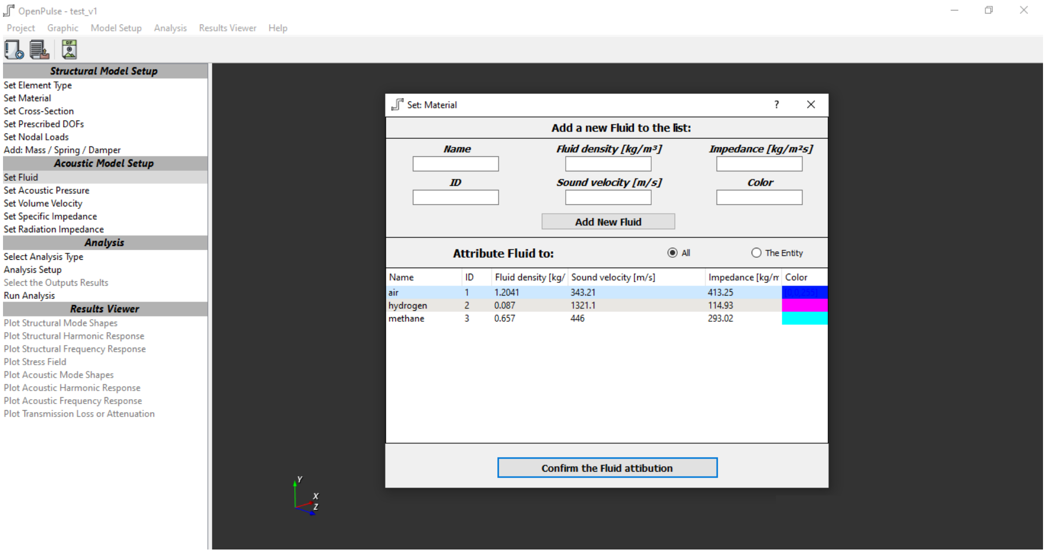


Figure 7: OpenPulses's interface: Set fluid

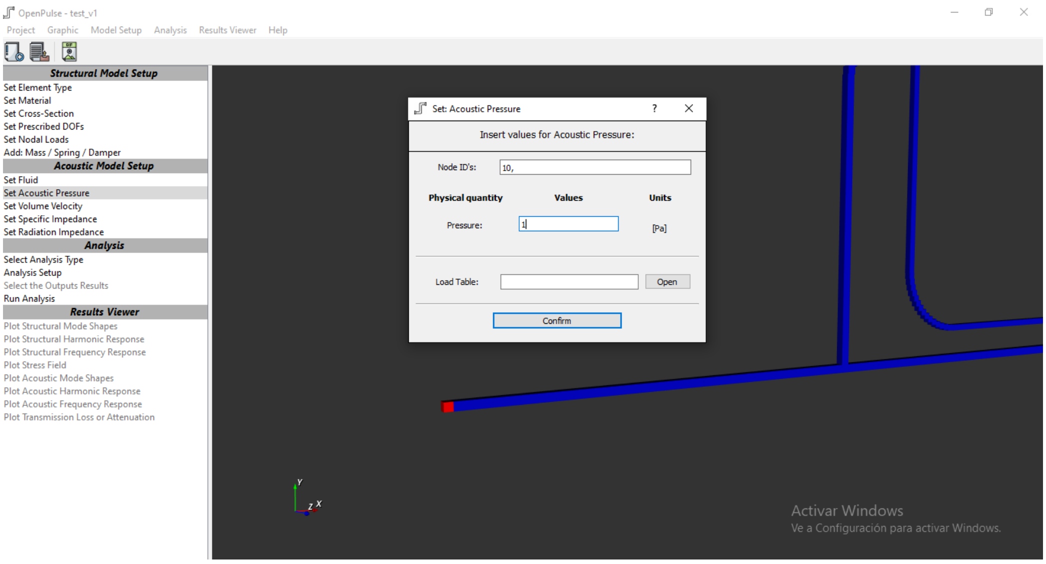


Figure 8: OpenPulses's interface: Set Acoustic Pressure

After confirm the direct method as a preferred solution method, clicking on `Go to analysis setup` the user is lead automatically to the `Frequency setup`. The frequency range analysis for the current example was from 1 Hz to 250 Hz in steps of 1 Hz as shown in Figure 11.

After confirm the `Frequency setup`, got to `Run analysis` to finally solve the time-harmonic acoustic analysis. A solution finished advice will be displayed after certain time.

1.6 Results Viewer

The `Result Viewer` is enable after solve the analysis. The first of the three available plots is the `Acoustic Harmonic Response` which plots the pressure field distribution for a selected frequency as is shown in figure 12.

The second available plot is the `Acoustic Frequency Response` which plots the value of pressure field for an specific location in the geometry (Node). The magnitude, real and imaginary part of pressure can be plotted introducing the desired `Node ID` as is shown in figure 13.

Also can be exported/imported the absolute or real and imaginary parts of the pressure field results for a certain Node `Node ID`. The import data needs to have an specific file pattern to

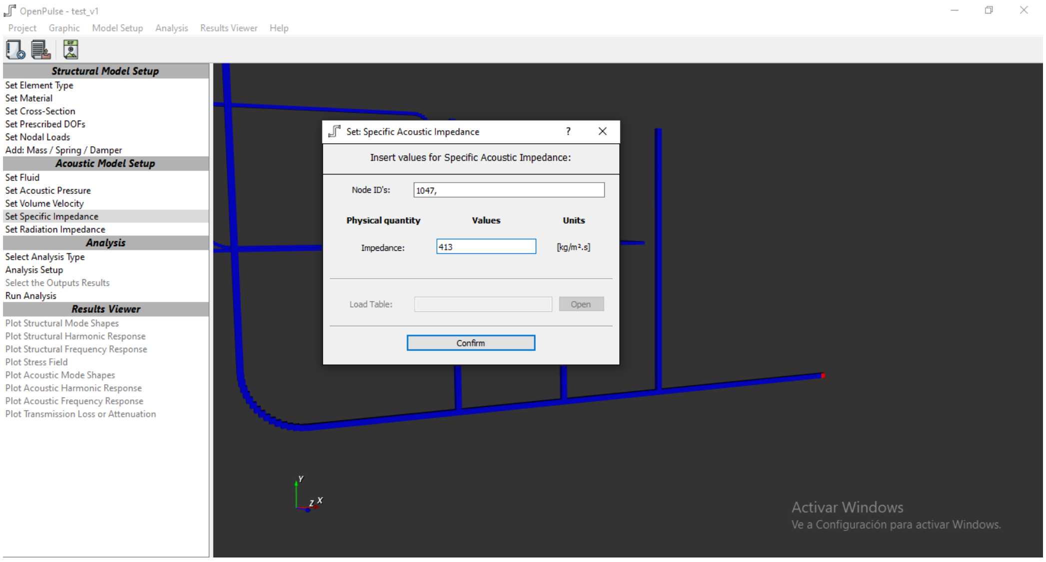


Figure 9: OpenPulses's interface: Set Specific Impedance

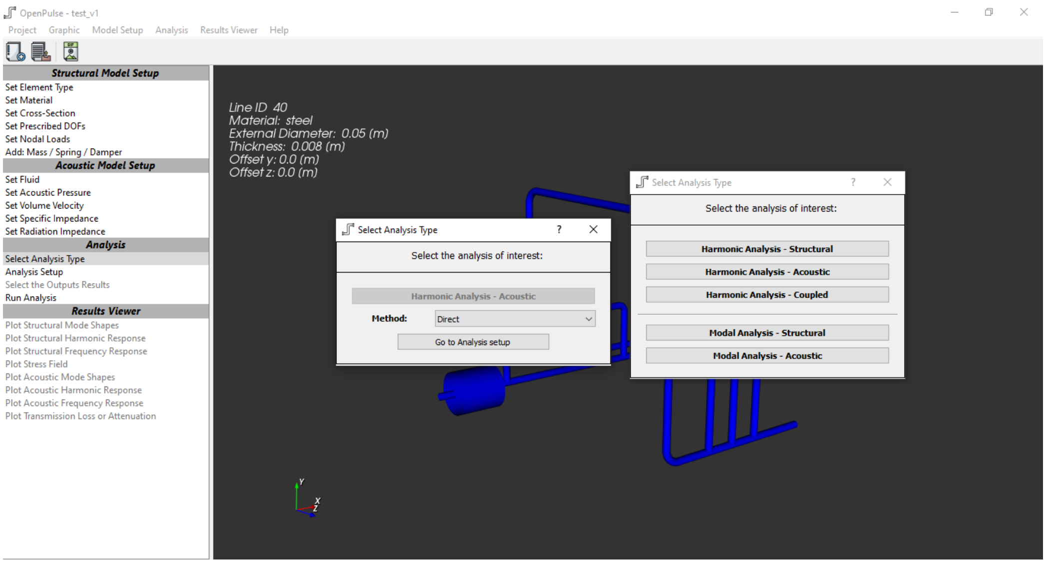


Figure 10: OpenPulses's interface: Select Analysis Type

import data successfully. This is, the columns needs to be separated with coma and the order of the data in the columns from left to right should be: frequency, real part of pressure, imaginary part of pressure and absolute value of pressure as is shown in figure 14a.

The pressure magnitude value showed in figure 14b is calculated as

$$SPL_Z = 20\,log_{10}(p_{RMS,node1047}/p_{ref}) \tag{1}$$

where $p_{RMS} = abs(p)/\sqrt{2}$ and $p_{ref} = 20 \times 10{-}6$.

The last available plot is the `Transmission Loss or Attenuation`, where both are intended for account the effects of acoustic filters but with a little difference in their conception. `Transmission Loss` is intended for acoustic filter which have the same input and output cross-section and its value is considered negative by default. On the other hand `Attenuation` is intended for acoustic filters which have different input and output cross-section and its value is considered positive by default.

Into the `Plot Transmission Loss or Attenuation` tree option, was set as the `Input Node ID` the node 10 and as the `Output Node ID` the node 1047 (Figure 15).

The plot of the `Transmission Loss` for the current example (`Node ID`: 1047) is shown in

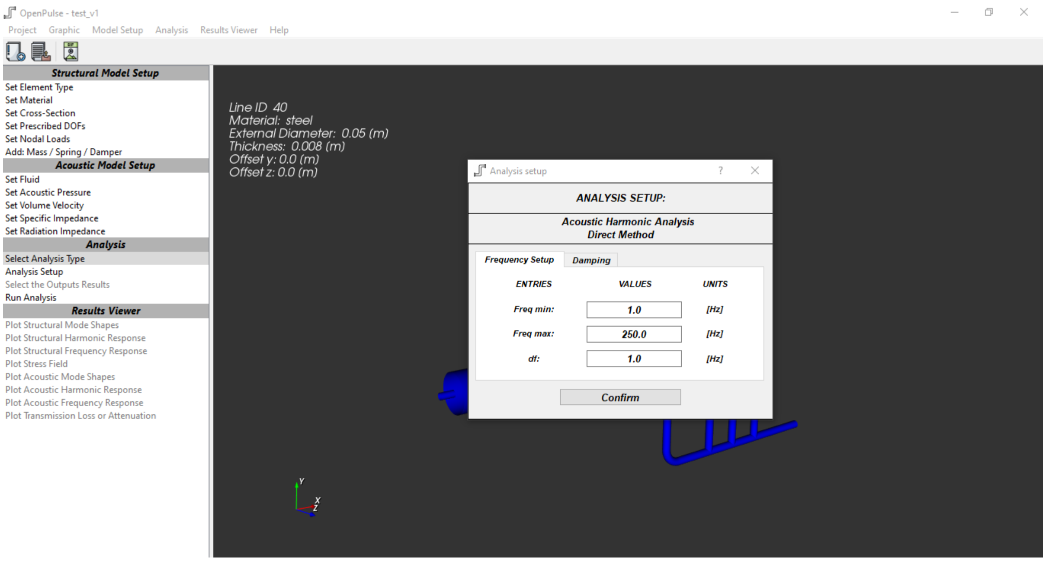


Figure 11: OpenPulses's interface: Select Analysis Type

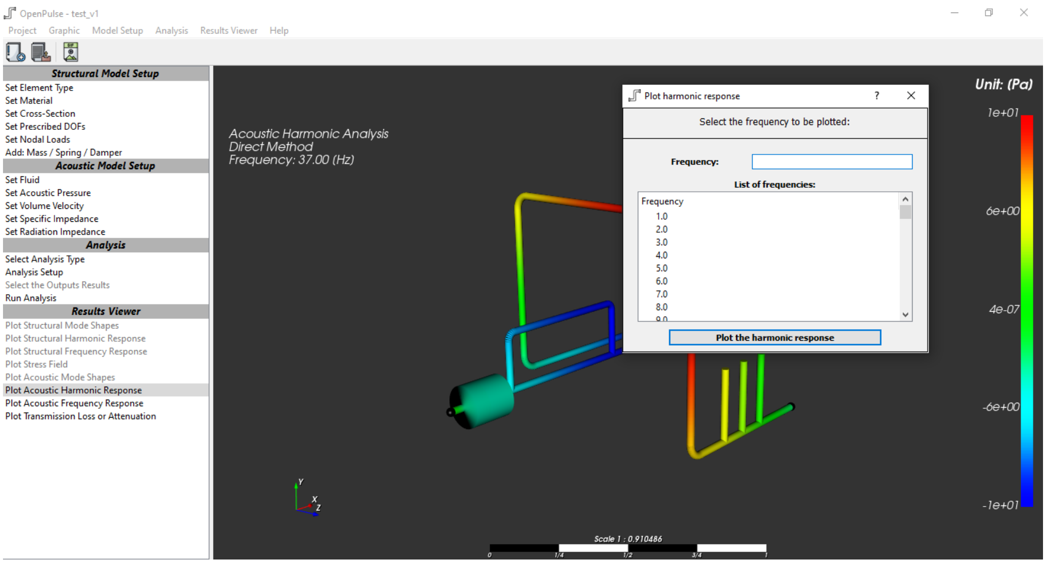


Figure 12: OpenPulses's interface: Plot Acoustic Harmonic Response

figure 16b and is calculated as

$$SPL_Z = -20\,log_{10}(p_{RMS,out} z_{f,in} / p_{RMS,in} z_{f,out}) \tag{2}$$

where $z_{f,in}$ and $z_{f,out}$ are the fluid specific impedances at the considered acoustic filter's input and output, respectively. On the other hand the `Attenuation` is calculated as

$$SPL_Z = 10\,log_{10}(W_{RMS,out} / W_{RMS,in}) \tag{3}$$

where $W_{RMS,out}$ and $W_{RMS,in}$ are the transmitted RMS power at the considered output of the filter and the incident RMS power at the considered input of the acoustic filter, respectively.

The TL/Attenuation plot also has the export/import option of the plotted data. As was described in the `Acoustic Frequency Response` plot the import data needs to have an specific file pattern to import data successfully. This is, the columns needs to be separated with coma and the order of the data in the columns from left to right should be: frequency and TL/attenuation data as is shown in figure 16a.

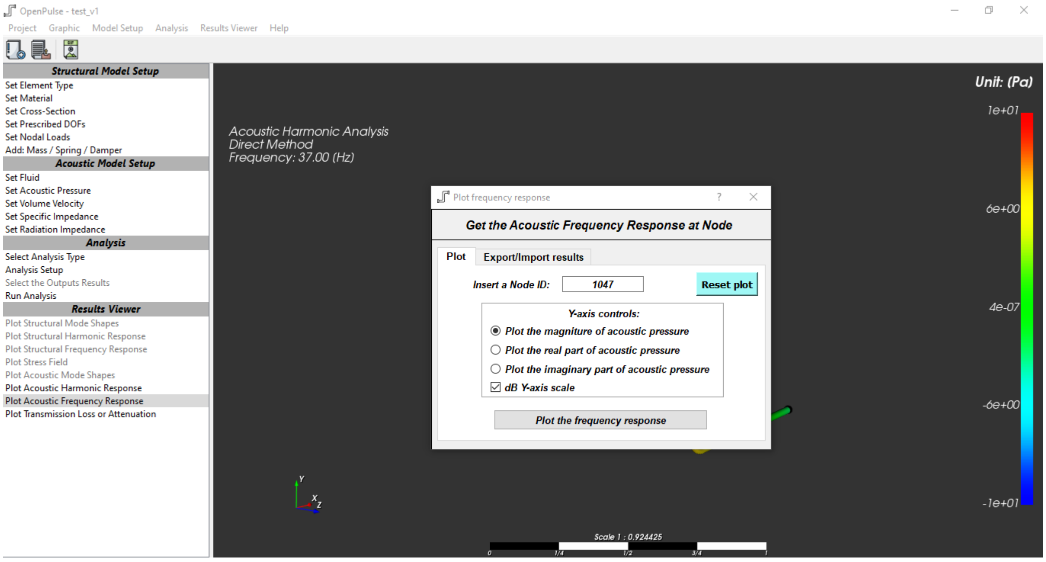
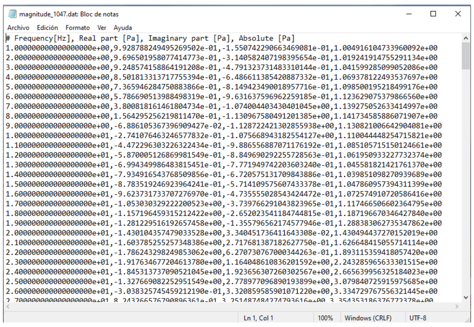
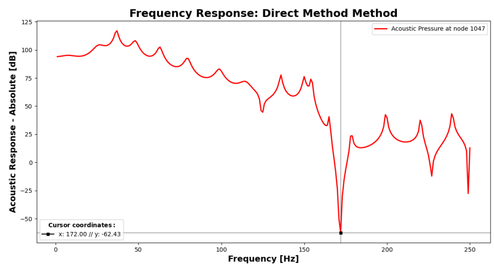


Figure 13: OpenPulses's interface: Plot Acoustic Frequency Response



(a)



(b)

Figure 14: OpenPulses's interface: view of a .dat file generated by the export function in OpenPulse (14a) and the magnitude frequency response plot at Node ID 1047 (14b)

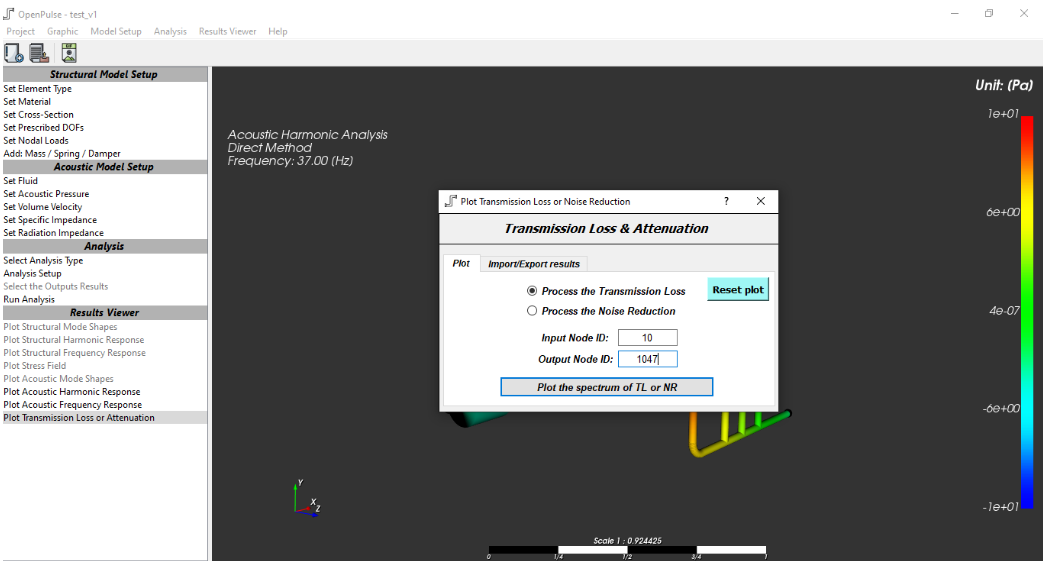
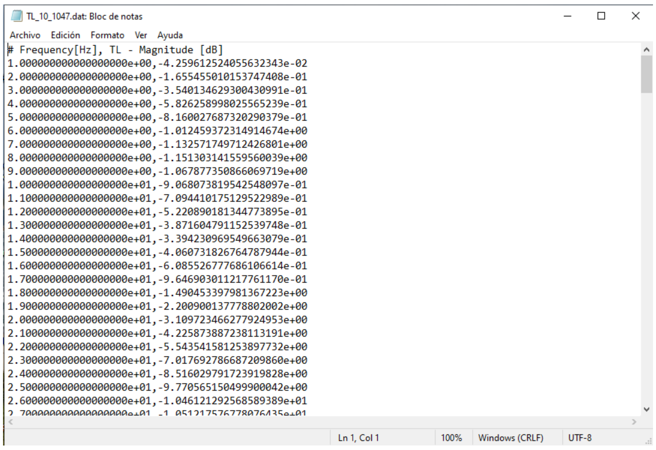


Figure 15: OpenPulses's interface: TL/Attenuation Plot



TL_10_1047.dat: Bloc de notas

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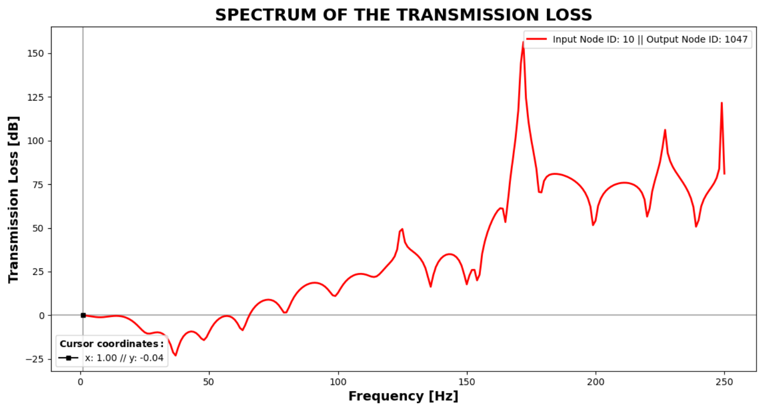
```
# Frequency[Hz], TL - Magnitude [dB]
1.0000000000000000e+00,-4.259612524055632343e-02
```

(a)



(b)

Figure 16: OpenPulses's interface: view of a .dat file generated by the export function in OpenPulse (16a) and the TL plot at Node ID Output 1047 and input 10 (16b)