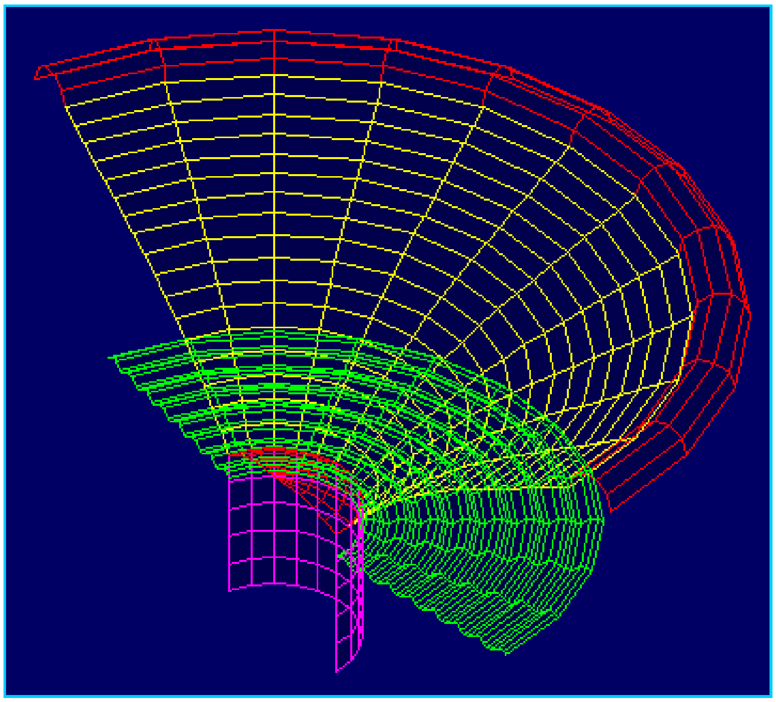
FINECone™



Acoustic Finite Element Dome/Cone
Simulation Program

T U T O R I A L

LOUDSOFT
www.loudsoft.com

FINECone Simulation of a 6.5 inch Woofer

The best simulation is made with a measured frequency and impedance response as reference (for comparison). When a good first simulation is found for one speaker, you can use this first simulation and make changes to improve your speaker.

Step1. Measure the frequency response, impedance, and parameters.

First you need to measure the impedance and frequency response under free field conditions (an-echoic room or using a simulated free field program). Then you should export these as .txt files with phase (BODE plot). Remember to remove any rings and make sure the driver is properly recessed in the baffle, which must be large (IEC baffle or larger is recommended).

Then measure the TS parameters, preferably using the fixed mass method. We will later import the curves and data into FINECone.

Step2. Draw the geometry of the driver

The safer and easier way is to modify one of the FINECone example DXF files. In this way, the names of all the layers are defined by default settings and they will import easily into FINECone. See the DXF hints.doc how to make the DXF file.

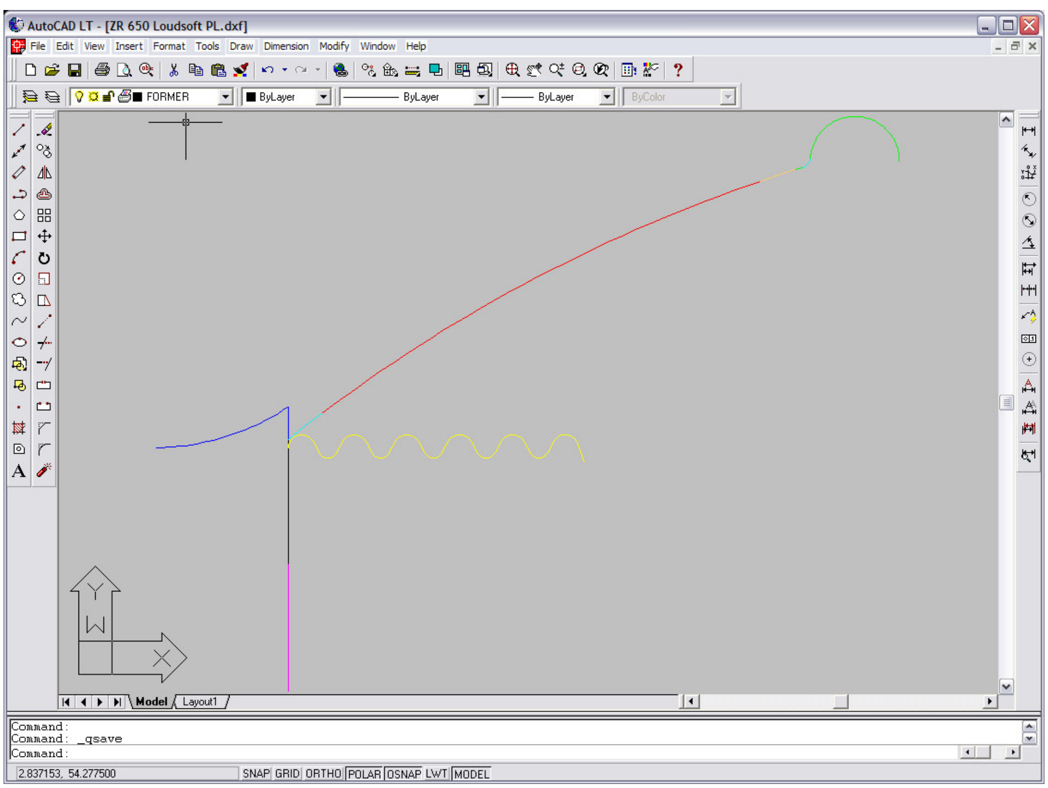


Figure 1. FINECone DXF Input file

Note that we cannot have double lines in the FINECone DXF file

Therefore the DXF file is simplified, especially regarding the VC former (Fig.1), so that the Voice Coil is only one line for the winding (magenta), and the VC former is starting with another line (black) up to the point where the spider is attached and one more line up to the cone

Likewise the dust cap and the flange, which is overlapping the VC former is modelled as an arc +ONE line.

The same applies for the surround flange on the cone, which is drawn as one line (orange) in the Diaphragm layer. The actual cone is glued to the first roll of the spider. Since we cannot model double lines we have simply split the cone into two arcs, as indicated by the cyan colour.

Step3. Start the simulation using the FINECone Wizard.

Press  button to start the FINECone Wizard (Fig. 2)

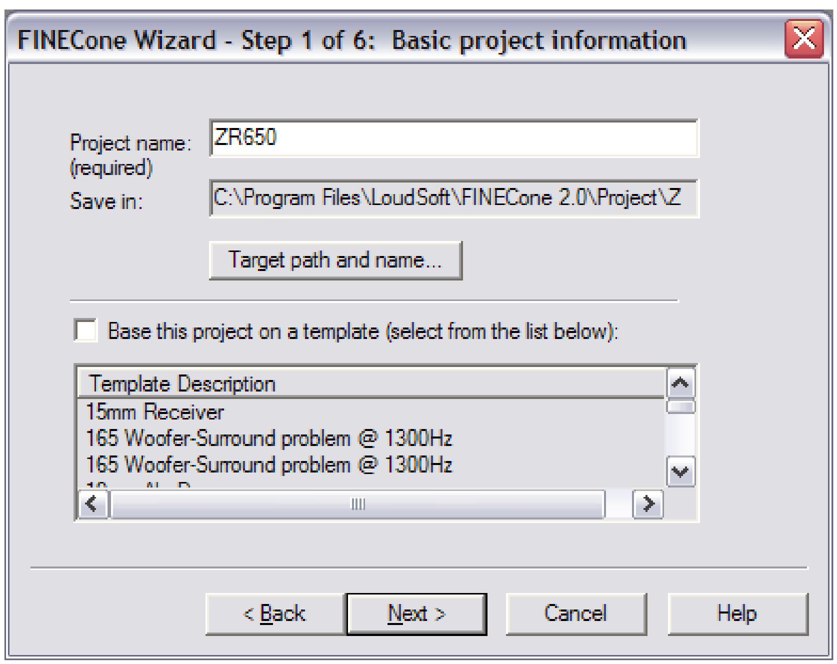


Figure 2. FINECone Wizard

If we had saved an earlier simulation as a template file (.FTE) we could select that as a start.

However this analysis is new and we therefore continue with next.

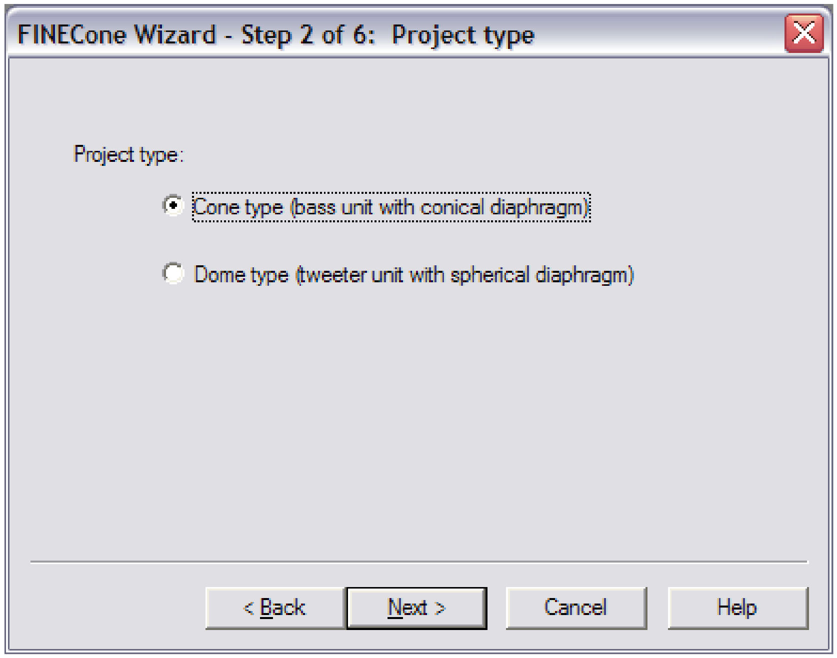


Figure 3. Choose Cone type (Project Type)

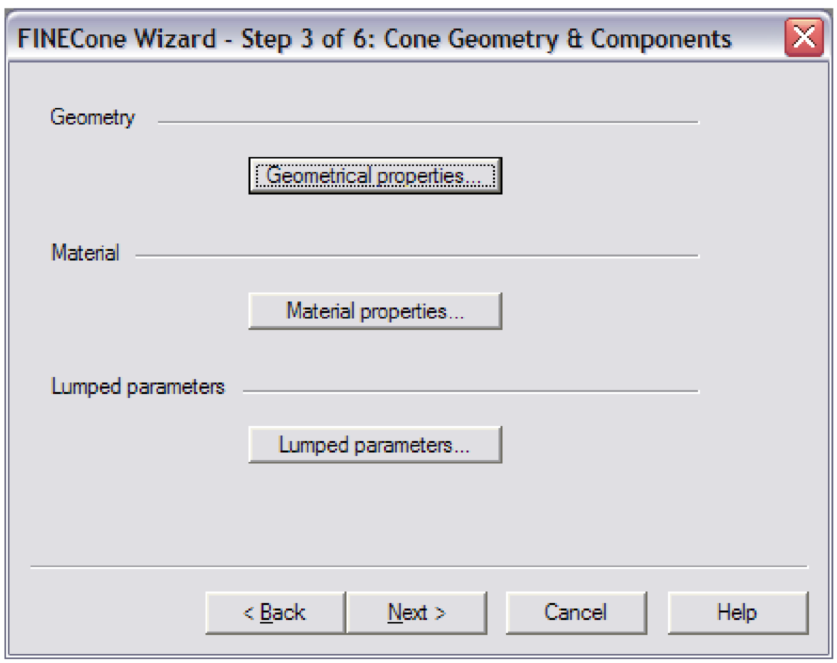


Figure 4. General FINECone Steps

The 3 buttons indicate the general procedure:

1. Define the Geometry,
2. Input material properties
3. Set other simulation parameters

Press 

button to input the geometry of the driver.

After opening the DXF file (Fig.5), we have found that two rows are not selected because the names of those layers are not the same as the default names. We have to choose dust cap and voice coil layers by finding the layer where the component is from the drop down menu as shown in Fig. 6.

Note that the DXF file is analysed as indicated by the green circles. A red circle would indicate that the lines were not properly attached.

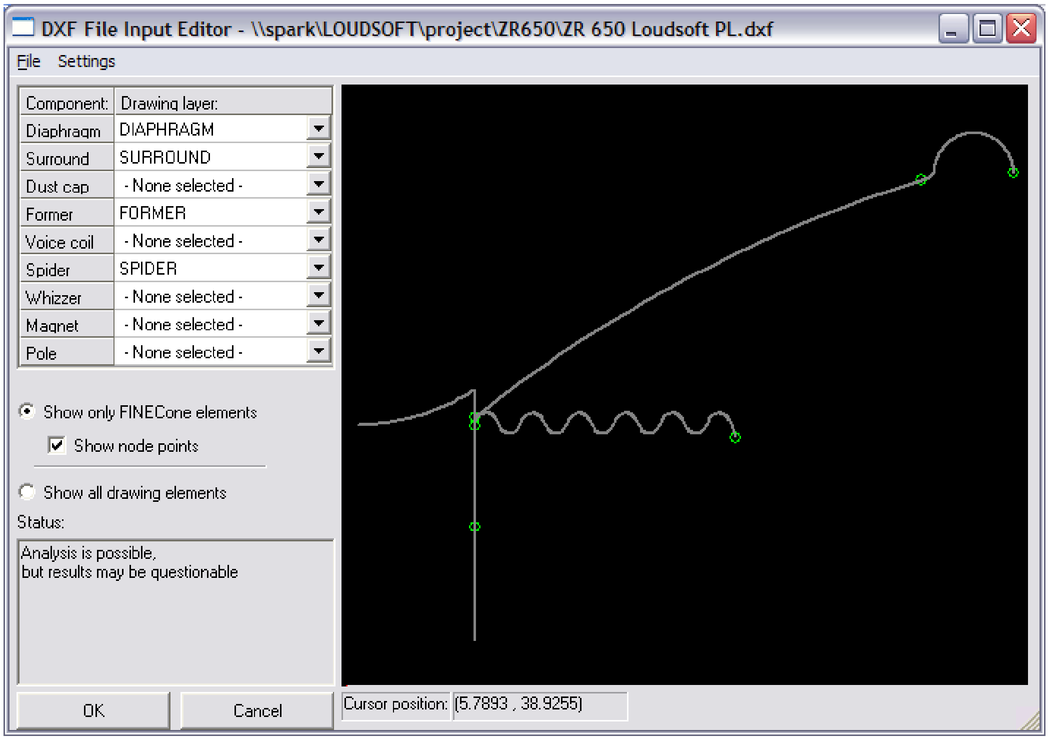


Figure 5. DXF Import -Input Editor

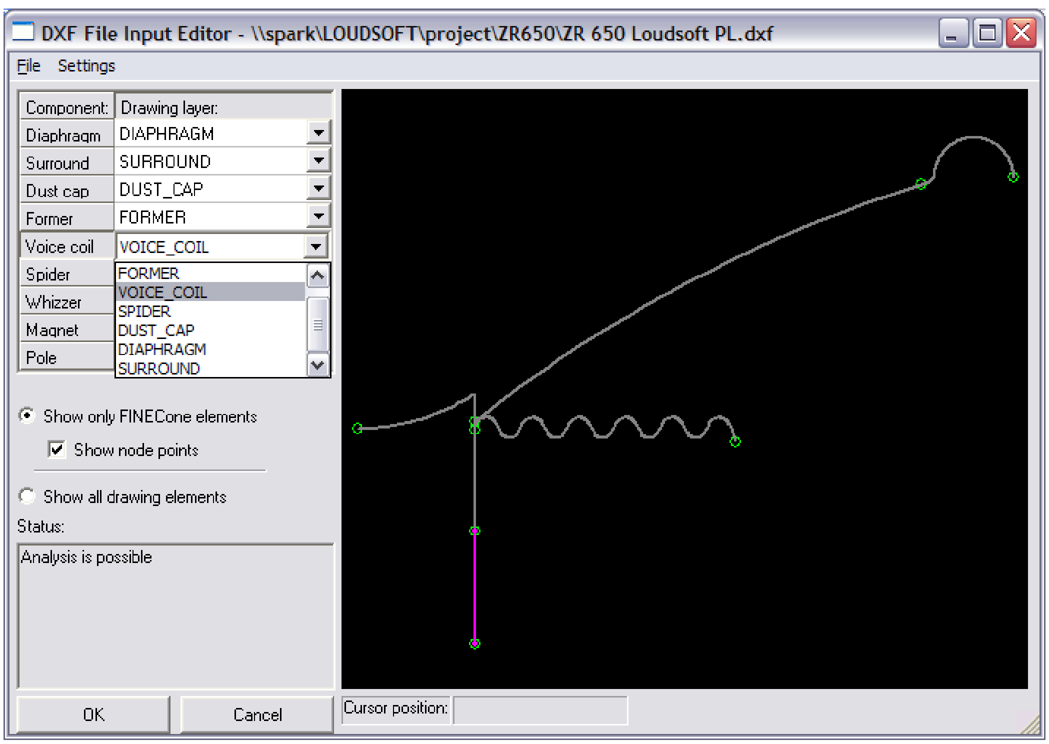
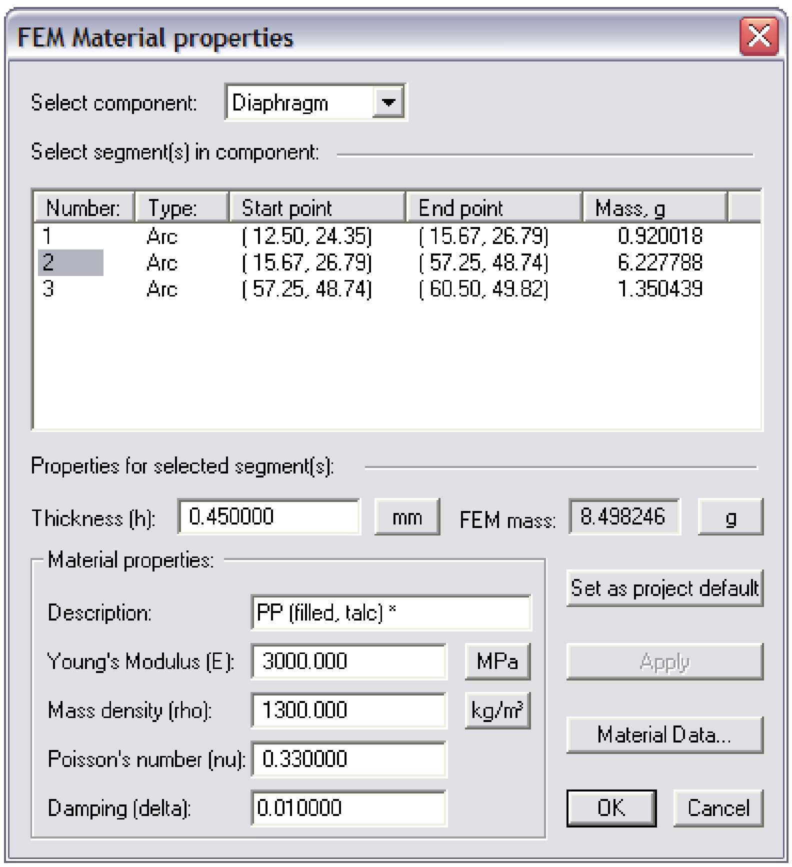


Figure 6. DXF layer - drop down menu

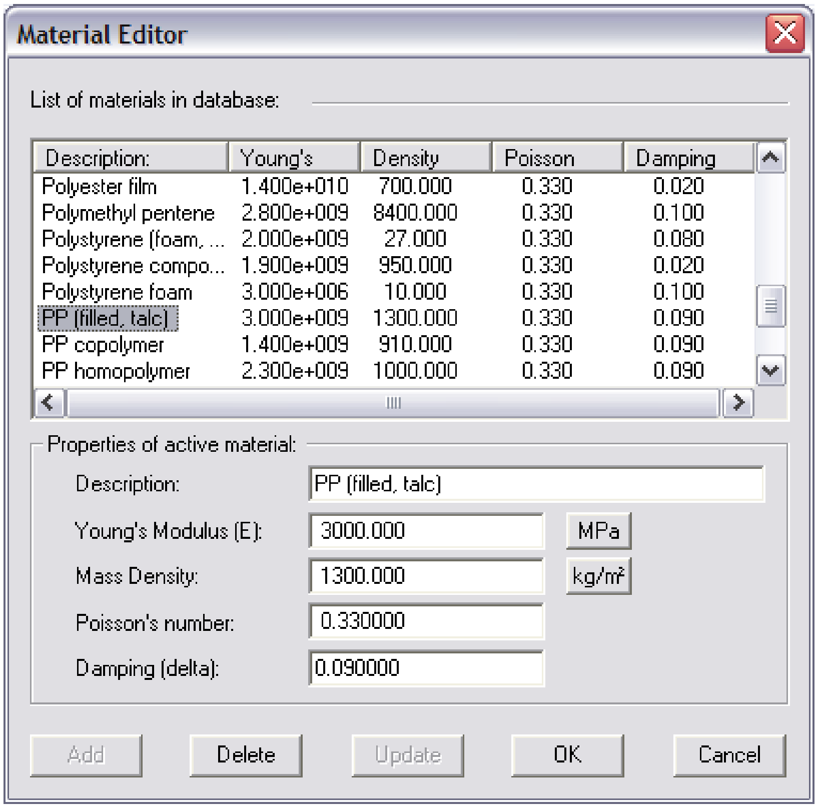
Press  button to input the materials of all components.

The preparation for this step is to decompose the driver into parts like those segments we have in our DXF file, and measure the thickness and mass of them.

Choose material of each segment of the diaphragm. We may select all the parts and choose material for all if they are same. However, the safe way is to do it one by one, for we may have different thicknesses for different parts. We should avoid making it the same by mistake.



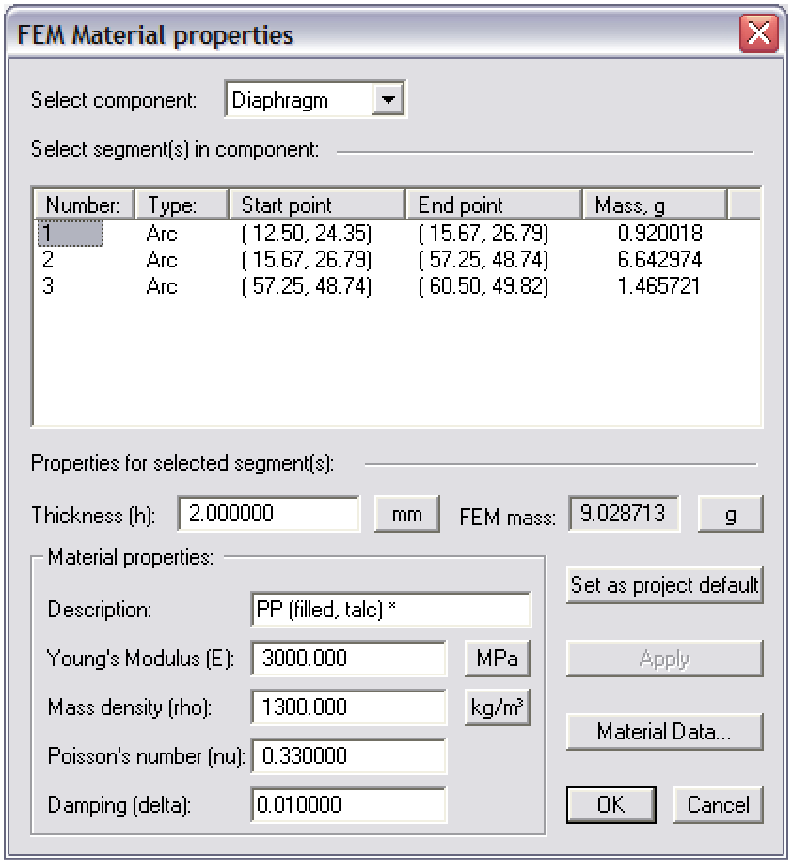
The cone thickness is 0.45mm, shown here as input for segment Number 2. Press “Material Data” to enter the database, where we have selected PP (filled, talc) material for the cone.



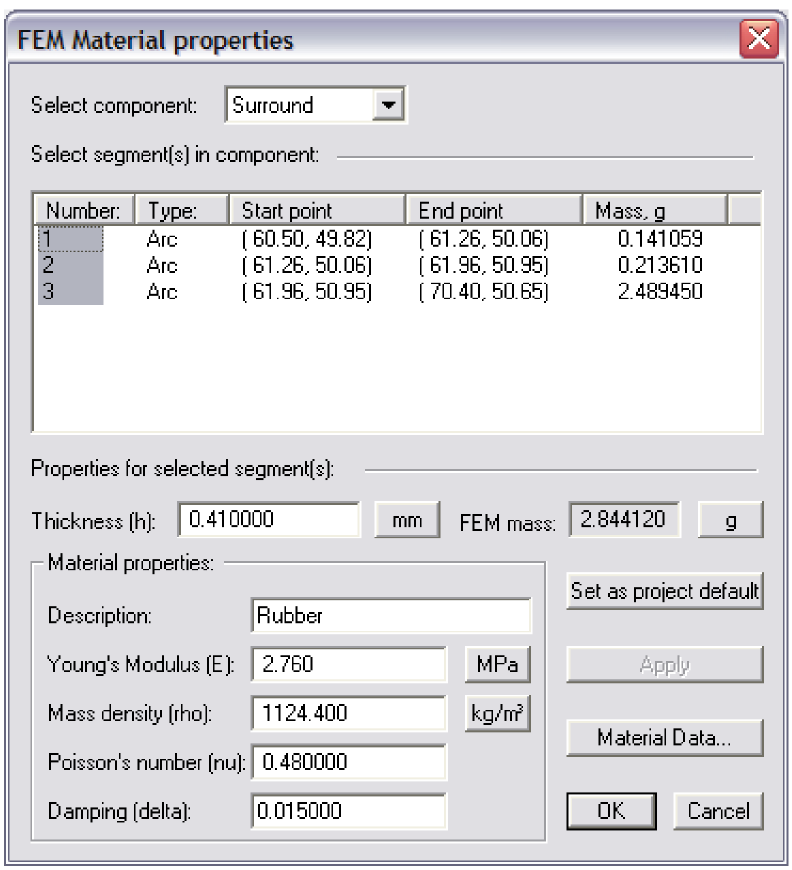
The influence of glue will be taken into account. The actual speaker has much glue between cone, VC former and spider. In our model this glue can be in three positions, on the inner part of the cone, on the upper part of the VC former, or on the inner part of the spider.

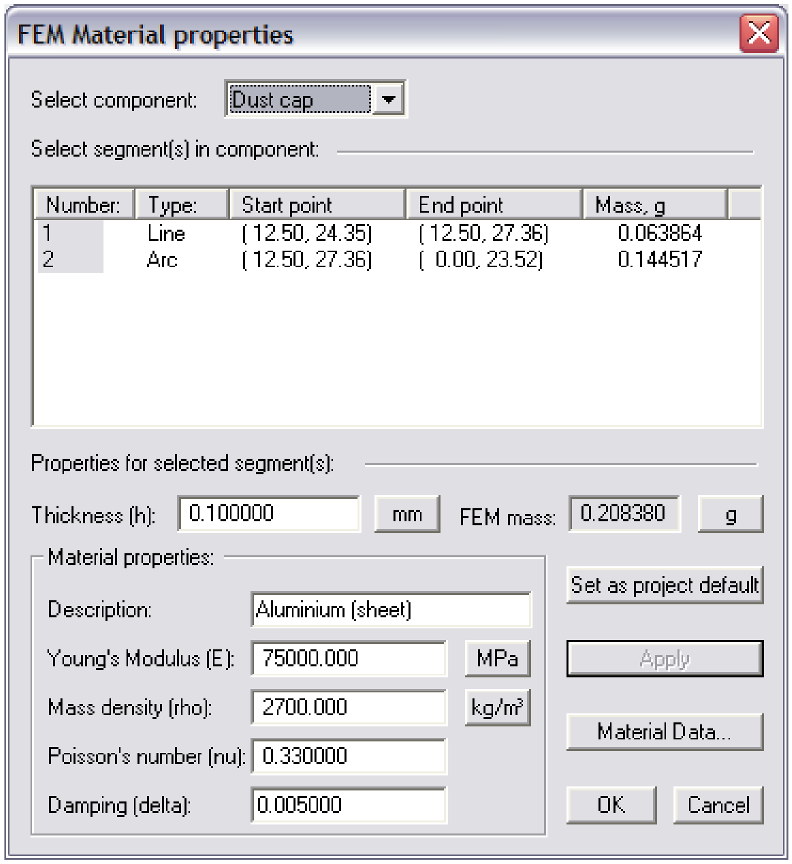
In this case, we choose to model the glue on the inner part of the cone, because we want to simulate the influence on the cone response. We do that by setting a larger thickness for that cone segment and change the density until the mass is same as the measured value.

This is done in the next picture, where the first cone segment (1) is specified with 2mm thickness. We may later change the stiffness by adjusting Young's Modulus

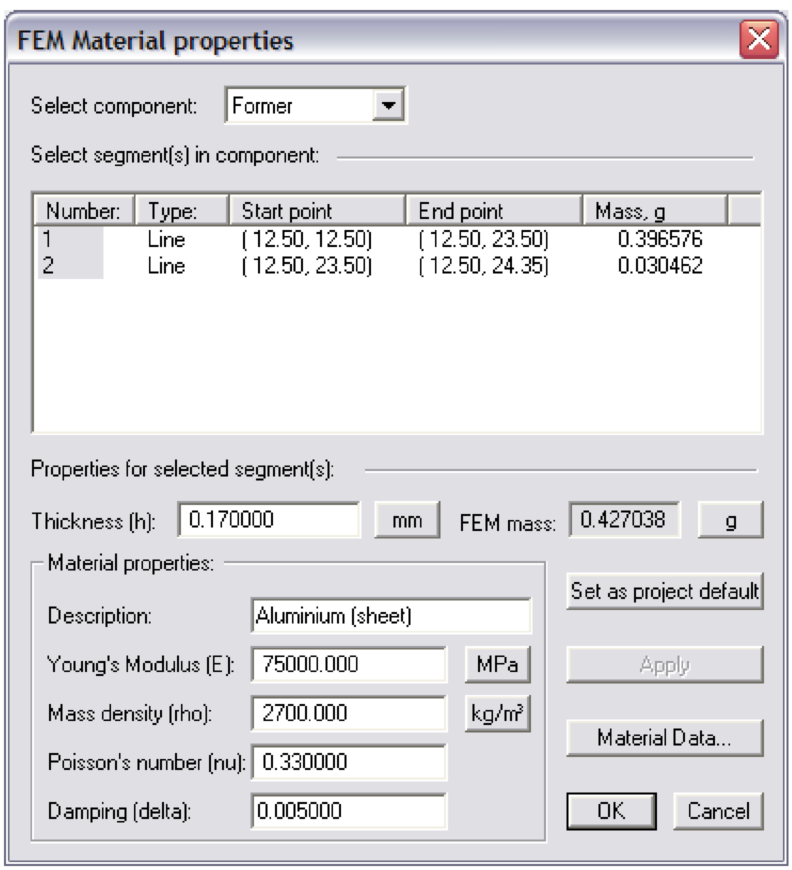


The surround is 0.41mm rubber from the database

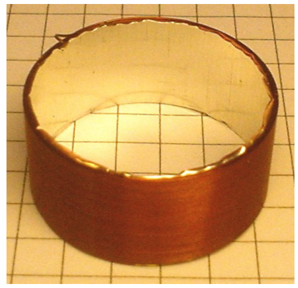


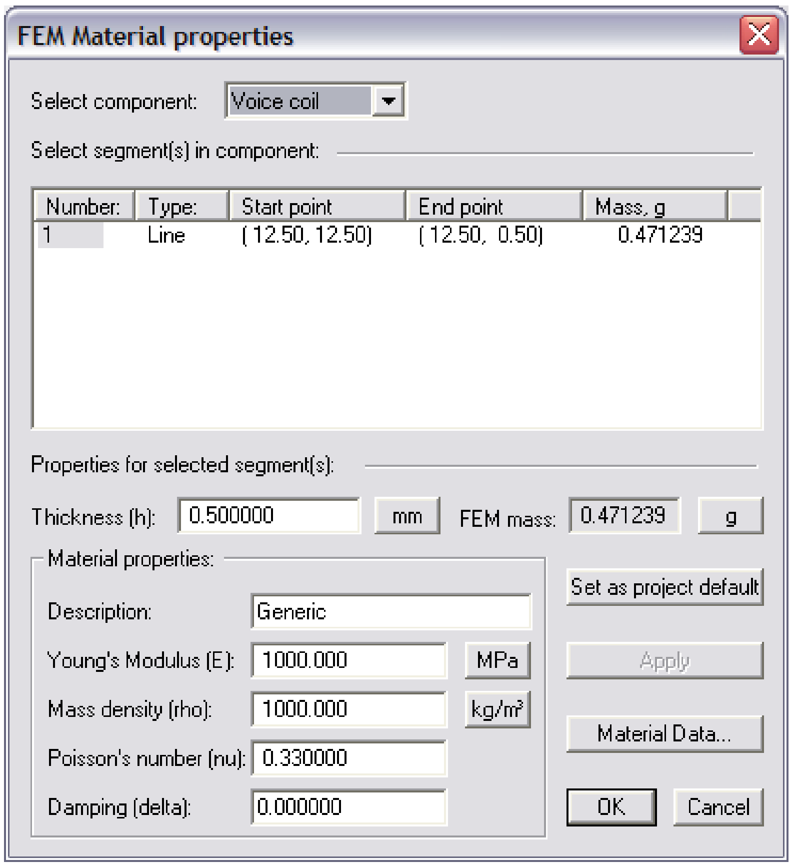


Note: Don't forget to press Apply *button, whenever you have made a change.*



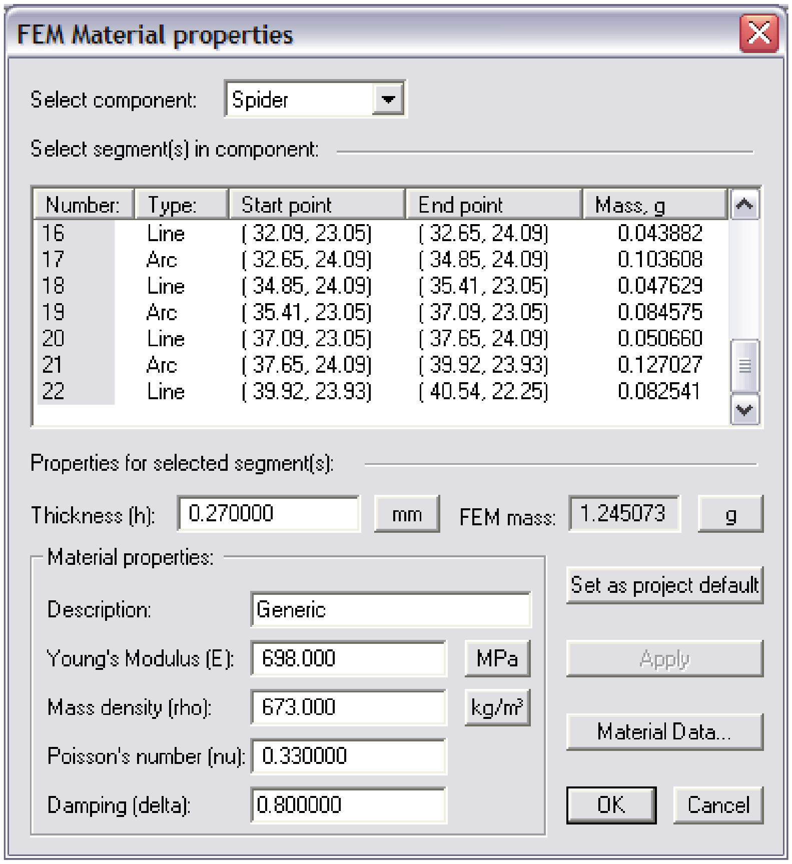
The important parameter of the voice coil is mass of the coil winding + former covered by it, see picture). So, we adjust the thickness to get the same mass as measured. The VC stiffness is not used.





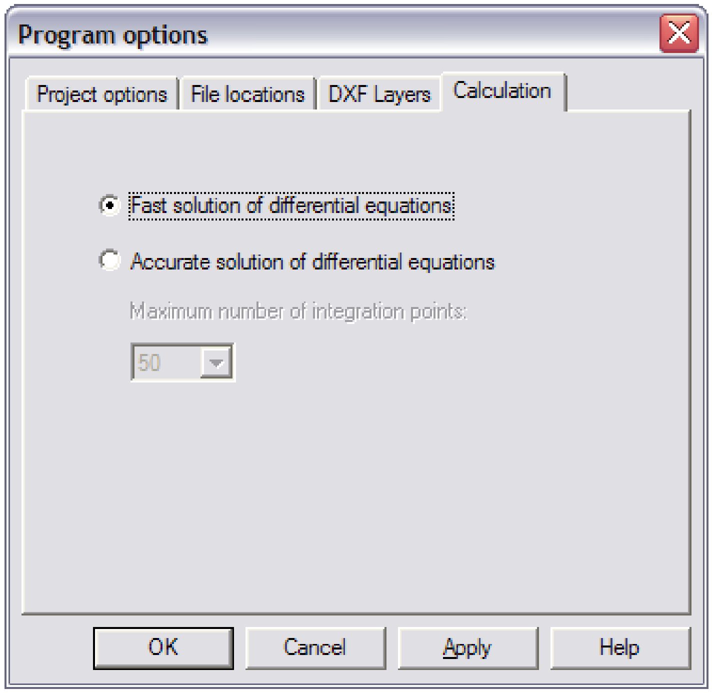
Since we don’t know the accurate material of the spider, just use the common material found from the example file.

Remember to select all segments with CTRL+A.



Note: The common error of setting materials is when we select more than one segment and set the materials for them together, yet, we may forget they have different values in some parameters, e.g. thickness.

For the initial simulations, we use the setting below to get faster calculation. (Tools/Program Options/Calculation)



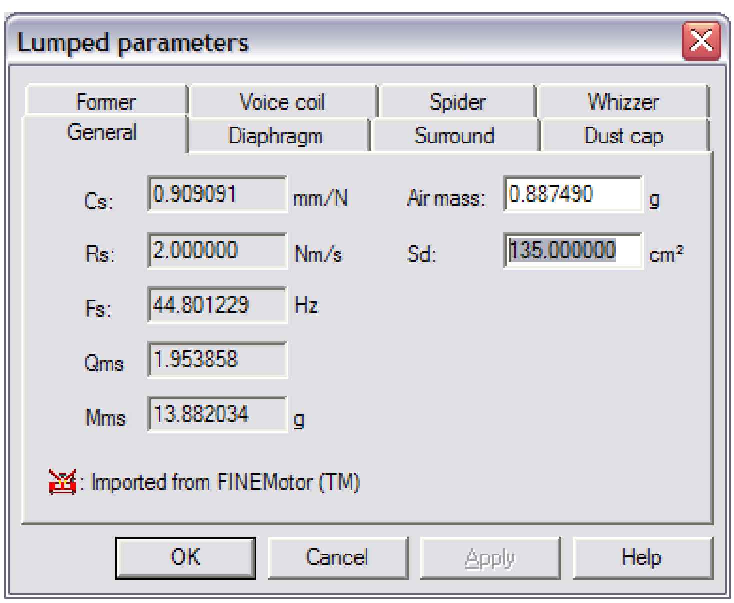
Note: When we change the number of segments in the DXF file, the materials setting of the changed layer must be defined again. (values cannot be stored when there are different segments)

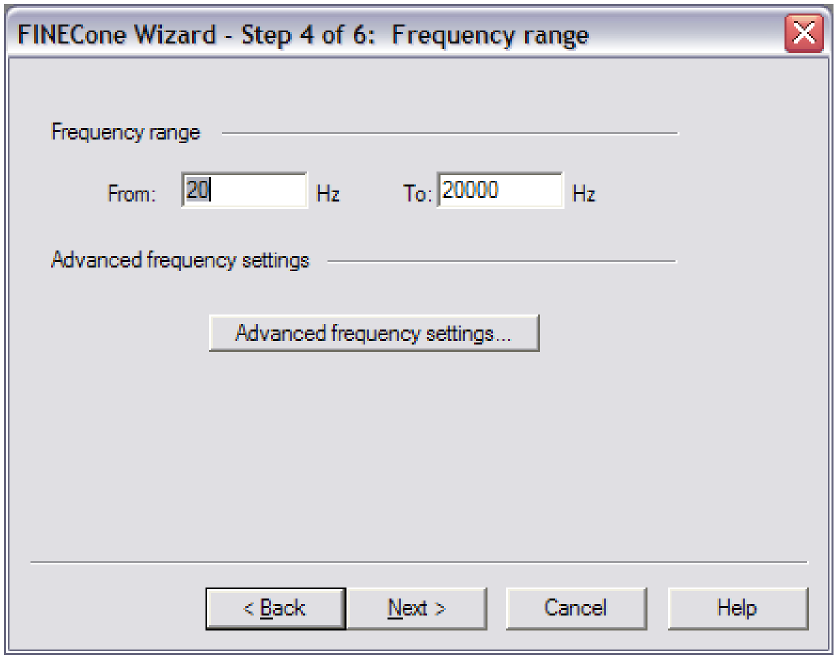
Press 

button to get the lumped Mms values.

Input the Effective Cone Area Sd, and get the air mass calculated automatically. The air mass will automatically be included in the FEM calculations.

The other shown Lumped parameters are not used in the accurate FEM calculations (except Re and BL). However they can be found from the FEM calculations and used for comparison (See the Reference Manual).

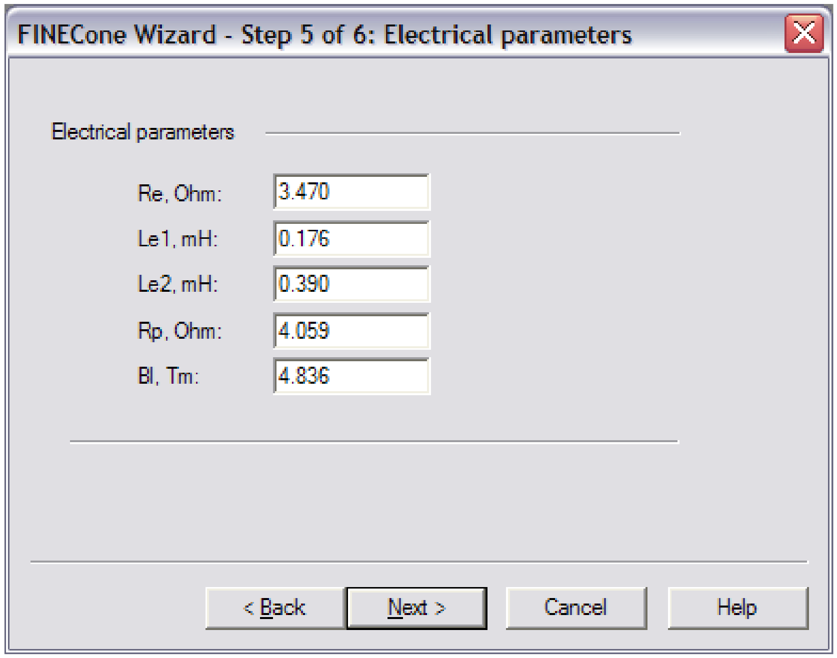


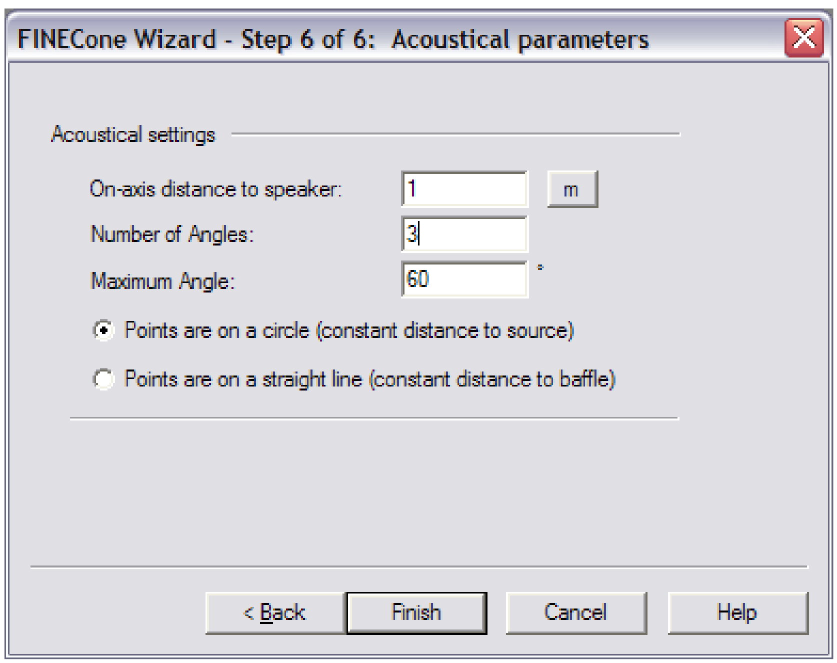


The TS parameters below are measured with MLSSA.

"Title: Measured Parameters"
"Method: Mass-loaded (9.900 grams)"
"DCR mode: Fixed (3.86 - 0.39 ohms)"
"Area (Sd): 134.78 sq cm"
"Series resistance: 75.00 ohms"
"Stimulus level: 1.00 volts"
61.460 "Fs Hz"
3.470 "Re Ohms"
22.155 "Res Ohms"
4.975 "Qms "
0.779 "Qes "
0.674 "Qts "
0.176 "L1 mH"
0.390 "L2 mH"
4.059 "R2 Ohms"
12.583 "Vas(Sd) litres"
13.597 "Mms grams"
493.179 "Cms æM/Newton"
4.836 "Bl Tesla-M"
87.568 "SPLref(Sd) dB "

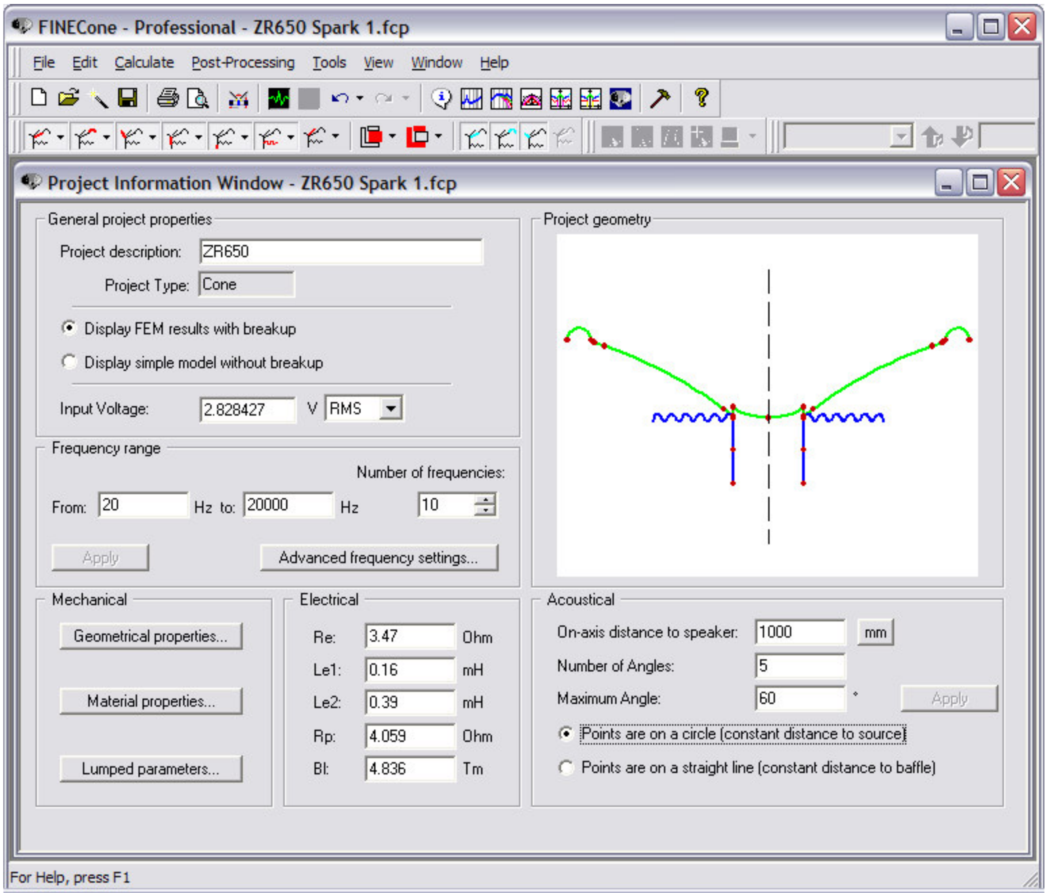
Start the simulation using some of the values: Re and Bl from here in the next step. Use the value from L1, L2 and R2 for Le1, Le2 and Rp.





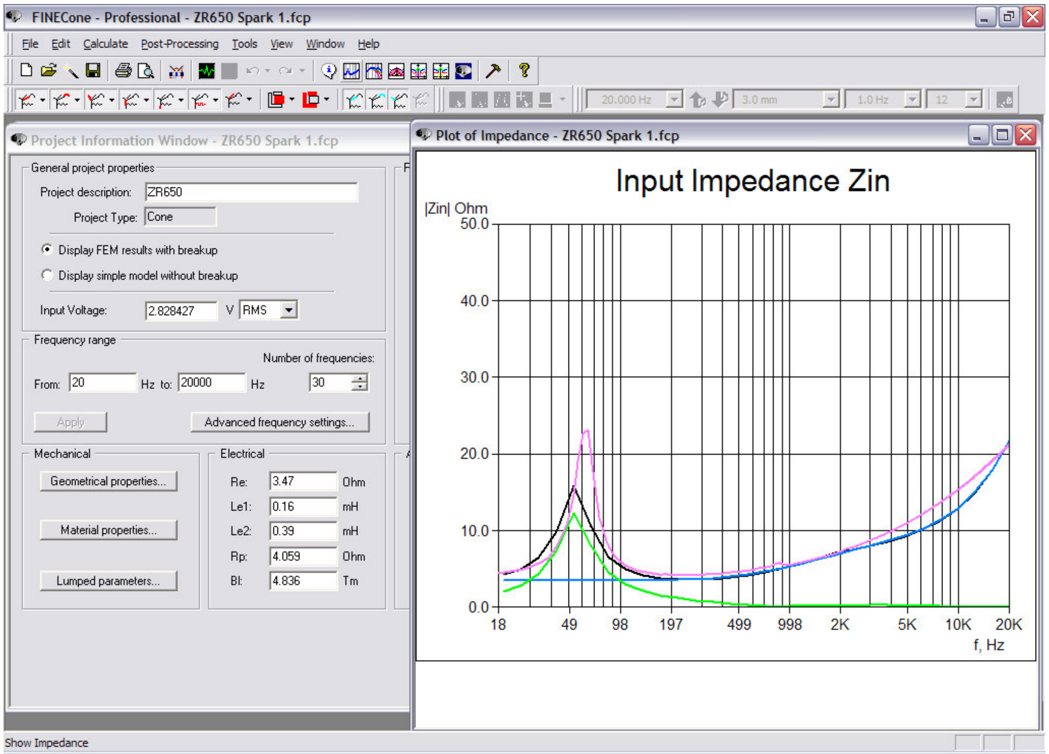
3 angles mean 0, 30 and 60 deg off axis responses.

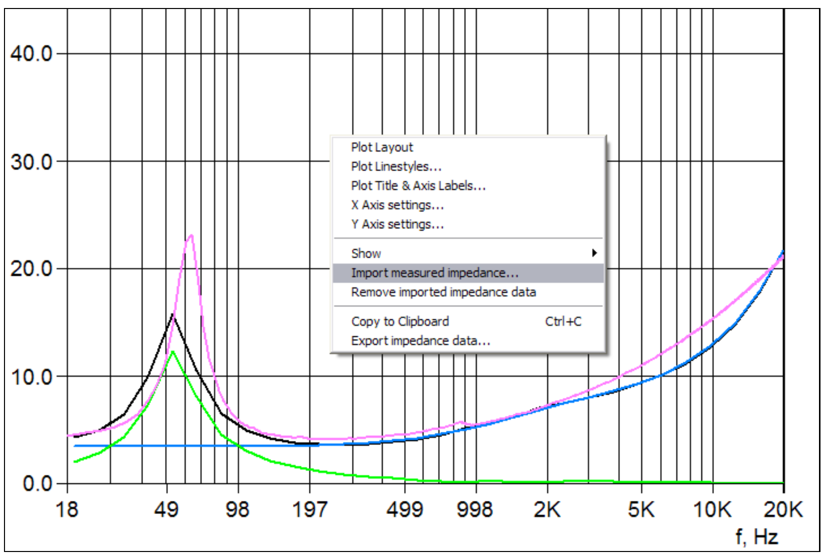
The Finite Element (FEM) calculation is done automatically after Finish is pressed.



Step4. Fit the impedance curve

Now is the time to take a look of the impedance curve we have calculated in FINECone.

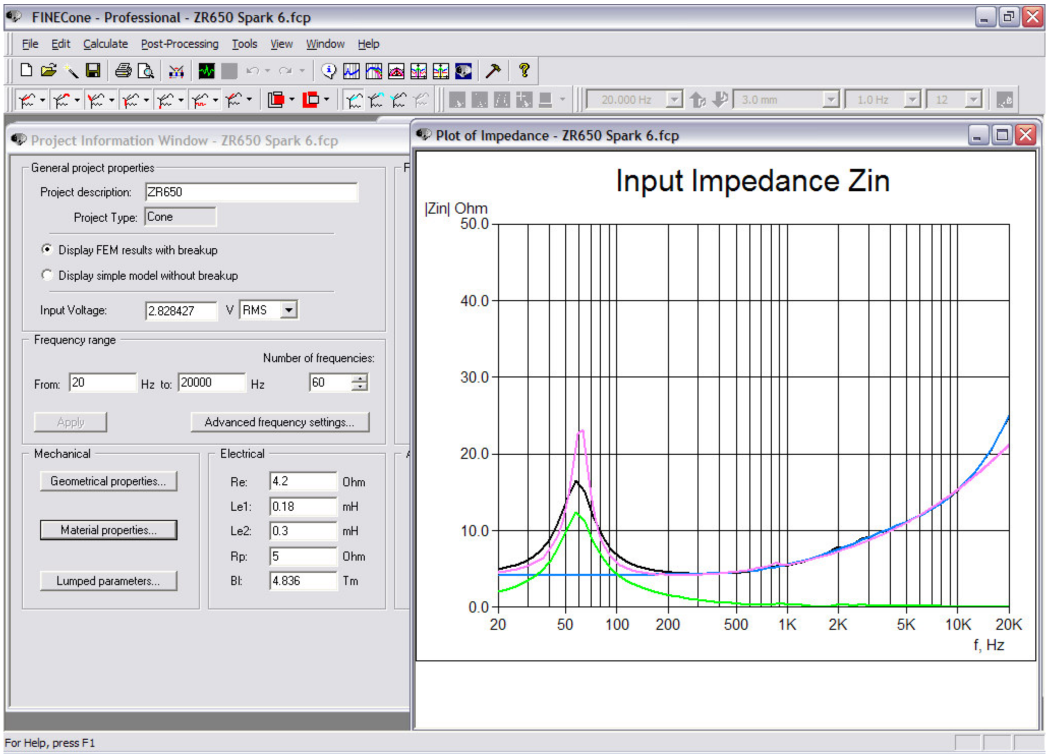




The pink curve was imported in *.txt format from MLSSA by right-clicking the impedance curve and selecting "Import measured impedance". You can also select the LOUDSOFT format FSIM and FINELab format *.LAB

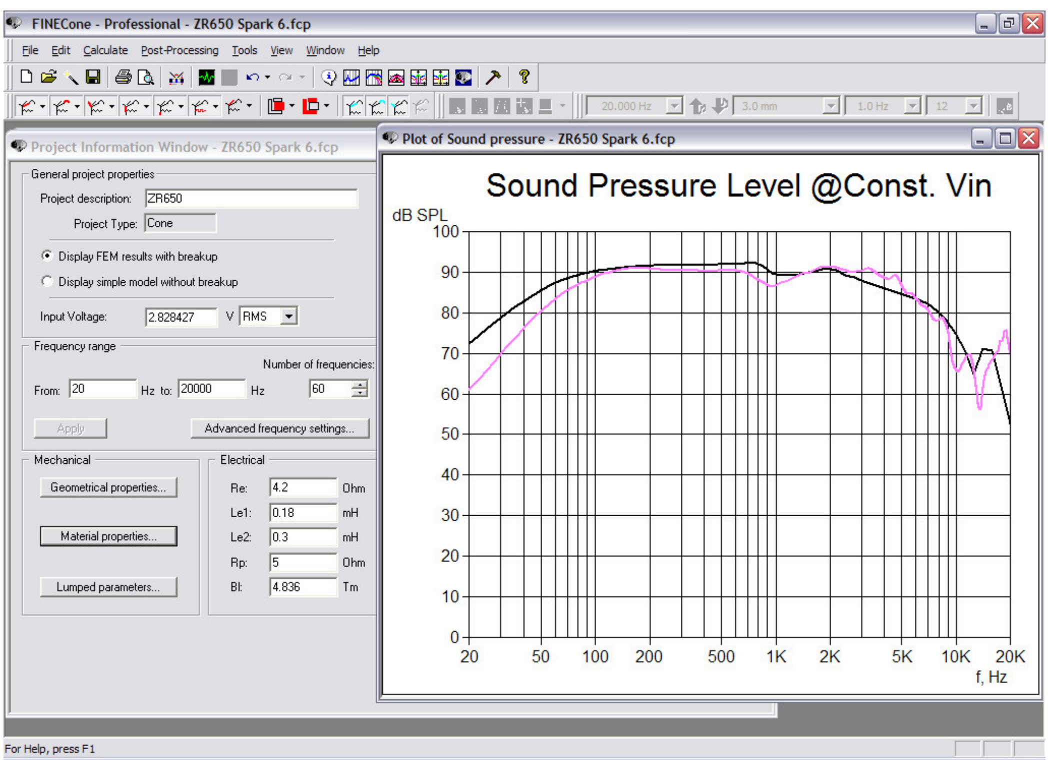
The simulated impedance curve (black) is lower than the measured curve around 300Hz. It is because Zmin is a little larger than Re. So, we should increase the value of Re.

Then we change the values of Le1, Le2, and Rp, to get good agreement at frequencies up to 10 kHz.



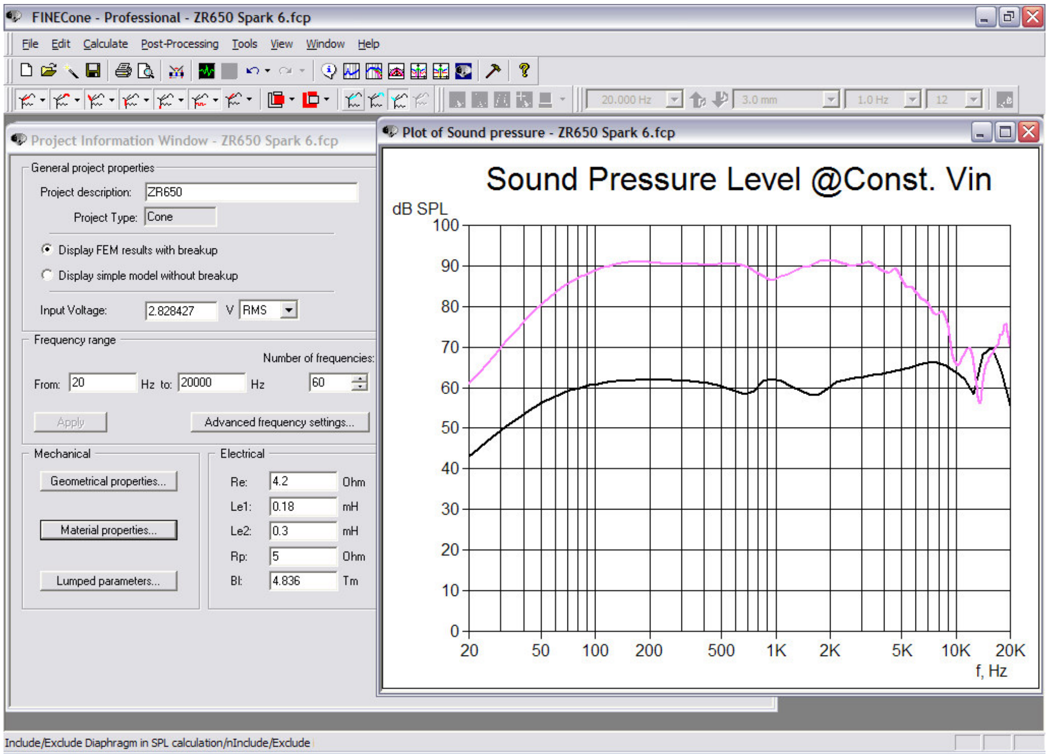
Step5. Fit the SPL curve

Finally, we work on the SPL curve

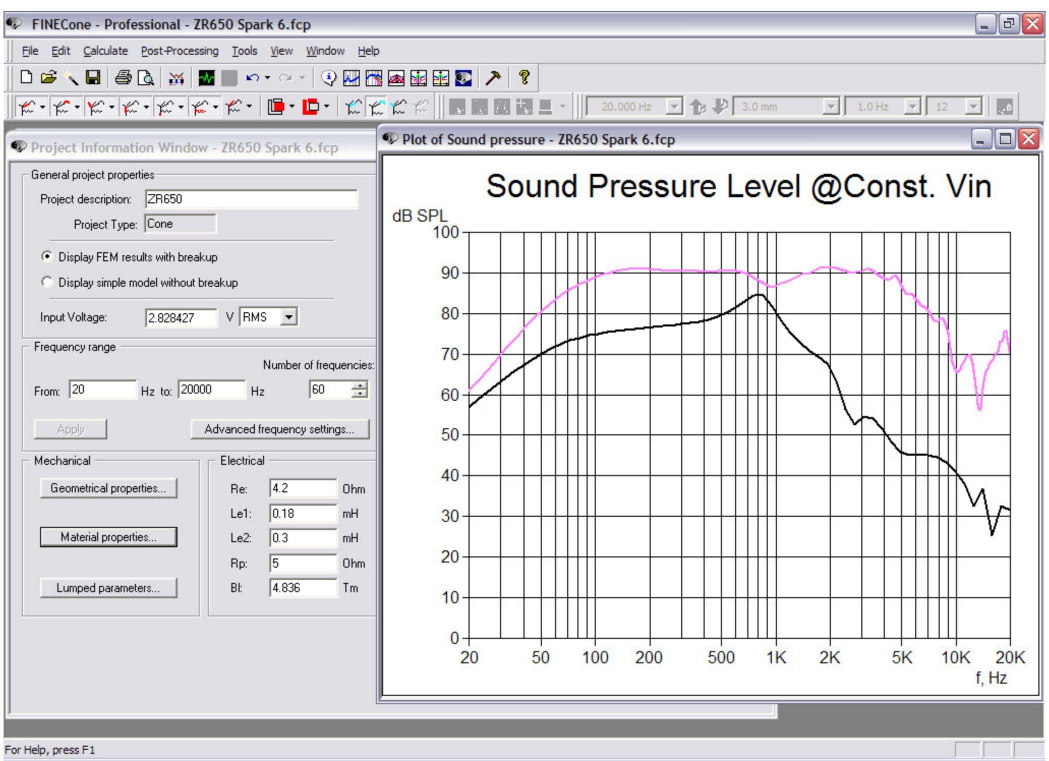


At low frequencies, the black curve has more extension than the actual curve, because the black (simulated) curve is simulated assuming an infinite baffle, but the pink (real) curve is measured in a smaller finite baffle.

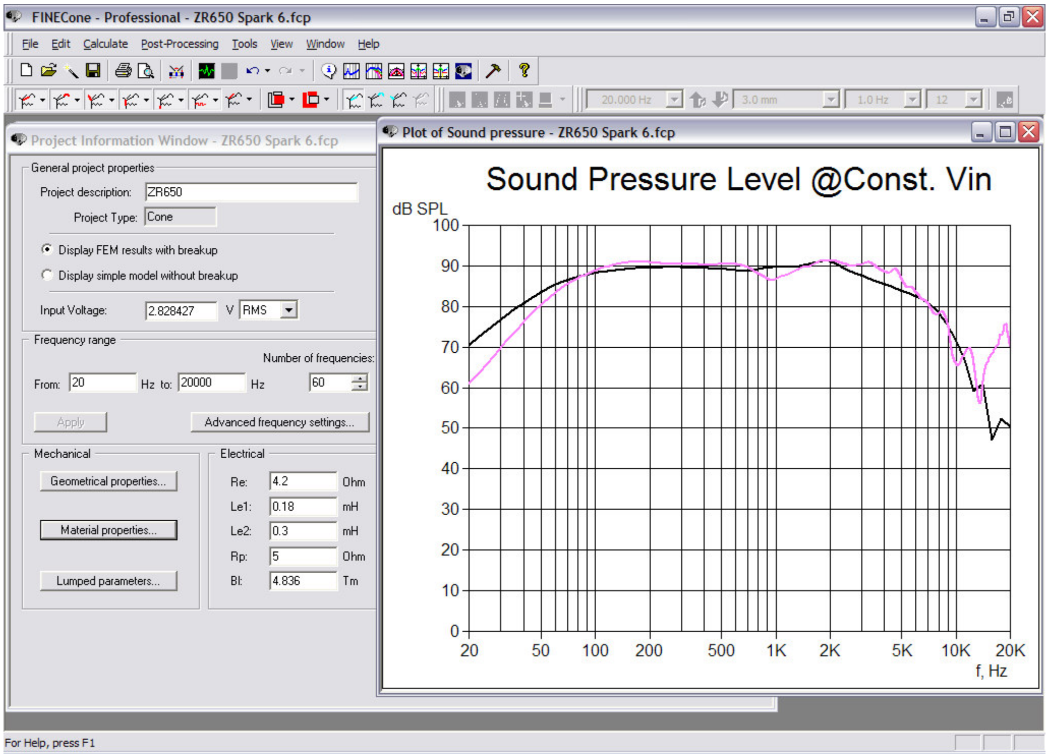
Using  buttons, we can study the effect of the 3 main components: Cone / Surround / Dust Cap.



The dust cap only affects the very high frequencies.



The surround produces more SPL than the dust cap, and it has a peak around 800Hz, close to the dip in the measured curve. So we may change the surround parameters to get a better simulation.

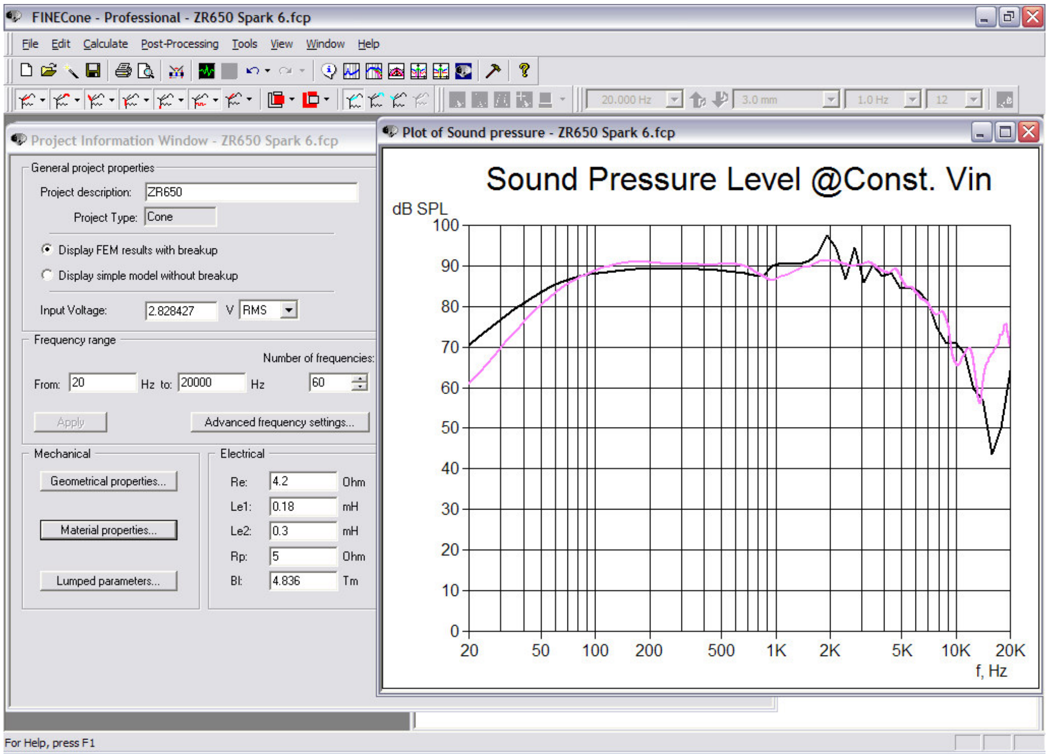


The cone dominates at almost all frequencies. To get better agreement, we should first simulate the cone accurately.

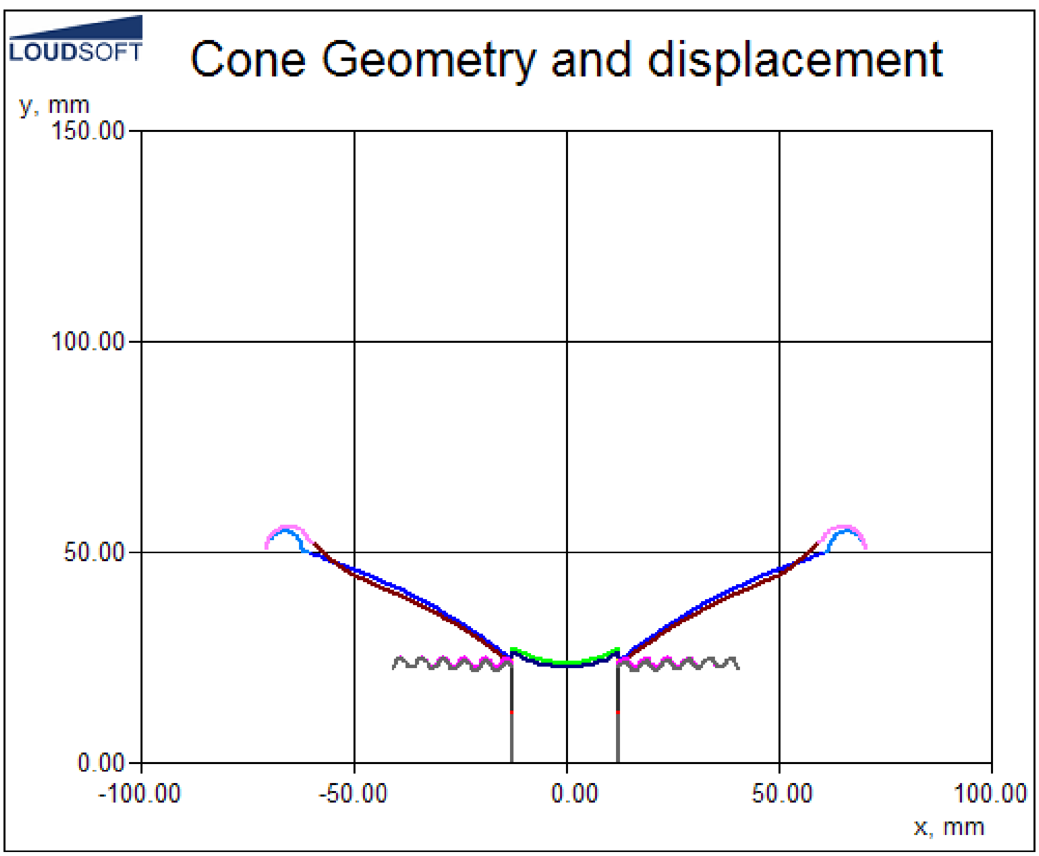
Note: During the first simulations, the fast calculation is usually good enough. It saves lots of time.

If the SPL curve looks very smooth, it may be because the damping is too high. The rule is that we use less damping during the first simulations to be sure to see all the break-up details. After that, we will change the damping to the correct value.

Reducing the damping of the cone from 0.09 to 0.01, we get the following responses.



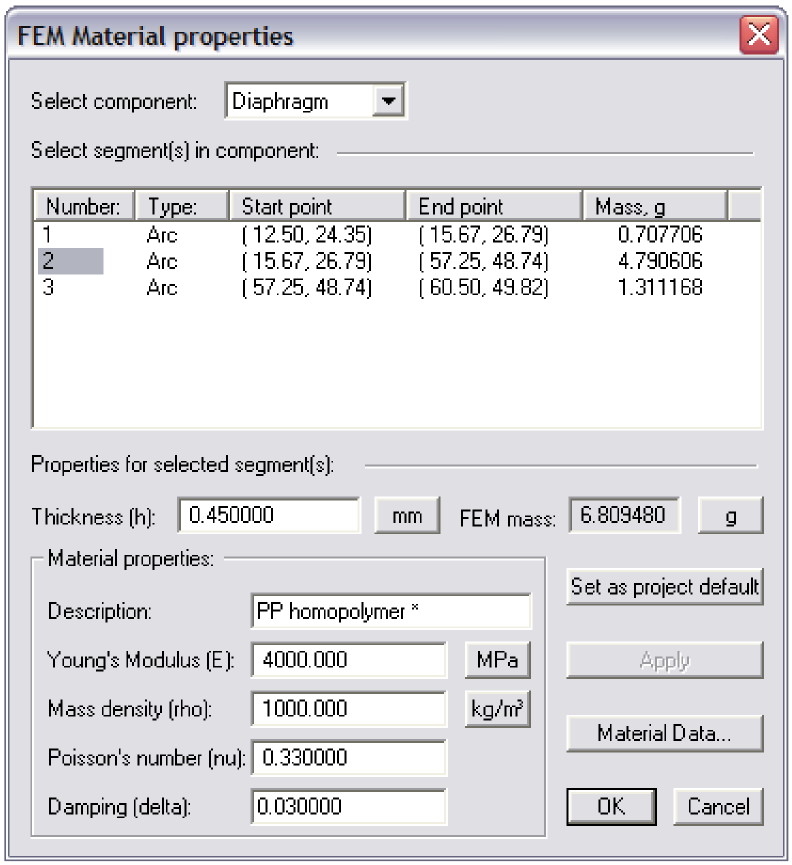
Firstly, let's find the reason for the disagreement around 1k Hz. Press button, and set the *selected frequency* around 1k Hz.



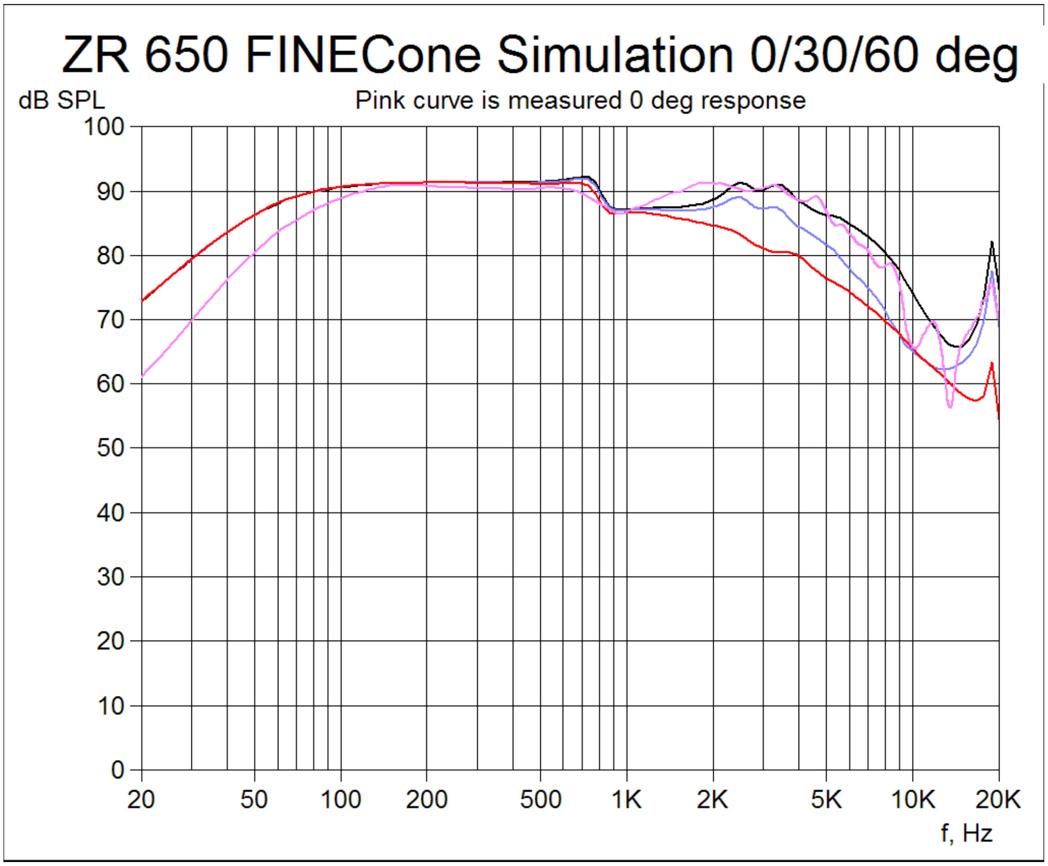
It is very clear that the outer part of the cone is bending. So, let's open the cone material properties.

We will change the thickness of the outer part of the diaphragm back to 0.45 to get the correct stiffness, but increase the density to 2300 to keep the mass, since this part is a combination of cone and surround flange. The glue also influences the stiffness, so we should change the Young's Modulus to move the peak/dip to its right position.

Finally we find the correct damping of the cone, which is lower than the Material data



Then repeat this at the other disagreement, until we find an acceptable agreement.



The final result is a good simulation of the actual measured ZR 650 response (pink curve). The 30 and 60 degree off-axis responses are also calculated and shown.

The simulation accuracy is focused between 100-10kHz. It is possible to increase the simulation accuracy considerably by splitting the cone into 5-7 segments and also split the VC former in smaller segments. Examples made in this way can be found in the FINECone Project directory.

Note: Many simulations will show a lower SPL in the range 700-3000Hz. This is normal and a result of the chosen calculation method

FINECone example2: 6.5 inch Alu Cone Woofer

We will verify a FINECone model compared to a real driver to see the accuracy. The FINECone model can then be used to simulate new materials, cone shapes and many other things.

The actual driver is a 6.5-inch woofer in a plastic frame with a 90mm ceramic magnet and 33mm voice coil. It has a curved aluminium cone with a rubber surround and a large plastic dust cap.

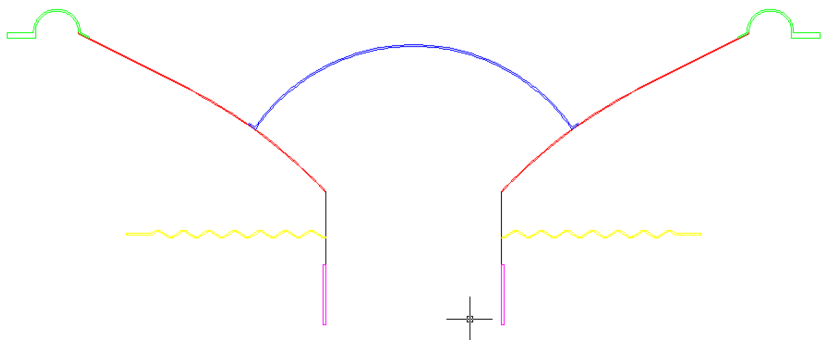


Figure 1. The main geometry of the acoustical components

Thiele/Small parameters:		
Fs	47	Hz
Re	5,50	ohms
Qms	4.93	
Qes	0.49	
Qts	0.44	
Le1	0.22	mH
Le2	0.47	mH
Rp	4.91	ohms
Vas	23.93	ltrs
Mms	12.64	g
Cms	907	m/N
Bl	5.65	Tm

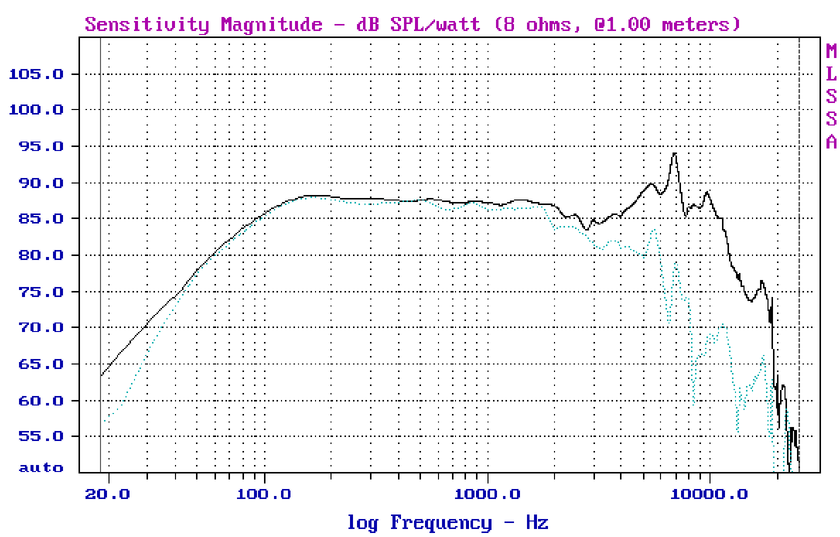


Figure 2. The (0/30deg) response is measured using MLSSA. The on-axis curve is imported in FINECone
FINECone FEM (Finite Element Modeling)

The following is a short description showing how the 6.5 inch woofer was modelled in FINECone.

These are the steps in FINECone FEM:

- Define Geometry by importing DXF file
- Define Material Properties of speaker components using material database
- Define Electrical Parameters and import FINEMotor data if available

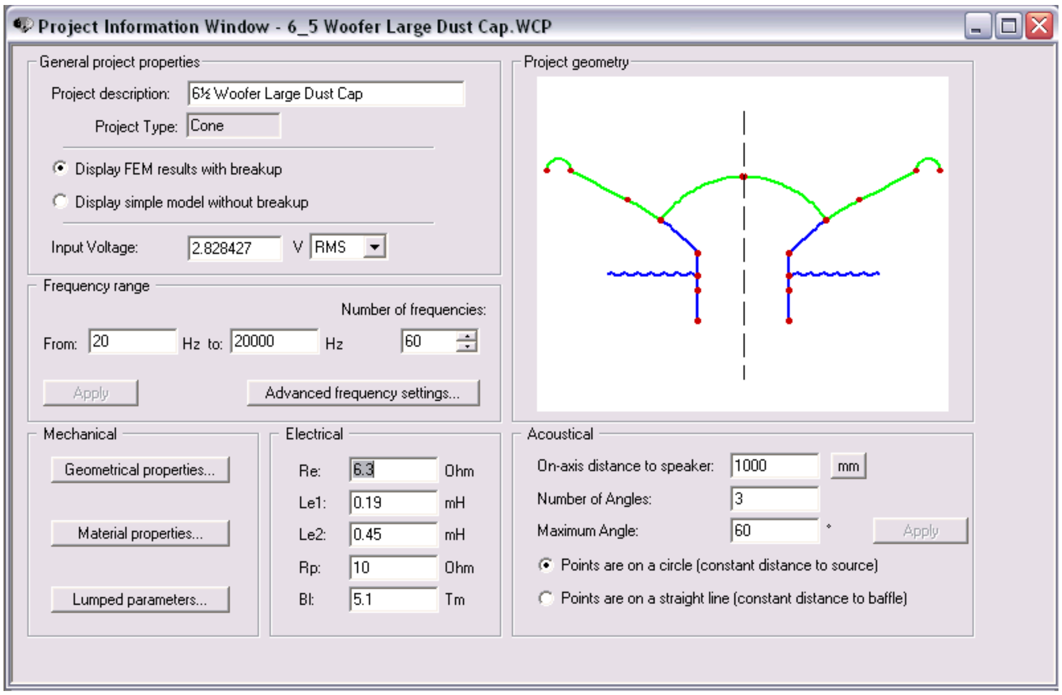


Figure 3. FINECone Main Window

Since all meshing, number of elements, DOF (Degrees of Freedom) and Constraints etc. are done automatically by the Program, we will just make a sketch of the geometry in AutoCAD and import the DXF file into FINECONE.

The model must be axi-symmetric, and only the right half is used. This implies that the coordinate of the leftmost point is on the symmetry axis where X=0. Usually this is the midpoint of the dust cap. The DXF-drawing is shown in Fig. 4

DXF-Import

The imported DXF geometry is shown here (Diaphragm (Cone) layer chosen):

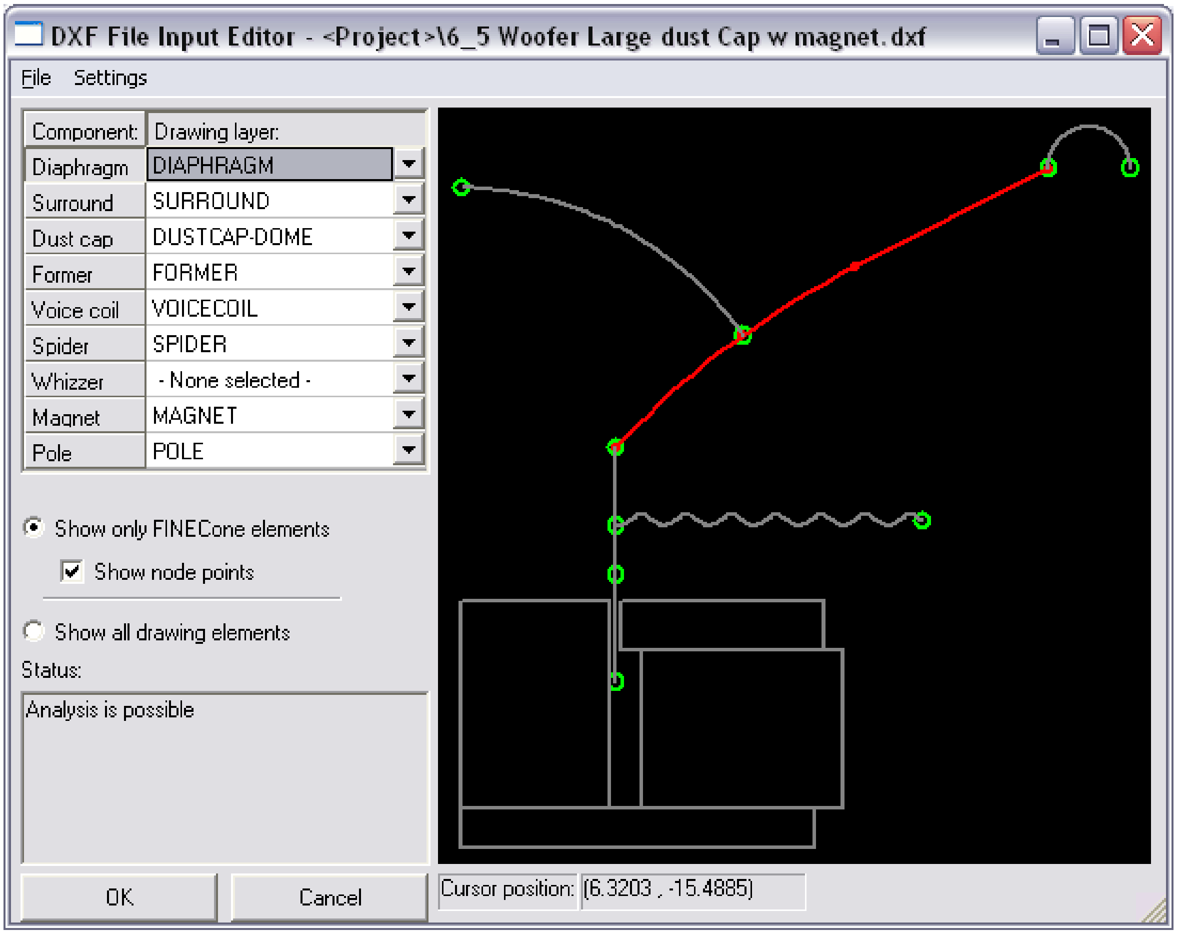


Figure 4. DXF Import and Automatic Error Checking

We have used the default names for the layers, and the entire drawing will be imported directly!

Note. You can change the default layer names in Tools/Program Options/DXF Layers

The Status window reports: Analysis is possible. This means that the DXF error checking has analyzed the DXF file and found no errors. See also the FINECone Reference Manual, which gives many more details.

FINECone will now start the calculation using default parameters. These must be changed to give meaningful results in this case.

Therefore we select FEM Material Properties

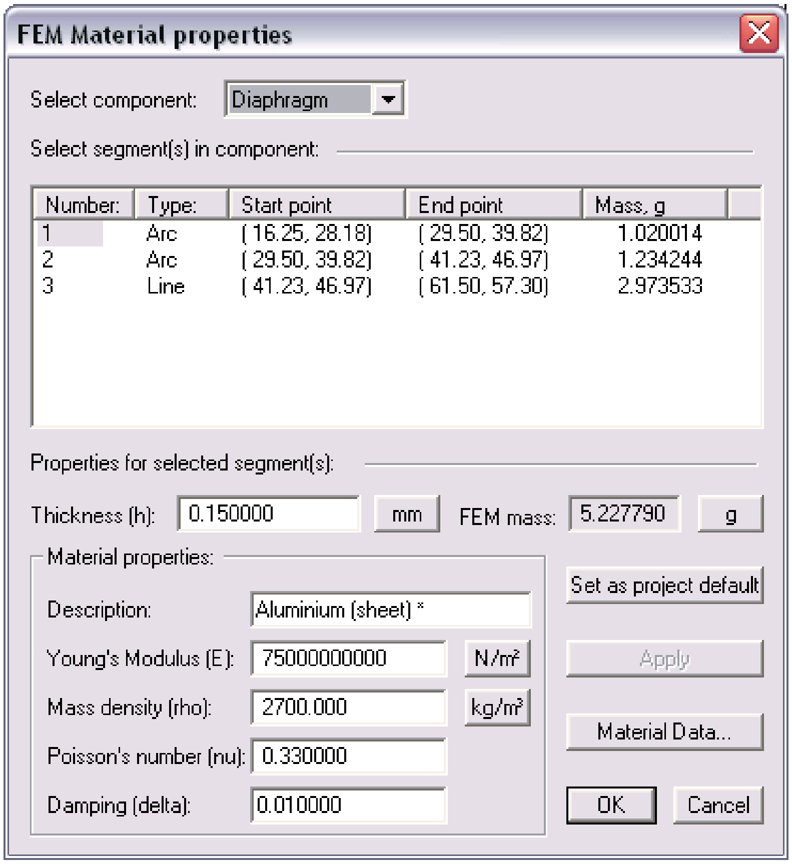


Figure 5. Material Properties Input

The diaphragm / cone is made in 3 segments. Basically this cone is designed with a large radius (arc) which is connected to a line (see previous fig). The large arc, however, was divided into two arcs both connected to the dust cap.

The cone material is chosen as Aluminium [sheet]. The * indicates that the material from the database is changed by increasing the damping from 0.05 to 0.1, in order to model the actual speaker material correctly.

The surround material is obtained from the Material Database, selected by the button on the lower right (Fig. 5):

Here is selected "Rubber ", which is a typical surround rubber material.

Note: you can edit the materials or add new materials in the database at any time.

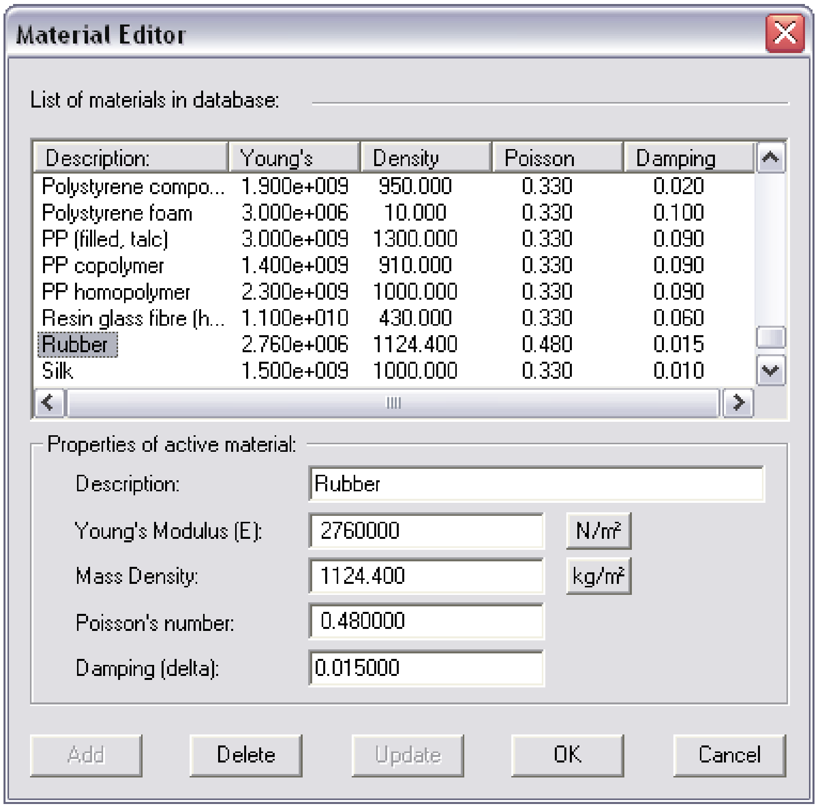


Figure 6. Material Editor

Now the electrical parameters should be entered. Here the values from MLSSA SPO were used first. To help the user to match an existing impedance curve, a measured impedance curve can be imported by selecting “Advanced Settings”

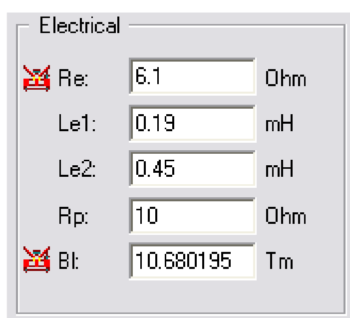


Figure 7. Electrical Input with FINEMotor inputs

If you have a FINEMotor file (*.FM2) from the latest version, it can be imported directly into FINECone. The parameters in Fig. 7 marked with [icon] are imported From FINEMotor (See also later and the FINECone Reference Manual).

The resulting frequency response is shown in Fig. 8:

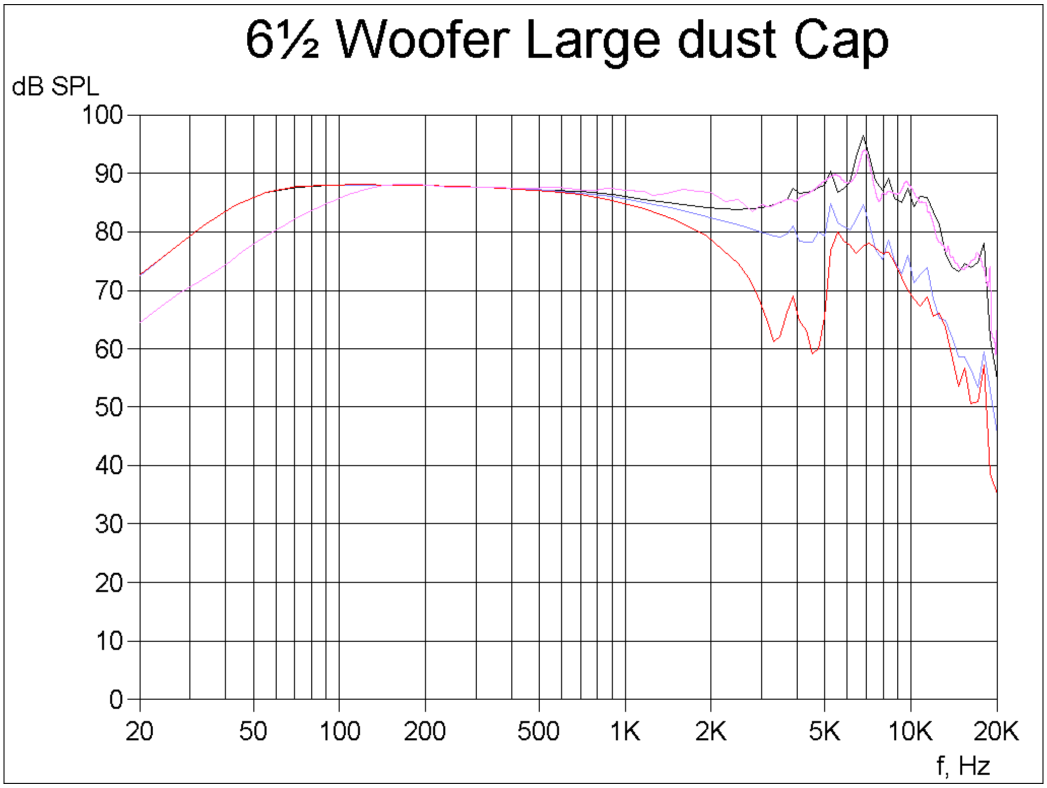


Figure 8. The agreement between the calculated FINECone response (black) versus the measured response (magenta), is remarkable at high frequencies (break-up region)

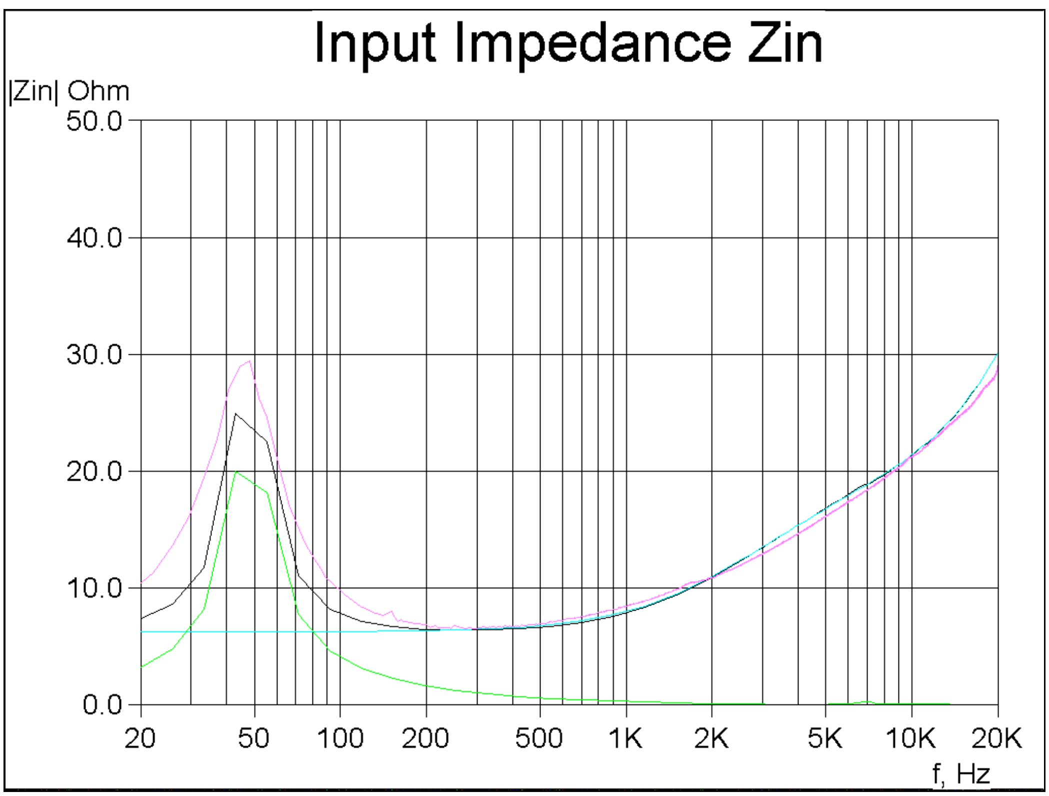


Figure 9. The blue curve is calculated electrical impedance and green is mechanical impedance. The magenta curve is the imported impedance curve for comparison.

Post processing

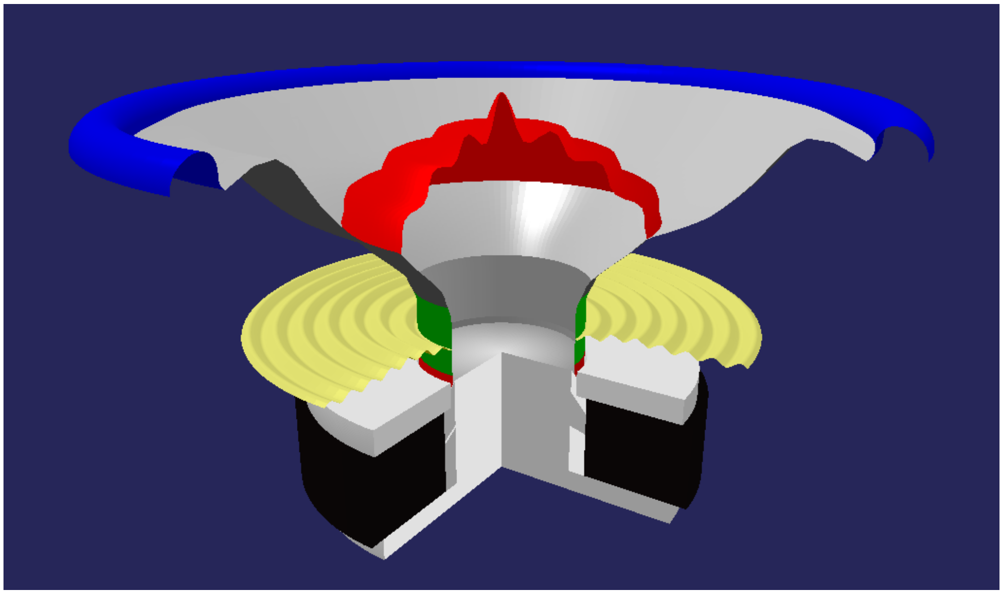


Figure 10. This is the 6.5" woofer break-up animated at 7162Hz, which is the frequency of the large peak. Note the heavy break-up in the outer part of the cone.

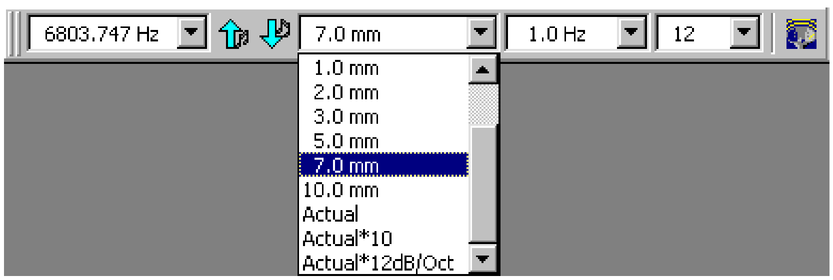


Figure 11. 3D Animation Menu

The 3D animation menu is shown above. The left column is the frequency, which is being animated. Select from the drop-down box or step up/down with the arrows.

The next column has the amplitude set to 7mm. Under that you can select the actual amplitude. But this is only visible at very low frequencies, being only fractions of a mm above Fs. Even Actual*10 is difficult. The last setting: Actual*12dB/oct increases the amplitude by 12dB/oct above Fs. This will compensate the real amplitude, which decreases by 12dB/oct above Fs.

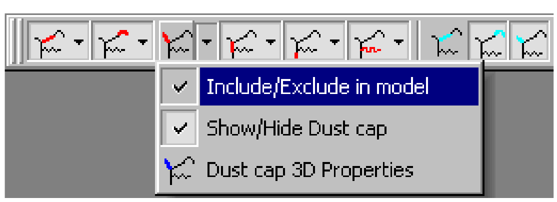


Figure 12. Include/exclude components

In this menu you can control the visibility for all components, and the SPL from the acoustic elements can be included or excluded from the total acoustic output. This feature is extremely useful because you can isolate the output from each component, which is not possible with a real driver. For example the response in the next figure has only the dust cap active.

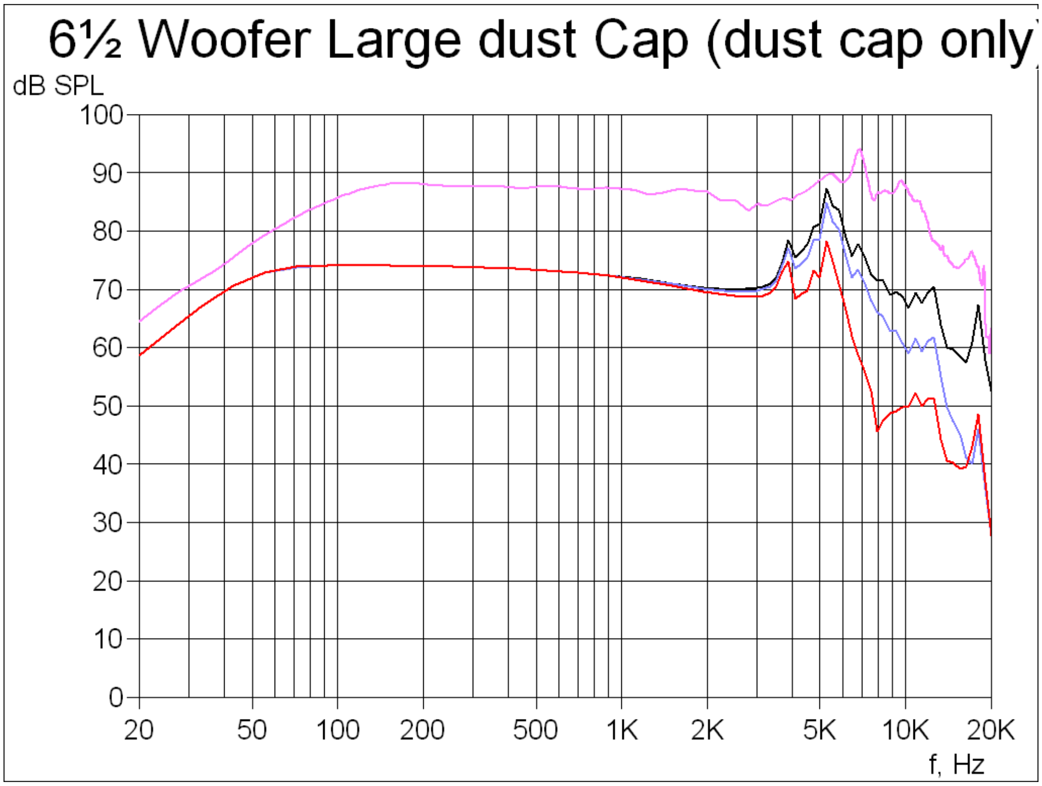


Figure 13. Response of the large Dust Cap ONLY. The dust cap has a large peak around 5kHz. By going back to the 3D animation this mode can be analyzed in detail.

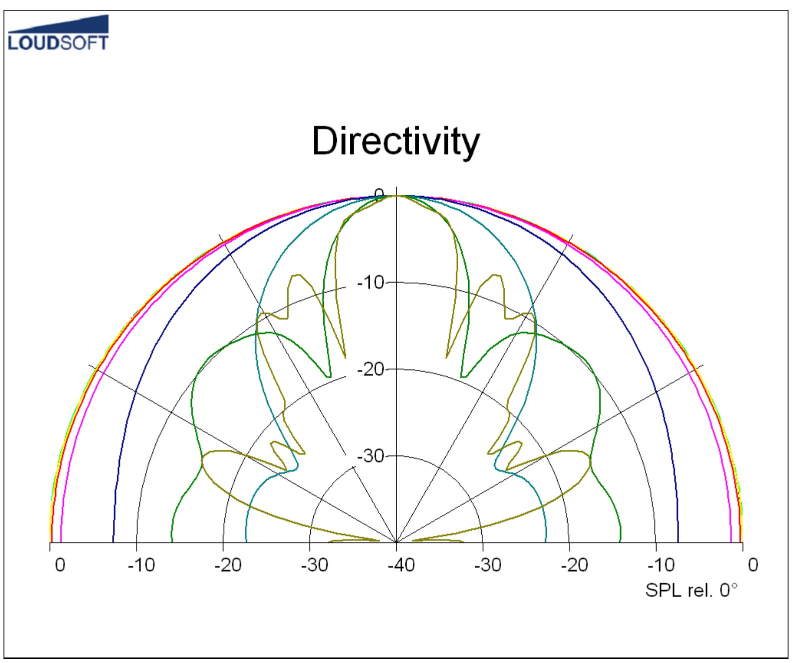


Figure 14. Directivity at 10 frequencies

FINECone example3: 165mm Woofer with 1300Hz problem

In the following example we have modeled a 165mm woofer which has a severe response problem around 1300Hz.

The measured response is imported and shown as the pink response. Note that this analysis is only accurate up to ~10 kHz. The low end measured response is different from the FINECone simulation because the driver was measured in a small baffle, and the response above 10 kHz is not accurate because the FEM analysis was done in Fast Mode (calculation time less than 7 seconds with a 1.5 GHz PC).

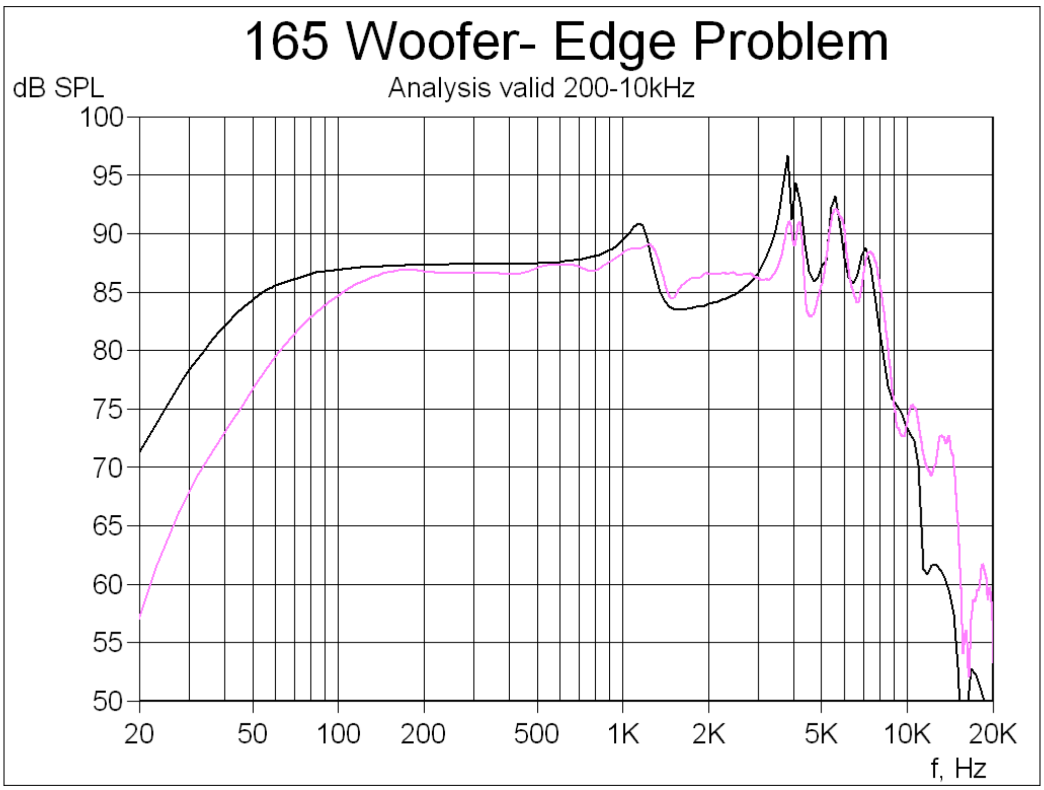


Figure 15. 165 Woofer with edge problem

The FINECone simulated response in Fig. 15 fits well to the imported measured response. There is much break-up from 3-8 kHz, but we will concentrate about the peak and dip around 1300 Hz, because that is quite annoying and very difficult to handle in the x-over.

The Project Geometry is shown in Fig 16. The red dots indicate intersections between segments. Note that we have split the surround into 5 segments. All 5 segments have the same thickness 0.4mm, which can be seen in the FEM Material properties in Fig. 17.

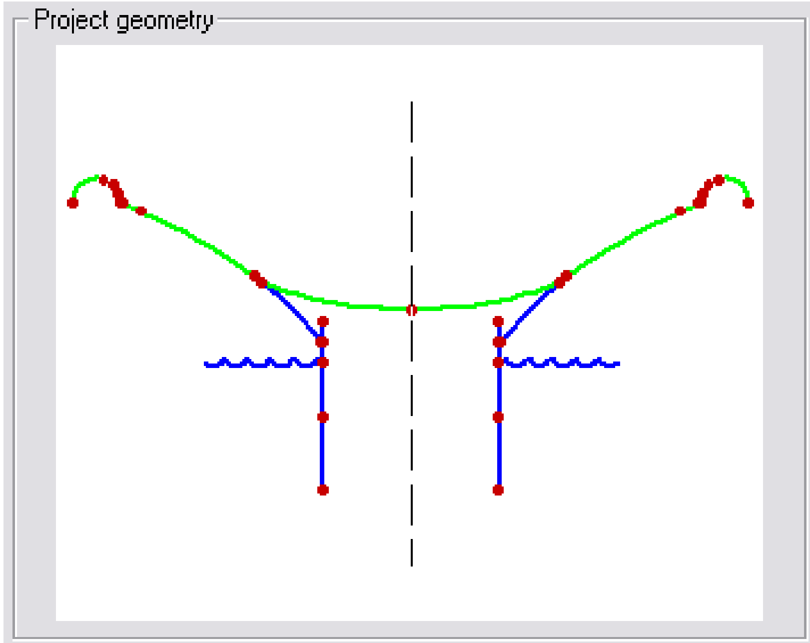


Figure 16. Project Geometry for 165 Woofer with 5 segments in surround

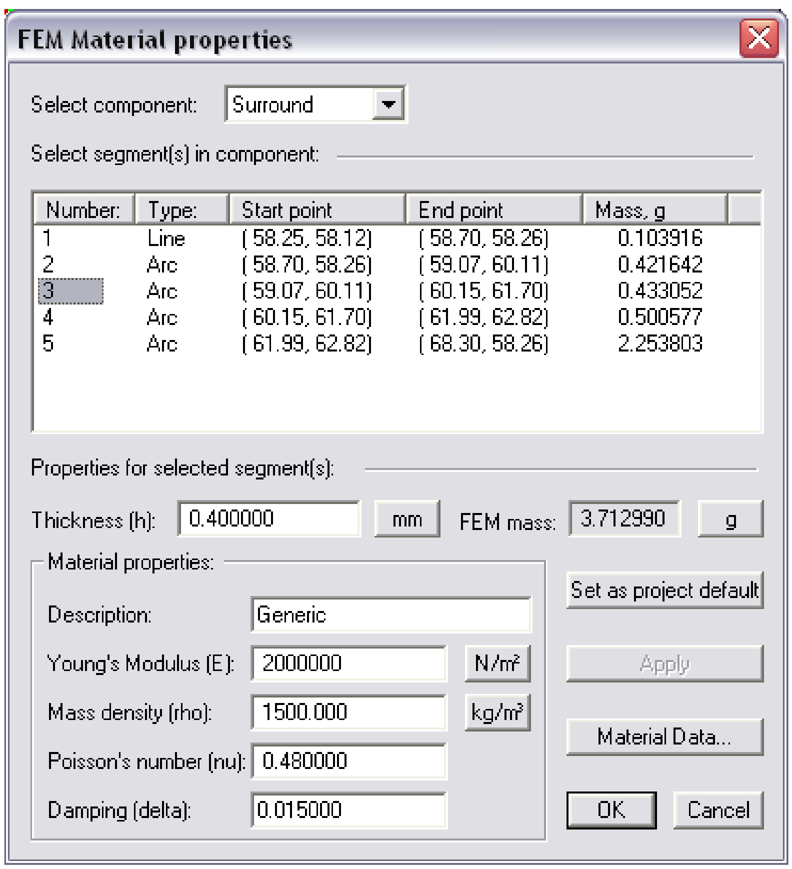


Figure 17. FEM Material properties for 165 surround

In order to find out what is happening around 1300 Hz we have this time used 2D animation, which some times is better to show where the maximum movement of the components is. Fig. 18 shows the cone edge and surround is moving excessively (brown curve).

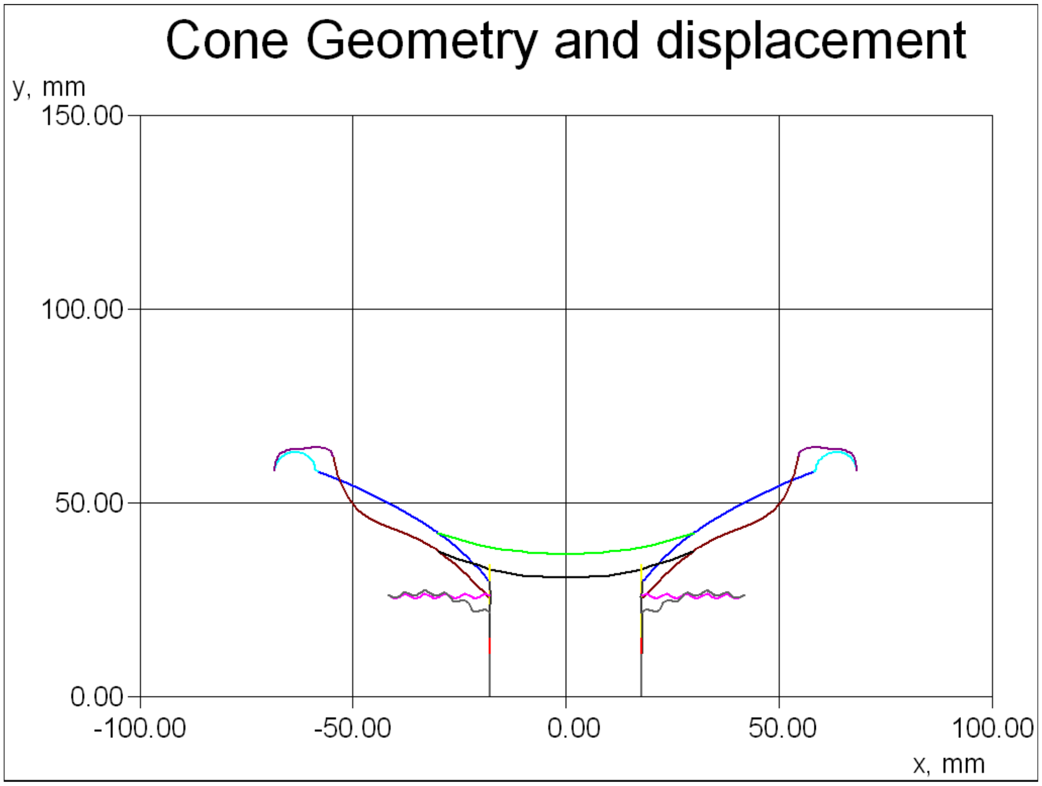


Figure 18. 165 Woofer Cone displacement (brown), maximum at cone edge.

There are many ways to correct this problem, for example by changing the cone profile to a large cone angle or change the geometry or thickness of the surround. Here we will change the thickness of the inner part of the surround.

In Material Properties we select segments 1, 2 and 3 and change the thickness to 0.8mm. After Apply and OK the calculation is done automatically.

The new simulation is shown in Fig. 19, and shows a much smoother response around 1300 Hz. The pink curve is showing the response before the change was applied. That response was exported as an FSIM file (see also Fig. 20). This file was then imported after the changed surround was calculated.

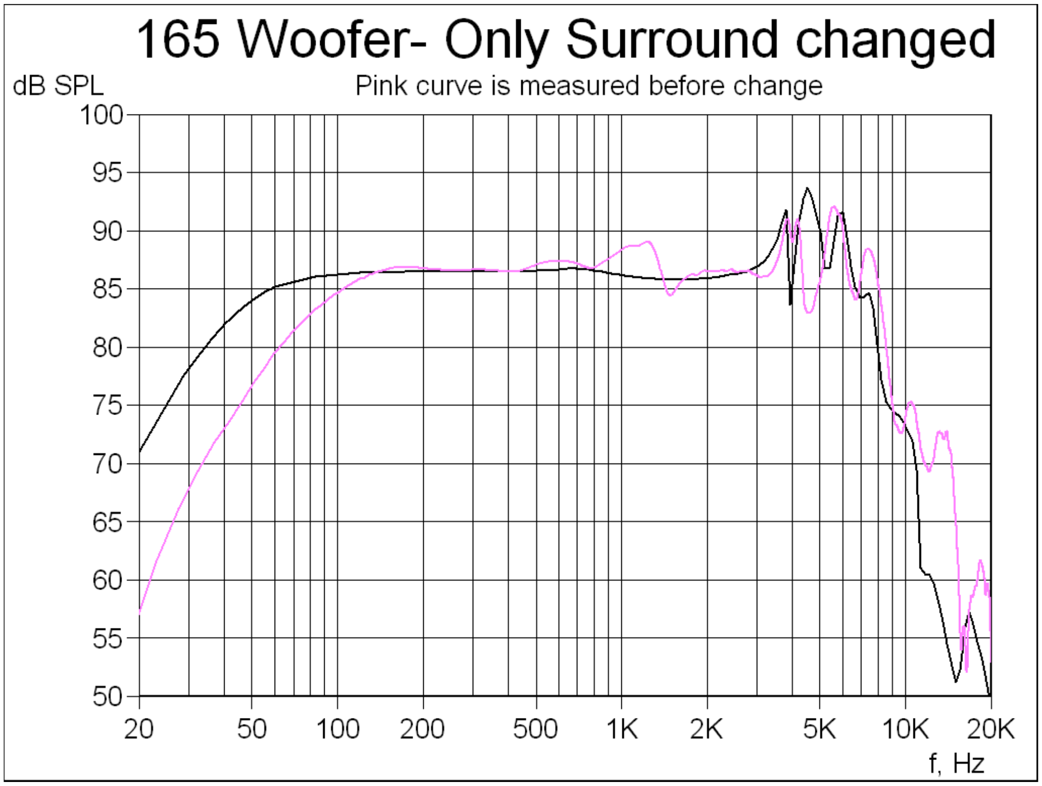


Figure 19. 165 Woofer with increased thickness of inner surround

Fig. 20 shows a screen plot from FINE X-over 3, where we have used the exported responses from FINECone as input for the woofer section. The orange response is using the 165W before the simulated change. The final response (black) is much improved. (File: 2-way 165W Improved.fbx).

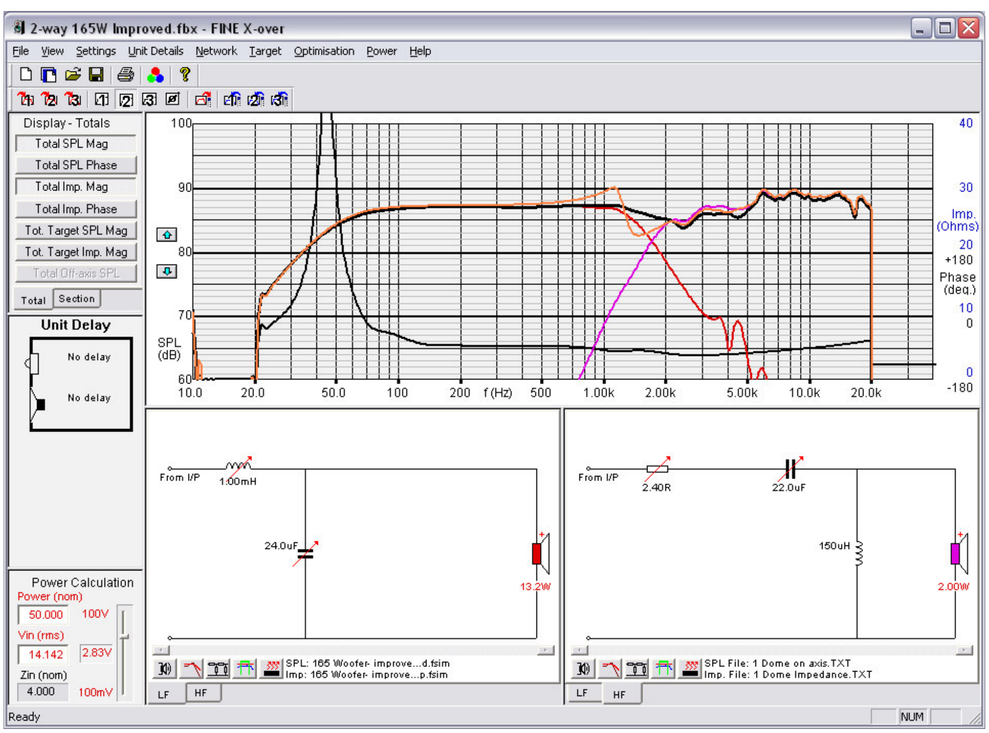


Figure 20. FINE X-over 3 using 165W exported from FINECone. Orange curve is with the bad woofer

FINECone example4: Woofer with whizzer cone (Dual Cone)

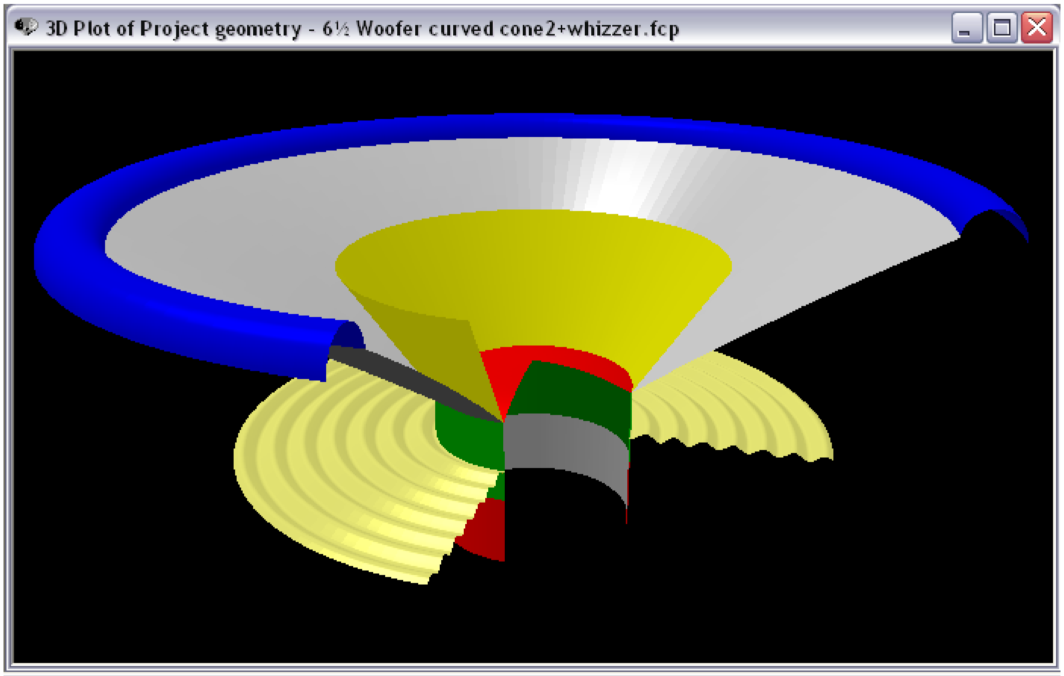


Figure 21. 6inch woofer with whizzer cone (Dual Cone)

The whizzer cone (Dual Cone) is quite easy to simulate in FINECone. Now the whizzer cone calculation accuracy is greatly improved. In addition the acoustical output from the whizzer cone can be excluded from the SPL, which is shown as the pink curve in Fig. 22.

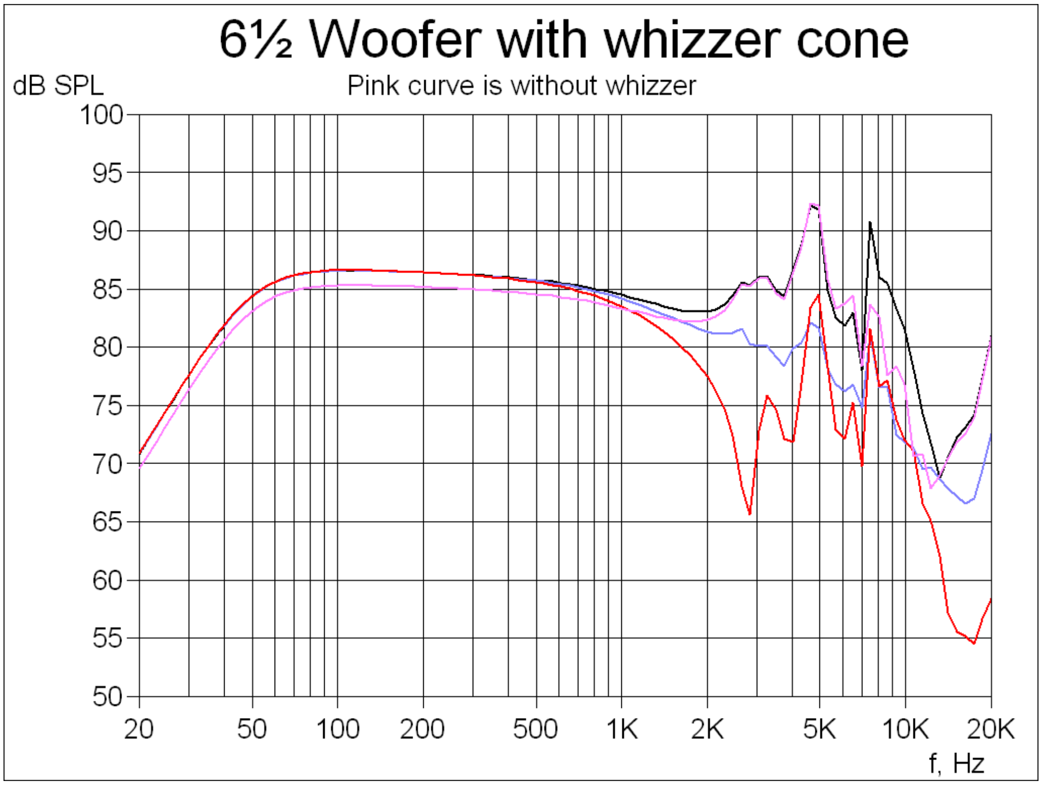


Figure 22. 6 inch Woofer with added Whizzer Cone. Pink curve is without whizzer cone

FINECone example5: 38mm Headphone transducer

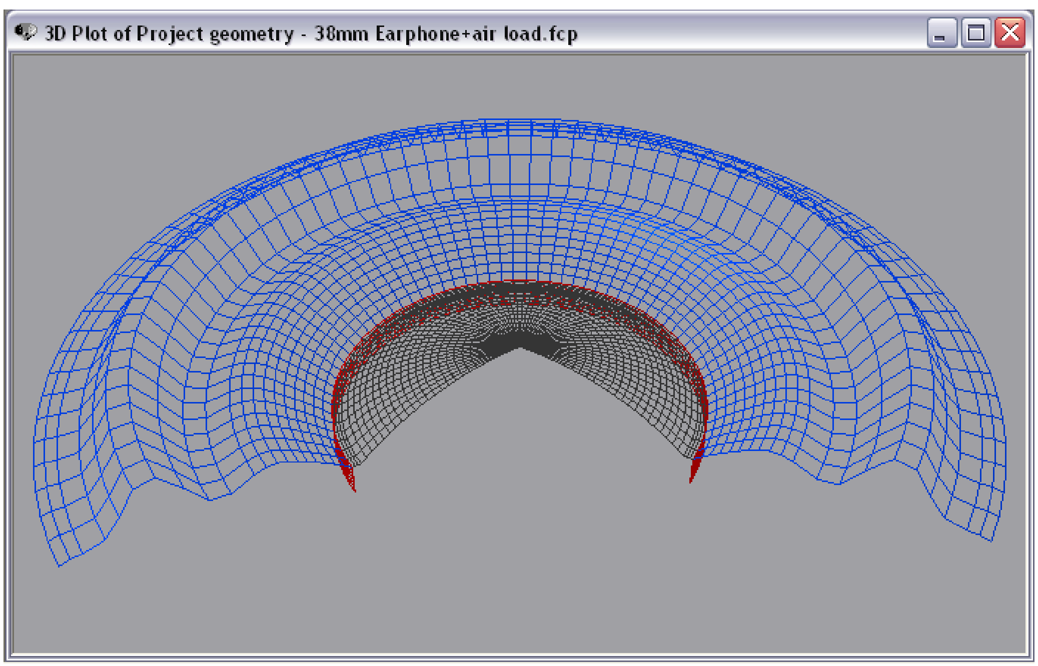


Figure 23. 38mm Headphone transducer simulated in FINECone: Break-up @ 3165 Hz

The 38mm headphone was first modelled in FINECone with only the main acoustical parts: Diaphragm inside (dome) and diaphragm outside (surround) and voice coil. The diaphragm is 25u PEI which is used for both dome and surround since the diaphragm is made in one piece.

The resulting response is here shown as the pink curve in Fig. 24. There is serious break-up from approximately 3000 Hz and the first mode is shown as 3D animation in Fig. 23. This first break-up mode is showing up in the middle of the outer diaphragm (surround) where it is almost flat.

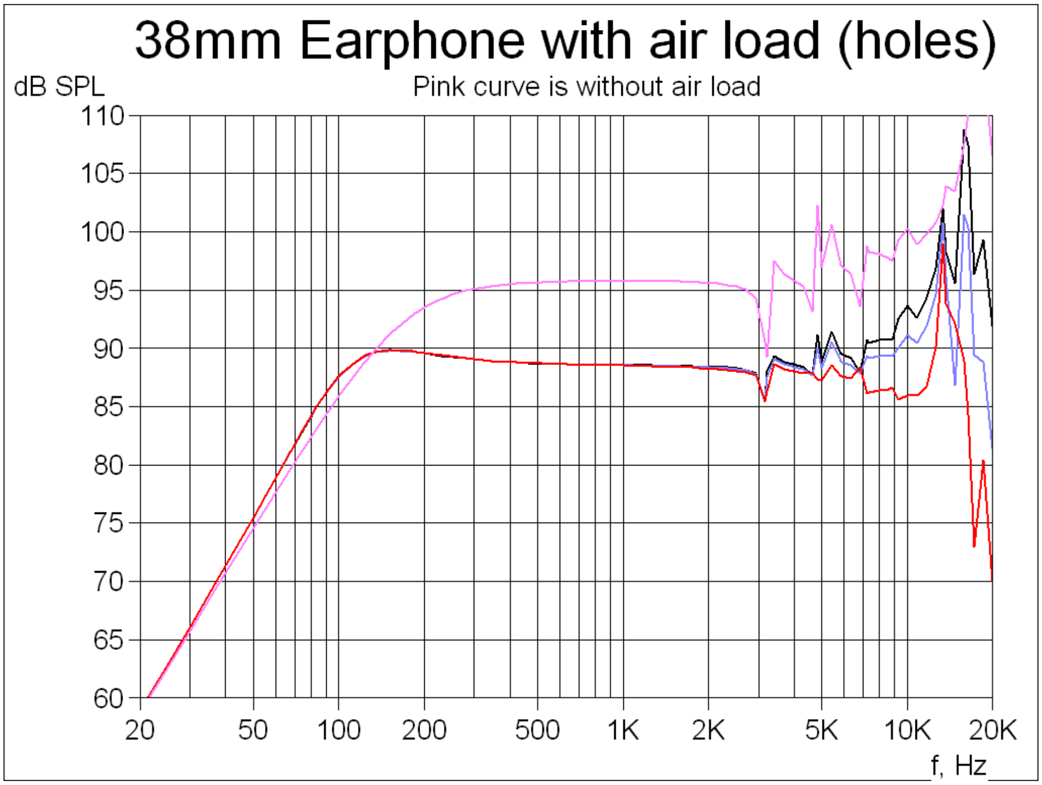


Figure 24. A 38mm Headphone simulated frequency response with air load (rear holes)

The actual transducer has a number of holes behind the outer diaphragm/surround all covered with a cloth acting mainly as damping material. The net effect of this may be calculated as an effective air load mass using the well-known Helmholtz formula. We can incorporate this air load mass in the FINECone simulation by adding it as "Air load" in Lumped Parameters. The main curve in Fig. 24 is showing the resulting response, which is some 7 dB lower in SPL due to the extra load mass.

We also note that the effective Fs is reduced from approximately 180 Hz down to 100 Hz with the air load mass.

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