## FINECone™



Acoustic Finite Element Dome/Cone Simulation Program

# TUTORIAL



### 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 subtron to start the FINECone Wizard (Fig. 2)

FINECone Wizar	d - Step 1 of 6: Basic project information	K
Project name: (required) Save in:	ZR650 C:\Program Files\LoudSoft\FINECone 2.0\Project\Z Target path and name	
Template De 15mm Receiv	roject on a template (select from the list below): scription /er	
165 Woofer-S	Surround problem @ 1300Hz Surround problem @ 1300Hz	_
	< Back Next > Cancel Help	

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.

FINECone Wizard - Step 2 of 6: Project type
Project type:
C Dome time (tweeter unit with soberical disphragm)
So Donie type (tweeter unit with spherical diaphragin)
< <u>B</u> ack <u>N</u> ext > Cancel Help

Figure 3. Choose Cone type (Project Type)

FINECone Wizard	Step 3 of 6: Cone Geometry & Components	×
Geometry	Geometrical properties	
Material	Material properties	
Lumped parameters	Lumped parameters	
	< <u>B</u> ack <u>N</u> ext > Cancel He	elp

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 Geometrical properties... 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 <u>Material properties...</u> 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.

FEM Mater	rial prop	erties		
Select com Select segn	ponent: [ nent(s) in co	Diaphragm 💽		
Number: 1 2 3	Type: Arc Arc Arc	Start point (12.50, 24.35) (15.67, 26.79) (57.25, 48.74)	End point ( 15.67, 26.79) ( 57.25, 48.74) ( 60.50, 49.82)	Mass, g 0.920018 6.227788 1.350439
Properties f Thickness (	or selected (h): 0.45	segment(s):	m FEM mass	8.498246 g
Descriptio	roperties: - on:	PP (filled, talc) *		Set as project default
Young's N	/lodulus (E)	: 3000.000	MPa	Apply
Mass den Poisson's	isity (rho): number (nu	1300.000 i): 0.330000	kg/m²	Material Data
Damping	(delta):	0.010000		OK Cancel

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.

laterial Editor					>
List of materials in data	base: —				
Description:	Young's	Density	Poisson	Damping	~
Polyester film	1.400e+010	700.000	0.330	0.020	
Polymethyl pentene	2.800e+009	8400.000	0.330	0.100	
Polystyrene (foam,	2.000e+009	27.000	0.330	0.080	
Polystyrene compo	1.900e+009	950.000	0.330	0.020	
Polystyrene foam	3.000e+006	10.000	0.330	0.100	
PP (filled, talc)	3.000e+009	1300.000	0.330	0.090	
PP copolymer	1.400e+009	910.000	0.330	0.090	
PP homopolymer	2.300e+009	1000.000	0.330	0.090	<b>_</b>
<		1111		>	
- Properties of active r	material:				
Description:	PP (f	illed, talc)			
Young's Modulus	(E): 300	0.000	MPa		
Mass Density:	130	0.000	kg/m	7	
Poisson's number	: 0.33	30000			
Damping (delta):	0.09	0000			
Add D	elete	Update	OK	Cano	el

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

FEM Material proper	ties		
Select component: Di Select segment(s) in com	iaphragm 💽		
Number: Type: 9 1 Arc ( 2 Arc ( 3 Arc (	itart point 12:50, 24:35) 15:67, 26:79) 57:25, 48:74)	End point (15.67, 26.79) (57.25, 48.74) (60.50, 49.82)	Mass, g 0.920018 6.642974 1.465721
Properties for selected se Thickness (h): 2.0000	egment(s):	m FEM mass:	9.028713 g
Material properties: — Description:	PP (filled, talc) *		Set as project default
Young's Modulus (E):	3000.000	MPa	Apply
Mass density (rho): Poisson's number (nu):	1300.000	kg/m²	Material Data
Damping (delta):	0.010000		OK Cancel

The surround is 0.41mm rubber from the database

FEM Materia	FEM Material properties						
Select compo Select segme	onent: 🛛	Surround 🗾 💌	]				
Number: 1 2 3	Type: Arc Arc Arc	Start point ( 60.50, 49.82) ( 61.26, 50.06) ( 61.96, 50.95)	End (61 (61 (70	point 26, 50.06) 96, 50.95) 40, 50.65)		Mass, g 0.141059 0.213610 2.489450	
Properties for Thickness (h)	selected ): 0.410	segment(s):	nm	FEM mass	: 2	2.844120	g
Description	:	Rubber			S	et as project d	lefault
Young's Mo	odulus (E):	2.760		MPa		Apply	
Mass densi Poisson's n Damping (d	ty (rho): umber (nu lelta):	1124.400 ): 0.480000 0.015000		kg/m³		Material Data	a

FEM Material pro	perties		
Select component: Select segment(s) in	Dust cap 🗸	]	
Number: Type: 1 Line 2 Arc	Start point (12.50, 24.35) (12.50, 27.36)	End point (12.50, 27.36) (0.00, 23.52)	Mass, g 0.063864 0.144517
Properties for selecte	ed segment(s):	om FEM mass	0.208380 g
- Material properties			
Description:	Aluminium (shee	t)	Set as project default
Young's Modulus (	E): 75000.000	MPa	Apply
Mass density (rho):	2700.000	kg/m²	Material Data
Poisson's number   Damping (delta):	nu):   0.330000		OK Cancel



FEM Mater	ial prope	erties		
Select com Select segn	ponent:   nent(s) in co	Former 🗾	]	
Number: 1 2	Type: Line Line	Start point (12.50, 12.50) (12.50, 23.50)	End point (12.50, 23.50) (12.50, 24.35)	Mass, g 0.396576 0.030462
Properties for Thickness (	or selected h): 0.170	segment(s):	nm FEM mass	; 0.427038 g
Descriptio	roperties: - in:	Aluminium (shee	t)	Set as project default
Young's N	fodulus (E):	75000.000	MPa	Apply
Mass den Poisson's	sity (rho): number (nu	2700.000	kg/m²	Material Data
Damping	(delta):	0.005000		OK Cancel

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.



FEM Mater	ial prop	erties		
Select com Select segn	ponent:   nent(s) in co	Voice coil 🛛 💌	]	
Number:	Type:	Start point	End point	Mass, g
1 Properties for Thickness (	Line or selected h): 0.50	(12.50, 12.50) segment(s): 0000 r	(12.50, 0.50)	0.471239 : 0.471239 g
Material p	roperties: -			Set as project default
Descriptio	in:	Generic		ost de project del duit
Young's N	fodulus (E)	: 1000.000	MPa	Apply
Mass den	sity (rho):	1000.000	kg/m²	Material Data
Poisson's	number (nu	a): 0.330000		indendroida
Damping	(delta):	0.000000		OK Cancel

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.

FE	M Mater	ial prop	erties			X
S	elect com	ponent:	Spider 💌	]		
S	elect segn	nent(s) in co	omponent:	-		
Г	-			[ = 1 - 1 -	[	-
	Number:	lype:	Start point	End point	Mass, g 🔷	•
	16	Line	( 32.09, 23.05)	( 32.65, 24.09)	0.043882	
	17	Arc	( 32.65, 24.09)	( 34.85, 24.09)	0.103608	
	18	Line	( 34.85, 24.09)	( 35.41, 23.05)	0.047629	
	19	Arc	( 35.41, 23.05)	( 37.09, 23.05)	0.084575	
	20	Line	( 37.09, 23.05)	( 37.65, 24.09)	0.050660	1
	21	Arc	( 37.65, 24.09)	( 39.92, 23.93)	0.127027	
	22	Line	( 39.92, 23.93)	( 40.54, 22.25)	0.082541	5
I.					¥	
F	Properties f	or selected	segment(s):			-
Т	hickness (	h): 0.27	0000 r	nm FEM mass:	1.245073 g	
Г	Material p	roperties: -				
	Descriptio	n:	Generic		Set as project defau	ilt
	Young's N	1odulus (E)	: 698.000	MPa	Apply	
	Mass den	sity (rho):	673.000	kg/m³	Material Data	1
	Poisson's	number (nu	ı): 0.330000		Matchar Data	
	Damping	(delta):	0.800000		OK Cancel	

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)

Program options			
Project options File locations DXF Layers Calculation			
<ul> <li>Fast solution of differential equations</li> </ul>			
C Accurate solution of differential equations			
Maximum number of integration points:			
OK Cancel <u>Apply</u> Help			

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 Lumped parameters... 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).

Lumped parameters					
Former	Voic	e coil	Spider	N	/hizzer
General	Diaph	ragm	Surround	Du	ust cap
Cs: 0.9	09091	mm/N	Air mass:	0.887490	g
Rs: 2.0	00000	Nm/s	Sd:	135.00000	0 cm <sup>2</sup>
Fs: 44.	801229	Hz			
Qms 1.9	53858	]			
Mms 13.	882034	g			
절: Imported from FINEMotor (TM)					
0	Ж	Cancel	App	oly	Help

FINECone Wizard - Step 4 of 6: Frequency range
Frequency range
Advanced frequency settings
Advanced frequency settings
< <u>B</u> ack <u>N</u> ext > Cancel Help

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 "BI Tesla-M"
                             п
  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.

FINECone Wizard - St	ep 5 of 6: Electrical parameters
Electrical parameters	
Re, Ohm:	3.470
Le1, mH:	0.176
Le2, mH:	0.390
Rp, Ohm:	4.059
BI, Tm:	4.836
<	Back Next > Cancel Help

FINECone Wizard - Step 6 of 6	: Acoustical parameters
Acoustical settings	
On-axis distance to speaker:	1 m
Number of Angles:	3
Maximum Angle:	60 *
<ul> <li>Points are on a circle (const</li> </ul>	tant distance to source)
C Points are on a straight line	(constant distance to baffle)
< <u>B</u> ack	Finish Cancel Help

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

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

PINECone - Professional - ZR6	🐶 FINECone - Professional - ZR650 Spark 1.fcp 🛛 📃 🗖 🔀				
Eile Edit Calculate Post-Processi	ng <u>T</u> ools <u>V</u> iew <u>W</u> indow	Help			
🗅 😂 🔨 🖬 🎒 🖪 💥 🚪	🛯 🖿 🗠 + 🖓 🖉	2 📉 📾 🔛 🔛 💽 🥕	ę		
*****	- 🗠 + 🕒 - 🗖 -			- to +P	
Project Information Window	- ZR650 Spark 1.fcp				
General project properties		Project geometry			
Project description: ZR650					
Project Type: Cone			I		
<ul> <li>Display FEM results with break</li> </ul>	up	0			
C Display simple model without b	eakup				
Input Voltage: 2.828427	V RMS 💌	~~~	my prom		
Frequency range	Frequency range				
Number of frequencies:					
From:  20 Hz to:  20000 Hz  10 💼					
Apply	Apply Advanced frequency settings				
Mechanical	Electrical	Acoustical			
Geometrical properties	Re: 3.47 0	hm On-axis distance to s	peaker: 1000 mm		
	Le1: 0.16 m	H Number of Angles:	5		
Material properties	Le2: 0.39 m	H Maximum Angle:	60 *	Apply	
	Rp: 4.059 0	hm 📀 Points are on a c	ircle (constant distance to sour	ce)	
Lumped parameters	BI: 4.836 T	m C Points are on a s	traight line (constant distance t	o baffle)	
For Help, press F1				1.	

### 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 rightclicking 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  $\square$  buttons, we can study the effect of the 3 main components: Cone / Surround / Dust Cap.

FINECone - Professional - ZR650 Spark 6.fcp	
Elle Edit Calculate Post-Processing Tools View Window Help	
🗅 🚅 🔪 🔛   🚔 💁   💥   🏧 📖 🗠 • 🖂 🤍 🖓 🔛 🗖	
<b>☆・☆・☆・☆・☆・☆・☆・ □</b> ・ <b>□</b> ・ <u>☆</u> ☆	🕻 🏀 📗 🖬 🗱 🗮 👻 🛛 20.000 Hz 💌 🏠 🥠 3.0 mm 🔍 1.0 Hz 💌 12 💌 🛃
Project Information Window - ZR650 Spark 6.fcp	🗣 Plot of Sound pressure - ZR650 Spark 6.fcp
<ul> <li>✓ Project information Window - 2R650 Spark 6.fcp</li> <li>General project properties</li> <li>Project description: ZB650</li> <li>Project Type: Cone</li> <li>© Display FEM results with breakup</li> <li>© Display simple model without breakup</li> <li>Input Voltage: 2.628427 V FIMS ▼</li> <li>Frequency range</li> <li>Number of frequencies:</li> <li>From: 20 Hz to: 20000 Hz 60 ÷</li> <li>Aceply</li> <li>Advanced frequency settings</li> <li>Mechanical</li> <li>Geometrical properties</li> <li>Lamped parameters</li> <li>Bit 4.836 Tm</li> </ul>	BSPL 100 90 80 70 60 50 40 30 20 10 0 0 0 0 0 0 0 0 0 0 0 0 0
	20 50 100 200 500 1K 2K 5K 10K 20K f, Hz
Include/Exclude Diaphragm in SPL calculation/nInclude/Exclude	

The dust cap only affects the very high frequencies.

FINECone - Professional - ZR650 Spark 6.fcp	
Eile Edit Calculate Post-Processing Tools View Window Help	
D 📽 🔪 🖬   🖨 🖪   💥   🏧 📖 🗠 • 🖓 -   🍕 🔛 🗖	
<b>☆・☆・☆・☆・☆・☆・☆・   </b> ■・ <b>  </b> ●・☆	「 🏠 🏀 📗 📰 🌉 📕 = - 📗 20.000 Hz 🔽 🎓 🦊 3.0 mm 🛛 🔽 1.0 Hz 🔽 12 💌 🛃
Project Information Window - ZR650 Spark 6.fcp	🗣 Plot of Sound pressure - ZR650 Spark 6.fcp 📃 🔲 🔀
General project properties	Sound Procedure Loval @Const Vin
Project description: ZR650	
Project Type: Cone	
Display FEM results with breakup	
C Display simple model without breakup	
Input Voltage: 2.829/27 V BMS V	80
Number of frequencies:	
From: 20 Hz to: 20000 Hz 60 🛨	60
Advanced frequency settings	
Mechanical Electrical	
Geometrical properties Re: 4.2 Ohm	
Le1: 0.18 mH	30+++++++++++++++++++++++++++++++++++++
Material properties Le2: U.3 mH	20
hp. jo Unm	
Europea parameters Bi. 14.000 mm	
	20 50 100 200 500 1K 2K 5K 10K 20K f, Hz
Facility areas E1	
For help, press F1	

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  $\boxed{\mathbb{H}}$  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

FEM Mater	FEM Material properties						
Select com	Select component: Diaphragm 💌						
Select segn	nent(s) in c	omponent:					
Number:	Type: Arc	Start point (12.50, 24.35)	End point (15.67, 26.79)	Mass, g 0.707706			
2 3	Arc Arc	( 15.67, 26.79) ( 57.25, 48.74)	( 57.25, 48.74) ( 60.50, 49.82)	4.790606 1.311168			
Properties fo	or selected	segment(s):	- 1				
Thickness (	Thickness (h):         0.450000         mm         FEM mass:         6.809480         g						
Material p	roperties: -			Set as project default			
Descriptio	Description: PP homopolymer *						
Young's N	Aodulus (E)	: 4000.000	MPa	Apply			
Mass den	isity (rho):	1000.000	kg/m³	Material Data			
Poisson's	number (ni	u): 0.330000		indenal D'dtd			
Damping	(delta):	0.030000		OK Cancel			

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		
BI	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

🕫 Project Information Window - 6_5 Woofer Large Dust Cap.WCP 📃 🗖 🔀					
General project properties		Project geometry			
Project description: 6½ Woofer	r Large Dust Cap				
Project Type: Cone					
Display FEM results with break	kup				
C Display simple model without t	breakup				
Input Voltage: 2.828427	V RMS				
Frequency range	Musekas of features in a				
From: 20 Hz to: 200	00 Hz 60 🛨				
Apply	Advanced frequency settings	i			
- Mechanical	Electrical	Acoustical			
Geometrical properties	Re: 6.3 Ohm	On-axis distance to speaker: 1000 mm			
	Le1: 0.19 mH	Number of Angles: 3			
Material properties	Le2: 0.45 mH	Maximum Angle: 60 * Apply			
	Rp: 10 Ohm	<ul> <li>Points are on a circle (constant distance to source)</li> </ul>			
Lumped parameters	BI: 5.1 Tm	C Points are on a straight line (constant distance to baffle)			

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):

🗖 DXF File	e Input Edito	or - <project></project>	-\6_5 Woofer Large dust Cap w magnet.dxf 🛛 📃 🗖 🔀
Eile Setting:	s		
Component:	Drawing layer:		$\frown$
Diaphragm	DIAPHRAGM	-	ه کې
Surround	SURROUND	-	5
Dust cap	DUSTCAP-DO	ME 👤	
Former	FORMER	-	
Voice coil	VOICECOIL	-	
Spider	SPIDER	-	A.
Whizzer	- None selecte	ed - 💽	
Magnet	MAGNET	-	
Pole	POLE	-	Ý
<ul> <li>Show only</li> <li>Show</li> <li>Show all of Status:</li> </ul>	y FINECone eler v node points drawing element:	nents s	
Analysis is po	ossible		
ОК		Cancel	Cursor position: (6.3203 , -15.4885)

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 <u>FEM Material Properties</u>

FEM Material properties 🛛 🔀						
Select component:  Select segment(s) in component:						
Number: Type: 1 Arc 2 Arc 3 Line	Start point (16.25, 28.18) (29.50, 39.82) (41.23, 46.97)	End point ( 29.50, 39.82) ( 41.23, 46.97) ( 61.50, 57.30)	Mass, g 1.020014 1.234244 2.973533			
Properties for selected segment(s): Thickness (h): 0.150000 mm FEM mass: 5.227790 g						
Description:	Description: Aluminium (sheet) *					
Young's Modulus (E):	7500000000	N/m²	Apply			
Mass density (rho): Poisson's number (nu	2700.000	kg/m³	Material Data			
Damping (delta):	0.010000		OK Cancel			

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.

Naterial Editor 🛛 🛛 🔀									
List of materials in database:									
Description:	Young's		Density	Pois	son	Damping	~		
Polystyrene compo	1.900e+	009	950.000	0.3	330	0.020			
Polystyrene foam	3.000e+	006	10.000	0.0	330	0.100			
PP (filled, talc)	3.000e+	009	1300.000	0.0	330	0.090			
PP copolymer	1.400e+	009	910.000	0.0	330	0.090			
PP homopolymer	2.300e+	009	1000.000	0.0	330	0.090			
Resin glass fibre (h	1.100e+	010	430.000	0.3	330	0.060			
Rubber	2.760e+	006	1124.400	0.4	480	0.015			
Silk	1.500e+	009	1000.000	U.;	330	0.010	<u> </u>		
<			1111			3			
Properties of active material:									
Description:		Rubb	er						
Young's Modulus (E):		2760000			N/m²	]			
Mass Density:		1124.400 kg		kg/m²					
Poisson's number:		0.48	0000						
Damping (delta):		0.015	5000						
Add D	elete		Update		OK	Cano	el		

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"

Electrical						
💥 Re:	6.1	Ohm				
Le1:	0.19	mH				
Le2:	0.45	mH				
Rp:	10	Ohm				
Bl:	10.680195	Tm				

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 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 <u>the SPL from the acoustic elements can be included or excluded</u> <u>from the total acoustic output</u>. 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  $\sim 10$  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

FEM Material properties 🛛 🔀									
Select component: Surround									
Select segment(s) in component:									
Number:	Type:	Start point	End point	Mass, g					
1 2	Line Arc	( 58.25, 58.12) ( 58.70, 58.26)	(58.70,58.26) (59.07,60.11)	0.103916 0.421642					
3	Arc Arc	( 59.07, 60.11) ( 60.15, 61.70)	( 60.15, 61.70) ( 61.99, 62.82)	0.433052 0.500577					
5	Arc	(61.99,62.82)	( 68.30, 58.26)	2.253803					
Properties for selected segment(s):									
Thickness (h): 0.400000 mm FEM mass: 3.712990 g									
Material properties:									
Descriptio	on:	Generic		Set as project derault					
Young's M	Modulus (E)	: 2000000	N/m²	Apply					
Mass der	nsity (rho):	1500.000	kg/m²	Material Data					
Poisson's	number (n	u): 0.480000		material Data					
Damping	(delta):	0.015000		OK Cancel					

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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