ICA 2019 AACHEN

PROCEEDINGS of the
23rd International Congress on Acoustics

9 to 13 September 2019 in Aachen, Germany

Measurement of the Back Loading of a Loudspeaker Mounted on a Closed Enclosure - A First Approach

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ABSTRACT

In this paper, a simple way to measure the parameters related to the back loading of a loudspeaker mounted on a closed enclosure fully fill with filling material is presented. If the electro-mechano-acoustical parameters of the loudspeaker in free air are known or can be measured, then by measuring one more time the parameters of the loudspeaker but this time mounted on a closed enclosure, it is possible to calculate the back-loading parameters due to the enclosure, including the filling material. This method could also be used to measure the effect of filling material in the back cavity of midrange units, tweeters and compression drivers.

Keywords: Enclosure, acoustic impedance filling material,

1. INTRODUCTION

Determine the acoustic impedance of the filling material of a loudspeaker enclosure always has been a tedious task (1). After adding the filling material and the mechanical reinforcements to stiffen the enclosure, it turns that the calculation of the box volume becomes uncertain. It was shown in (2) that the mechanical impedance of the loudspeaker including the air load reflected to the electrical side is equal to velocity to current ratio multiplied by the force factor. In this paper such ratio will be measured in order to work without the influence of the electrical part of the loudspeaker. A laser method will be used to determine the parameters of the loudspeaker. In order to perform the calculations, the parameters will be measure first in free air and then mounted on closed enclosure without filling material.

2. ISOLATING THE MECHANICAL IMPEDANCE

As it was mention before it is possible to isolate the mechanical mobility of the loudspeaker without the influence of the electrical part, Figure 1 shows an example of such function. Figure 2 shows respectively the real and imaginary parts of the mechanical impedance, both results shown in the figures correspond to a JBL 2206 12” loudspeaker, this function shows at low frequencies the viscoelastic effect of the suspension.

$$\frac{v}{i} Bl = Z_{ES} \tag{1}$$

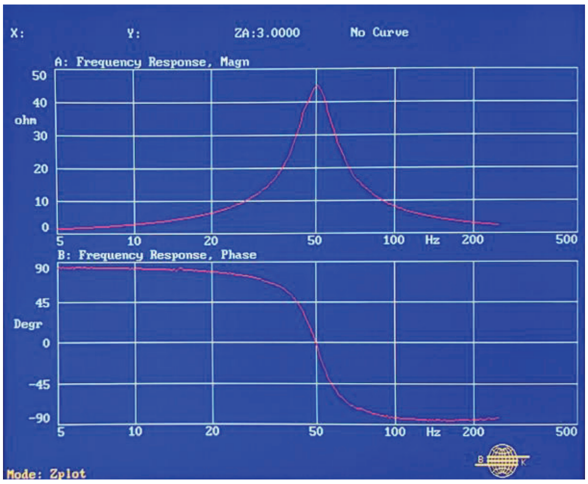

Figure 1 - Mechanical impedance reflected to the electrical side of a JBL 2206.

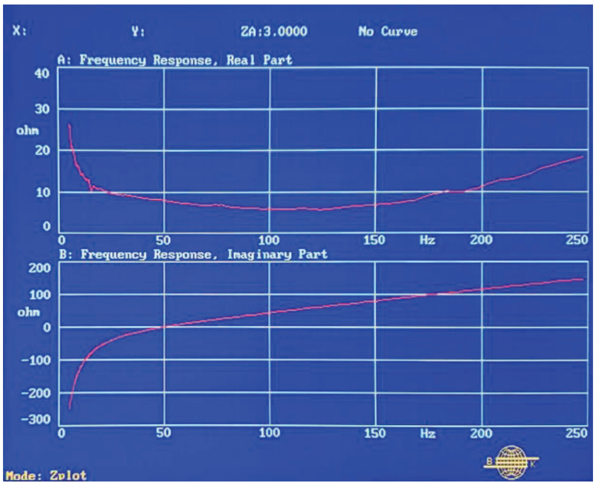

Figure 2 - Real and Imaginary part of the mechanical impedance of a JBL 2206.

3. THE MODELS

Figure 3 and 4 show respectively the well-known impedance type equivalent circuits of a loudspeaker including the viscoelastic behavior of the suspension in free air and mounted on a closed enclosure, not considering the electrical side. The equivalent circuit shown in Figure 4 includes a simplified model of the filling material valid at low frequencies and the compliance of the air in the enclosure full of filling material. The complete model of the filling material can be found in (3) and (4). Since the circuit in Figure 4 can be simplified to a similar circuit as the one shown in Figure 3, the laser method can be used to measure the parameters of the loudspeaker mounted first on an empty enclosure and then in one with filling material. Since the parameters of the loudspeaker in free air has previously been measured, then the parameters of the closed enclosure can be calculated. The equivalent circuits shown in figure 3 and 4 are suitable to describe the measurement presented in this paper.

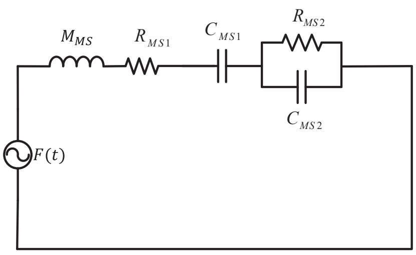

Figure 3 – Mechanical equivalent circuit of a loudspeaker in free air including viscoelasticity.

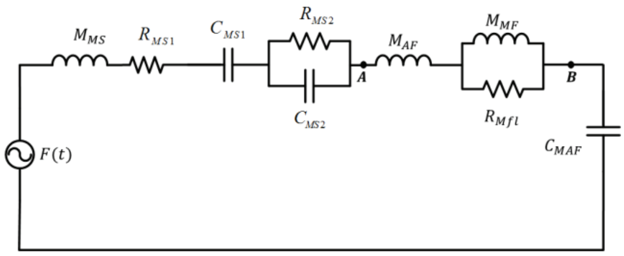

Figure 4 – Mechanical equivalent circuit of a loudspeaker including viscoelasticity mounted on a fully filled enclosure.

Were:

$F(t)$	Force driving the mechanical part N
M_{MD}	Mass of the driver not including the air load kg.
R_{MS1}	Mechanical resistance component (TGM) Voigt branch N.s/m
C_{MS1}	Mechanical compliance component (TGM) Voigt branch m/N
R_{MS2}	Mechanical resistance component (TGM) Maxwell branch N.s/m
C_{MS2}	Mechanical compliance component (TGM) Maxwell branch m/N
M_{MAF}	Mass load of the air in the fiber-filled area on the transducer Kg

M_{MF}	Mass of the fibers kg
R_{Mfl}	Mechanical resistance due to flow resistance N.s/m
C_{MAF}	Compliance of the air in the fiber filled area m/N

4. RELATIONSHIP BETWEEN THE MECHANICAL RESISTANCE AND THE RESONANCE FREQUENCY IN DIFFERENT CONDITIONS

When the parameters of the loudspeaker in free air are measured, the mechanical resistance is calculated at the resonance frequency. The traditional model of a loudspeaker assumes that the mechanical resistance is constant within the piston range of the loudspeaker, but this is not true. Figure 5 shows the measured mechanical resistance of a JBL 2206 12” loudspeaker superimposed with the constant resistance. Let us assume that the resonance frequency of the loudspeaker in free air is f_s. When the loudspeaker is measured in a closed enclosure without filling material, the resonant frequency shift to the right toward the frequency f_c due to the change in compliance, it is easy to notice that the mechanical resistance diminishes. When the loudspeaker is measured in an enclosure with filling material, the resonance frequency shift again but this time to the left towards f_{cf} because the loudspeaker now “sees” a larger volume and now the mechanical resistance increases. Figure 6 shows the mobility of this loudspeaker for the 3 cases mention above.

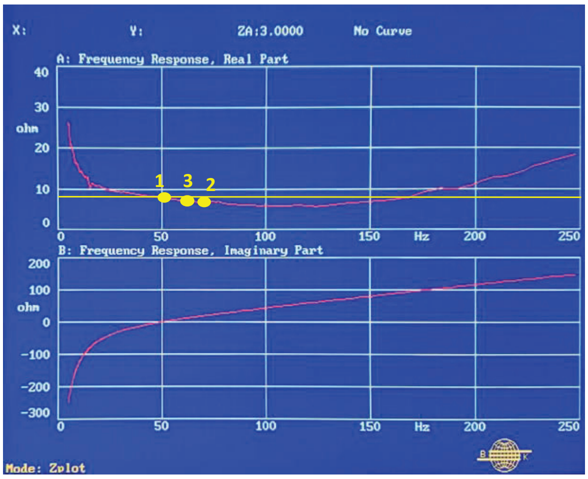

Figure 5 - Mechanical impedance of a 2206 JBL 12”loudspeaker

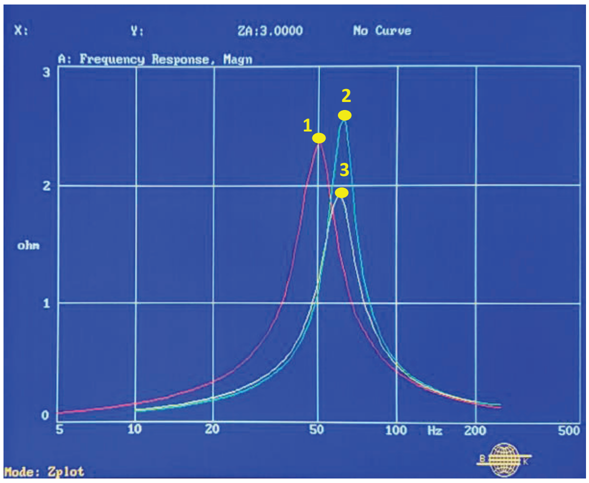

Figure 6 - Velocity to current ratio of a JBL 2206

1. Resonant frequency of the loudspeaker in free air (fs)
2. Resonant frequency of the loudspeaker mounted on a closed enclosure without filling material (fc)
3. Resonant frequency of the loudspeaker mounted on a closed enclosure fully filled with filling material (fcf)

5. MEASUREMENT OF THE PARAMETERS OF THE LOUDSPEAKERS IN FREE AIR AND MOUNTED ON A CLOSED ENCLOSURE WITH AND WITHOUT FILLING MATERIAL

5.1 Volume calculation

The laser method is used to measure the parameters of the loudspeakers. Three measurements have to be performed in order to do the calculations: In free air, mounted on an empty enclosure and in one fully filled with filling material. Using the first two measurement, the volume of the box without filling material can be calculated, using the next two measurements, it is possible to calculate the characteristics of the filling material.

Table 1

Free Air Parameters			
	12 " Woofer	6.5" Full Range	8" Full Range
Sd(m2)	0.0475	0.0134	0.0219
Re(Ohm)	5.90	7.50	6.2
fs(Hz)	50.26	94.26	59.303
Bl (Txm)	15.89	5.28	8.883
Qms	2.90	3.80	1.87
Qes	0.46	1.00	0.427
Qts	0.39	0.79	0.347
Mms (g)	61.55	6.33	14.63
Rms (Kg/s)	6.73	1.00	2.96
Cms (um/N)	163	455	494
Vas (l)	51.90	11.37	33.767
No (%)	1.41	0.92	1.603

Table 2

Empty Parameters			
	12 " Woofer	6.5" Full Range	8" Full Range
Sd(m2)	0.0475	0.0134	0.0219
Re(Ohm)	5.90	7.50	6.2
fc(Hz)	62.04	136.67	123.92
Bl (Txm)	16.23	5.15	8.62
Qmc	3.47	6.13	3.9
Qec	0.57	1.55	0.913
Qtc	0.49	1.24	0.737
Mmc (g)	64.70	6.43	14.13
Rmc (Kg/s)	7.26	0.907	2.83
Cmc (um/N)	102	211	116.67
Vac (l)	32.00	5.27	7.967
No (%)	1.29	0.843	1.617

Table 3

Filled Parameters			
	12 " Woofer	6.5" Full Range	8" Full Range
Sd(m2)	0.0475	0.0134	0.0219
Re(Ohm)	5.80	7.50	6.2
fcf(Hz)	59.92	131.94	119.43
Bl (Txm)	16.22	5.39	9.02
Qmcf	2.81	4.18	2.04
Qecf	0.56	1.40	0.82
Qtcf	0.47	1.05	0.64
Mmcf (g)	67.90	6.60	14.3
Rmcf (Kg/s)	9.11	1.30	3.79
Cmcf (um/N)	104	222	124
Vacf (l)	33.40	5.50	1.71
No (%)	1.25		

	12 " Woofer	6.5" Full Range	8" Full Range
Calculated volume from measurement (L) filled box	88.1	10.76	10.82
Calculated volume from measurement (L) empty box	86.40	10.05	10.31
Calculated volume using a ruler (L) empty	86.45	10.5	10.5
Error (%) for empty box case	0.057	4.29	1.81

Using the first and the third measurement the increase of volume "seen" by the loudspeaker due to filling material can be calculated. Tables 1, 2 and 3 show the results of the measured parameters and Table 4 shows the results of the calculated volumes in empty box and filled box. The volumes found for the empty box case, are compared with the volumes measured with a ruler.

The volumes of the boxes without filling material were calculated using the traditional parameters and the traditional equivalent circuit, considering C_{ms} and C_{mc} in series. After removing the compliance of the loudspeaker, the acoustical compliance of the box was calculated, then the volumes are calculated using the well known definition of compliance (5):

$$C_{AB} = V / \rho c^2 \tag{2}$$

Were:

ρ = 1.18 m/s

c = 340 m/s

The volume seen by the loudspeaker in the box fully filled with filling material is calculated with the same procedure.

5.2 Filling material parameters

By measuring the velocity to current ratio and then the reciprocal value of this parameter multiplied by Bl, it is possible to find the mechanical impedance first and then the acoustical impedance for the three cases previously described. Figure 7 shows the resistance and the imaginary part of the acoustical impedance of the 8” loudspeaker described in tables 1, 2 and 3 in free air, green function, in a closed enclosure without filling material, red function and in an enclosure fully filled with filling material, orange function.

The boxes were carefully built so the resistance of the loudspeaker in free air is almost superimposed to the resistance of the box without filling material, which means that the box introduces almost no losses.

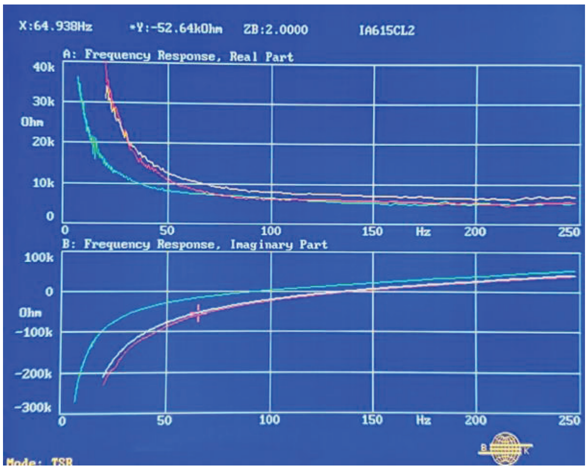

Figure 7 - Mechanical impedance of and 6.5” speaker in free air, and in a box without and with filling material (green, red and orange respectively).

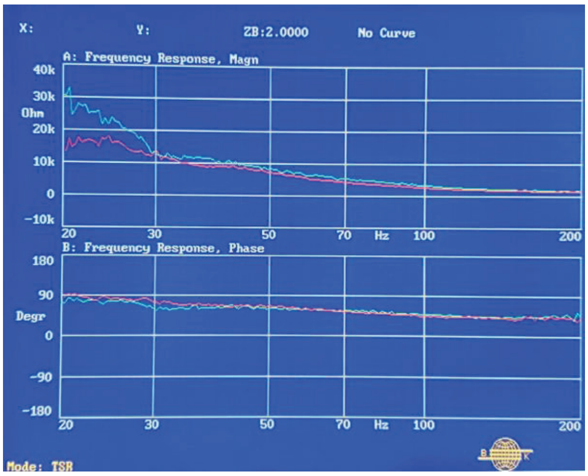

Figure 8 - Acoustic impedance between points A and B shown in Figure 4, superimposed results obtained using a 6.5” and 8” speaker (green and red curves respectively).

Figure 8, is the subtraction of the acoustic impedance of the fully filled case minus the acoustic impedance of the empty enclosure case; these curves were calculated with measurements done using the same 10.5-liter enclosure with the same amount of filling material. The acoustic impedances used for these calculations were measured respectively with the 6.5” and 8” loudspeakers previously described, green and red curves. Almost the same values were obtained with the two loudspeakers. These curves represent the impedance between the points A-B in the circuit shown in Figure 4.

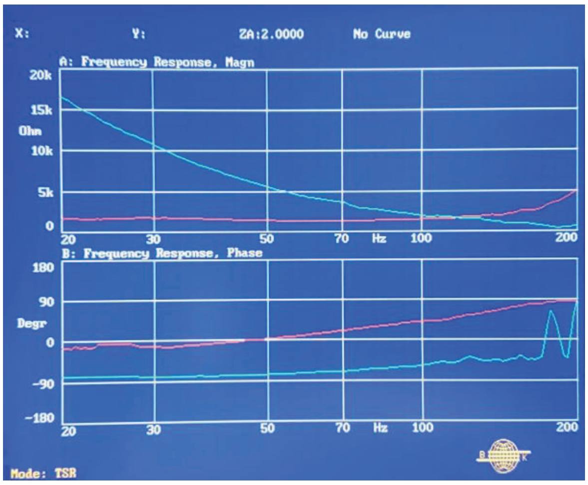

Figure 9 – JBL 2206 case.

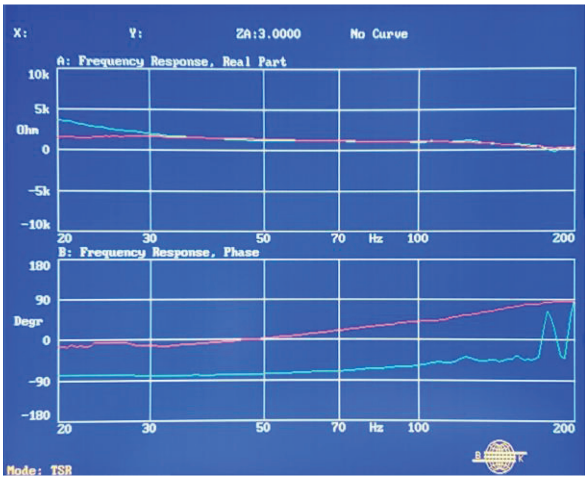

Figure 10 – JBL2206 case.

The curves showed in figures 9 and 10 correspond to a 12” JBL 2206 not described in the tables above. The green curves correspond to the loudspeaker mounted on an 86.45-liter enclosure fully filled with filling material; the red functions correspond to the acoustic impedance between points **A-B** in figure 4.

Figure 9, shows the magnitude and phase for both cases; it can clearly be observed how the magnitude increases for the case were the loudspeaker is mounted on the filled enclosure due to the compliance of the box green curve and how its phase is -90 degrees with respect to the filling material alone red function.

Figure 10, shows the real and imaginary parts for the previous case, it can clearly be observed that the real part of the box coincide with real part of the filling, so the increase in the magnitude in figure 9 is only due to the compliance of the box while the resistive part remain the same.

6. LOUDSPEAKER MODELING USING THE FILLING MATERIAL CURVE

With the information presented in tables 1, 2 and 3 it is possible to calculate a single value to represent the mechanical or acoustical resistance of the filling material and then replace this value in the loudspeaker model, or, use the magnitude and phase response of the filling material to model the loudspeaker. Figure 11 show the result of modeling the sound pressure level, the magnitude of the electrical impedance and the voice coil displacement of the 8” loudspeaker in a 10.5-liter box. Red curves represent the results obtained with a single value 1278 acoustic Ohm, the green curves were calculated with the magnitude and phase response of the acoustic impedance shown in figure 8. It is clear that the results are different.

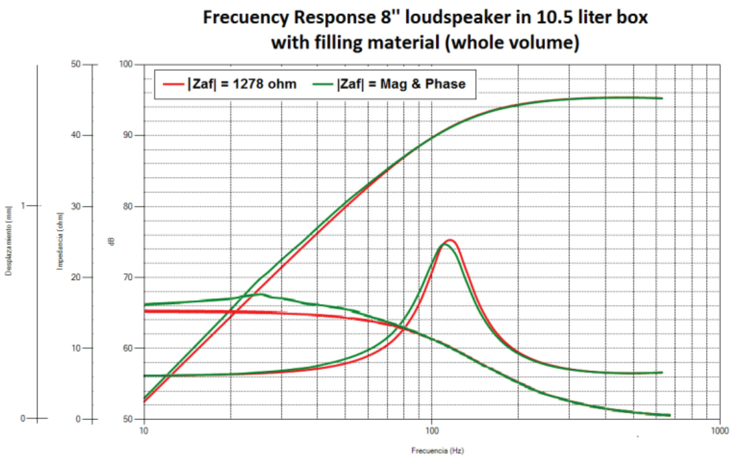

Figure 11 – Loudspeaker simulation

7. CONCLUSIONS

It has been shown that by measuring the velocity to current ratio of a loudspeaker in free air, in an empty enclosure and in a fully filled enclosure, it is possible to determine the volume of the empty enclosure, the volume of the box with filling material and the characteristics of the filling material.

Further research has to be done to be able to measure the characteristics of partially filled enclosures.

ACKNOWLEDGEMENTS

Authors want to thank Celso Llimpe for his help in the preparation of this paper, to Ayrton Urviola for his help in the calculations, to Paul Castro for his help in the measurements in the impedance tube, and to Victor Centa for the loudspeaker modeling.

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