Enhancing Air Compliance of loud speaker cabinet by using Activated Carbon Felts

[1]ShashikumarJakkaraju, [2]Radhika.G, [3]Dr.NikhilRaj, [4]Dr.johnPaul

Abstract--- *At present Fiber glass material is used as stuffing material in sub-woofer cabinet enclosures. It increases Air Compliance and increase the apparent volume of the cabinets since it has properties of sound absorption and insulation. Air Compliance has direct impact on frequency response of the cabinet. By changing air Compliance we can optimize the response. Activated carbon felt can be used in the place of fiber glass because of large absorption coefficient at lower frequency due to adsorption property. Activated carbon Felt have large porosity and large surface area. It is observed Activated carbon felt of range 10 to 15 mm has large absorption coefficient at lower frequencies. The excess absorption of sound energy is due to surface reactance.*

Keywords--- *Adsorption, Compliance, Surface Reactance, Activated carbon felt.*

I INTRODUCTION

Designing miniature Subwoofer enclosure has a great demand. One need to understand and should have a sound knowledge over the thiele/small parameters while designing the enclosures. The system resonance frequency and bass response depends on the volume of the enclosure. By reducing the enclosure volume it is difficult to increase bass response of the system. The best option is enhance the air compliance of the enclosure by any other means. Air compliance is the springiness associated by the Driver enclosure to that of the springiness of the Driver suspension.by stuffing the enclosure by sound absorbing material air compliance can be increased.

II LITERATURE REVIEW

Research into how sound interacts with activated carbons was initiated following suggestions that using activated carbon in loudspeaker enclosures provides “compliance enhancement [1-3],” thus enabling smaller loudspeaker cabinets to be used while preserving reproduction bandwidth. Activated carbon is a material that exhibits adsorbing and desorbing properties. Adsorption occurs when molecules from a surrounding gas are attracted to a material’s microstructure and held in place on the surface by van der Waals forces (weak physical-attraction forces); desorption is the opposite process. Activated carbons possess a complex porous structure, with a large internal surface area, and a considerable adsorption capacity caused by free electrons in he deformed graphene layers [4-8].

The sorption of activated carbon has been very extensively studied, but usually using pressures that are far in excess of those found in typical audible sound waves. The dynamic pressure fluctuations that occur with sound waves are very different than the static pressures commonly used in activated carbon studies [9]. Furthermore,

1,2, H&S department, Malla Reddy College of Engineering Hyderabad, India.
3,4, ECE department, Malla Reddy College of Engineering Hyderabad, India.

Received: 27 Feb 2019 | Revised: 20 Mar 2019 | Accepted: 30 Apr 2020

activated carbon has a complex microstructure, which makes it difficult to determine whether it is sorption or another phenomenon that explains the compliance enhancement.

A. Activated carbon

Since carbon grains are smaller than lead shot particles it is assumed that the behavior within carbon is isothermal over the bandwidth of interest. The effective porosity for activated carbon is usually greater than one [10-12]. The number of moles of air that must be injected into a constant volume to achieve a given pressure change is larger than would be required if the material was not present and the chamber was just filled with air [13].

To demonstrate that adsorption could explain the low frequency behavior, a simple formulation is derived from the ideal gas law, which explicitly models the moles adsorbed in the activated carbon,

$$\varepsilon V_s \Delta p + P \Delta v_2 = \Delta n R T,$$

where Δn quantifies the number of moles adsorbed and desorbed from the air saturating the activated carbon.

Activated carbon can adsorb and desorb gas molecules onto and off its surface. Research has examined whether this sorption affects low frequency sound waves, with pressures typical of audible sound, interacting with granular activated carbon. It is made by carbonizing organic matter like coconut husks in an inert atmosphere and then oxidizing this material by exposure to carbon dioxide or steam activated carbon has large surface area. At lower frequencies a layer of activated carbon provides strong attenuation than any other porous absorbers. This is due to reduction in surface reactance rather than surface resistance. The activated carbons contains mesoscopic pores which are the voids between grains and

microscopic pores within the grains. At certain frequency the pressure in both of them mismatch and result in dissipation in sound energy [14]. Activated carbon can absorb air and adsorb water vapor [15] this increases compliance.

Adsorption increases absorption of sound. Activated Carbon granules are heavy. We can replace them by activated carbon felts. They are lightweight and can be bending easily. These sheets have shown remarkable absorption of sound at lower frequencies [16]. We can use Activated carbon felt to stuff the sub-woofer enclosures to increase the compliance and volume of the enclosure.10mm to 15mm of sheets has shown large absorption of low frequency sound than normal activated carbon granules. The compliance ratio decreases with increase in virtual volume of the cabinet. Quality factor can be brought to optimal value and cutoff frequency can be lowered for better bass response.

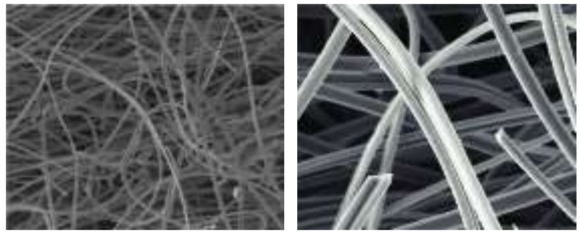

Fig. 1: Activated Carbon felts

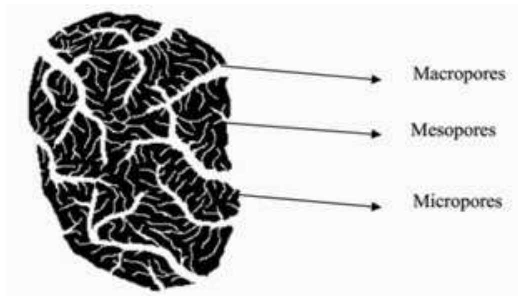

Fig. 2: Macropores, Mesopores and Micropores of ACF

III DESIGN INFLUENCING FACTORS

Air compliance, the quality factor of loud speaker and the stuffing material influences to obtain lower resonance of the cabinets.

III.I. Air compliance of loud speaker

To bring close relation between the air compliance and resonance frequency we need to introduce the compliance ratio α , α is simply the ratio between the equivalent volume and the volume of the enclosure which the driver is mounted in.

$$\alpha = \frac{V_{as}}{V_b}$$

Resonance frequency

$$f_c = \sqrt{1+\alpha}\, f_s$$

Air compliance based on volume of box, density of air and velocity of sound in air [17]

$$C = \frac{V_b}{\rho c^2}$$

Further compliance can also be

$$AC = \left(\frac{f_b}{f_s}\right)^{\frac{1}{0.31}} .V$$

This equation suggests that Air compliance depends on the volume of the enclosure, i.e. more volume more air compliance. The acoustic compliance of air in the loud speaker cabinet depends on density of air and its speed. Compliance can be enhanced by reducing the air density in the cabinet.

III.II. Quality factor of loud speaker

Like parallel resonant circuit that has inductance and capacitance shows the Quality factor in a graph of impedance Vs frequency, likewise loudspeaker has quality factor which depends on two elements. The mass of moving components is analogous to Inductance and restoring spring action of the spider and suspension-capacitance. For a flat frequency response the quality factor should be of order 0.7. Damping reduces the Q so damping is essential.

If the quality factor of the enclosure with the driver is equal to the quality factor of the driver then the air inside the cabinet has no effect on the final quality factor. The resonant frequency of the cabinet will also be same as of driver. The Quality factor of the enclosure is [18]

$$Q_{tc} = \sqrt{1+\alpha} Q_{ts} \quad Q_{ts}$$

total quality factor of the system, it value should be less than 0.7 in order to have lower cut of frequency of the system. This suggests the volume of the enclosure should be always greater for better cut of frequency to generate good bass response. The cut off frequency at -3db is given by [18]

$$f_l = f_c \left(\left(\frac{1}{2Q^2_{ts}} - 1 \right) + \sqrt{\left(\frac{1}{2Q^2_{ts}} - 1 \right)^2 + 1} \right)^{\frac{1}{2}}$$

We cannot always create larger enclosures instead we can back the volume by stuffing the absorbing material. Fiber glass material is one of it.

IV EXPERIMENTAL ANALYSIS

To study the experimentally, a sub-woofer driver is chosen. The frequency of sub-woofer is 28.6Hz,Vas=2.75 Cu. ft and its total quality factor 0.7.An enclosure is built for the Driver whose volume is 1.5 cu. ft. MDF Blocks of thickness 12mm are made with the dimensions of rare inner panel size of the enclosure. when one such block is added in the enclosure, it reduces effective volume of the enclosure to 0.06cu ft volume for every decrease of 0.06 cu. ft volume the resonance frequency of enclosure is measured and noted for with and without activated carbon felt, the dimensions of ACF is width and height of rare panel and its thickness is 24mm (model Z-006).we observe the decrease of resonance frequency at low frequency by introducing activate carbon felt is almost 11%

Received: 27 Feb 2019 | Revised: 20 Mar 2019 | Accepted: 30 Apr 2020

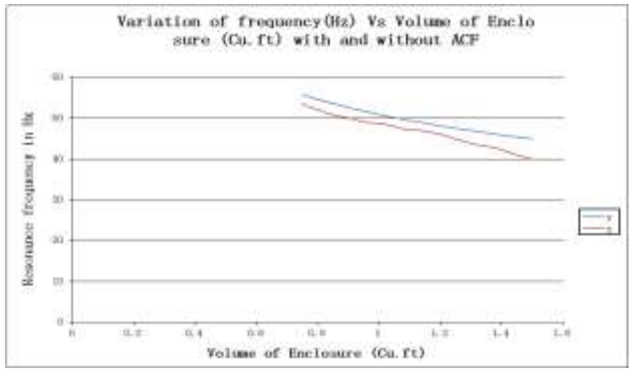

Fig. 3: Variation of frequency w.r.t. enclosure

--Z line represents the frequency variation curve with respective to Volume of enclosure in presences of ACF,--Y line represents frequency variation curve with respective to Volume of enclosure without ACF. We observe resonance frequency of enclosure decreasing by addition of ACF.

V CONCLUSIONS

Activated carbon felts can enhance the air compliance of the driver enclosure due to surface reactance and adsorption. The thin layer of Activated carbon felts are light weight, flexible then activated carbon granules they can be easily used for acoustic applications like, home theaters, small size sub-woofer enclosures. They can be used for enhancing air compliance of the driver enclosure, hence improving bass response. Further research need to be carried out on ACF for improving the acoustics properties.

REFERENCES

[1] Manoharan, Rajesh, et al. "Selection of Intermediate Routes for Secure Data Communication Systems using Graph Theory Application and Grey Wolf Optimization Algorithm in MANETs." *IET Networks* (2020).
[2] Rajesh, M., Gnanasekar, J.M. Path Observation Based Physical Routing Protocol for Wireless Ad Hoc Networks. *Wireless Pers Commun* **97,** 1267–1289 (2017). https://doi.org/10.1007/s11277-017-4565-9
[3] Rajesh, M. Streamlining Radio Network Organizing Enlargement Towards Microcellular Frameworks. *Wireless Pers Commun* (2020). https://doi.org/10.1007/s11277-020-07336-9
[4] J. R. Wright, “The virtual loudspeaker cabinet,” J. Audio Eng. Soc. 51, 244–247 (2003).
[5] T. J. Cox and P. D’Antonio, Acoustic Absorbers and Diffusers (Taylor & Francis, London, 2009), pp. 77–78.
[6] Y. Cho, “Least squares estimation of acoustic reflection coefficient,” Ph.D. dissertation, University of Southampton, U.K., 2005.
[7] B. Castagnede, A. Moussatov, D. Lafarge, and M. Saeid, “Low frequency in situ metrology of absorption and dispersion of sound absorbing porous materials based on high power ultrasonic non-linearly demodulated waves,” Appl. Acoust. 69(7), 634–648 (2008).
[8] S. Brunauer, P. H. Emmett, and E. Teller, “Adsorption of gases in multimolecular layers,” J. Am. Chem. Soc. 60, 309–319 (1938).
[9] M. M. Dubinin and V. A. Astakhov, “Description of adsorption equilibria of vapors on zeolites over wide ranges of temperature and pressure,” Adv. Chem. Ser. 102, 69–85 (1970).
[10] E. P. Barrett, L. G. Joyner, and P. P. Halenda, “The determination of pore volume and area distributions in porous substances. I. Computations from nitrogen isotherms,” J. Am. Chem. Soc. 73, 373–380 (1951).
[11] S. J. Gregg and K. S. W. Sing, Adsorption, Surface Area and Porosity, 2nd ed. (Academic, London, 1982), pp. 1–303.
[12] S. Brunauer, L. S. Deming, W. E. Deming, and E. Teller, “On a theory of the van der Waals adsorption of gases,” J. Am. Chem. Soc. 62, 1723–1732 (1940).
[13] J. W. Hassler, Activated Carbon (Chemical Publishing Company, New York, (1963) pp. 1–397.

[14] L. Wojnar, Image Analysis, Applications in Materials Engineering (CRC Press, Boca Raton, FL, 1998), pp. 1–256.

[15] J. Serra, Image Analysis and Mathematical Morphology (Academic, Orlando, 1983), pp. 1–610.

[16] O. Umnova, D. Tsilklauri, and R. Venegas, "Influence of boundary slip on acoustical properties of microfibrous materials," J. Acoust. Soc. Am. 126, 1850–1861 (2009).

[17] T. J. Cox and P. D'Antonio, Acoustic Absorbers and Diffusers (Taylor & Francis, London,Third Edition 2009).

[18] J. R. Wright, "The virtual loudspeaker cabinet," J. Audio Eng. Soc. 51, 244–247 (2003).

[19] Hugo KARPINSKI;Rodolfo VENEGAS olga UMNOVA;Jonathan Andrew HARGREAVES,"Sound propagation in activated carbon felts," INTER-NOISE-2016.

[20] Bechwati, F, Avis, MR, Bull, DJ, Cox, TJ, Hargreaves, JA, Moser, D, Ross, DK, Umnova, O and Venegas, RG ,"Low frequency sound propagation in activated carbon" ,april 2012.

[21] Niels Elkjær Iversen, "Introduction to loudspeaker modeling & design"Technical University of Denmark DTU,September 2014.

[22] N. Raj and R. K. Sharma, "A High Swing OTA with wide Linearity for design of Self Tuneable Resistor*", International Journal of VLSI design & Communication system (VLSICS)*, Volume 1, No. 3, pp. 1-11, 2010.

[23] N. Raj, A.K. Singh, A.K. Gupta, "Modeling of Human Voice Box in VLSI for Low Power Biomedical Applications", *IETE Journal of Research*, Vol. 57, Issue 4, pp. 345-353, 2011.

[24] N. Raj, A.K. Singh, and A.K. Gupta, "Low power high output impedance high bandwidth QFGMOS current mirror", *Microelectronics Journal,* Vol. 45, No. 8, pp. 1132-1142, 2014.

[25] N. Raj, A.K. Singh, and A.K. Gupta, "Low-voltage bulk-driven self-biased cascode current mirror with bandwidth enhancement", *Electronics Letters*, Vol. 50, No. 1, pp. 23-25, 2014.

[26] N. Raj, A.K. Singh, and A.K. Gupta, "Low Voltage High Output Impedance Bulk- driven Quasi-floating Gate Self-biased High-swing Cascode Current Mirror", *Circuit System & Signal Processing Journal,* Vol. 35, No. 8, pp. 2683-2703, 2015.

[27] N. Raj, A.K. Singh, and A.K. Gupta, "High performance Current Mirrors using Quasi- floating Bulk", *Microelectronics Journal*, Vol. 52, No. 1, pp. 11-22, 2016.

[28] N. Raj, A.K. Singh, and A.K. Gupta, "Low Voltage High Performance Bulk-driven Quasi-floating Gate Self-biased Cascode Current Mirror", *Microelectronics Journal*, Vol. 52, No. 1, pp. 124-133, 2016.

[29] N. Raj, A.K. Singh, and A.K. Gupta, "Low Voltage High Bandwidth Self-biased High Swing Cascode Current Mirror", *Indian Journal of Pure and Applied Physic,* Vol. 55, No. 4, pp. 245-253, 2017.

[30] Raj N. and Gupta A. K., "Analysis of Operational Transconductance Amplifier using Low Power Techniques", *Journal of Semiconductor Devices and Circuits (STM Journal),* Vol. 1, No. 3, pp. 1-9, 2015.

[31] Raj N. and Gupta A. K., "Multifunction Filter Design using BDQFG Miller OTA", *Journal of Electrical and Electronics Engineering: An International Journal (EEEIJ Journal),* Vol. 4, No. 3, pp. 55-67, 2015.

[32] N. Raj, A.K. Singh, and A.K. Gupta, "Low Power Circuit Design Techniques: A Survey", *International Journal of Computer Theory and Engineering*, Vol. 7, No. 3, pp. 172-176, 2015.