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Improvement of resonance frequency in Sub woofer Driver

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Abstract—*Present days reproducing of sound with good quality has great demand and increasing day by day .Ideally, the high-fidelity equipment,like high end audio systems,power amplifiers,audiophile,home audio system must produce less noise and distortion and a flat frequency response within the human listening frequency range.A lot of research is going on to develop popular type of system for reproducing music since from 1970's.the audio equipment must produce the sound of audible rang i.e,for healthy young person it ranges from 20Hz to 20,000Hz.the electrical technology is so developed that audio receivers can produce humans range quite easily.the out put of audio signal produced by high-fidelity systems should be again feed into the suitable audio drivers which can reproduce the sound,because of this reason the demand of production of quality loudspeakers has increased and producing human range frequency drivers is not that easy and also expensive.miniature has great demand.At present the parameters that influence the production of low frequency is presented.The thiele parameters that influences for the production of low frequency drivers is discussed ,they are Peak Diaphragm Displacement Volume (V_d),suspension compliance (C_{ms}),Displacement-Limited acoustic power output rating(P_{AR}),the voice coil movement in one direction without leaving the uniform magnetic field (X_{max}),the air compliance inside the box(V_{as}),excursion limit (X_{lim}),the speaker cone surface area that is connected to rubber(S_D) and the weight of the cone assembly and the driver radiation mass load(M_{ms}).the resonance frequency of any driver generally depends on the reciprocal of stiffness and effective mechanical mass of the driver these in turn depends on other parameters.by improving them drivers for producing low frequency can be constructed.*

Key words—*thiele parameters, resonance frequency , suspension compliance, excursion limit, Total mechanical mass of driver,maximum linear peak excursion, Displacement-Limited acoustic power output rating*

1. INTRODUCTION:

A great demand is there for studio monitors,bookshelf speakers,sub woofer systems which are useful for the production of sound in radio studios,film making,recording studios and television studios.for designing them we should know and have a sound knowledge of the performance data of every individual loud speaker while constructing enclosure.many affordable methods was proposed and presented to audio engineering society.Thiele and small made many efforts and discovered the parameters which can give the relation between enclosures and speakers.they named it as "thiele-small parameter" thiele was a senior engineer of design and development for Australian broadcasting commission and small is a common wealth post graduate research student in the school of electrical engineering at university of Sydney.the general parameters which give the performance data are

S_d - Total piston radiating area of driver [m^2].
X_{max} - The linear excursion of driver [mm].
Re - DC resistance of coil [ohms].
Le - Inductance of voice coil [H].
F_s - Driver free air resonance [Hz]. Point at which driver impedance is maximum.
F_3 - -3 dB cutoff frequency [Hz].
V_{as} - It is the volume of air that has the same stiffness as the driver's suspension when acted on by a piston of the same area (S_D) as the cone.
V_d - Maximum linear volume of displacement of the driver [m^3].
Q_{ms} - Q of driver due to mechanical losses at resonance[dimensionless].
Q_{es} - Q of driver due to electrical losses at resonance [dimensionless].
Q_{ts} - Q of driver due to all losses at resonance [dimensionless].
C_{ms} - Mechanical compliance which is reciprocal of stiffness of driver [m/N].
M_{ms} - total mechanical mass of driver which including air load and measured in [mg] or total moving mass of a driver including air loads

Rms - Mechanical losses of driver [kg/s]
B - Magnetic flux density in gap [T].
l - Length of wire immersed in magnetic field [m].
c - Propagation velocity of sound [~342 m/s].
ρ_o = Density of air(1.18 kg/m3)
α = system compliance ratio
V_B= net internal volume of enclosure
P_{AR}=Displacement-Limited acoustic power output rating
k_p = power rating constant.
k_η = efficiency constant
η_0=Half space acoustic load
k_3 = frequency ratio constant for system

2.DERIVATION OF BASIC THEORY:

From large signal system specifications[1] the value of M_{ms} and C_{ms} can be derived as

$$M_{ms} = \frac{\rho_0 c^2}{4\pi^2 k_3^2 \alpha} \frac{S_D^2}{f_3^2 V_B}$$

But

$$S_D^2 = \frac{P_{AR}}{X_{max}^2 k_p f_3^4}$$

$$M_{ms} = \frac{\rho_0 c^2}{4\pi^2 k_3^2 \alpha k_p} \frac{P_{AR}}{X_{max}^2 f_3^6 V_B}$$

$$M_{ms} = \frac{\rho_0 c^2 k_\eta^2}{4\pi^2 k_3^2 \alpha k_p} \frac{V_B P_{AR}}{X_{max}^2 \eta_0^2}$$

for C_{ms}

$$C_{ms} = \frac{\alpha k_p}{\rho_0 c^2 k_\eta^{4/3}} \frac{X_{max}^2 \eta_0^{4/3}}{P_{AR} V_B}$$

Resonance frequency of a driver is given as

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{1}{M_{MS} C_{MS}}}$$

Equivalent volume of compliance depends on

$$V_{AS} = \rho_0 c^2 C_{MS} S_D^2$$

3.DISCUSSIONS FROM RESULTS:

Resonance frequency(F_0)

the frequency at which the driver moves with minimal effort is called resonance frequency of the driver.this is the key parameter,it will tell the min frequency that a speaker can deliver .the moving parts mass of the speaker and the stiffness of the suspension and the spider will decides the resonance frequency of the speaker. when you tap a speaker it will make a sound with the same frequency as its resonant frequency.If the driver reaches below the resonance frequency F_0,its starts to roll off.Below F_0**,** the frequency response starts to fall down.Therefore the lower the F_0,the better is the sub woofer. Better sub woofer should have a minimum of resonance frequency 20Hz.The mid range woofers will produce 250Hz to 2000Hz and high frequency producers tweeters produces 2000Hz to 20kHz, the resonance frequency will be more and significantly higher.the resonance frequency of driver depends on C_{ms},M_{ms} keele equations of large system specification they depend on X_{max} ,P_{AR} this again depends on square of peak displacement volume of the driver diaphragm V_d [6]

Q parameters

Q_{ms}, Q_{es}, and Q_{ts} are Q parameters measurements which will control the suspension when it reaches the resonant frequency (F_0). The suspension will prevent the voice coil to touch the pole of the magnet when placed.Q_{ms} is a measurement of the control coming from the speaker's mechanical suspension system,the mechanical suspension is made by using the spider.Q_{es} is a measurement of the control coming from the speaker's electrical suspension system which comprise of the voice coil and the magnet. When the voice coil is kept in the uniformed constant magnetic field it generates the current and oppose the coil motion this is called as electrical damping.Q_{ts} is called the 'Total Q' of the driver and is derived from an equation and is product of Q_{es} and Q_{ms} and the result is divided by the sum of the both.

C_{ms}

C_{ms} is the force exerted by the mechanical suspension of the speaker and the reciprocal of stiffness which is measured in meters per Newton.It is also called as the compliance of the speaker. the cone of the speaker is suspended with certain stiffness. If the suspension is stiff, the driver is not having good compliance. So, the easy it is to move the speaker cone, the more compliance it has.

the equation given by B.D.Keele [1] of C_{ms} it is evident that force exerted by mechanical suspension of the speaker depends on the the voice coil that can move in one direction before hard limit occurs .A higher C_{ms} will yield a lower Fs. X_{max} plays vital role in deciding the roll off frequency of the drive.suspension compliance is inversely proportional to square of the effective surface area of the diaphragm [1].

M_{ms}

This parameter is the combination of the weight of the cone assembly plus the 'driver radiation mass load'

The equation derived From large signal system specifications for M_{ms} by B.N.Keele[1].he has given the beautiful relations among the M_{ms},C_{ms} and X_{max}.the values of X_{max} will effect the M_{ms} in turn influence the natural frequency of the driver.the equation also depends on effective surface area of the diapharam.M_{ms} is also influenced by the S_D.the more it is the more the value it has.For cinema halls and outdoor studio monitors speakers should have more S_D.

V_d

It is the Peak Diaphragm Displacement Volume it depends on P_{AR} [6]— in other words the volume of air the cone will move depend on Displacement-Limited acoustic power output rating. It is the product of X_{max} ,Maximum peak linear excursion of drive and S_d the Surface area of the cone.It is noted in cc. The low frequency drivers like subwoofers will have highest V_d figure.

$V_d = X_{max} * S_D$,the value of the Peak Diaphragm Displacement Volume depends on the surface area of cone [1] ,it is evident the value of the peak Diaphragm displacement volume influence the roll-off frequency of the drive.because of this reason for generation of distortion-less and smooth frequencies

Large diaphragm drivers are used.this is suitable for only outdoor application not for living room.

X_{max}/X_{lim}.

In the typical structure of speaker coil assembly.the area between the pole piece and the magnet,the magnetic field is uniform constant and strong. the voice coil has to move linearly and should maintains same number of turns within this strong magnetic field, then only the sound signal are reproduced faithfully.If the voice coil moves beyond the excursion limit ,less number of turns of the voice coil will be within the the magnetic filed. If this takes place, the signal reproduced is no longer proper and hence distortion occurs noise is produced and even damages the speaker.thus we should take care that voice coil should move that distance in one direction **X_{max}** which will maintains same number of turns with in the magnetic zone always.If excursion is increased beyond the limit, the back of the voice coil former will eventually slam into the magnet, risking permanent damage to the driver.**X_{lim}** is the amount by which the voice coil can move in one direction before this hard limit occurs.the "excursion limit".X_{lim} is always larger than X_{max} .A good driver can have an X_{lim} that is X_{max} *2 but X_{lim}=X_{max} + 25% is more realistic.many people say X_{lim}=X_{max} + 10 % gives a better estimation of how the sub is likely to be used.it is fairly safe and driver is not damaged.

From Moving-Coil Loudspeaker Topology As An Indicator Of Linear Excursion Capability[2], starts by defining X_{max} as for voice coil height > air gap height as

$$X_{max} = \frac{\text{voice coil height - air gap height}}{2}$$

for voice coil height < air gap height it is defined as

$$X_{max} = \frac{\text{voice coil height - air gap height}}{2} * 15\% \text{ voice coil height}$$

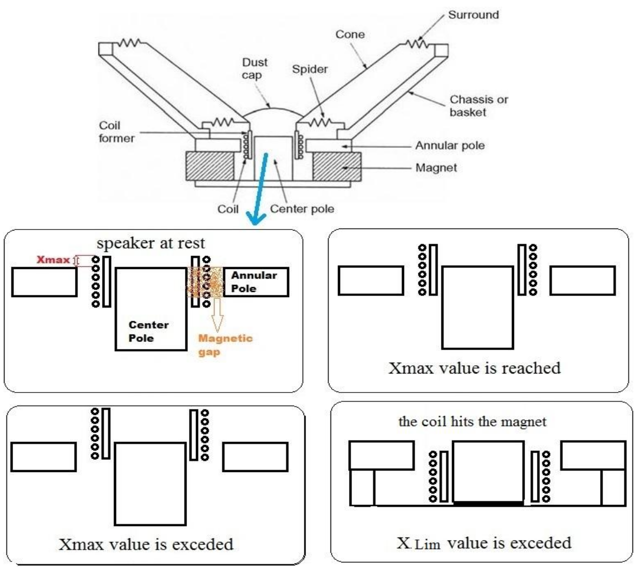
In Design Parameters and Trade-Offs in Large Diameter Transducers[3]

$$\mathbf{X_{max} = \frac{H_c - H_g}{2} + 0.25 * T}$$

Where T=top plate thickness

For finding X_{max}, many people has given their opinion,by creating more its value the resonance is lowered,this parameter plays vital role for construction of sub woofers

tiele-Small Parameter	Free-air Resonance	Diaphragm Diameter	Maximum Excursion	Driver Radiating Area
Measurement Unit	(Hz)	(inches)	(mm)	(cm^2)
Parameter Name	**F_0**	**Diameter**	**Xmax**	**Sd**
128H	20,00	10,20	7,87	527,0
2215B	20,00	13,20	4,06	883,0



from 2 JBL subwoofer of model128H & 2215B by increasing X_{max} value and by decreasing S_D we can generate same frequencies thus we construct compact size subwoofers for living room

V_{as}

The air inside the cabinet has its own compliance. When you try to compress the air inside a box, you will encounter resistance.If the box is small, the air is harder to compress and therefore less compliant, and if the box is larger,the air is easier to compress, therefore more compliant. In conclusion, $\mathbf{V_{as}}$ describes the volume of the air inside the enclosure, in which the speaker compliance matches the air compliance inside the box.there is a direct dependency of V_{as} on force exerted by speakers mechanical suspension.the roll-off frequency of the sub woofer also depends on V_{as}.

4.CONCLUSIONS:

low frequency generation drivers are important.by having the knowledge of driver specification one can design desired driver.generating 20hz range driver is very difficult.the Diaphragm Displacement Volume (V_d),suspension compliance (C_{ms}),the voice coil movement in the magnetic zone (X_{max}),the compliance of the air inside the box(V_{as}),excursion limit (X_{lim}),the surface area of the diaphragm (S_D) and the weight of the cone assembly and the driver radiation mass load(M_{ms}) influence the resonance frequency of driver.more over S_D of the driver says how much volume of air can be displaced and it is clear the it does not appear in small-signal response[4].this will tell we can design different diameter drivers which can have same F_s,Q_{es},Q_{ms},V_{as},V_d values and can be used in identical enclosures[4].In home theater systems LFE is important,the bass frequencies are of order 20Hz to 125Hzs.using big S_D is not recommended like 12 inches,15 inches & 18 inches in living rooms.we can design driver of 4,5 & 6inches having same thiele parameters to produce the similar frequency as the big drivers do,but the draw back is they produce more modulation distortion.the discussions in the present paper will help in producing the low frequency drivers.putting [5]drivers in the vented boxes can also bring the frequency down and response considerably below resonance frequency.

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