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Subject: Electro-mechanical properties and diaphragm motion

Posted by [Wayne Parham](#) on Fri, 17 Apr 2009 20:56:32 GMT

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Qms does not describe the damping of the cone. It describes damping of the suspension. This is a very important distinction. I'll try to explain, generally, some of the details and how it all works together. Motor strength and electro-mechanical parameters (Bl, Cms, Rms or the Thiele/Small transformations Fs, Qts, Vas etc.) are very important for describing the pistonic behavior of the driver. You'll enter those values into Hornresp and it will tell you what the horn will do with the driver described by those parameters. But this only describes how the system acts when the cone moves purely as a rigid piston, with no ripples across its surface. That only happens at low frequency, from midrange frequencies down, in the pistonic range. The pistonic range is different for every woofer, depending on cone material and shape and also on its acoustic loading. Think of the woofer as a mass/spring system. The cone is a weight and the suspension is a spring. You can determine exactly what the resonant frequency is by knowing the stiffness of the suspension and the mass of the cone. There is another property - resistance to motion - which determines the amount of ringing there will be after excitation. A shock absorber in a car is such a resistance. Without it, the car would bounce a long time after hitting a bump. This resistance damps the resonance, and the amount of resistance sets the mechanical damping of the system. A speaker's motor is connected to its cone, so the motor interacts with the cone/suspension and its damping. The suspension should not provide much resistance to motion, so without electrical damping, the cone would be free to vibrate. But when you short the voice coil, back-EMF tends to resist motion providing a sort of motor braking effect. That's why the damping factor of an amplifier modifies the tuning of the speaker - resistance in the woofer circuit sets the damping of the system. Electrical damping is almost always an order of magnitude greater than mechanical damping. The thing is, all this sets the values of the mass/spring system. It determines how the mass will move as a whole. That's why most mathematical models assume a rigid piston - they only describe the motion of the mass as a solid lump. Since the radiating surface is a flat (or cone or dome shaped) disk, the motion of the disk makes waves. But again, the model assumes the disk is perfectly rigid and non-bending. This is where the simulation deviates from reality most strongly. In truth, the cone only operates as a rigid piston at bass and midrange frequencies, depending on its size, shape and composition material. This is referred to as the pistonic range. At higher frequencies, the cone begins to bend and twist, making its surface motion look like ripples on a pond. In this frequency range, the cone itself acts like many smaller mass spring systems along its surface. Non-pistonic motion is sort of like several masses connected together along a flexible surface. The surface becomes elastic, partially decoupling each section from one another. In truth, the cone is elastic in both the pistonic and non-pistonic ranges. The difference is that in the pistonic range, the forces required to bend the diaphragm are small enough that it operates as a rigid piston. Above the pistonic range, the cone flexes and ripples appear across its surface, effectively decoupling regions from one another. This is purely a technical distinction, but mechanical engineers find this important as it tells them how the cone will act structurally. In the non-pistonic range, the lumped mass model isn't effective anymore. You have to know how the cone flexes, and this is much more complex than the simple mass/spring model. You could model it, but not with the tools available to most of us. So this makes it important to understand that above the pistonic range, you really need measurements to gain any visibility. There are some rules of thumb that are moderately useful. Cone damping is usually highest in paper and some composites, lower in plastics and lowest in metals. However, the rigidity of these materials is just the opposite,

with metals being strongest, followed by plastics and composites and lowest in paper. The reason is pretty easy to see - stuff that is more rigid tends to breakover sharper, like how plastic can bend but glass shatters. Diaphragm flex is also modified by shape and features like corrugation. Surface features can break up standing waves by modifying the structure of the cone, providing additional strength in some places. These kinds of features can increase the pistonic range or increase damping. Usually the things that extend the pistonic range tend to reduce internal damping and vice versa. This is not always the case, but usually if the cone is made stiffer, it tends to breakup later but harder. Again, think of the analogy of plastic and glass. Speakers designed to be used over a wide range are generally made to favor damping over trying to extend the pistonic range. The idea seems to be that you can't avoid breakup modes in a wide band transducer, so its better to make them well behaved. One thing that is rarely considered in direct radiators but that you'll find in horns is the final range of surface deformation - the plastic range. Do not be confused by the name, it has nothing to do with the material. Plastic deformation can happen to any homogenous solid material, such as metal, ceramic, plastic, polymer or resin. Woods, laminates and composites are a little different because they are not homogenous, having fibers and different things in them, but the principles of elastic verses plastic deformation still apply. When the ripples across the surface move with enough force to irreversibly deform the diaphragm, it is said to have deformed plastically. After a few cycles of this, the cone will break or tear. Ironically, compression drivers with aluminum diaphragms are often enjoyed by hifi enthusiasts because they are smooth sounding. This is because aluminum, as a material, has no elastic range. Any force applied to aluminum causes plastic deformation which causes stress fractures. But this tends to damp the surface modes, and makes the driver sound smoother. Basshorns driven hard, especially ones with higher compression ratio, sometimes push the cones into their plastic range. It's usually when a woofer that isn't really suited for a basshorn is used and the internal stresses cause massive cone flex that bends it enough to crease or tear it.

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