Subject: Webster's equation verses FEA / BEM
Posted by Wayne Parham on Mon, 24 Mar 2008 18:55:44 GMT
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There has been some discussion over the years about how accurate the Webster's equation is at describing horns. It is a mathematical model, and with all models, it is accurate at some level but misses some of the details. It is a one-dimensional model for axisymmetric Salmon shapes: parabolic, conical, exponential and hyperbolic. It makes an assumption of equal cross-section pressure. All of these things are simplifications, as all models truly are.Does that make it "wrong"? Is any model that misses some detail "wrong"? Or is it a useful tool that can be used to approximate a real device with a mathematical abstraction. Obviously, this is the case.Over the last couple of decades, a new suite of tools has been evolving, called Finite Element Analysis, or FEA. It is a way of reducing a model into many component pieces and analyzing each one separately. Deformation/stress analysis can be made of complex shapes. Heat flow and magnetic flux are modeled with FEA. Recently, an adaptation called Boundary Element Modeling or BEM has been used for acoustics problems. You can model wave propogation and resonance with it, so better models can be made of oddly shaped acoustic apertures, chambers and devices.Here are a few links about BEM for acoustics:The Sound Field at the Mouth of a Horn, Rick Morgans, Colin Hansen, Anthony Zander, David MurphySimulation of the acoustic field produced by cavities using the Boundary Element- Rayleigh Integral method (BERIM) and its application to a horn loudspeaker, S. M. Kirkup and A. ThompsonBoundary-Element-Method.com

Subject: Re: Webster's equation verses FEA / BEM
Posted by akhilesh on Tue, 25 Mar 2008 16:50:05 GMT
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Hi Wayne,Interesting, and useful. What is missing, IMHO, is the correlation between subjective listening preferences and BEM models, which are presumably more accurate than the older models. BTW, for more info, can you tell us what the input to these models is and what they predict?-akhilesh

Subject: Re: Webster's equation verses FEA / BEM
Posted by Martin on Tue, 25 Mar 2008 18:42:42 GMT
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"There has been some discussion over the years about how accurate the Webster's equation is at describing horns. It is a mathematical model, and with all models, it is accurate at some level but misses some of the details. It is a one-dimensional model for axisymmetric Salmon shapes: parabolic, conical, exponential and hyperbolic. It makes an assumption of equal cross-section pressure. All of these things are simplifications, as all models truly are."Wayne, very interesting

post. I am at present working on my horn models again I did use Webster's 1D wave ion to derive my 1D acoustic element, I use many (sometimes 100's of) elements to model arbitrary expanding horn geometries. I am expecting brand new copies of Morse and Feshback's physics text in the mail this week. This is the reference used most often by Earl Geddes in his text so hopefully my understanding will increase into the limits of Webster's equation after a little "light" reading.I am also looking harder at the horn mouth impedance. For example calculating the actual pressure profile over the "surface" of the mouth and the impact of edge defraction around the mouth on this acoustic impedance are two of the things I am working through right now. I am also very interested in trying to couple 2D or 3D wave fields to more accurately model the air motions in the horn profile. Again the goal is to use a simple acoustic element with more degrees of freedom.I think modeling is really key to understanding horns and the skill at which you apply the approximations will be key to the accuracy of the results. I personally have done some FEM work on my geoemtries but never any BE modeling. Thanks for the links, I will study them to see what I can learn and apply to my own models.Gotta love a simple elegant model,Martin

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Subject: Re: Webster's equation verses FEA / BEM
Posted by Wayne Parham on Tue, 25 Mar 2008 22:11:33 GMT
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As you might imagine, you can make a horn model as simple or as complex as you want (and/or have the programming and processing power for). The simplest models assume linear motor properties, rigid piston diaphragm motion and constant cross-section pressure with wavefront propogation being perpendicular to the flare walls. Better models allow any wavefront shape and include standing wave nodes, rarefactions, diffractions and reflections. Even better to add the ability to model motor nonlinearities with respect to inductance, flux modulation and compression. Better still to include the materials and geometry of the diaphragm, so flex can be modeled.Are models that don't include all these features wrong? Well, yes, I suppose in the strictest sense, they are. But then again, there aren't any fully complete models that I know of. So I guess that means all analysis is wrong. Maybe it is better to say our best models are still incomplete, but getting better all the time.Even the simplest models are and can be useful, if you know their limits and what you're looking for. As an example, a model that doesn't includes diaphragm flex can't predict breakup modes so high frequency prediction is off, usually way off. But a rigid piston model predicts low frequencies just fine, where the diaphragm moves as a piston.As you know, computer technologies tend to evolve pretty quickly. It is the fastest growing technology I can think of. These kinds of tools are all based on computers, so our ability to make complex models is getting better all the time. Think about what computer graphics processing we could do in 1980. The fastest processors in the world with the most sophisticated graphics boards would barely make a decent scanline image. The best stuff was vector graphics back then, nothing in terms of ray tracing was being done. We just didn't have the horsepower. Today you can do things on a desktop computer that you couldn't have done on the best workstation 10 years ago, or the biggest mainframes of 25 years ago.This kind of reminds me of the evolution of understanding of heavenly bodies. There was a time people thought the earth was the center of the universe. When that model failed to explain why planets moved in retrograde at some times, they added epicycles to improve the model. Was this right? No. Was it an improvement? Yes. But in the end, people realized the earth wasn't the center, and putting the sun in the center made

a much better model.Same thing with our understanding of horns, I expect. Someone makes a model and we use it for a while. Someone later adds features to improve the model, and we use that. At some point, we gain a better understanding and the model changes again. In the process, sometimes weird artifacts pop up like epicycles that seem to explain certain things, but may not be right at all. Still, if the model fits reality to some degree, then to that degree it is useful.

Subject: Re: Webster's equation verses FEA / BEM
Posted by Wayne Parham on Tue, 25 Mar 2008 22:35:09 GMT
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Excellent, Martin. I know whatever you come up will be extremely useful. You're always very thorough. Please keep us posted here.I agree with you about the importance of (mathematical) modeling in understaning horns. Physical models are important too, but you can make many mathematical models in a relatively short period of time. Makes it much easier to narrow down your choices to target your efforts. That way, physical models can be made of the ones you think are closest to what you want.This topic reminds me of the struggles faced by James Watson and Francis Crick when trying to discover the structure of DNA. They worked fairly closely with Maurice Wilkins and Rosalind Franklin, who shared their experimental data with them. Linus Pauling, on the other hand, was somewhat arrogant and self-promotional. A sort of competition sprung up between Watson and Crick and Pauling as a result. Linus Pauling published the structure of the alpha helix in 1951, a fundamentally important structural component of proteins. In 1953, he published an incorrect triple helix model of DNA. But Watson and Crick weren't convinced in the model, thinking it just didn't seem right and wouldn't hold itself together. Shortly afterward, they realized the double helix structure, which seemed to fit perfectly. They published this now famous structure and were ultimately awarded the Nobel Prize for it.

Subject: Re: Webster's equation verses FEA / BEM
Posted by SteveBrown on Wed, 26 Mar 2008 17:21:18 GMT
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Wayne, you said: "This kind of reminds me of the evolution of understanding of heavenly bodies. There was a time people thought the earth was the center of the universe."As it happens, my 16-year-old step daughter thinks that SHE is the center of the universe and I defy you to convince her otherwise..

Subject: Re: Webster's equation verses FEA / BEM
Posted by Wayne Parham on Wed, 26 Mar 2008 17:31:10 GMT
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