Are the Fibers Moving in my TL Slowing the Speed of Sound?

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Starting in the late 1960's, a theory was proposed that the fibers used to damp standing waves in a TL were moving and effectively lowering the speed of sound and therefore the quarter-wave tuning frequency. This was based on some measurement results for a tapered TL stuffed with long haired wool fiber, the measured tuning frequency was much lower than expected based on a calculation using only the length of the TL and the speed of sound in air.

The moving fiber theory spawned an elegant mathematical model, and the use of long fiber wool became the standard for TL design and construction. TLs were designed and built using these methods and the measurements of the finished design were hit or miss when correlated with the predictions. This continued for over 30 years.

From 2000 to 2001, two separate studies were conducted that produced modern design software for TL loudspeakers. TL designs were built and measured, both empty and stuffed, and the results showed that while the fibers did provide viscous damping of the standing waves the speed of sound was not significantly reduced. The moving fiber models were shown to be very inaccurate, but the moving fiber myth has still not died.

In January of 2026, the following statement was sent to me as part of a longer e-mail (I do not remember the sender or the rest of the e-mail’s specifics, I just saved the following portion and the response in my notes).

"... whatever you add to manage the resonances adds mass to the air in the line. The thinking is there for a TL is mass loaded line. The air and the stuffing adds mass to the air and load on the back of the driver lowering resonances.“

This thinking is not atypical of other old school TL builders; the moving fiber theory is still very much alive and is not easily debunked. Long fiber wool and slowing of the speed of sound is in their minds the basic ingredients to a successful TL design.

My response :

“Adding parasitic mass to the oscillating air column was a popular theory from the late 1960's until the early 2000's, many people still cling to it today. It has been shown by several engineers correlating measurements to calculations to be incorrect. I tried to use it for years and could never correlate measurements with analysis predictions.

Adding parasitic mass associated with fibers to the oscillating air column to lower resonances means that the speed of sound has been significantly reduced. Density drives speed of sound and speed of sound drives resonant frequencies and standing waves in TLs (along with geometry). The density of air is 0.075 lb/ft^3 (1.205 kg/m^3) and typically a TL is stuffed with fiber at a density of 0.5 lb/ft^3. If the combined density of the oscillating "fluid" in a TL increases by a factor of almost 7, then the speed of sound and the standing wave frequencies must plummet. But this does not happen.”

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"Focusing only on the mass of fiber combining with the air is the flaw in the theory. Suppose you had a volume packed with 0.5 lb/ft^3 of fiber (fiber and air density is now ~0.575 lb/ft^3) and you compress the volume to half its original size. Picture in your mind releasing it, the fiber tangle will slowly rebound towards the original volume. It returns to the original volume because the fiber tangle has stiffness, it is slow returning because of the friction between fibers as they shift and rub against each other during expansion. The fiber tangle has mass, stiffness, and friction (damping).

The predominant theory of fiber damping in TLs used today is that the air moves through the fiber tangle and is damped by viscous forces, related to the oscillating velocity of the air interacting with the stationary fiber tangle. The fibers do not move acoustically but act as a skeletal structure. There is a slight slowing of the speed of sound as the compression and rarefication cycle of the air moves away from an adiabatic process towards an isothermal process. There are examples of TL design software that are consistent with this theory and the predictions match the measured result closely, everything checks."

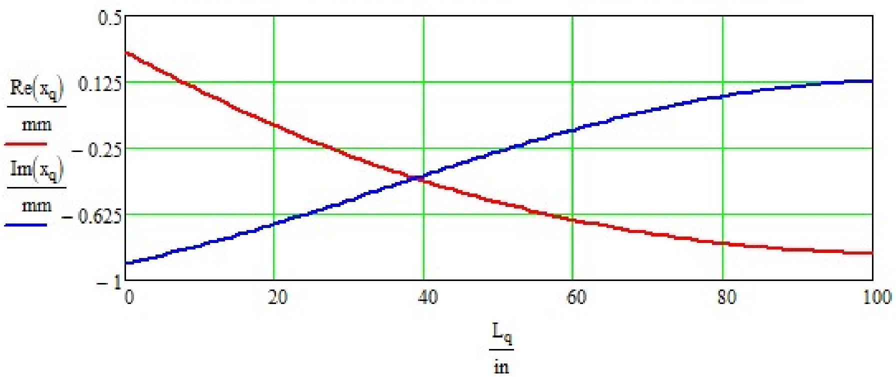
Thinking of the fiber tangle (or a foam lining) as a structure with mass, stiffness, and damping is the key. You cannot derive a theory of air motion in a TL acoustically coupling to the damping material without including all three physical properties of the damping material. No magical or mystical properties involved.

Some more food for thought. The following slide plots the RMS oscillating air displacements in a typical straight constant cross-sectional area end loaded TL at the first four standing wave frequencies (SPL = 90 dB/2.8284 volts/m and 0.5 lb/ft^3 of fiber stuffing). The fiber damping is intended to **keep** the SPL output from the first standing wave, the tuning frequency, and **attenuate** the higher harmonics to control the ragged/wiggling/wavey SPL response. The oscillating air motions are tiny, no resemblance to fluid flow producing vortices (another one of my pet peeves).

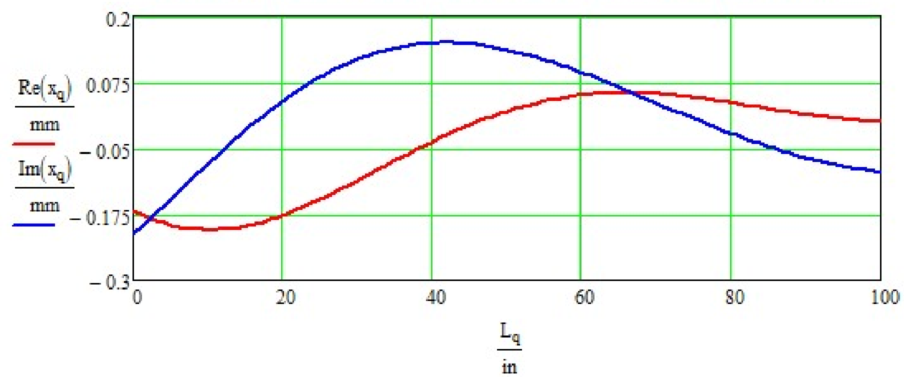
Conclusions : I don't believe the moving fiber models for TL simulations; measurements do not correlate with predictions. Modeling the fiber (or foam) as frequency dependent viscous damping that does not acoustically move with the air produces computer models that accurately predict measured results. The newer (post 2000) simulation programs for designing TLs are all based on this principle and have proven to be very accurate.

Typical RMS Oscillating Air Displacements in a Damped TL at the Standing Wave Frequencies

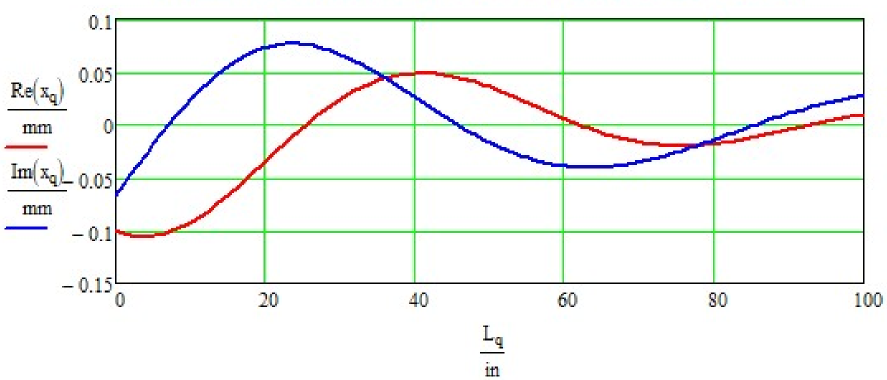
Displacement Profiles in the Pipe - Impedance Null (32 Hz)



Displacement Profiles in the Pipe - 3/4 Standing Wave (101 Hz)



Displacement Profiles in the Pipe - 5/4 Standing Wave (162 Hz)



Displacement Profiles in the Pipe - 7/4 Standing Wave (225 Hz)