A knowledge of the surface impedance of a resonant surface backing a fibrous layer can be insufficient when calculating the absorption of the combined system

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1 Introduction

Complex structures, such the acoustically absorbing honeycomb (AAH) structure [1] shown in Fig. 1, can be modeled in full 3D with the thermo-viscous acoustics module in COMSOL Multiphysics [2] to obtain the absorption as well as the complex surface impedance. The latter can then be used in a simpler 1D model of the impedance tube, where the surface impedance is used as the tube's boundary condition instead of explicitly modeling the actual structure. The same could be done with a fibrous layer, first modeling its full thickness, and then replacing that fiber domain with its surface impedance; the equivalence is shown in Fig. 2.

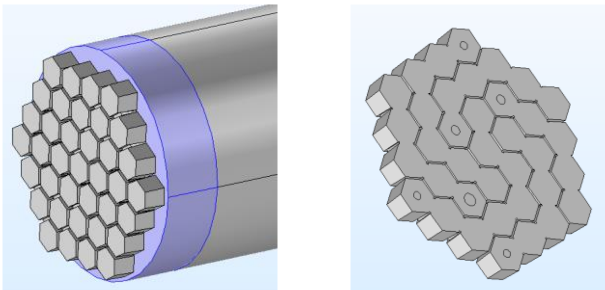

*Figure 1: **Left** – Virtual 100 mm impedance tube with complex-connected honeycomb structure at the end. The blueish region is initially an air domain and is later replaced with a fibrous layer. **Right** – The interconnected hexagons form channels of various lengths with various openings.*

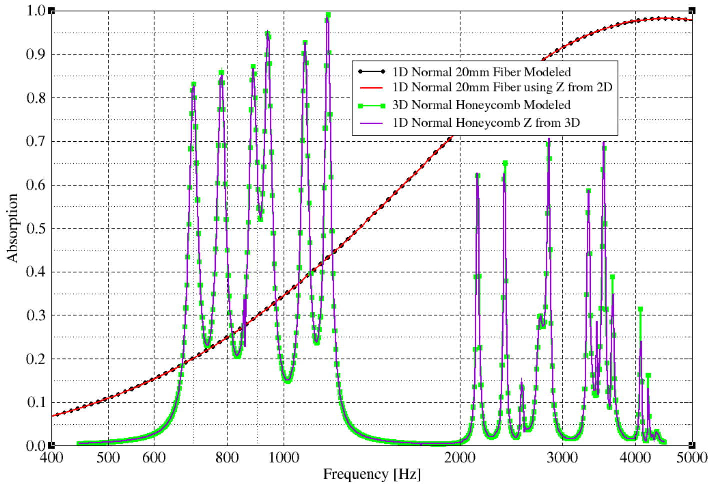

Figure 2: Demonstration that modeling the complex honeycomb in 3D (green) can be replaced with the surface normal impedance in a 1D model (purple). The same can be done for a fibrous layer.

2 Modeling Results

However, care must be taken when using the surface impedance in more complex, multilayer models. For example, it has been found that when trying to model a fibrous layer in 1D, overlaying a surface whose normal impedance was determined from the 3D thermo-viscous AAH model, the results do not match those of the full 3D model where the fiber layer is included along with the explicitly-modeled 3D structures. In both cases the fibrous layer was modeled as a complex fluid using the Delany-Bazley formulation, with its 20 mm depth.

As can be seen in Fig. 3, the full 3D model (dark blue) shows the individual peaks and valleys are completely averaged out and the absorption curve is very smooth. On the other hand, when the surface impedance of the

AAH is used on the back side of the fibrous layer (light blue), the peaks are almost identical to the untreated sample, but the troughs are less deep. These dramatically different results prompted us to perform some experimental verification.

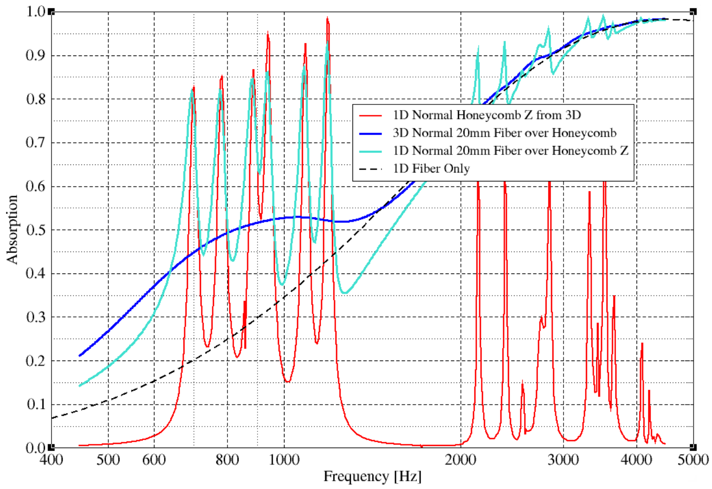

*Figure 3: **Red** – AAH from 3D model. **Dark Blue** – 20 mm Fiber. 20,000 MKS-Rayl/m, over 3D AAH model. **Light Blue** – 20 mm Fiber over the AAH surface impedance. **Black Dashed** – 20 mm Fiber only.*

3 Experimental Results

A 3D printed version of AAH, with 4 resonances, was tested in a 100 mm impedance tube, with and without an overlaying 20 mm fibrous layer with a flow resistivity of approximately 15,000 MKS-Rayl/m. As seen in Fig. 4, the behavior of the AAH with a top fiber layer (green curve) behaves very similarly to the full 3D AAH model with fiber.

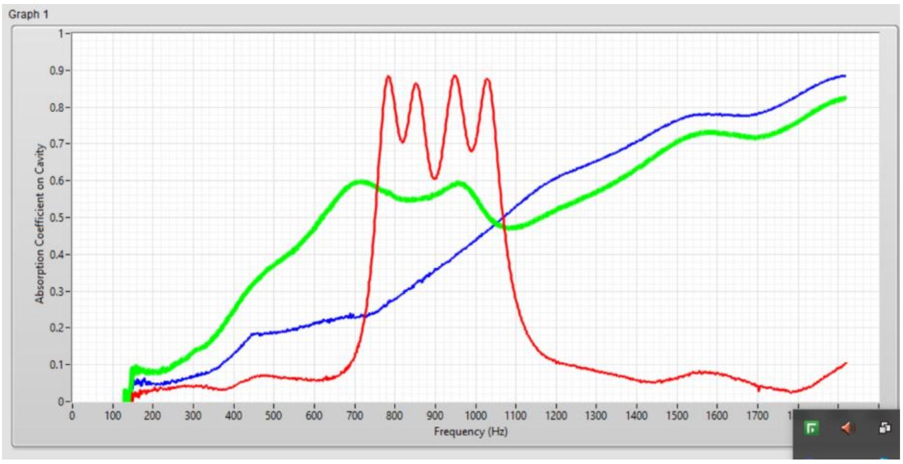

*Figure 4: **Red** – AAH test article only. **Blue** – 20 mm Fiber only, approximately 15,000 MKS-Rayl/m. **Green** – 20 mm Fiber over the AAH test article.*

4 Conclusion

One cannot take the normal surface impedance of a complex structure and add layers of other materials, e.g., represented by complex fluids, to obtain the absorption of the composite structure. Instead, a full model of the materials, including the structure, is required to obtain the true absorption. This is likely due to the near-field hole-to-hole interactions, which are significantly affected by the presence of the fiber layer, are completely eliminated when only using the apparent far-field surface impedance of the structure.

5 References

[1] J. Jonza, T. Yoo, T. Herdtle, J. Kalish, R. Gerdes, G. Eichhorn, *Acoustically Absorbing Lightweight Thermoplastic Honeycomb Panels*, INTER-NOISE and NOISE-CON Congress and Conference Proceedings 254 (2), 210-219.

[2] COMSOL Multiphysics v. 5.5. www.comsol.com. COMSOL AB, Stockholm, Sweden.