Modeling and Testing of Carbon-Fiber Doubly-Resonant Underwater Acoustic Transducer

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Abstract

This work focuses on the COMSOL Multiphysics® finite element modeling of a new underwater sound source [1] and the comparison of its results with an experimental test. Deep-water low-frequency organ pipe transducers are used in underwater ocean acoustic tomography, long-range navigation and communications. Such sound sources can be used for navigation of underwater gliders in the Arctic [2-5]. When the single-resonance organ-pipes do not provide sufficient bandwidth, a doubly-resonant organ pipe provides transmission of arbitrary waveforms over a much wider frequency band. As with the single-resonance pipes, the sources can be used at all depths and are efficient and very light if built from composites. The doubly-resonant organ pipes comprise an inner resonator tube with thin walls tuned to a certain frequency surrounded by a larger-diameter tube, Figure 1. The projector is driven by a monopole acoustic source attached by shock-mounts inside the inner resonator. These resonating tubes are open on both ends and typically made of aluminum or carbon-fiber. The tubes are asymmetrically shifted along the main axis and sound pressure can penetrate from the internal pipe though the area under the shifted external pipe into that external pipe and back. By changing the length of the shifted area, the coupling coefficient of two resonators can be regulated to achieve the desired bandwidth. The resulting resonant frequency is proportional to the pipe length. The radiated power from the resonators is proportional to the area of the orifices and the square of the propagated frequencies. To achieve a symmetrical frequency response the radiated power both resonators should have close resonant frequencies and a precise level of resonance coupling. The frequency response is very sensitive to the resonator parameters and the resonator needs to be tested in water and adjusted according to the testing results. It is time consuming especially for a new design. The numerical simulation helps to predict the required parameters of the resonator and save some time necessary for fine-tuning in water. The sound source was designed and then simulated with finite element analysis. We used the COMSOL Acoustic-Structure Interaction interface and made the simulation for an aluminum variant of the resonator. The prototype of an aluminum variant sound source was built and tested in an acoustic pool. The test results were very close to the simulation. Finally, we built the carbon fiber prototype with the stiffness of pipes close to aluminum variant. The doubly-resonant sound source was tested in water at the Woods Hole Oceanographic Institution and it exhibited a high electro-acoustical efficiency and a high power output over a large operating band. The parameters of the sound source, after a little fine-tuning, were reasonably close to the COMSOL simulations.

Reference

[1] Morozov A.K. Broadband Sound Source for Long Distance Underwater Sound Propagation, patent application US 20120269037.

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[3]Morozov A.K., Manley J.E., Jones C.P., Unmanned Vehicles and Acoustics for Under Ice Environmental Monitoring Proceedings of Arctic Technology Conference, 3-5 December 2012.

[4] Morozov, A.K., T.W. Altshuler, T Clayton P. Jones, L.E. Freitag, P. A.Koski, and S. Singh, Underwater Acoustic Technologies for Long-Range Navigation and Communications in the Arctic, In Int. Conf. Underwater Acoustic Measurements: Technologies & Results, Kos, Greece, J. S. Papadakis and L. Bjorno, 2011.

[5] Morozov A.K, Altshuler T.W, Jones C.P., Freitag L.E., Koski P.A. Acoustic Technology for Glider Long-Range Navigation and Communications. 6-th Biannual NRC-IOT Worshop on underwater vehicle technology. National Research Council Canada (NRC), Institute for Ocean Technology (IOT) St. John's, Newfoundland, Canada October 21-22, 2010.

Figures used in the abstract

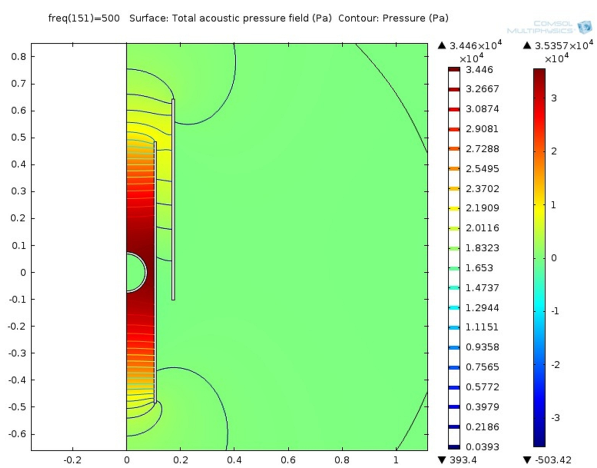

Figure 1: Sound pressure in the resonant system at 500 Hz.