

Modelling of Thermoacoustic Effect for Sound Generation: Literature's Theory State of the Art Compared to a New Complete Model.

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Abstract

Electroacoustic transducer using a coil/magnet core inducing the vibration of a membrane system in order to generate sound waves are the most common and widely used way to generate sound. Piezoelectric devices are also used for sound generation for specific applications like underwater sound generation for sonars. If the efficiency of those transducers have been proven, they are all generating sound with a mechanical vibration which is a resonant mechanism and no wideband sound generator alternative solutions are currently available. The thermoacoustic effect is based on applying an alternative current to a material with a high thermal conductivity and a low thermal capacity. The heat profile of the material follows the current profile and the compression dilatation of the air on the surface of the material due to the fluctuating heat generates an acoustic wave whose frequency is proportional to the input frequency of the current. Since no resonating part are involved in the process the generation is wideband.

Since the publication in Letters to Nature by Shinoda in 1999 [1] of a working thermoacoustic device based on porous silicon, the interest for the thermoacoustic effect and its application have gained momentum. The thermoacoustic effect has been known for over a century since Arnold and Crandall [2] have tried to theorize the principles but the limitations in terms of relevant thermophone materials have prevented the research to be pursued. Nanomaterial and the ease of access to new fabrication process have allowed new processed materials to be used as thermophones. Recent papers are using various suspended metal wires (in carbon [3], aluminum [4]...) or other carbon based structures (2D paper [5], 3D foam [6]) as thermophones. However, if the number of potential efficient thermophone is on the rise, a general theory about thermoacoustic generation is still missing. Many papers have their own model or try to improve pre-existing models [7-13] but the hypotheses, the models and the parameters used change between one paper to the other, leading to differences in the results and their interpretations.

This paper will propose a global and flexible theoretical model of the thermoacoustic sound generation that makes no assumption on the behavior of the propagating medium or the generating solid. The model's equations are based on the conservation of mass, momentum and energy and are solved for planar, cylindrical or spherical source in liquid or solid mediums. The presented model will be compared to the main pre-existing models and will analyze the influence of the hypothesis made in the previous models on the results. Once this model is validated it will be available to help designing thermophone and improve their efficiency.

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