

Thermoacoustic sound generation model in porous nanomaterials

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Traditional sound generation transducers are using a magnet/coil/membrane system to induce a particle velocity boundary condition to move the air in order to produce sound. Piezoelectric devices are also electromechanical transducer that are also used for sound generation in cases where common loudspeakers fail to perform (underwater sound generation, high frequency sound generation...) However, both devices share the same limits being having a non-flexible design and no broad band sound generation (resonant behavior).

The thermoacoustic principle is a novel way of generating sound. When an alternative current is applied to a nanomaterials having a high thermal conductivity and low thermal capacity, the heat profile of the material will follow accurately the electrical one. The air in the vicinity of the sample will compress and dilate due to the rapid heating and cooling, thus creating a pressure boundary condition, as opposed to a velocity one, generating a sound wave. Theoretically this principle is independent of the geometry of the sample and is broadband, ranging from a few Hertz to several Mega Hertz.

This principle was known for more than a hundred years^[1] but has recently gained interest due to new technologies improving the ease of fabrication and access of certain nanomaterials. In the last two decades many nanomaterials have been tested as potential thermophone sources^[2] like suspended metal wires (carbon, gold, aluminum...) or carbon based material in different shapes (laser scribed, paper, sponge, nanotube forest, foam...).

Nevertheless, due to the only recently gained momentum of the field and of the complex geometry of most thermophones, there is no current global theory about thermoacoustic generation. Models are approximated on a case by case basis and focus mostly on the acoustical hearing range in air. This paper will propose a novel broadband model that takes into account the complex geometry of 3D thermophones, and most specifically, foam like material. The thermal equilibrium is assumed to not be achieved inside the sample and a two temperature method will be used to analyse the 1D response of a thermophone in free field. The model's equations are based on the conservation of mass, momentum, energy in the fluid and the conservation of energy in the solid. This model will then be compared to the solution provided by one of the most recent approach for thermoacoustic generation^[3] (based on a one temperature model), assuming a continuous thermophone but considering the sound propagation in the solid.

Keywords

Thermoacoustic - Thermophone - Porous Material - Two Temperature Model

References

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