INFLUENCE OF TEMPERATURE GRADIENTS ON THE FAR FIELD RADIATION OF FLAMES INSIDE A COMBUSTION CHAMBER

Rafael Piscoya, Martin Ochmann
University of Applied Sciences; Luxemburger Str. 10, 13353 Berlin, Germany;
piscoya@tfh-berlin.de , ochmann@tfh-berlin.de

The interaction between sound waves and combustion plays a significant role in the behaviour of flames that are inside a combustion chamber. Therefore, numerous research works are being carried out to understand the effects of sound waves on the flame structure, and several methods and models are being developed to characterize the sound sources inside the chamber. However, the noise pollution is determined by the sound radiated to the outside of the combustion chamber and the prediction of the sound radiation, in particular of the external radiation pattern, becomes a subject of great importance, too.

The sound field outside the combustion chamber can be determined using well-established acoustical methods like the Boundary Element Method (BEM) or the Equivalent Source Method (ESM) if the vibration of the combustion chamber is known. The BEM and the ESM programs that we have implemented, use the normal velocity of the structure or the sound pressure at a Kirchhoff surface surrounding the flame to compute the sound pressure distribution in the far field, but the impedance of the structure could also be used as input for the calculation, depending on the information that is available.

When the combustion chamber is not totally closed and has an exit to allow hot gas to escape from the chamber, there is a region of hot air or gas (inhomogeneous medium) surrounded by air at ambient temperature (homogeneous medium) immediately outside the chamber exit. In this case, the BEM or ESM would provide some error because both methods assume that outside the vibrating structure, the homogeneous Helmholtz equation holds. Since the BEM and ESM work also with fictitious surfaces, the problem could be still solved with both methods if the control surface is extended to enclose the region of hot gas. This approach was taken in earlier works to determine the sound radiation of open flames (see [1],[2]).

In the present work, we consider the region of hot gas as a volume outside the control surface (combustion chamber) with a certain (conceived) temperature distribution and solve the wave equation rearranged in form of an inhomogeneous Helmholtz equation. The Helmholtz equation is solved by taking its integral form and replacing the volume integral in terms of surface integrals alone using the Dual Reciprocity BEM approach [3],[4]. This work is an extension of a previous work considering a spherical open flame, which has an analytical solution [5].

In Fig. 1a the geometry of the problem is illustrated. The combustion chamber is defined by surfaces S_0 and S_1 and the volume of hot gas is delimited by S_2. In a first approximation, the normal velocity of the chamber walls is taken to be zero, while a velocity distribution is given only at the exit (S_1). For the case under study, the temperature distribution assumed inside S_2 is shown in Fig 1b.

The sound radiation obtained from this configuration is compared with the case where no temperature gradient is considered at the exit of the combustion chamber. The same velocity distribution at S_1 is used in both cases. In Fig. 2 the sound power and the radiation patterns at three different frequencies are compared. At low frequencies, the temperature distribution does not affect the sound radiation at all. Beyond 500 Hz, the sound power shows a slight decrease and the radiation patterns tend to broaden with increasing frequency.

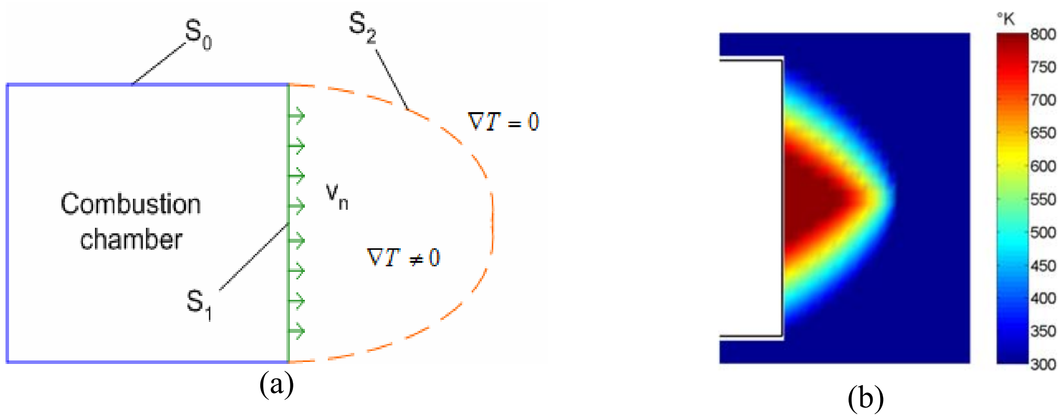

Figure 1: a) Geometry of the combustion chamber; b) Temperature distribution at the chamber exit.

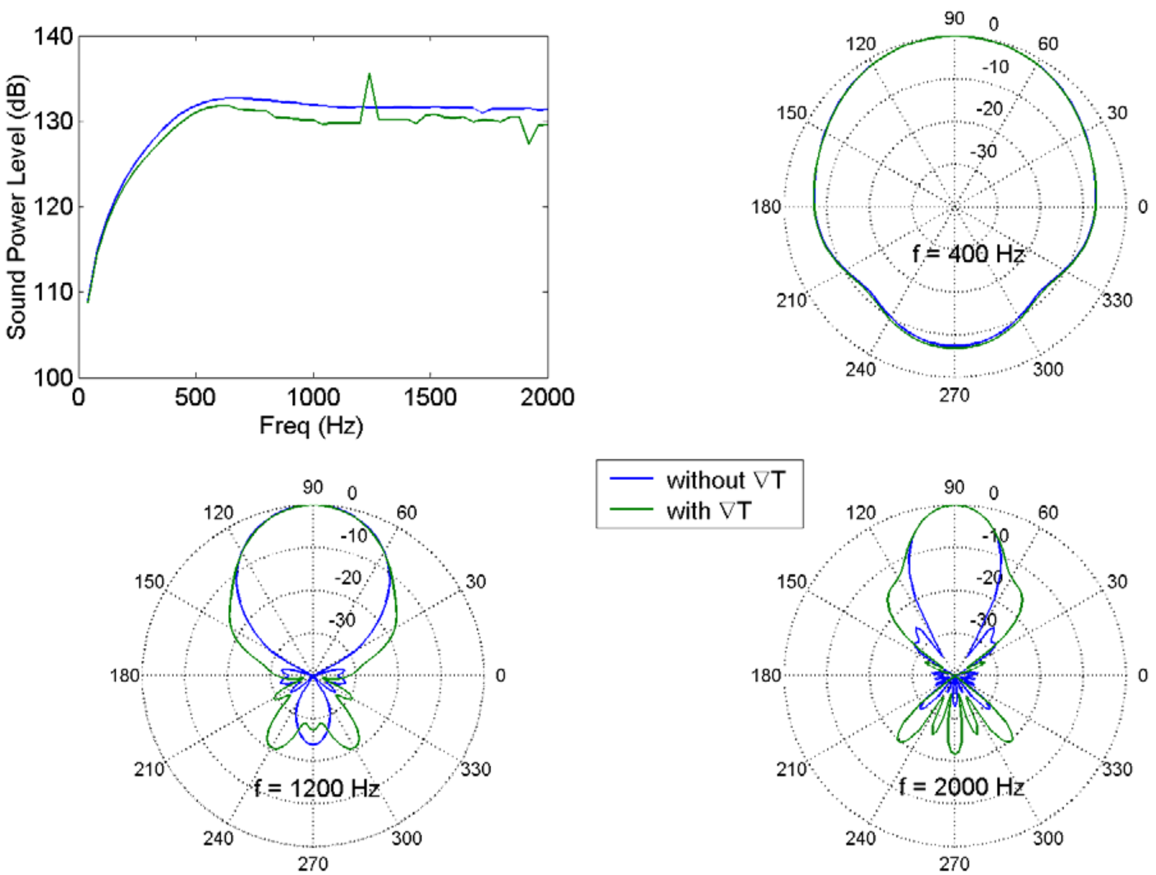

Figure 2: Comparison of the sound power level and the radiation patterns between the cases $\nabla T = 0$ and $\nabla T \neq 0$.

References

[1] H. Brick, R. Piscoya, M. Ochmann, P. Költzsch: Prediction of the Sound Radiated from Open Flames by Coupling a Large Eddy Simulation and a Kirchhoff-Method. Proceedings Forum Acusticum – Budapest (2005)

[2] R. Piscoya, H. Brick, M. Ochmann, P. Költzsch: Application of equivalent sources to the determination of the sound radiation from flames. Proceedings 13th International Congress on Sound and Vibration - Vienna (2006)

[3] E. Perrey-Debain, Y. Gervais, M. Guilbaud: Calcul de la propagation acoustique en milieux non homogènes infinis par la DRBEM, C. R. Acad. Sci. Paris t. 326, Serie II b (1998), 649-656

[4] E. Perrey-Debain: Analysis of convergence and accuracy of the DRBEM for axisymmetric Helmholtz-type equation. Engineering Analysis with Boundary Elements **23** (1999), 703–711

[5] R. Piscoya, M. Ochmann: Schallabstrahlung einer kugelsymmetrischen Flamme. Fortschritte der Akustik - DAGA 2007, Stuttgart