COMPARISON OF THE SOUND RADIATION OF OPEN FLAMES SIMULATED BY A HYBRID APPROACH USING LES AND ESM

Haike Brick[a], Rafael Piscoya[a], Martin Ochmann[a], Peter Költzsch[b]

[a] University of Applied Sciences; Luxemburger Str. 10, 13353 Berlin, Germany;
[b] Technical University Dresden, 01062 Dresden, Germany
[brick, piscoya, ochmann]@tfh-berlin.de , Peter.Koeltzsch@ias.et.tu-dresden.de

In the German research project "Combustion noise", simulation tools for combustion noise are in development [3]. This is a complex task taking into account that it involves both the noise generation due to the processes in the reactive zone (i.e. turbulent flow and combustion) as well as the propagation of sound waves through a turbulent region to the surrounding medium. Due to its complexity, a direct numerical simulation (DNS) is not possible and hybrid methods have to be applied. The use of the Equivalent Source Method (ESM) coupled to a incompressible Large-Eddy-Simulation (LES) to compute the sound field of open flames is one of the subjects that are being investigated by the research project. The LES provides velocity data from the flow field on a control surface, which entirely encloses the combustion zone and with the ESM it is possible to determine the acoustic field outside this control surface by evaluating the surface data.

In the course of the research project, the sound radiation of open flames of three different types was investigated, i.e. non-premixed jet flames (H3 and HD), which are benchmark flames of the TNF workshop [2], a non-premixed swirled flame (TD1) and a premixed swirled flame (TECFLAM). Previous results for the H3 and HD-flame are published in [1], [4], [8]. Details for the used ESM, like positioning and characteristics of the equivalent sources can be found in [9] and [10], the LES approach is described in detail in [5-7]. In the present work, the focus lies on a comparison of the characteristics of the sound radiation of the investigated flames.

With the ESM, the sound power and the directivity of the radiated sound field for selected frequencies were determined. Fig.1 shows the radiated sound power level of the HD-, H3-, TD1- and TECFLAM-flame. In case of the first three flames (HD, H3 and TD1), also measurements of the sound power were done. For the HD flame, the resulting sound power is in good agreement with the measured spectra. For the H3- and TD1-flame, the measurement results differ significantly from the simulation results. Though H3- and TD1-flame are very different types of flames (jet vs. swirled flame), the characteristics of the measured and simulated spectra are very similar, also with respect to the discrepancies between measurement and simulation. The LES-model for the simulation of non-premixed swirled flames is currently in progress and an improvement of the results is expected for the future. The sound level spectrum of the the premixed swirled flame (TECFLAM-flame) shows a minimal decrease of the sound power with increasing frequency compared to the other flames. A comparative measurement of the radiated sound power for this flame is not available yet.

All flames show a uniform radiation at low and middle frequencies up to about 250 Hz. At higher frequencies the directivity is focusing in direction of the flame axis for the jet flames and TD1. For the TECFLAM-flame, the focus is directed perpendicular to the flame axis with increasing frequency – radiation pattern of jet flame and swirl flame are nearly „orthogonal“! Fig.2 shows the directivity at a frequency of 2000 Hz for the four investigated flames, where the mentioned characteristics in the higher frequency range can be observed.

In the presentation details of the flame's simulation will be given and the drawbacks and opportunities of the simulation process will be discussed.

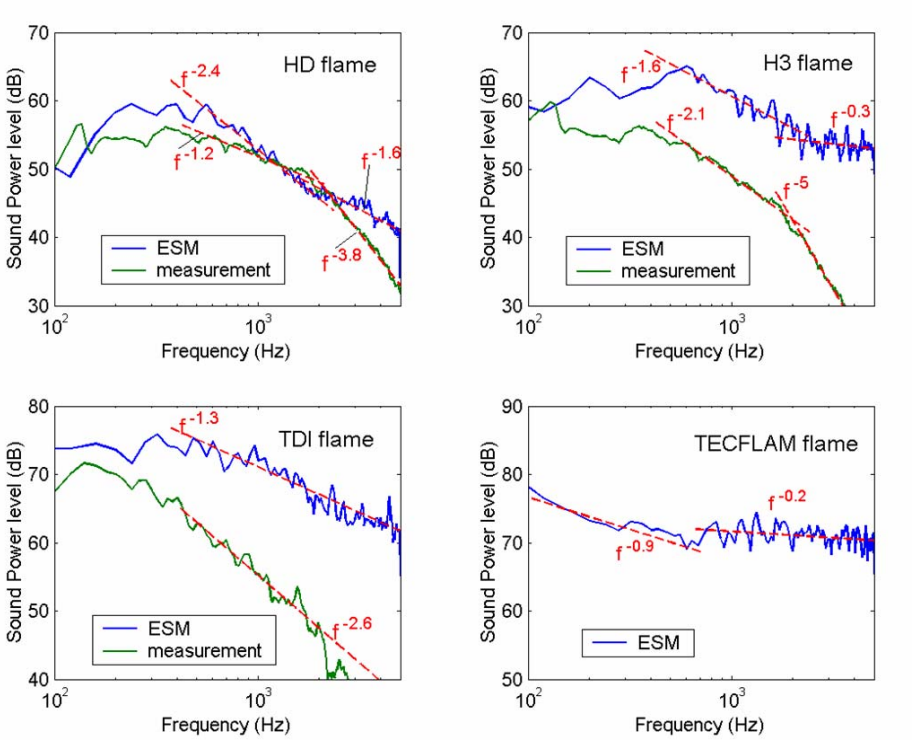

Fig.1: Spectra of sound power level for different open flames

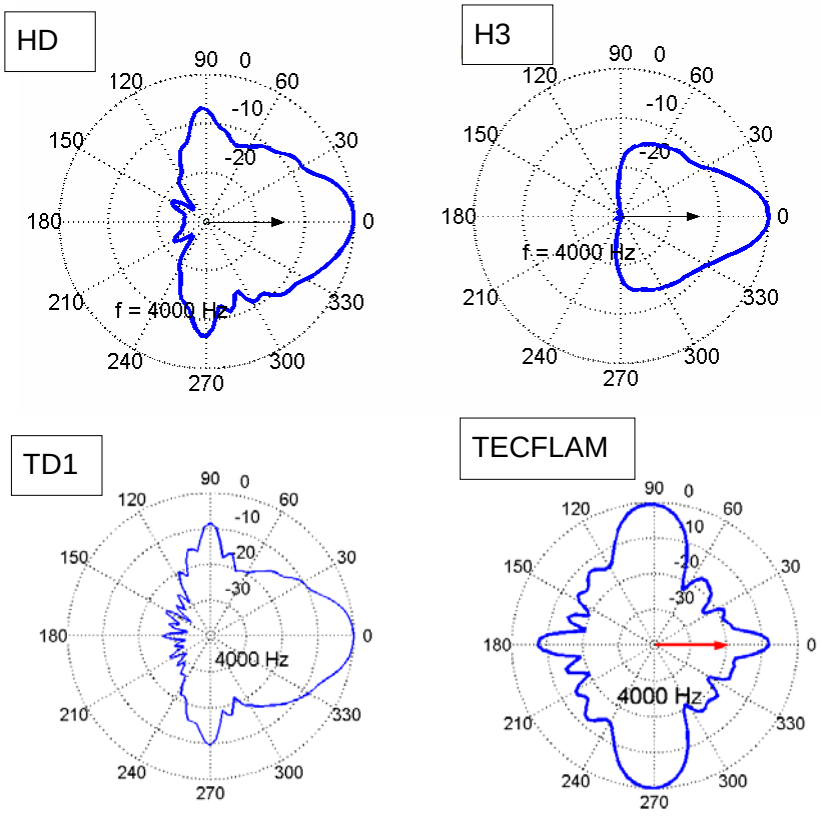

Fig.2: Directivity of the investigated open flames at a frequency of 4000 Hz, the arrows indicate the flame axis and the flow direction

References

[1] 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. Barlow (ed.), *Proc. of the TNF Workshop*, Sandia National Laboratories, Livermore, CA, URL: `www.ca.sandia.gov/TNF`

[3] Combustion Noise Initiative, URL: `http://www.combustion-noise.de`

[4] F. Flemming et al.: A hybrid approach for the evaluation of the radiated noise from a turbulent nonpremixed jet flame based on Large Eddy Simulation and equivalent source & boundary element methods, *Proc. ICSV12*, Lisbon, Portugal (2005)

[5] F. Flemming: On the Simulation of Noise Emissions by Turbulent Non-Premixed Flames. Dissertation, Darmstadt University of Technology, Germany (2006)

[6] M. Freitag, J. Janicka: Investigation of a strongly swirled unconfined premixed flame using LES. *Proc. Combust. Inst.* **31**, 1477-1485, (2007)

[7] A. Kempf, F. Flemming, J. Janicka: Investigation of lengthscales, scalar dissipation, and flame orientation in a piloted diffusion flame by LES. *Proc. Combust. Inst.*, **30**, 557-565 (2005)

[8] R. Piscoya, H. Brick, M. Ochmann, P. Költzsch: Equivalent Source Method and Boundary Element Method for calculating combustion noise. *Acta Acustica united with Acustica*, 2007, submitted

[9] R. Piscoya, M. Ochmann, H. Brick, P. Költzsch: Modelling of the combustion noise by means of the equivalent source method (ESM). *Proc. Joint Congress CFA/DAGA'04*, Strasbourg, France, 119-120 (2004)

[10] R. Piscoya, H. Brick, M. Ochman, P. Költzsch: Numerical aspects of the Equivalent Source Method applied to Combustion Noise. *Proc. 12th Int. Congress on Sound and Vibration ICSV12*, Lisbon, Portugal (2005)