ACOUSTIC STREAMING MEASUREMENTS BY PIV

E. SAINT ELLIER[1,c], Y. BAILLY[1], L. GIRARDOT[1], D. RAMEL[1], P. NIKA[1]

[1]Institut FEMTO-ST - Franche-Comté Electronique Mécanique Thermique et Optique - Sciences et Technologies, Belfort

[c]Corresponding author: Tel.: +33384578236; Email: emeline.saint@femto-st.fr

KEYWORDS:

Main subjects: flow visualization, thermoacoustic
Fluid: pulsed flow
Visualization method(s): particle image velocimetry
Other keywords: image processing, acoustic streaming

ABSTRACT: The focus of this study is placed on the streaming flows and the non-linear effects of the Rayleigh streaming in a cylindrical acoustic resonator. It was achieved within the framework of researches in thermoacoustics. Indeed in this domain, acoustic streaming lead to a degradation of the thermoacoustic machines performances [4]. And therefore knowing and evaluating experimentally these effects would be useful to later either suppress or use them in order to improve the system performances. Acoustic streaming is what is called to describe the threedimensional second order steady flow induced in any fluid flow that is dominated by its fluctuating components. It is superimposed on the first-order acoustic oscillations [3]. By being the source of a steady mass flux that modifies the axial temperature gradient inside the stack, the acoustic streaming reduces the machines efficiency, since it doesn't contribute to energy conversion (in case of an engine).

Previous studies have been developed on acoustic streaming measurements. However few experimental works has been done. We can quote Nabavi M and al. [2] who applied PIV to steady acoustic waves inside a square section straight resonator at atmospheric pressure. For a wider analysis of non linear acoustic effects, we can report to the study carried out by Debesse P. and al. [1] who adapted the PIV to the second order flow measurements inside a linear thermoacoustic engine.

The work presented here offers an alternative method. Performed by PIV, the study allows highlighting the acoustic streaming within a straight resonator by analyzing the velocity fields. It has been applied to a 6.84m half-wave resonator. It is made of five segments of stainless steel with an inside diameter of 56.3mm. A shaker, acting as acoustic source, provides a standing acoustic wave which frequency and displacement amplitude can be defined in order to satisfy the outbreak conditions of acoustic streaming (based on the drive ratio –ratio of the acoustic pressure amplitude over the mean pressure). The seeding system was achieved thanks to an aerosol generator of DEHS (Di-2-Ethylhexyl-Sebacat). The droplets generated have a size of the order of 3µm and have a lifetime of 4 hours avoiding the resonator obstruction. The PIV measurements are conducted at atmospheric pressure and phase synchronised (so that the time period is swept) together with temperature readings and pressure measurements. In addition to the PIV measurements the resonator is indeed equipped with several pressure transducers and thermocouples.

The methodology developed can then trace the temporal evolution of the acoustic velocity and extract the streaming profiles for different drive ratios Dr.

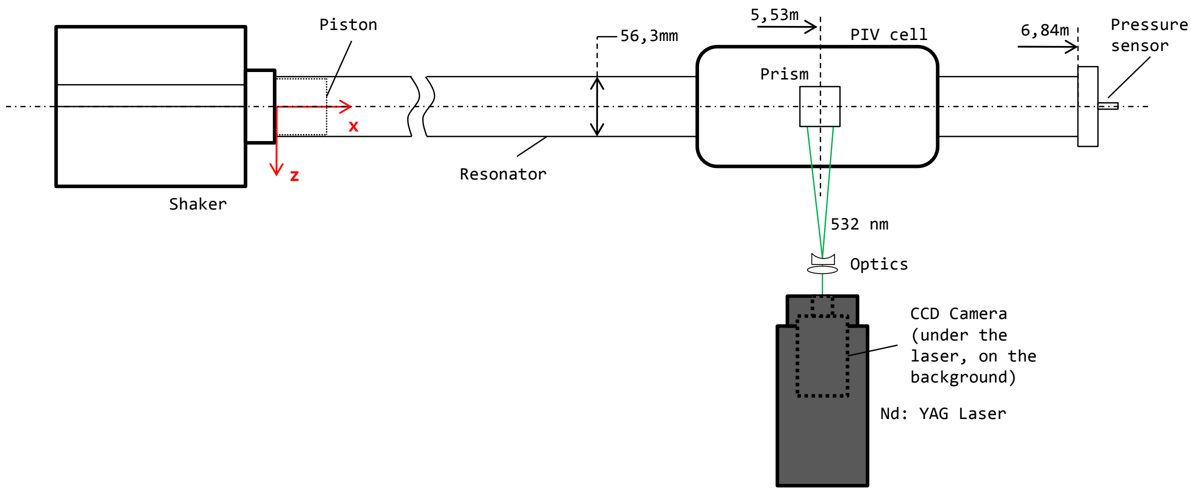

Fig. 1 Acoustic resonator and PIV instrumentation set-up.

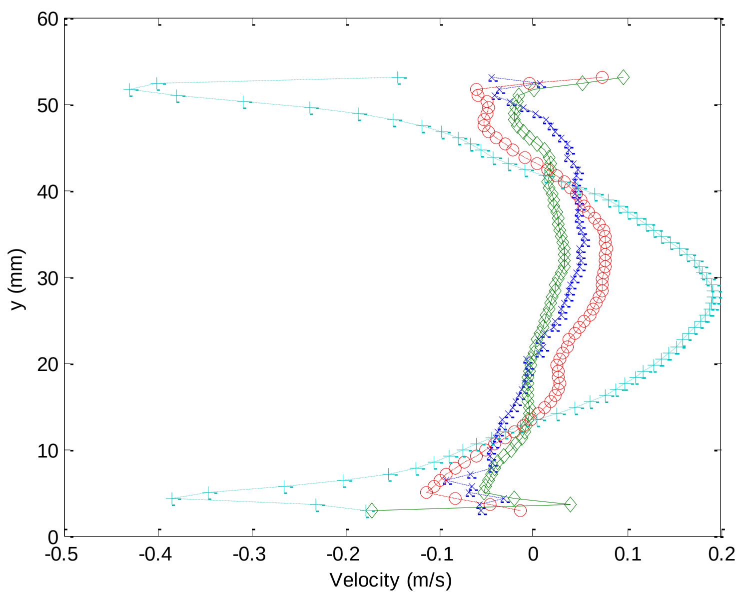

Fig. 2 Streaming velocity profiles for different drive ratios, ×: Dr=3.3%, ◊: 4.2%, o: 4.8%, +: 5.5%.

References

1. Debesse P., Baltean-Carles D., Lusseyran F., François M-X., *Adaptation de la vélocimétrie par images de particules à l'analyse des effets non linéaires en thermoacoustique*, CFTL, Toulouse
2. Nabavi M., Siddiqui K., Dargahi J., *Measurement of the acoustic velocity field of non linear standing waves using the synchronized PIV technique*, Experimental Thermal and Fluid Science, 2008, Vol. 33, p. 123-131
3. Riley N., *Acoustic streaming*, Theoritical and Computational Fluid Dynamics, 1998, Vol. 10, p. 349-356
4. Swift G. , *Thermoacoustics : A unifying perspective for some engines and refrigerators*, 2001, p. 188-198