XXIII International Symposium on Combustion Processes, 3-6 September, 2017, Rynia

Acoustical characterization of the blowout of turbulent diesel oil combustion

Viktor Józsa*

Budapest University of Technology and Economics, Department of Energy Engineering, 1111 Budapest, Műegyetem rkp. 3, Hungary

Abstract

The tightening pollutant emission standards have changed the burner design from non-premixed to premixed configurations in steady-operating combustion chambers. The typical applications incorporate, gas turbines, boilers, and furnaces. As the concentration of nitrogen oxides (NO_X) are principally affected by the flame temperature in practical applications, and the flow field has a negligible effect on its formation, lean combustion has taken over the non-premixed design [1]. To lower the flame temperature, the more dilution air is better. However, the lean blowout limits the applicable air-to-fuel equivalence ratio. Combustion noise used to be considered as a pollution source. As acoustic phenomena emerge near the blowout, it drew scientific attention to understand and control of the flame at near-blowout conditions [2].

Presently, a diesel oil-fueled atmospheric lean premixed prevaporized-type swirl burner, shown in Fig. 1, is investigated at 15 kW combustion power. The combustion air was preheated to 400 °C, and the fuel was atomized by an airblast atomizer at 0.3 bar atomizing gauge pressure. The estimated swirl number was varied from 0.34 to 0.83 by increasing the combustion air flow rate. More details on the test rig can be found in the literature [3,4]. The acoustic signal was measured by a SVAN 971 Class 1 sound level meter at 12 kHz sampling frequency.

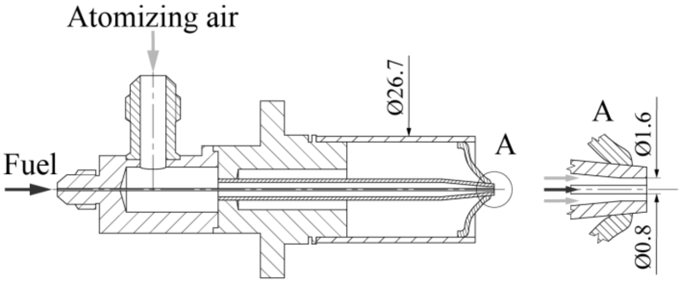

Fig. 1. The investigated burner.

Based on the swirl number, a straight, a transitory, and a V-shaped flame were distinguished based on the variation of swirl number [5]. By increasing the swirl number, the acoustic spectrum shift to the lower frequencies in parallel [2]. Hence, the phenomenon proposes a spectral analysis. Due to the considerable time evolution, the Short Time Fourier Transform (STFT) or Gábor Transform was performed first, analyzing the spectra of various stages in the flame shape. Since the blowout and its neighbor time regimes are short, narrow windowing is necessary which leads to a poor decomposition in the frequency domain even overlapping [6]. In order to overcome this issue, the Continuous Wavelet Transform (CWT) was used to calculate the spectra. The superiority of CWT over STFT originates from the fact that the typical dominant

* Corresponding author. tel.: +36-1/463-2596; fax: +36-1/463-1762, e-*mail address*: jozsa@energia.bme.hu

frequencies near the blowout are in the order of 100 Hz [2,7]. Figure 2 contains the comparison of the two methods in a 1.37 s time frame, containing the blowout at ~1 s.

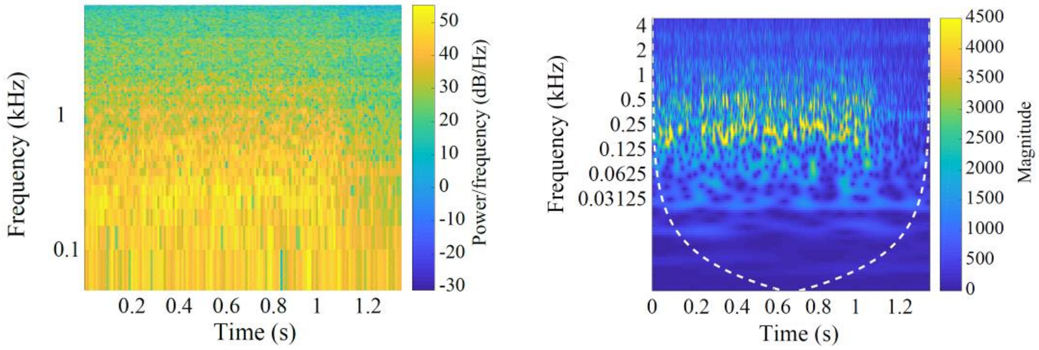

Fig. 2. STFT with 50% overlap (left) and CWT (right) of a flame blowout.

The solution of STFT is poor in the low-frequency regime, showing only the dominant frequency around 180 Hz. However, CWT reveals the first mode at 188 Hz and the second mode at 500 Hz, also highlighting their time evolution. Compared with the straight flame, the dominant alter significantly in time, and the number of these frequencies decreases from six to two. The transitory regime is also populated with characteristic peaks, however their time evolution can also be detected. A dominant mode around 500 Hz remains in the V-shaped operation, while 188 Hz mode starts to emerge. By approaching the blowout, the spectrum is governed by this latter mode, while the previous ones fade, leading to unstable combustion then flame extinction.

Acknowledgements

This paper was supported by the János Bolyai Research Scholarship of the Hungarian Academy of Sciences.

References

[1] A.H. Lefebvre, D.R. Ballal, Gas turbine combustion, third, CRC Press, Boca Raton, 2010.
[2] Y. Huang, V. Yang, Dynamics and stability of lean-premixed swirl-stabilized combustion, Prog. Energy Combust. Sci. 35 (2009) 293–364. doi:10.1016/j.pecs.2009.01.002.
[3] V. Józsa, A. Kun-Balog, Stability and emission analysis of crude rapeseed oil combustion, Fuel Process. Technol. 156 (2017) 204–210. doi:10.1016/j.fuproc.2016.11.004.
[4] A. Kun-Balog, K. Sztankó, V. Józsa, Pollutant emission of gaseous and liquid aqueous bioethanol combustion in swirl burners, Energy Convers. Manag. (2017). doi:10.1016/j.enconman.2017.03.064.
[5] J.M. Beér, N.A. Chigier, Combustion aerodynamics, Robert E. Krieger publishing company, inc., London, 1972.
[6] S. Chaudhuri, B.M. Cetegen, Blowoff characteristics of bluff-body stabilized conical premixed flames with upstream spatial mixture gradients and velocity oscillations, Combust. Flame. 153 (2008) 616–633. doi:10.1016/j.combustflame.2007.12.008.
[7] N. Noiray, A. Denisov, A method to identify thermoacoustic growth rates in combustion chambers from dynamic pressure time series, Proc. Combust. Inst. 36 (2017) 3843–3850. doi:10.1016/j.proci.2016.06.092.

Keywords: liquid fuel combustion; lean blowout; combustion noise; FFT; Wavelet; spectrogram; turbulent combustion; swirl burner; lean combustion; combustion diagnostics