Diagnosis of Flame Instabilities Using Physics-Based and Data-Driven Approaches

Somnath De, Chandrachur Bhattacharya, Sudeepta Mondal, Arijit Bhattacharya, Achintya Mukhopadhyay, Swarnendu Sen, and Asok Ray

Abstract Recently, the concept of lean combustion is widely used in different industrial sectors, such as aero-engines, land-based automobile engines, power plants, marine engines, and many more for reduced emission and economic fuel consumption. In contrast, the leaner fuel-air ratio in such a technique results in thermoacoustic instability when acoustic field and combustion variables cause a positive feedback, and a lower reaction rate of the combustion which promotes lean blowout or LBO. The occurrence of thermaocoustic instability and LBO in the running engines not only badly affects the engine performance but also leads to numerous casualties. Therefore, early prediction of those instabilities for a lean combustion operation is of utmost necessity so that the operator can get adequate lead time to take the precautionary steps. In the current chapter, we review on a few innovative approaches from the well-established nonlinear dynamics and data-driven methods to identify the transition of flame to LBO. We find three recurrence quantification analysis measures, namely, Laminarity, Determinism, and Trapping time to be promising to quantify the proximity to LBO. Further, log-likelihood ratio (LLR) based on Hidden Markov machined seems to be very useful for early LBO prediction. LLR addresses the online classification of two different kinds of transient regimes in the combustion systems. Further, we demonstrate a simple FFT based measure that can analyze the audible noise generated by the combustion process and identify the operational state of the

S. De (✉)
Department of Mechanical Engineering, Institute of Engineering & Management, Kolkata
e-mail: somnathde.mec@gmail.com

A. Mukhopadhyay
e-mail: achintya.mukhopadhyay@jadavpuruniversity.in

C. Bhattacharya · S. Mondal · A. Ray
Department of Mechanical Engineering, Pennsylvania State University, University Park, USA
e-mail: axr2@psu.edu

S. Mondal
RTX Technology Research Center, East Hartford, CT, USA

A. Bhattacharya, A. Mukhopadhyay, S.Sen
Department of Mechanical Engineering, Jadavpur University

A. De et al. (eds.), *Recent Developments in Power and Propulsion Applications*, Green Energy and Technology, https://doi.org/10.1007/978-981-96-8602-5_15

644225_1_En_15_Chapter-online ☑ TYPESET ☐ DISK ☐ LE ☑ CP Disp.:18/7/2025 Pages: xxx Layout: T1-Standard