Abstract

Strict emission norms have led to development of low NO_x combustion technologies. These technologies however, are susceptible to lean blowout (LBO) and thermoacoustic instability (TAI) which can prevent the combustor to run safely and reliably. The LBO/TAI limit depends on several operating conditions outside of human control. Therefore, it is importance to devise reliable techniques that can early predict LBO and TAI limits so that onset of LBO/TAI can be prevented. To understand and develop metrics for early detection of LBO and TAI, we study the flame behavior in isolated and interacting flame in various configurations. We explore the dynamical characteristics of thermoacoustic instability (TAI), in a Rijke tube with an inverse diffusion flame (IDF). We uncover various significant differences in the dynamic characteristics of inverse diffusion flame and lean premixed flame at the thermoacoustic instability state. Next, the flame behavior in a lean premixed single-burner combustor (SBC) prior to LBO is studied. The SBC suffers LBO without a preceding TAI, as the equivalence ratio is reduced. We show that the dynamical transition to LBO in this case is considerably different than when LBO occurs with a preceding TAI. We find that the recurrence network (RN) is a robust LBO detection tool suitable for real-time flame monitoring. Next, we study flame behavior of two interacting candle flame oscillators (CFO). Interacting CFOs have significantly different dynamics as compared to a single isolated CFO. The dynamical transition observed due to interaction between similar and dissimilar CFOs are found to be significantly different. Next, we study the LBO phenomenon in an annular combustor (AC) and a linear array combustor (LAC). By visual inspection of flame, we observe significant differences in LBO behavior in AC and LAC as compared to SBC. Next, we study the dynamical transition to LBO in the AC and LAC. Additional complexity due to interacting flames causes established early detection tools to lose sensitivity. We propose topological data analysis (TDA), a novel dynamical science-based tool, for LBO detection. The results indicate TDA is a computationally inexpensive tool for early LBO prediction in SBC, AC, and LAC and can be used for real-time flame monitoring. Finally, the findings of this thesis work are summarized and future work recommendations are prescribed.