RESPONSE OF LAMINAR FLAMES TO ACOUSTIC WAVES

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1 Introduction

Noise problems often arise in technical combustion systems like domestic gas boilers or gas turbines. These problems are related to the interaction of acoustic waves in the complete system with the flame. Acoustic waves could lead to fluctuations in the heat release of the flame, which could amplify the acoustic wave which leads to an increase in the acoustic energy in the system, provided the Rayleigh criterion is satisfied. If this happens near eigenmodes of the system, this might lead to acoustic instability, observed through noise and possibly even system failure if the velocity and pressure amplitudes are very high.

The feed-back mechanism between the acoustic field and the heat-release fluctuations can have different origins. Sometimes, pressure waves lead to fluctuating fuel flow near the fuel injector, thereby introducing equivalence ratio variations and as a result heat release variations. However, there are multiple other ways to arrange this coupling. Here, we will consider the response of fully-premixed laminar flames with fixed equivalence ratio to a fluctuating velocity field, resembling an acoustic wave. As the pressure change in such flames is negligible, pressure fluctuations are not of influence and are disregarded. However, there are still two different mechnisms involved by which the flame acts on this perturbation. In case of flat flames stabilised on surface burners, heat-loss fluctuations are generated by the oscillating flame front, subsequently leading to heat release fluctuations. On the other hand, Bunsen-type flames are less sensitive to heat loss fluctuations to the burner. These flames display an oscillating flame surface area, leading to a fluctuating heat release in a different way. We will consider both cases due to their different physical nature.

Nowadays, lean premixed flames stabilised on surface burners or small Bunsen-type conical flames stabilised on perforated plates are mostly used in central heating systems. This study discusses the main physical phenomena expected to play a role in those systems. Knowlegde of these 'generic' flame structures might give new insight in the field of turbulent flames as appearing for instance in gas turbines. A major part of this study focusses on the evaluation of the transfer function for two fundamental flame types: Bunsen-type flames on perforated burners with slits and holes and flat flames stabilised on surface burners. The broad range of applied burner systems used nowadays in central heating systems and other household appliances may be considered as mixed variants of these two limiting situations.

As burner-flame systems can be considered as low-Mach number reacting flows, the acoustic transfer matrix (or flame transfer matrix) $\mathbf{A}$, describing the response of the flame and burner to the acoustic field,