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Flame surface density and mean reaction rate measurements in a side-wall quenching flame at elevated pressure

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The flame surface density (FSD), indicating the ratio of flame surface to volume, is an important property of premixed, turbulent flames. In numerical simulations based on the flamelet concept, its evolution is prescribed by a transport equation complemented with models for closure [1]. In case of flame-wall interaction (FWI), a key aspect of many real combustion devices, these models need to be adapted to account for wall effects [2]. For validation, Direct Numerical Simulation (DNS) and experimental data are indispensably needed.
In this study, the FSD of a premixed, turbulent side-wall quenching (SWQ) flame during FWI at 1 and 3 bar is deduced from instantaneous flame front positions derived from measurements using planar laser-induced fluorescence of the OH radical (OH-PLIF). Velocity fields are simultaneously determined based on particle image velocimetry (PIV). Spatial distributions of the mean reaction progress are determined to characterize the flame brush which is limited to a smaller area closer to the wall at 3 bar. Accordingly, wall-normal profiles of the FSD exhibit an asymmetrical shape with a near-wall peak which is more pronounced during operation at higher pressure. With increasing frequency of flame quenching, the peak values increase which is rather attributed to a reduced flame brush thickness than increased flame wrinkling. This is supported by a flame-front conditioned FSD and its variability within the data set indicating that a wall-parallel reaction zone is the dominant flame front topology in regions close to the wall. To emphasize the impact of FWI, a second definition of the FSD, accounting for flame quenching, is used similar to previous studies [3]. In a last step, the local mean reaction rate is predicted based on the FSD. While integral values of the mean reaction rate show a decreasing trend with increasing probability of flame quenching, space-averaged values increase, as the size of the reaction zone, i.e. the flame brush thickness, decreases.

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