Influence of Ozone on Flame Acceleration and Deflagration-to-Detonation Transition in Narrow Channels

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Abstracts

This work studies the impact of ozone on flame acceleration and deflagration-to-detonation transition (DDT) in narrow channels. To investigate the acceleration of reaction waves at a microscale, flame chemiluminescence and schlieren imaging techniques were employed for dynamic analysis of reaction wave propagation in a 1×1 mm^2 square microchannel. The leftmost position in the figure represents the ignition point, and the reaction wave propagates from left to right. The experimental setup involved C_3H_8/O_2 mixtures at an equivalence ratio of 0.7. In the detonation experiments, it was observed that under lean stoichiometric conditions, the addition of ozone accelerated the deflagration flame speed and advanced the timing of detonation waves, as shown in Fig. 1. By analyzing the position-time relationship using the two imaging techniques, and subsequently taking the derivative of time using the central difference method, the velocity-time relationship of the reaction wave was obtained, as shown in Fig. 2.

The influence of ozone on the flame speed of C_3H_8/O_2 was investigated. With an initial gas temperature set at 1000 K, the effect of C_3H_8/O_2 mixtures on ignition delay time was calculated under different equivalence ratios and pressure ranges of 0-31 atm. The difference in ignition delay time was compared between cases without ozone and cases with the addition of 5000 ppm ozone. The results indicated that the reduction in ignition delay time was most significant when ozone was added at an equivalence ratio of 0.7 and a pressure of 1 atm. From the graph, it can also be observed that the effect of ozone on ignition delay time becomes smaller beyond 6 atm, as shown in Fig. 3(a). Furthermore, a detailed analysis of the oxygen reaction pathway was conducted for cases without ozone and with the addition of 5000 ppm ozone at a pressure of 10 atm, revealing little variation in reaction rates. From the earlier imaging results, it was also observed that the addition of ozone significantly affected the flame speed in the second stage (oblique shock). Under pressure influence, the reaction wave accelerated the flame propagation process, subsequently speeding up the DDT generation, as shown in Fig. 3(b).

Based on previous studies, maintaining a low temperature of the filling gas during the combustion process can reduce ozone decomposition effects and further explore the impact of ozone on the deflagration-to-detonation transition of other fuels. In the future, it is expected to combine Raman spectroscopy measurement techniques to understand and analyze the generation and transformation of combustion products during detonation processes.

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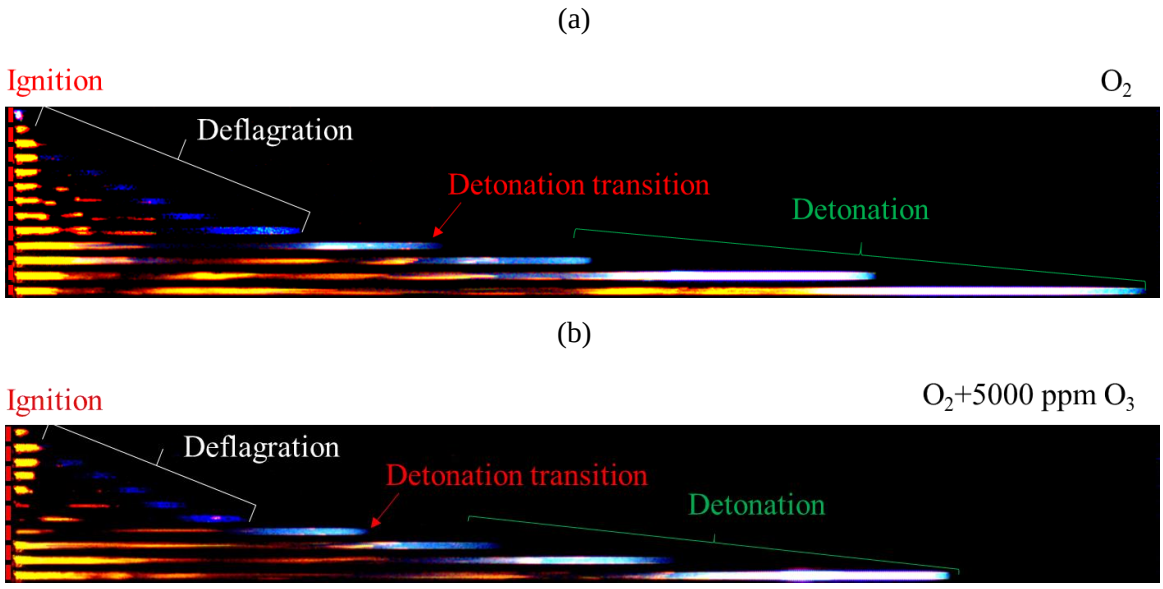


Figure 1: Flame fluorescence visualization images of reaction wave propagation in (a) propane/oxygen and (b) propane/oxygen/ozone along a channel's side.

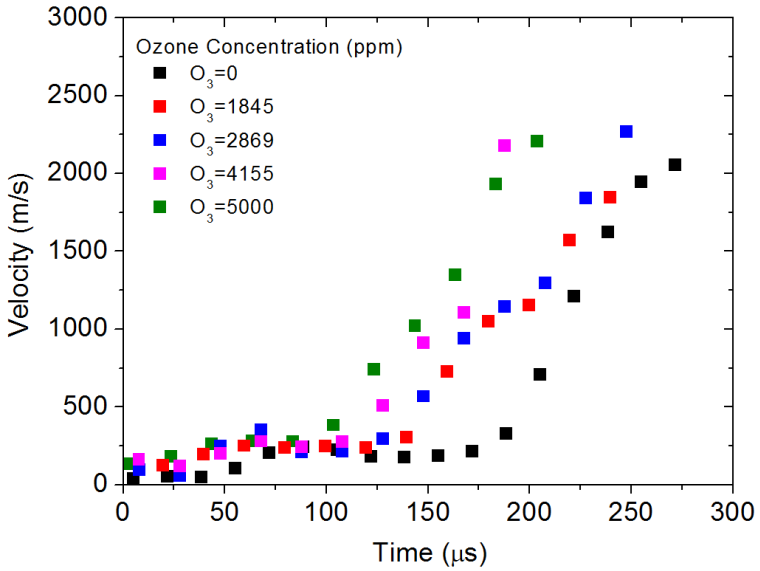
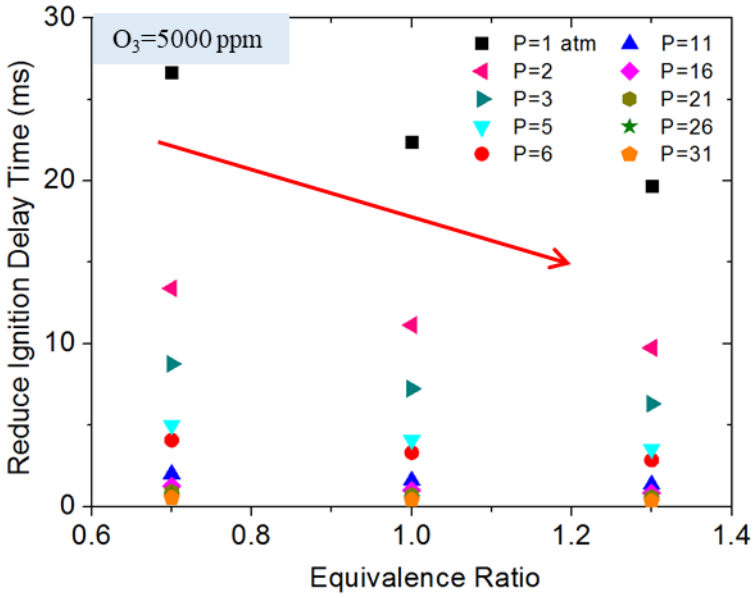


Figure 2: Flame velocity-time graph at different externally applied ozone concentrations in propane/oxygen at an equivalence ratio of 0.7.

(a)



(b)

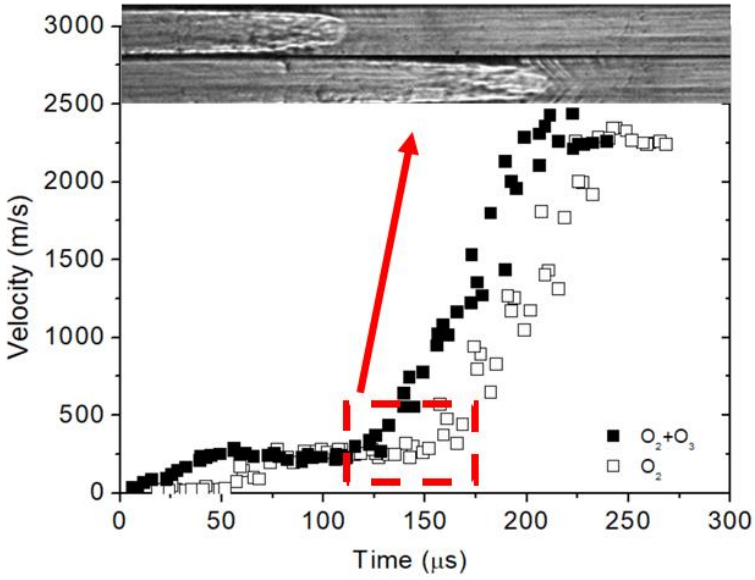


Figure 3: (a) Time measurement of reduced ignition delay by adding 5000ppm ozone concentration at different equivalence ratios and pressures. (b) The second-stage flame acceleration process is advanced after the addition of ozone.