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Laminar burning velocity of gasolines with addition of ethanol

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HIGHLIGHTS

- Laminar burning velocities of a gasoline and of model fuels (*n*-heptane, iso-octane, and toluene).
- Influence of ethanol of commercial gasoline and model fuel investigated up to 15% (vol).
- The results have been simulated using an updated detailed kinetic model.

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ABSTRACT

The adiabatic laminar burning velocities of a commercial gasoline and of a model fuel (*n*-heptane, *iso*-octane, and toluene mixture) of close research octane number have been measured at 358 K. Non-stretched flames were stabilized on a perforated plate burner at 1 atm. The heat flux method was used to determine burning velocities under conditions for which the net heat loss of the flame is zero. Very similar values of flame velocities have been obtained for the commercial gasoline and for the proposed model fuel. The influence of ethanol as an oxygenated additive has been investigated for these two fuels and has been found to be negligible for values up to 15% (vol). Measurements were also performed for ethanol and the three pure components of the model fuel at 298, 358 and 398 K. The results obtained for the studied mixtures, and for pure *n*-heptane, *iso*-octane, toluene and ethanol, have been satisfactorily simulated using a detailed kinetic mechanism.

1. Introduction

Laminar burning velocities are important parameters in many areas of combustion science such as the design of burners or engines and for the prediction of explosions. While numerous studies have been performed to measure the laminar burning velocity of mixtures containing hydrogen, methane and to a lesser extend hydrocarbons from C_2 to C_3, there are much less data available concerning fuels with a low vapor pressure (i.e. liquids under standard conditions). The most studied compounds amongst hydrocarbons containing more than four carbon atoms are *n*-heptane and *iso*-octane, which are the primary reference fuels for octane rating in spark-ignited internal combustion engines. (e.g. [1–20]). Among them, several studies concerned also binary mixtures of these two compounds (PRF mixtures, e.g. [10,11,20]). Toluene is often used as a surrogate of the aromatic moiety of fuels, and few measurements of its laminar burning velocities have been presented [21–24] To our knowledge, only two studies were performed with commercial gasolines [20,25]. Jerzembeck et al. [20] have shown that the laminar flame velocity properties of a commercial gasoline can be satisfactorily matched by a PRF mixture with a research octane number (RON) of 87. However, while the agreement was very good for lean mixtures, deviations were observed for stoichiometric and rich mixtures. A first purpose of this study is then to experimentally investigate if the use of a ternary mixture (a PRF mixture including toluene) can better match the laminar burning velocity of a commercial gasoline.

The current atmospheric issues have led to an increasing interest to shift from hydrocarbon fossil fuels to bio-fuels, particularly ethanol in the case of gasoline [26]. Ethanol is indeed an attractive renewable alternative fuel with a high octane number (RON/MON = 120/99) [27]. This explains why a larger number of studies of the laminar burning velocity of ethanol have been published in recent years [15,18,19,28–35]. Two studies have been published about a mixture of a large alkane (*iso*-octane) and ethanol [34,35], and one about a mixture of ethanol and PRF [36]. Since ethanol is an alternative as well as complementary fuel to gasoline of increasing importance, the second purpose of this study is then to characterize the influence of the addition of ethanol on the

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laminar burning velocity properties of a commercial gasoline and of the ternary mixture proposed to represent it. Finally, a model is proposed to simulate laminar burning velocities of the mixtures investigated in this study, as well as of each component taken separately.

2. Experimental facility

The measurements of laminar burning velocities were performed using a recently built flat flame adiabatic burner. This apparatus has already been used for measuring laminar burning velocities in the case of components and surrogate mixtures of natural gases [37] and diethylether [38]. It is based on the heat flux burner developed by the group of de Goey [39]. The apparatus consists of a burner head mounted on a plenum chamber. The burner head is a thin perforated plate made of brass of 30 mm diameter which is used to stabilize the flame. Each small hole of the plate has a 0.5 mm diameter and the pitch between the holes is 0.7 mm. Eight type K thermocouples of 0.5 mm diameter are soldered into the plate surface and are positioned at different distances and angles from the center to the periphery of the burner. The plenum chamber is encompassed by a thermostatic oil jacket, the temperature of which is set to the desired initial temperature of the unburned gas mixture. The circumference of the burner plate is heated with thermostatic oil set at least to 50 K above the temperature of the unburned gas mixture. The difference between the temperature of the fresh gases and that of the burner has to be high enough to be able to create a heat flux toward the fresh gases equal to that from the flame toward the burner. Furthermore, a higher temperature gap between the burner and the fresh gases induces

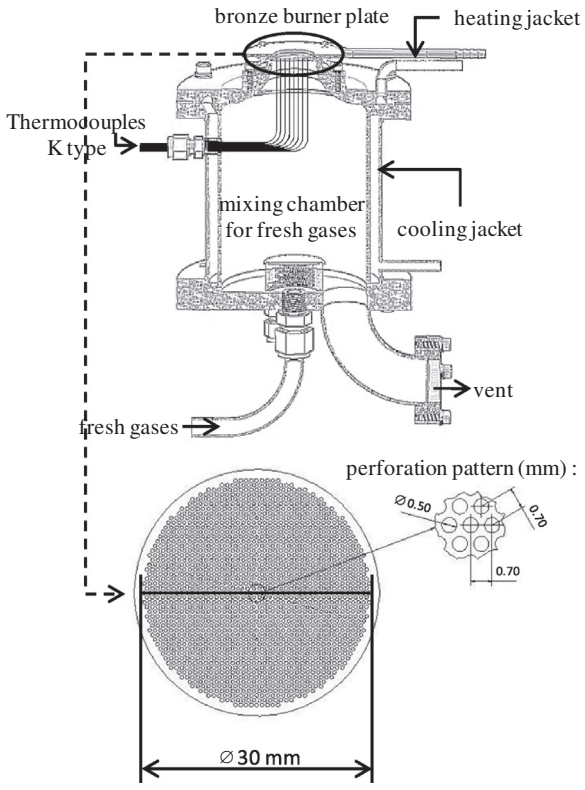

Fig. 1. Scheme of the heat flux burner.

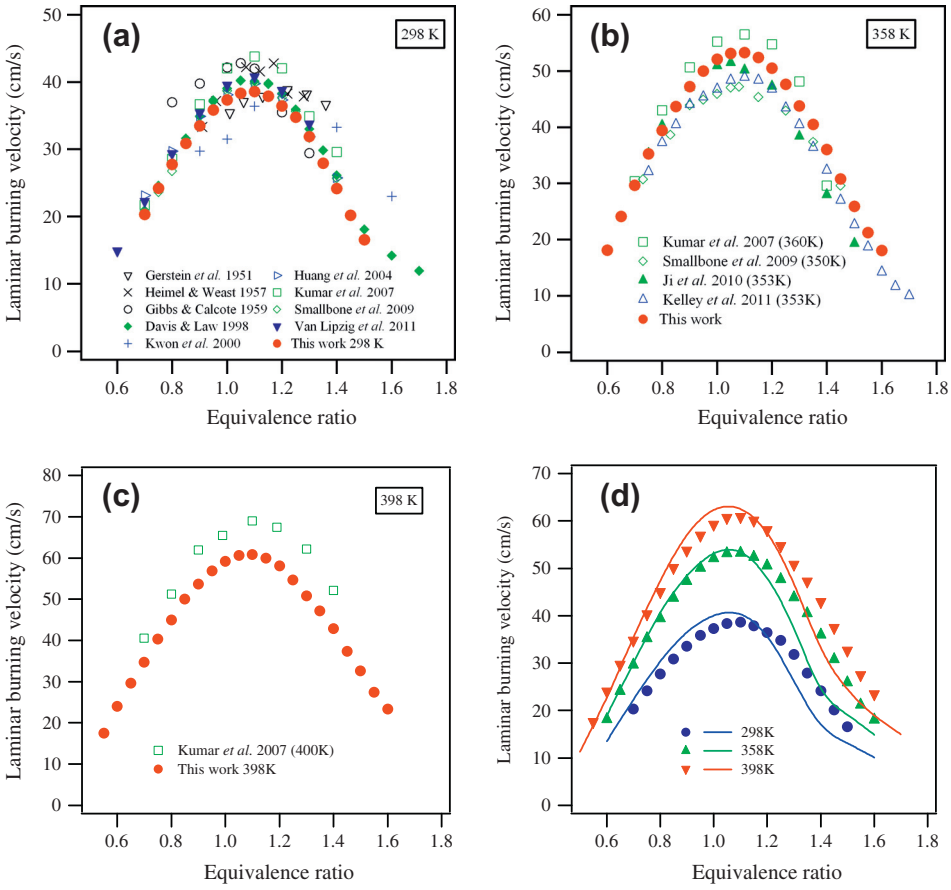

Fig. 2. Laminar burning velocities of *n*-heptane at (a) 298, (b) 358, (c) 398 K and (d) comparison of the simulations and the present experimental results (points are experiments – present work and literature [1–7,10,16,17,36] – and lines simulations).