LAMINAR FLAME SPEEDS OF CF_3H-PROPANE-AIR MIXTURES AT ELEVATED PRESSURES

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INTRODUCTION

A fundamental property of interest in characterizing the effectiveness of fire suppressants is the effect of addition of inhibitors on the laminar flame speed of a fuel as a function of pressure and temperature of the unburned mixture. The effects of CF_3H and C_2F_6 on the laminar flame speed of mixtures of gaseous fuels and air are currently being investigated in a laminar combustion bomb (a constant volume combustion device amenable to flame speed measurements at elevated and reduced pressures). Preliminary results for CF_3H-propane-air mixtures are reported here. The data show little reduction in the burning rate at elevated pressures for addition of 1% CF_3H but about 25% reduction in the burning rate for 2% CF_3H.

EXPERIMENT AND DATA ANALYSIS

The experimental apparatus consists of a spherical container 15.24 cm in diameter with one inlet port through which the combustible mixture is introduced. Ignition is provided by two extended electrodes at the center of the bomb. A pressure transducer monitors the pressure of the device as the fuel is consumed. The surface of the bomb was coated with vacuum grease to avoid corrosion by the products of combustion. The bomb was initially evacuated, and precalculated partial pressures of inhibitor, fuel and air were added. Care was taken to remove the acid combustion products before evacuating the bomb for the next experiment. A more detailed description of the apparatus is given in [1]. After introduction of the combustible mixture in the bomb, the flame is ignited at the center and a calibrated pressure trace is obtained. Given the initial conditions, it is possible to relate the pressure signal to the extent of reaction, and thus to the flame speed as a function of the temperature and pressure of the adiabatically compressed, unburned mixture ahead of the flame by solving the energy and mass conservation equations assuming that the combustion products achieve equilibrium. Allowances for variable properties of burned and unburned gases with temperature, and of heat transfer to the wall are made. The data analysis program is being updated to calculate equilibrium flame temperatures more accurately including HF and F production.

RESULTS

Initial tests were conducted to acquire control data for flame speeds of uninhibited flames. Data were obtained for methane at $\phi = 1.0$ and 1.3, and propane at $\phi = 0.8$, 1.0, and 1.3 (nominal). Concentrations of 1.0 and 2.0% of the total mixture (by volume) of the inhibitor CF_3H were added to propane mixtures for flame speed comparison. Figure 1 shows the calculated burning velocity and chamber pressure as a function of the unburned gas temperature for a stoichiometric propane-air mixture with 0 and 2% CF_3H. The noise in the lower unburned gas temperature data is a result of the combined effects of the spark and the very low heat release rate, which lead to uncertainties in the final pressure derivative, from which the flame speed is calculated. The results for propane at ϕ=1.0 indicate that adding 1% CF_3H (not shown) slowed flame speeds negligibly; however, the addition of 2% of the agent decreased the flame speed by about 25% The reasons for this behavior are unclear at this point, but may be related to the changing stoichiometry with addition of the inhibitor. Increasing the CF_3H concentration also modifies the heat release per unit mass and overall rates of reaction. Chemical kinetic modeling of this flame will help to explain the observed behavior.

FUTURE WORK

A complete set of data at two or three initial pressures, equivalence ratios and concentrations will be produced for propane, and a similar set will be produced for methane flames. From these data it should be possible to derive a correlation or a table that can be interpolated over a relatively wide range of pressures (~1-8 atm), temperatures (~400-600 K) and equivalence ratios. Numerical calculations of the flame structure will performed and the results will be interpreted to determine the reasons for the observed behavior.

REFERENCE

1. Metghalchi, M. and Keck, J. C. , Combust. Flame 38,143 (1980).

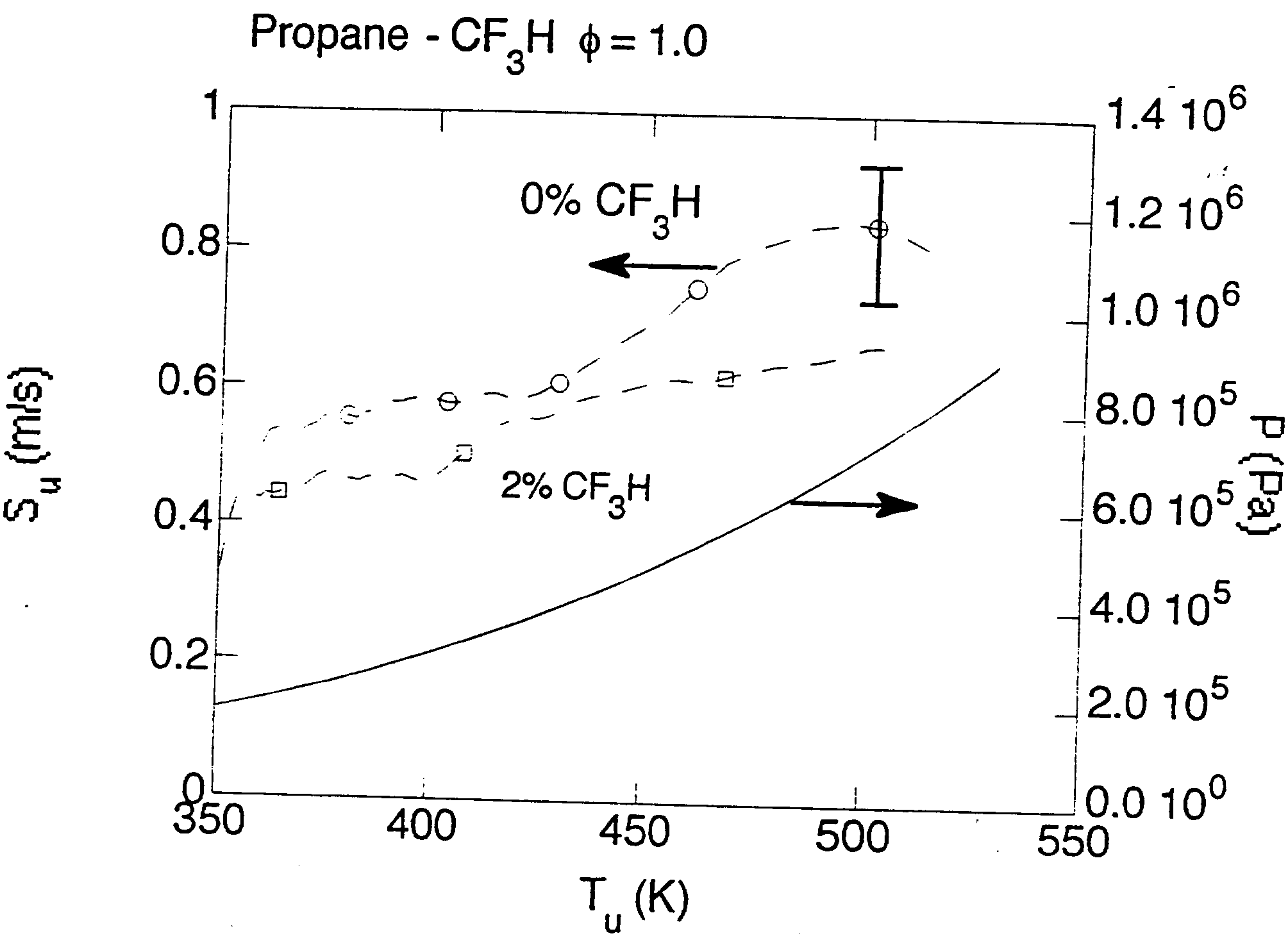

Figure 1 - Burning rate and chamber pressure as a function of unburned gas temperature for constant volume combustion of a stoichiometric propane-air mixture with 0 and 2% CF_3H added.