Module 5: Premixed Flame

Lecture 25: Effect of Oxygen Concentration on S_L

The Lecture Contains:

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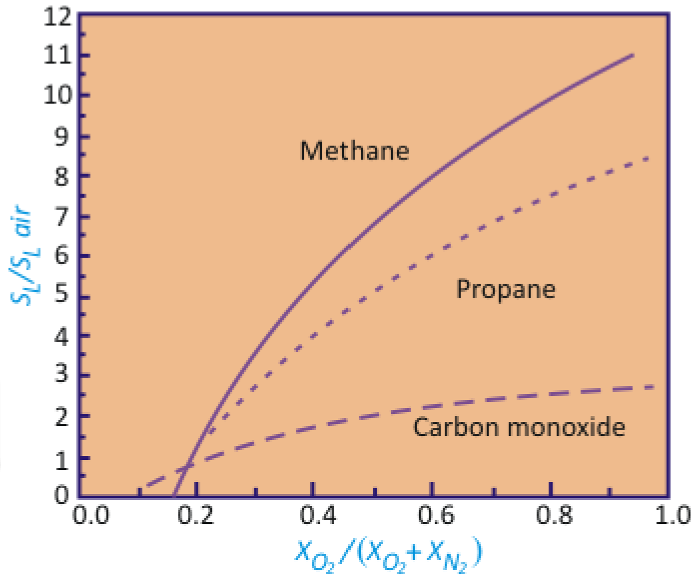
Effect of Oxygen Concentration on S_L

For various combinations of O_2 and N_2, there is a drastic increase in S_L.
For methane, S_L is increased by 10 times
For propane, S_L is increased by 7.5 times
For CO, S_L is increased by 2.4 times.

What is the reason for this change?

Higher the oxygen level, higher will be the adiabatic flame temperature
Thus higher burning velocity



(Figure 25.1)

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Effect of Initial Pressure and Temperature on S_L

$S_L \propto P^{(n-2)/2}$

This relation is supported by experimental data

n: Overall order of global chemical reaction

$n < 2$ for HC flames with $S_L < 50\ cm/s$

$n = 2$ for HC flames with $S_L \approx 50 - 100\ cm/s$

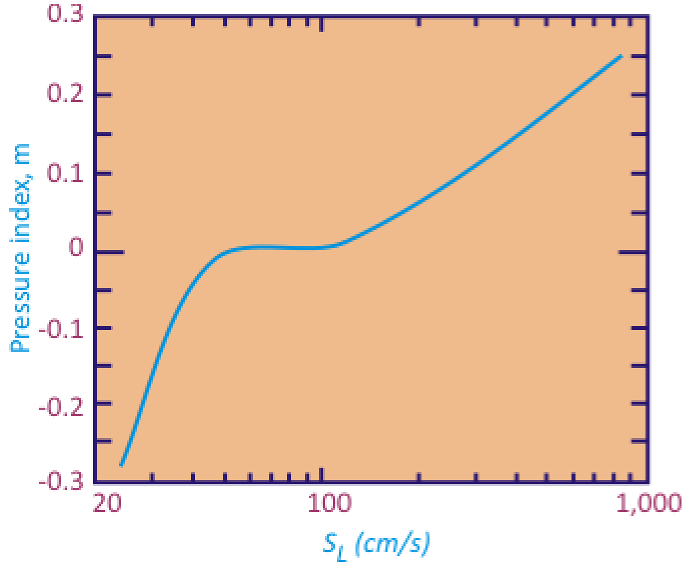
$n > 2$ for HC flames with $S_L > 100\ cm/s$

Pressure index, $m = (n-2)/2$

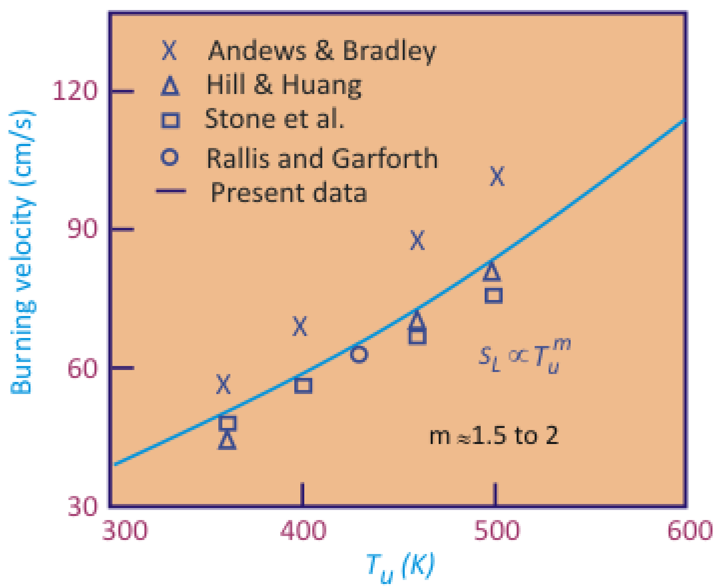
For $S_L < 50\ cm/s$, m is negative, indicating burning velocity increases with decreasing pressure

For $S_L \approx 50 - 100\ cm/s$, m is constant, indicating burning velocity is constant

For $S_L > 100\ cm/s$, m is positive, indicating burning velocity decreases with decrease in initial pressure



(Figure 25.2)



(Figure 25.3)

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Effect of Inert Additives

Inert gas additives produce the following effects

1. Reduction of burning velocity
2. Narrowing of flammability limits
3. Shifting of S_L peak

Why there is a shift in S_L peak ?

Addition of inert gas changes the ratio of thermal conductivity and sp. heat of the mixture, resulting in change in S_L.

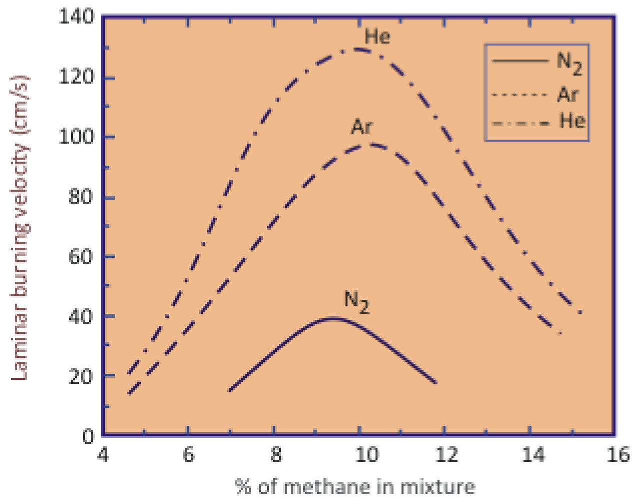
Burning velocity with He addition is higher than Ar and N_2. Why ?

Lower MW will lead to higher burning velocity

MW of He is much lower than Ar and hence higher S_L

Ar and N_2 have almost same thermal diffusivity

Hence for same heat release, Ar attains higher flame temperature $\rightarrow$ higher S_L.



Clingman et al 1995

(Figure 25.4)

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Lecture 25: Effect of Oxygen Concentration on S_L

Flame Quenching

Fuel	Oxidizer	SL (cm/s)	dq (mm)
CH_4	Air	40	2.5
CH_4	O_2		0.3
C_3H_8	Air	45	2.0
C_3H_8	O_2		0.25
C_2H_2	Air	140	0.8
C_2H_2	O_2		0.2
CO	Air		2.8
H_2	Air	210	0.5
H_2	O_2		0.2

Quenching diameter for various stoichiometric fuel-oxidizer ratio.

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Simplified Analysis for Quenching Diameter

Condition for flame propagation

Heat generated due to chemical reaction > heat lost due to conduction

Rate of heat generated per unit volume

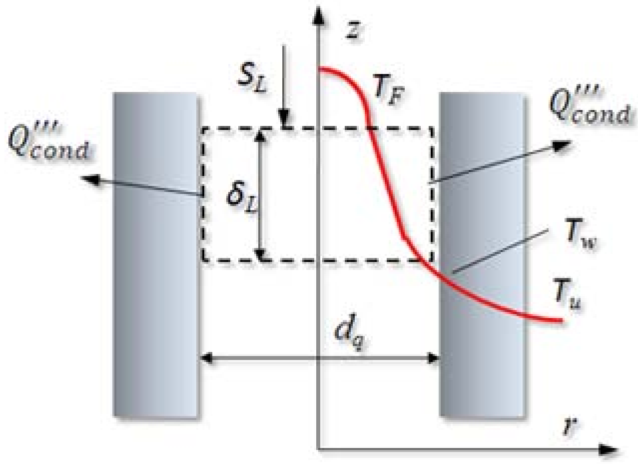
$$\dot{Q}''' = \overline{\dot{m}}_F''' \Delta\hat{H}_c = \dot{Q}_{cond}$$

Heat generated in flame volume

$$\dot{Q} = \overline{\dot{m}}_F''' \Delta\hat{H}_c \frac{\pi}{4} d_q^2 \delta_L$$

Heat loss rate due to wall conduction

$$\dot{Q}_{cond} = k_g \pi d_q \delta_L \frac{dT}{dr}$$



(Figure 25.5)

Assuming linear temperature distribution in flame,

$$\frac{dT}{dr} = \frac{T_F - T_u}{d_q/C}$$

Quenching diameter

$$d_q = \sqrt{4Ck_g \frac{T_F - T_u}{\Delta\hat{H}_c \overline{\dot{m}}_F'''}}$$

After simplification,

$$d_q = \sqrt{8C}.\,\delta_L$$

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