Course Name: Theory of Fire Propagation (Fire Dynamics)

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Week – 06

Lecture – 03

Module 4 – Burning of Liquid Fuels

Self heating and spontaneous combustion:

Self-heating and spontaneous combustion of high boiling point vegetable oils in porous substrate such as fabric materials are also encountered. Self-heating occurs due to the changes in the structure of the fuel and causes smouldering through the fuel bed. Both the porous substrate (if combustible) and the liquid undergo slow oxidation process. Self-heating hazard is of increasing order for coconut oil, olive oil, cotton seed oil, soybean oil, sunflower oil, linseed oil and Tung oil, indicated by the increasing values of their iodine numbers. Iodine number is the mass of iodine in grams that is consumed by 100 g of oil. Reactivity of a substance to oxygen depends on the number of double bonds it has.

Ignition delay:

Ignition time, also called the ignition delay, is the sum of evaporation time, mixing time and the induction time. Time required for mixing of the reactants is determined by the flow field and is usually much lesser in a convective environment, especially when the flow is turbulent. Induction time is defined as the time for the commencement of chemical reactions and is a function of temperature. Both piloted ignition and auto-ignition conditions reduce the induction time nearly to zero. Thus, it is generally the evaporation time that controls the ignition delay.

Flame spread over liquid fuel surface:

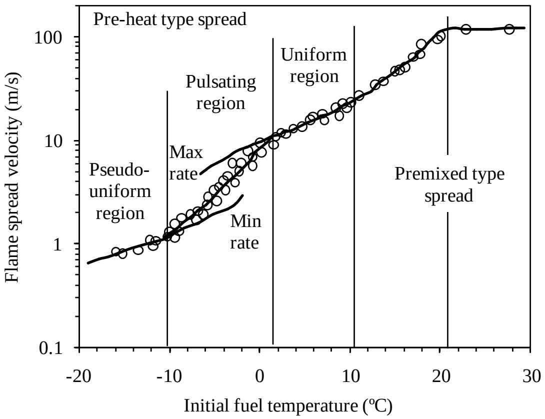
Transient flame propagation over liquid fuel surface depends on the fuel properties, initial fuel temperature, ambient conditions, and the strength and direction of the convective flow. Primary fuel properties, which dictate the flame propagation, are the flash and the fire points. Flame propagation can be classified as concurrent flame propagation or opposed flame propagation, depending upon the direction of flame spread with respect to that of the oxidizer flow. In concurrent flame spread, oxidizer flows in the same direction as that of the propagating flame and in opposed flame spread, oxidizer flow is opposite to the flame spread direction. In both cases, the oxidizer flow could be induced by forced and/or natural convection mechanisms.

Flame spread – factors affecting:

Concurrent flame spread is highly rapid and could be hazardous. In opposed flame spread, the heat transfer from the flame to the fuel surface and interface mass transfer processes are affected by the oxidizer flow, which is against the direction of the propagating flame. Consequently, the rate of flame propagation is generally low and the flame front is well defined. The rate of flame propagation in both the concurrent and opposed flow modes is also influenced by whether the fuel is above or below its flash point temperature. When the liquid fuel is at a temperature above its flash point, combustible mixture of fuel and oxidizer is present everywhere above the fuel surface. Upon ignition, the flame propagates just like in premixed gaseous reactant. Chemical kinetics affects the rate of flame propagation. Flame spread rate is as high as 1 m/s.

When the liquid is at a temperature below its flashpoint, the mass transfer process will be stronger and rate controlling. For sub-flash point liquid, sufficient amount of fuel vapor - air mixture within the flammability range will not be available above its surface. Propagating flame has to first preheat the downstream liquid fuel surface to its fire point temperature, such that a flammable mixture is generated for sustained flame propagation. In this case, liquid-phase transport processes will also become significant controlling mechanisms. The spread rates in these cases are appreciably slower. Flame spread is classified into regimes such as liquid controlled, gas-phase controlled and asymptotic flame spread, based on the liquid temperature. In asymptotic regime, flame spread rate remains almost a constant and insensitive to liquid temperature.

Flame spread – over methanol pool:



Variation of flame spread rate with initial temperature of methanol pool (Flash point = 15ºC, Boiling point = 64ºC)

(Akita, 14th symposium on combustion)

Flame spread – sub-flash point aspects:

In flame propagation over liquid fuels at sub-flash temperatures, the liquid fuel does not remain stationary beneath the flame. A re-circulatory convection current is observed in the liquid fuel surface ahead of the flame, which plays an important role in the flame propagation. This re-circulating subsurface flow causes the liquid to move away from the flame at the surface and return back at a certain depth. Existence of a temperature gradient on the fuel surface induces a surface tension gradient. Temperature decreases and the surface tension increases with distance upstream from the flame location. The surface tension tends to pull the liquid away from the flame. The ensuing liquid-phase convective heat transfer is higher than in-liquid conduction heat transfer.