Course Name: Theory of Fire Propagation (Fire Dynamics)

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Week – 07

Lecture – 04

Module 5 – Burning of Solid Fuels

Time to ignition - internal factors:

1. Thermophysical and thermochemical properties of the solid
2. Moisture content
3. Radiation properties such as spectral absorptivity and transmissivity
4. Spectral transmittance of the pyrolysis gases released by the surface due to heating
5. Kinetics of thermal solid-phase decomposition and composition of decomposition products, including char formation rate for charring materials.
6. Chemical kinetics of gas-phase combustion.
7. Influence of melting and bubble formation, and bubble bursts on the surface because of increasing gas pressure inside the solid.

Time to ignition – factors affecting:

Heat and mass transfer associated with external heating of a surface is considered to be an important factor for ignition. Ignition models are correlated with a simple thermal model based on inert heating of the solid. This is because the time taken for gas-phase reactions is very fast compared to solid heating time. For example, Quintiere (2006) reported the time for gas-phase reactions to be ~ 2 x 10^{-4} s, gas-phase transport, or mixing of fuel vapor with air ~ 4 s, and time for inert heating of solid (pyrolysis time) ~ 120 s. Pyrolysis time is an order of magnitude higher than the chemical or mixing time.

Types of ignition:

Solids are classified as charring and non-charring types. Wood is an example of charring type solid. Polyethylene is an example for non-charring type. Wood is a heterogeneous solid having moisture, volatiles (trapped gases), solid carbon and inert mineral (ash). Upon heating moisture and volatiles are released at appropriate temperatures of ≈ 100°C and ≈ 350°C – 400°C, respectively. Volatiles mix with ambient air and if this mixture is within flammability limits, it may be ignited using a pilot flame (piloted ignition) or if its temperature is more than Auto Ignition Temperature (AIT), auto ignition occurs. Fixed carbon, when heated to a temperature of ≈ 900°C, oxygen from ambient reaching its surface reacts. This surface reaction is called glowing ignition, as carbon displays radiant red colour. Non-charring solids, which are mostly polymers, do not produce the carbon (char) upon devolatilization. Polymer has a softening temperature and melting temperature, apart from the pyrolysis temperature. When the solid is heated to pyrolysis temperature, gas leaves the material. Polymers like polyethylene and PMMA melt and vapours form. The gas and vapours leaving the solid upon heating need not be the pure monomer component and can be multi-component in nature. The gas mixture leaving the solid must achieve the Lower Flammability Limit (LFL) of that mixture to be ignited in piloted ignition or must be in at a flammable concentration and at AIT to cause autoignition.