Course Name: Theory of Fire Propagation (Fire Dynamics)

Professor's Name: Dr. V. Raghavan

Department Name: Mechanical Engineering

Institute: Indian Institute of Technology Madras, Chennai – 600036

Week – 10

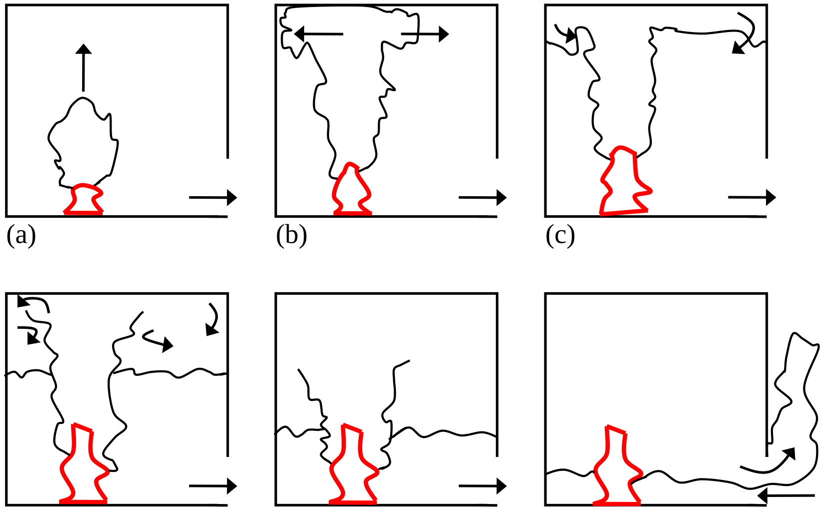
Lecture – 02

Module 7 – Enclosure Fires

Enclosure fires – smoke effects:

As the fire grows in size, the smoke layer descends, and its temperature increases. The smoke layer movement is because of air entrainment arising due to temperature gradients between the hot products of combustion and the surrounding cold air. The smoke layer affects the visibility in the enclosure. The growth stage in a compartmental fire is significant from the perspective of smoke movement. Well, within the growth of the fire, that is, in its initial stage itself, a fire should be detected, and safe egress of people should be carried out. During this stage, generally, the structure is not affected.

Enclosure fire – smoke movement:



Schematic of stages in the growth of enclosure fire to fully developed steady fire.

Enclosure fires – flash over:

Transition of the fire from a single object burning in the compartment to the sudden growth to its biggest possible size is called flash over. All flammable materials in the room are rapidly ignited due to this. Flashover is a thermal instability phenomenon between the growth stage and the fully developed fire as shown by the sudden/dramatic change in the slope of fire growth. Several definitions of flash over are found in literature. Some rules of thumb are also available to evaluate the onset of flashover. For example, temperature in the compartment reaches 500°C - 600°C, radiation to the floor of the compartment is 15 – 20 kW/m^2, flames appear from openings, and so on. Flashover forms the link between a developing or growing fire and the fully developed fire.

Enclosure fires – fully developed fire:

Fully developed fire is the longest and most dominant stage and is usually used as a basis for fire protection design of buildings, because during this stage, the structure is affected by the fire. From the analysis of this stage, it is possible to define or quantify the fire boundary condition, which can then be used to determine the thermal response of the structure, structural response of the structure and the evacuation protocol. Based on the ventilation conditions, it is observed that a fully developed fire follows two regimes - Ventilation Controlled (Regime I) and Fuel Controlled (Regime II). In Ventilation Control (Regime I) the fire is oxygen starved, and the smoke flowing out of the compartment has no oxygen whatsoever. Thus, it is likely to burn outside the enclosure.

Enclosure fires – fully developed fire & decay:

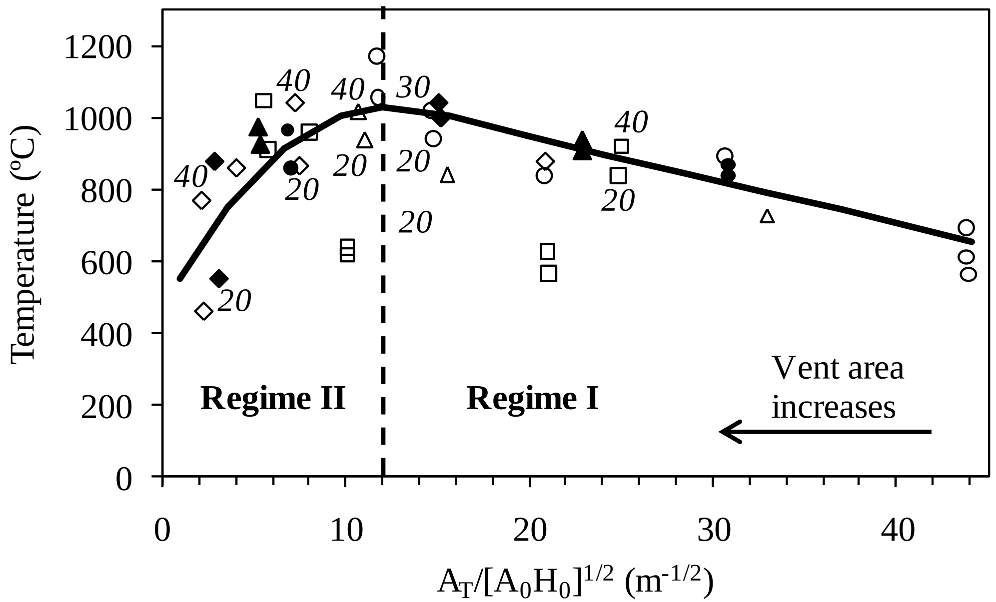
In Regime I, the ventilation conditions are such that air entrainment into the enclosure is lesser than that required for the fuel inside the to burn. In Regime II the fire is fuel starved. In this case, the smoke coming out of the compartment has oxygen, does not have excess fuel left over and will not burn outside the window. Fire will continue till fuel is left out in the compartment. Natural decay of fire occurs because of lack of fuel or oxygen. Artificial decay of fire occurs because of suppression (usually water). During the decay stage, heat release rate in the compartment reduces rapidly. Average temperature also decreases - a value of 80% of the peak temperature value is used to identify the decay. For most structures, temperature decays at a rate of 5°C/minute.

Enclosure fires – duration and severity:

Duration and severity of a compartment fire are the two main components in understanding the fire behaviour during the fully developed stage. Duration is calculated by dividing the **total mass of fuel** (fuel load) available (kg) by the **burning rate of fuel** (kg/s). Severity is assessed by the maximum compartment temperature. An important distinction must be made between a fire burning in the open (no compartment) and within a compartment. In a fire burning in the open, the rate of burning induces the rate of air entrainment. This results in air entrainment flows that feed the flame and corresponding growth. However, in a compartment the rate of burning and the rate of air entrainment need to be considered separately.

Enclosure fires – duration and severity:

Figure shows two scenarios observed in compartment fire during fully developed regime (Thomas & Heseldon). Symbols represent different vent shapes and the numbers represent the fire load densities in kg/m^2.



A_T = area of the enclosure without floor & openings.

A_0 = area of all the openings.

H_0 = height of the opening.

x-axis is called ventilation factor, $A_T/[A_0H_0]^{0.5}$.