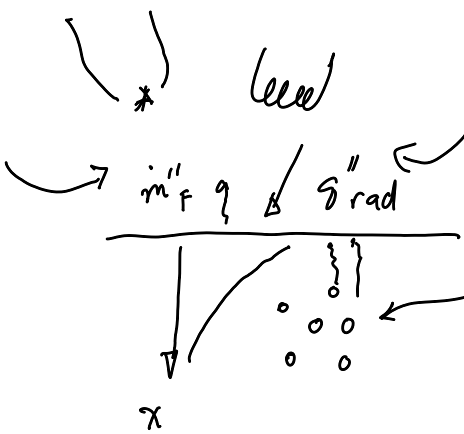
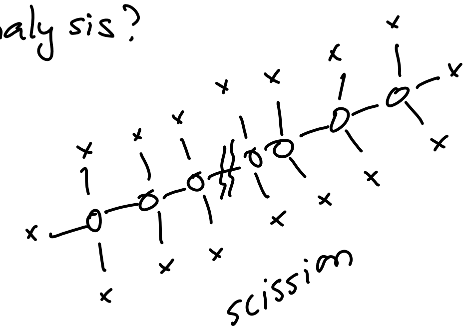
10/29/2010

THIS LECTURE

* Thank Fraser for cookies!!
* Thick & Thin Ignition of Solids
* Examples

Why is valid to model ignition of solids using only heat transfer (conduction) analysis?




ignition requires a series of processes.

$$t_{ign} = \underbrace{t_{pyrolysis}}_{\text{heat the mat'l to point that fuel vapor escapes [1 min]}} + \underbrace{t_{mix} + t_{react}}$$

$t_{mix}$: time for flammable mix [1 sec]

$t_{react}$: sufficiently energetic source [0.1 ms]

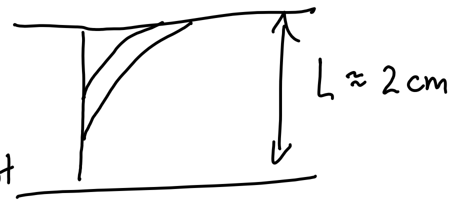
The time for ignition can be reasonably well approximated by the time required for pyrolysis.

Two limiting cases to analyze solid ignition.

Thin Limit & Thick Limit

- Thermally Thin Limit assumes a constant temperature in the solid. We use the Biot # $\frac{hL}{K}$ or some similar parameter to establish if the sample is thin.

- Thermally Thick Limit:



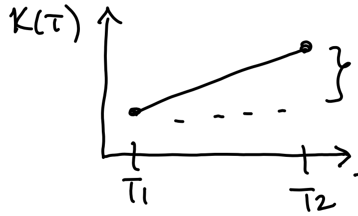

thermal wave has not hit the back side of sample.

$\delta \approx \sqrt{\alpha t}$ diffusion distance

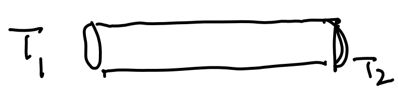
$\alpha \equiv \frac{K}{\rho c}$ thermal diffusivity.

$\boxed{7.5}$ Calculate time to ignite (piloted) certain samples. Radiative heat flux $\dot{q}''_R$ is $30 \frac{kW}{m^2}$. The initial sample temperature is 25°C. Assume samples are thick & that the convective heat transfer coeff is $15 \frac{W}{m^2 K}$. Calculate the critical heat flux.

We are using constant properties. Is this justified & why/when?




$K = K_0(1 + aT)$




$$K \frac{d^2T}{dx^2} = 0 \nLeftarrow \frac{d}{dx}\left(K \frac{dT}{dx}\right) = 0$$

K const ↑ real eqn is above

$\frac{\Delta K}{K} \ll 1$ then assume const.

The $K\rho c$ product specified is a calibrated parameter that allows the conduction model to represent experimental observations.

time to ignition

$$\frac{T_s - T_\infty}{\dot{q}''/h} = 1 - \exp(\gamma^2)\,\mathrm{erfc}(\gamma)$$

erfc ≡ complementary error function
= 1 − erf( )

$$\gamma \equiv h\left(\frac{t}{K\rho c}\right)^{1/2}$$

when $\gamma \ll 1$ $\quad t_{ign} \approx \frac{\pi}{4} K\rho c \left(\frac{T_{ig} - T_\infty}{\dot{q}}\right)^2$

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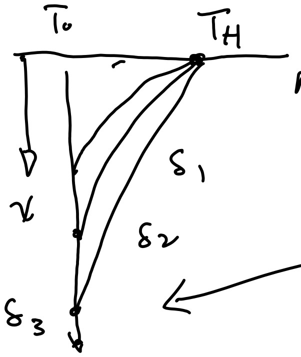
<u>Thick Fuels</u>

Heat Eqn 1.D unsteady....

$$\rho c \frac{\partial T}{\partial t} = K \frac{\partial^2 T}{\partial x^2}$$

subject to BC's & I.C.

1. 


Initial condition $T(x, t=0) = T_0$

Semi-∞ domain $T(x \to \infty, t) = T_0$

3 Basics of $x=0$ condition.

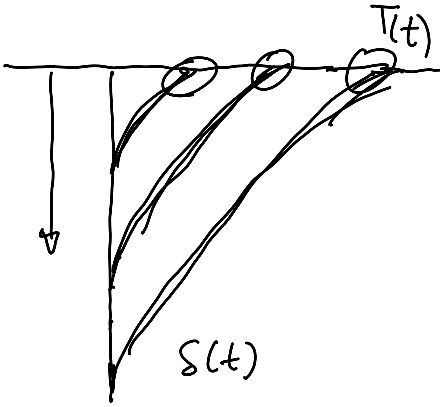
1. $T(x=0, t) = T_H$

solution is by Laplace transform, similarity transform.

$$\frac{x}{\delta(t)} = \eta$$

$$\delta \equiv \sqrt{\alpha t}$$

2. constant heat flux




$$\underset{\substack{\uparrow \\ \text{const.}}}{q''_0} = -\underset{\substack{\uparrow \\ \text{const}}}{k} \left.\frac{\partial T}{\partial x}\right|_{x=0,\,t}$$

$$q''_0 = +k\,\frac{T_{surf} - T_0}{\delta(t)}$$

$$q''_0 = \frac{k\,(T_{surf} - T_0)}{\sqrt{\alpha t}}$$

$$\frac{q''_0 \sqrt{\alpha t}}{k} = T_{surf} - T_0$$

$$\frac{\sqrt{\alpha}}{k} = \frac{1}{\sqrt{k \rho c}}$$

$$T_{surf}(t) = T_0 + q''_0 \left(\frac{t}{k\rho c}\right)^{1/2}$$