Jet Aircraft Propulsion

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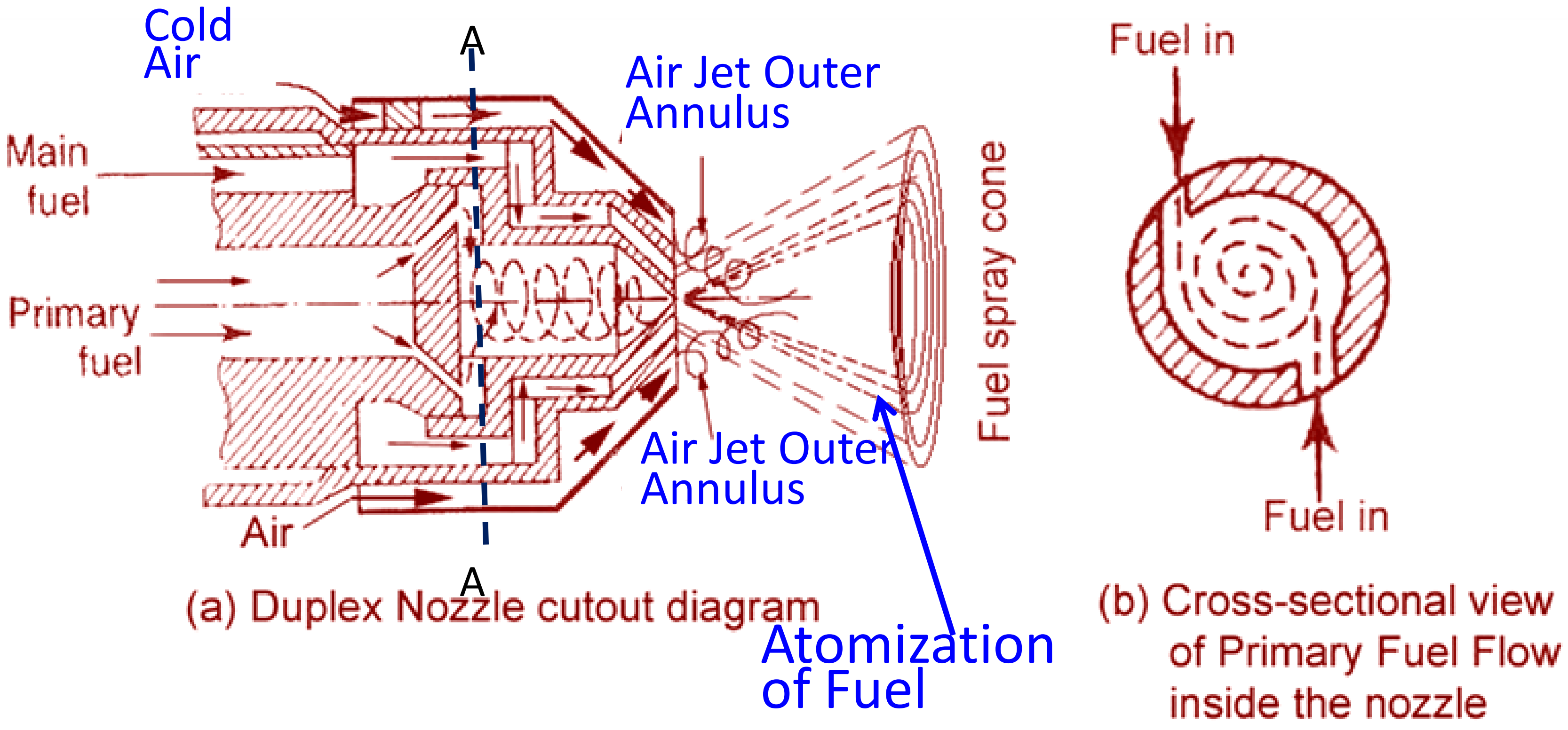
Lecture 26

Combustion

Fuel Injectors
Flame Stablization
Combustion Instability

Fuel injection

Most commonly used injection system in aircraft gas turbine engines is a *Duplex* injector



(a) Duplex Nozzle cutout diagram

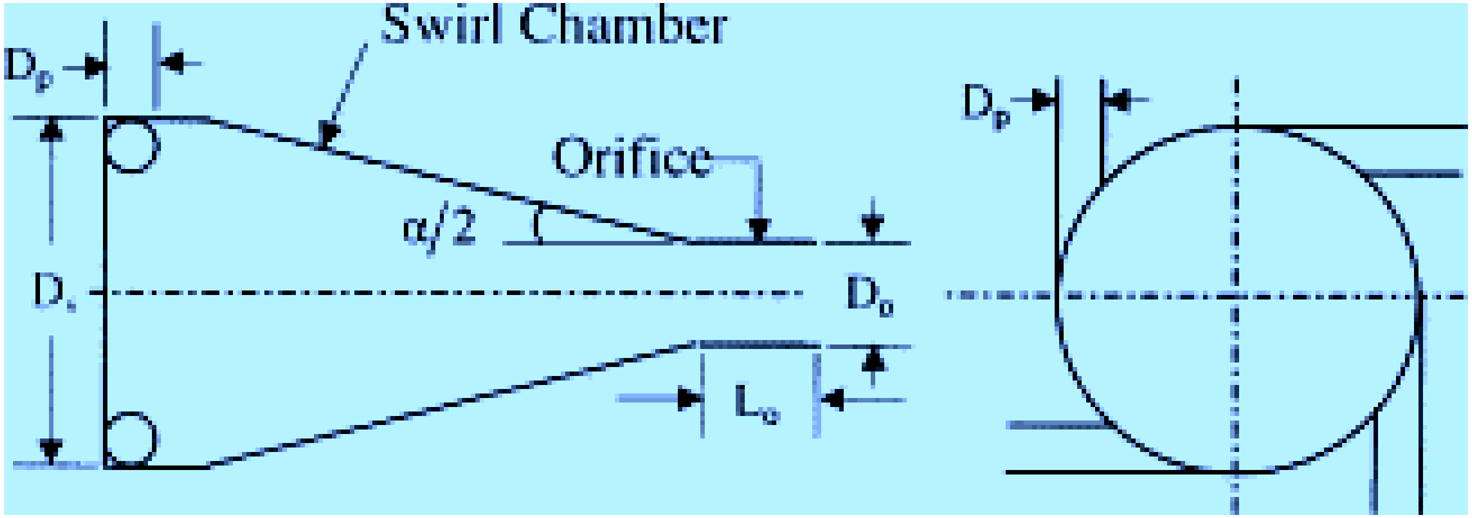
(b) Cross-sectional view of Primary Fuel Flow inside the nozzle

(At c/s AA)

- Two concentric fuel supply manifolds are present.
- For low flow rate, the central one, is used only (Fig.a & b). At higher fuel rates the annular one is additionally brought into operation.
- Both the fuel supply nozzles create concentric jets of conical shapes that spread out into the combustion chamber primary zone.
- The spreading out is the first step towards increasing the liquid fuel surface area many folds. The cone(s) surface, in a high pressure turbulent & vortical flow zone, breaks down to create freely floating liquid droplets.

- This later process increases the liquid fuel surface area again many times over.
- Thus, highly magnified surfaces aid very fast evaporation of the fuel, immediately followed by mixing with the primary air.
- Additional annular air passage around the fuel discharge nozzles, is employed to avoid carbon and other combustion product deposition on the face of the nozzles due to back flow. This happens quite close to the nozzle injection.
- A little away from it flame front is stabilized and combustion occurs.
- All of this is made to happen within the primary combustion zone (Fig.a).

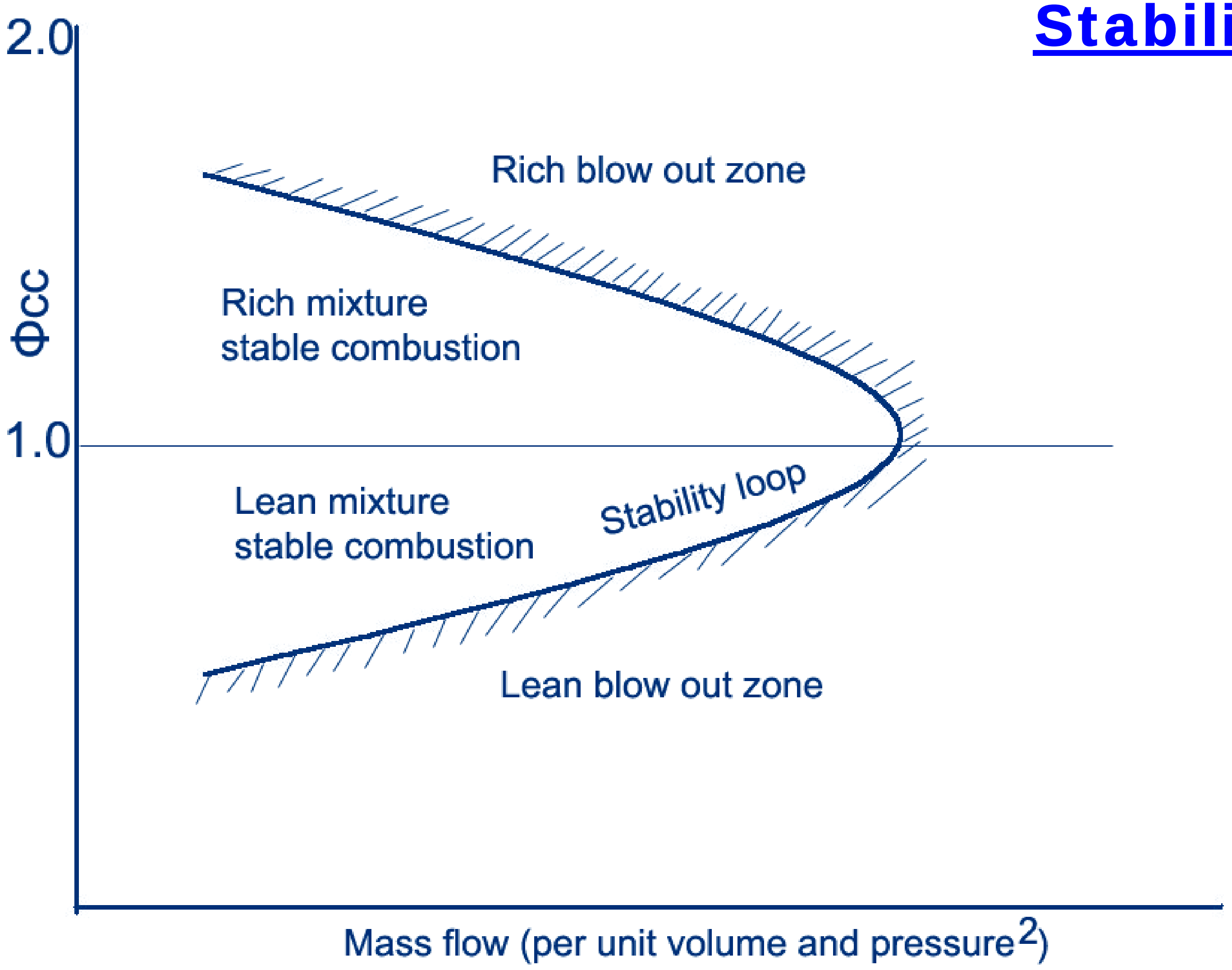
Simplex injectors have been used in many gas turbine combustors. It constitutes only one fuel supply nozzle and thus the range of fuel flow control is decided by a single nozzle flow control mechanism. This provides a much simpler fuel nozzle system. The later versions of simplex nozzle are also equipped with air spray for the same purpose as stated above.



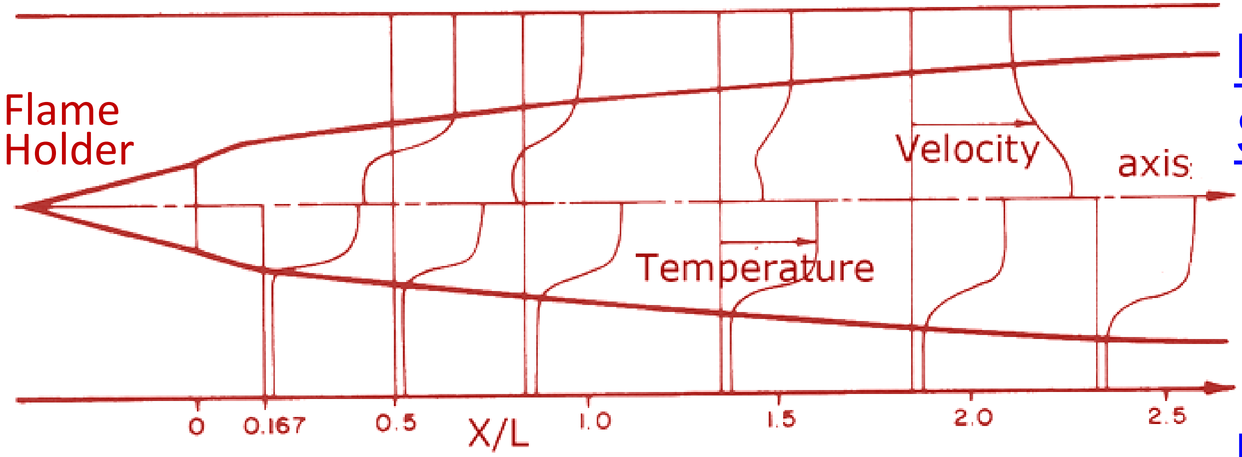
Stability limits

- For any combustion chamber there is both a rich and a weak limit to the air/ fuel ratio beyond which flame is unstable.
- The range between rich and weak limits is narrower at higher air velocities through the combustion zone.
- The *stability loop* must cover the operating region of the gas turbine engine including all flight regimes and all transient regions of accelerations and decelerations.
- While rich limit is attained during acceleration, weak limit may occur in decelerations.
- The *fuel flow rate* needs to be controlled accordingly, which is necessary also to avoid rapid temperature changes in the turbine blades.

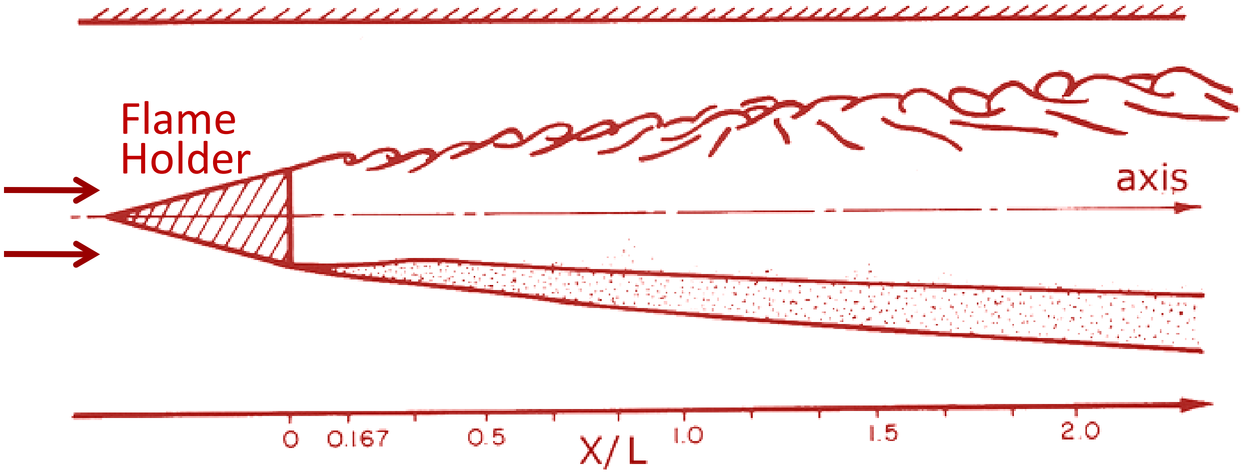
Stability limits



Flame Stablization



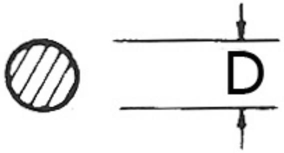
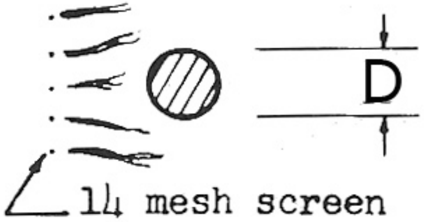
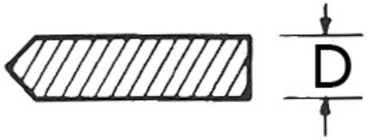
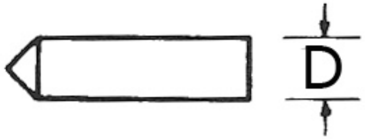
a) Temperature and Velocity Profiles



b) Flow quality as captured by photo

Flow behind a Flame Holder in the primary zone of a combustion chamber

Flame Stablizers

Flameholder Geometry	*D* or *d*, in.
	1/8 3/16 1/4
	1/4
	1/4 3/8 1/2 3/4
	1/4 3/8 1/2 3/4

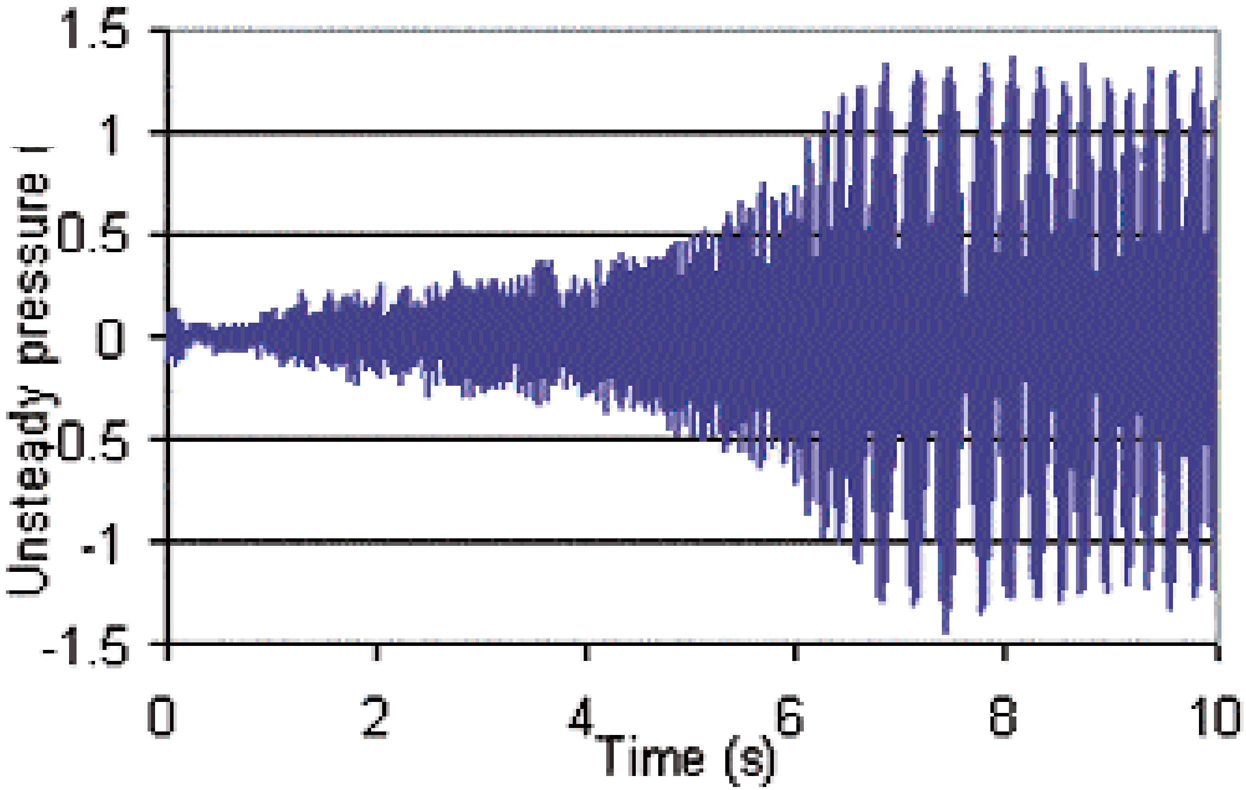
Combustion Instability

- Chemical reaction causes energy input in the engine,
- Three factors are responsible for any happenings : (i) local and instantaneous air-fuel mixture ratio, (ii) instantaneous pressure, and (iii) instantaneous temperature, which together decide the instantaneous heat release rate.
- Some of the root causes of instabilities are :

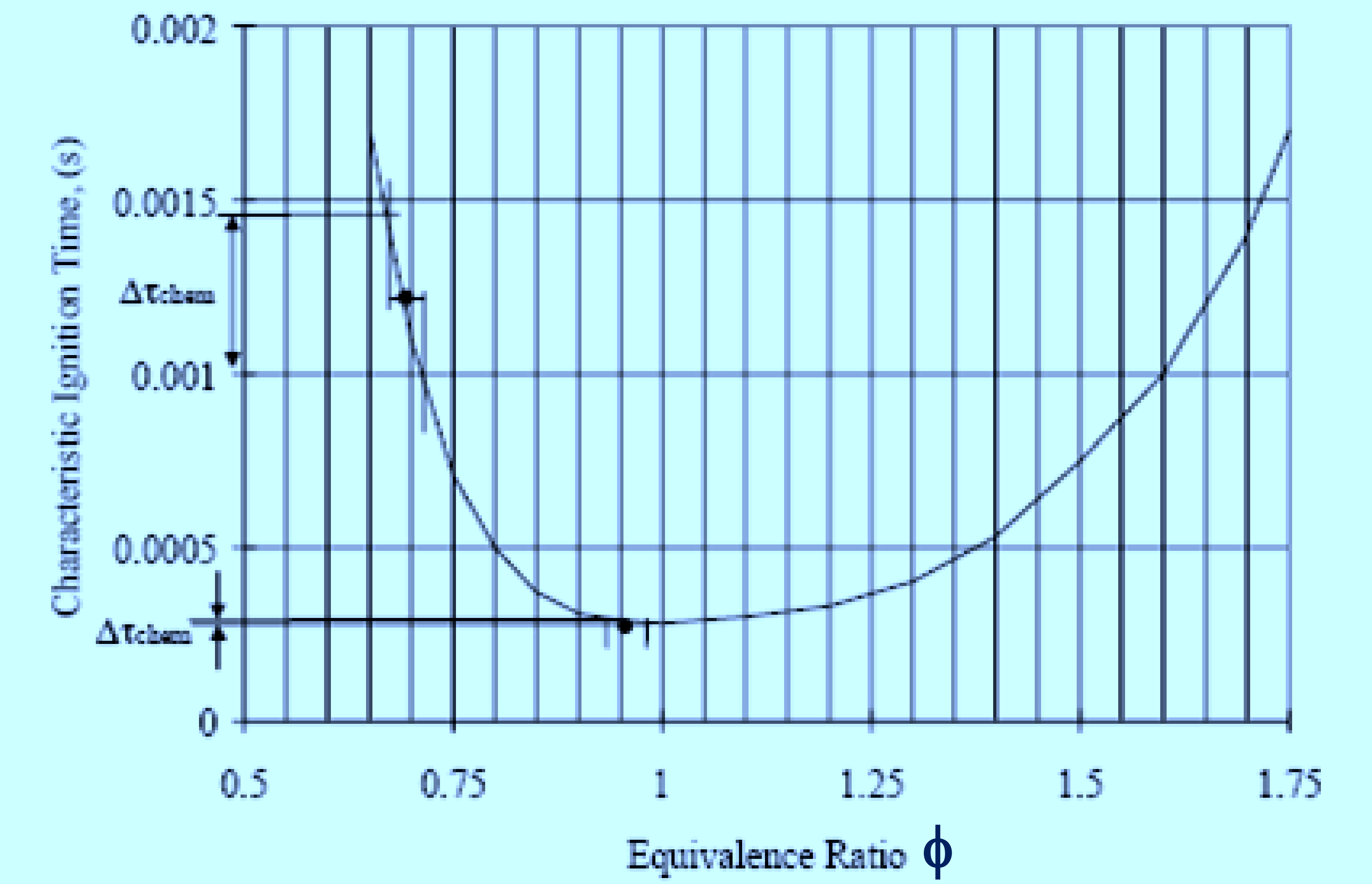
1) Changes in turbulent mixing rate
2) Flame area variation
3) Periodicity of the upstream air flow, induced by the instantaneous pressure field (Time unsteadyness)
4) Vortex formation and shedding (around the flame holder) due to or leading to fluid dynamic instabilities

- Combustion instabilities are developed either due to internal reasons or initiated by external sources.
- The first cause may be the result from pressure fluctuations inherent in a high pressure turbulent flow field giving rise to shear layer instabilities.
- The cause and the effect can get coupled giving rise to oscillating process.
- In the second cause the disturbance signal comes or imported from outside the combustion system – but results in similar instabilities.
- Whether such oscillation would be stable, decaying or amplifying depends on the nature of the excitation, coupling mechanism and inherent damping capability, if any, of the system.

A process that initiates instabilities does not drive it. Also, the frequency of the instability will be increased or decreased depending on the phase difference between the heat release and pressure fluctuations.



The sensitivity of the combustion process to ϕ: Eqv Ratio perturbations may be due to the dependence of flame speed chemical reaction time etc. upon ϕ



- It is quite evident from the above graph that the rate of change of chemical time decrease as we come closer and closer to the stoichiometric conditions from either side.

- At low ϕ conditions, perturbations in ϕ induces greater change in the chemical time and hence has a greater chance of initiating instabilities through significant local heat release fluctuations.

- From the graph it is quite clear that at near stoichiometric conditions we do not have significant changes in the chemical time owing to the perturbations in ϕ

Next

Intakes and Nozzles
By
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