Republic of Iraq

Ministry of Higher Education

and Scientific Research

Al-Mustaqbal University College

Chemical Engineering and Petroleum Industries Department

Subject: **Combustion engineering**

3nd Class

Lecture five

Primary Breakup

The primary breakup mechanism concerns the breakup of the intact liquid core and can be divided into four regimes. NamelyRayleigh regime, the first and second wind-induced regimes and last the atomization regime. In order to make a quantitative classification of the regimes the Ohnesorge number **Oh** is introduced:

$$Oh = \frac{\sqrt{We_l}}{Re_l} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots$$

Herein the number W_{el} and the Reynolds number Re_{el} are defined as:

$$We_l = \frac{u^2 \, D \, \rho_l}{\sigma}$$

$$Re_l = \frac{u \, D \, \rho_l}{\mu_l}$$

ρ is the density, σ is surface tension, μ is the dynamic viscosity, u is the jet velocity and **D** is the diameter of the nozzle. The subscript l denotes the properties of the liquid. The Weber number is the ratio between inertial or aerodynamic and surface tension forces. The Reynolds number is the ratio between inertial and viscous forces. Substitution of
and into gives:

$$Oh = \frac{\mu_l}{\sqrt{\sigma \, \rho_l \, D}}$$

Thus, the Obnesorge number is ratio between viscous forces and surface tension forces. Now all relevant liquid properties are incorporated, so the various regimes can be classified in the space Oh as function of the jet velocity, or alternatively Re_l. In this figure the four regimes and the relevant zone for diesel injection applications are indicated.

Now the four regimes are described in more detail by increasing jet velocity. Rayleigh regime Breakup at low jet velocity due to axisymmetric oscillations initiated by liquid inertia and surface tension forces. Ddroplet $> D_{nozzle}$,the breakup length Ljet is long and by increasing jet velocity u also Ljet increases.

First wind-induced rigime Liquid inertia and surface tension forces are amplified by aerodynamic forces. The relevant Weber number for this regime is:

$$We_g = \frac{u^2\ ref\ D\ \rho_g}{\sigma}$$

Here u_{ref} is the relative velocity between liquid and surrounding gas and the subscript g denotes the gas properties. $D_{droplet} \approx D_{nozzle}$, Ljet $> D_{nozzle}$ and by increasing jet velocity u the breakup length L_{jet} decreases.

Second wind-induced regime The flow in the nozzle is turbulent. Instable growth of short wavelength surface waves initiated by the turbulence and amplified by aerodynamic forces. $D_{droplet} < D_{nozzle}$ and increasing jet velocity u the breakup length L_{jet} decreases.
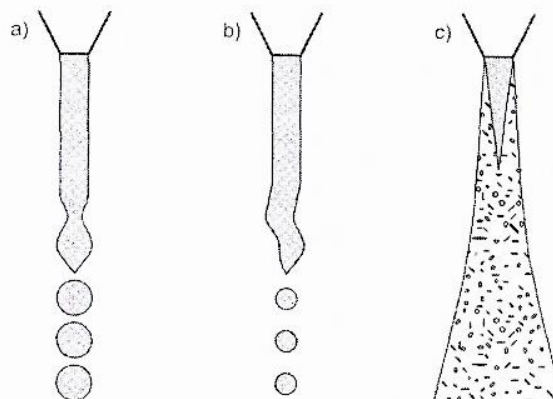

Figure   Schematic representations of the primary breakup regimes: (a) Rayleigh regime, (b) wind-induced regime, (c) atomization regime [Sti03]

Atomization regime Breakup surface directly at the nozzle hole, so the intact core length L_{jet} goes to zero . Conical spray develops immediately after leaving the nozzle. $D_{drople} << D_{nozzle}$.

Secondary Breakup

The secondary breakup mechanism concerns the breakuo due to aerodynamic forces that are induced by the relative velocity between the droplets and the surrounding gas .on the gas-liquid interface growth of waves occur ,while in the same time surface tension counteracts the disintegration process .Similar to the first wind induced regime for the liquid core the gas Weber number is the relevant dimensionless quantity to identify the process.

$$We_l = \frac{u^2 \, D \, \rho_l}{\sigma}$$

Decreasing the droplet diameter **D** raises the surface tension force **σ** this the critical relative takes place.
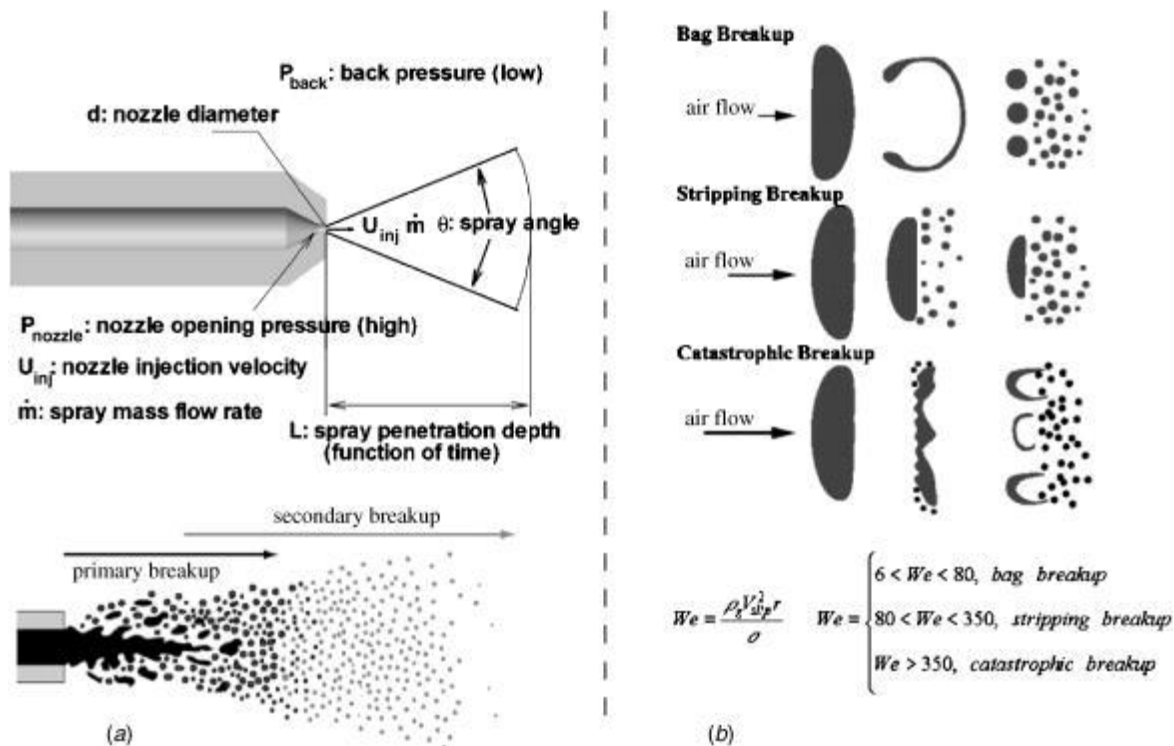
Solid Fuels

Solid fuel refers to various types of solid material that are used as fuel to produce energy and provide heating usually released through combustion . Solid fuels include wood , charcoal, peat, coal and pellets made from wood and other grains. Solid fuels

have been used by humanity for many years to create fire. Coal was the fuel source which enabled the industrial revolution, from firing furnaces, to running steam engines. Wood was also extensively used to run steam locomotives. Both peat and coal are still used in electricity generation today.

The use of some solid fuels (e.g. coal) is restricted or prohibited in some urban areas, due to unsafe levels of toxic emissions. The use of other solid fuels such as wood is increasing as heating technology and the availability of good quality fuel improves. In some areas, smokeless coal is often the only solid fuel used. In Ireland, peat briquettes are used as smokeless fuel. They are also used to start a coal fire.

wood

wood may be burned directly as a fuel or it may be converted into charcoal or producer gas .the principal chemical component of wood are cellulose and lingo cellulose .The major non inflammable component is water which contains 25%-50% .Ash is very small usually less than 0.6% the calorific value of pure of pure cellulose is 16 MJ/Kg .the formation of wood in nature is an endothermic process absorbing approximately 21MJ/Kg this is liberated during combustion

combustion characteristics of wood

1-Easily ignited and burnt below 50% moisture.

2-Does not burn readily in large pieces of layers of semi fused ash forming on the surface

3-produces a long non smoky flame when burned in excess air

peat

Peat is a brown fibrous mass of partially decayed plant material that has accumulated in situ under waterlogged conditions .World resources of peat are estimated at $1200*10^8$ tons.Moisture contains 25%water for cut peat and average values dry basis 16-20 MJ/Kg.

combustion characteristics of peat

1-Low C,V. and high proportion of moisture reduces furnace temperature and efficiency .

2-Low bulk density 350 Kg/m3 reduces capacity of furnace and increases storage and transport capacity.

3-friable nature causes appreciable losses on handling.

Drying of solid fuels

The drying and sorting apparatus for preparation of solid fuel and other solid materials having substantial surface moisture. Ambient air is preheated by indirect heat exchange or other unfired means sufficiently to provide heat needed by the downstream process. The air is then passed up vertically through a bed containing the solid materials, heating and fluidizing them along with the surface moisture. When in a fluidized state, the smaller/lower density particles rise to the top of the bed. At least a portion of the surface moisture on the particles is evaporated. The quantity and temperature of the air flow is sufficient to retain the evaporated surface moisture in the vapor phase. Feedstock of solid materials is added to an intermediate location of the bed. The larger more dense fluidized particles are removed from bottom locations of the bed. The smaller less dense fluidized particles are removed from top location of the bed. The temperature and vapor holding capacity of the air leaving the bed is substantially higher than at ambient conditions. The air is again heated by indirect or unfired means downstream of the bed for reducing relative humidity of the air substantially below saturation prior to passage through a bag house for fine particle collection after which the air along with the superheated water vapor is discharged to atmosphere.