Republic of Iraq
Ministry of Higher Education
and Scientific Research
Al-Mustaqbal University
Chemical Engineering and Petroleum Industries Department

Subject: Combustion engineering

3nd Class

Lecture six

Combustion of liquid fuels

Spray formation and droplet behavior

Oil fired furnaces and boiler, diesel engines, and gas turbines utilize liquid fuel sprays in order to increase the fuel surface area and thus increase the vaporization and combustion rate. For example breaking up a 3 mm sphere of liquid into 30µm drops results in 1 million drops . The droplet mass burning rate is approximately proportional to diameter squared, and the increase in burning rate is 10000 times if we assume that the large single droplet and 1 million small droplets burn under the same ambient conditions.

In spray combustion the liquid fuel injection into a combustion chamber, the liquid undergoes atomization which cause the liquid to breakup into a large number of droplet of various sizes and velocities . Depending on the density and the ambient conditions, some of the droplets may continue to shatter and some may be recombine in droplet collisions. During this time vaporization take place. Fuel vapor produced by vaporization mixes with the surrounding gas ,combustion of the vapor- air mixture occurs. The hot products of combustion mix with the vapor and droplets.

If enough time or combustor length is enough ,the entire amount of fuel will be converted to combustion products. Carbon produced in the combustion process may either continue to oxides to produce final gaseous or may agglomerate to form exhaust particulates.

Spray region divided into

1-The spray formation region .

2-The vaporization region .

3-The combustion region .

In some sprays the breakup region will overlap the vaporazition

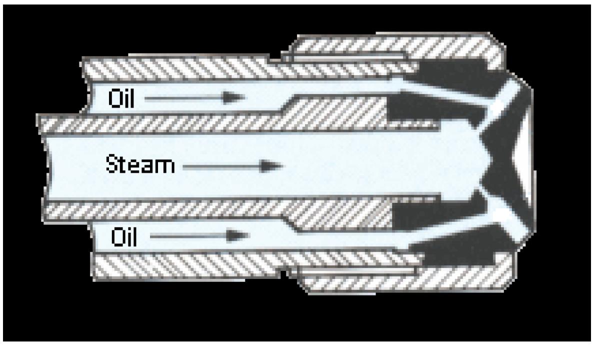
Types of spray

1- simple pressure nozzles

simple pressure nozzles either with 4-10 small holes or a pintle are used in predominantly in diesels.

2-Air or steam atomization

Air or steam atomization nozzles are used in burners and furnaces. The burner lance consists of two concentric tubes, a one-piece nozzle and a sealing nut. The media supplies are arranged so that the steam is supplied down the centre tube and the fuel oil through the outer tube. Consequently, the steam space is completely isolated from the oil space.The steam atomizer consists of an atomizer body that has a number of discharge nozzles arranged on a pitch circle in such a way that each oil bore meets a corresponding steam bore in a point of intersection. Oil and steam mix internally forming an emulsion of oil and steam at high pressure. Oil burners with*0T 0T*internal mix steam atomizing*0T 0T*are tolerant to viscosity changes, do not require high fuel oil pump pressures, and are frugal in . the use of steam

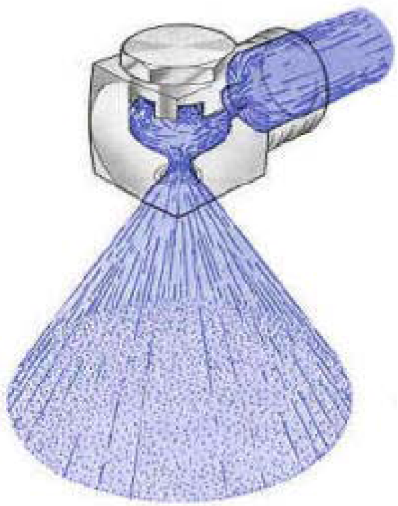


Fig(1) steam atomization

3-Swirl types nozzles

A-Tangential

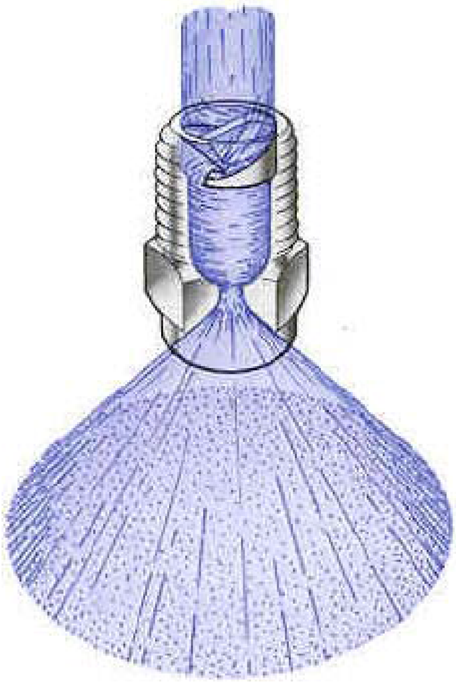
Liquid enters under pressure and is forced through an offset orifice and into a swirl chamber. As the liquid leaves the orifice the droplets follow a trajectory influenced by the orifice shape and the swirl chamber design. The result is a consistent spray angle and uniform droplet distribution. Droplet size and spray distribution are very predictable and not dependent upon a laminar flow. The "free passage" of vaneless full cones are determined by the largest particle size that can pass through the incoming orifice. Vaneless full cones provide the largest free passage that the capacity allows.



Fig(2) Tangential nozzle

B-Axial

Liquid enters under pressure and is forced through a stationary turbine vane located inside the nozzle. As the liquid leaves the orifice the droplets follow a trajectory influenced by the orifice shape and vane design .The result is a consistent spray angle and uniform droplet distribution.



(Fig(3

BREAKUP REGIMES

Diesel engine sprays are usually of the full cone type .The disintegration of liquid jets is described by two main mechanisms. The first mechanism is the breakup of the intact liquid core into droplets and is called primary breakup length, which is defined as the length of the intact liquid core. The second mechanism is the breakup of droplets into smaller ones, which is called secondary breakup. Here the size of the droplets is a characteristic parameter. Both breakup length and droplet size are dependent on the properties of the liquid and the surrounding gas. At least as important is the relative velocity between the liquid and the surrounding gas.

The primary breakup is the most important mechanism in fuel injection system, because it determines the size of the droplets that separate from the liquid core, hence therefore also determines evaporation behavior and it marks the starting point for further breakup into smaller droplets (secondary breakup). It is also far more difficult to analyze primary breakup both experimentally and numerically. In the following the breakup regimes are treated in more detail, but just for clearness the scheme in Fig. can be kept in mind to have the big picture right.

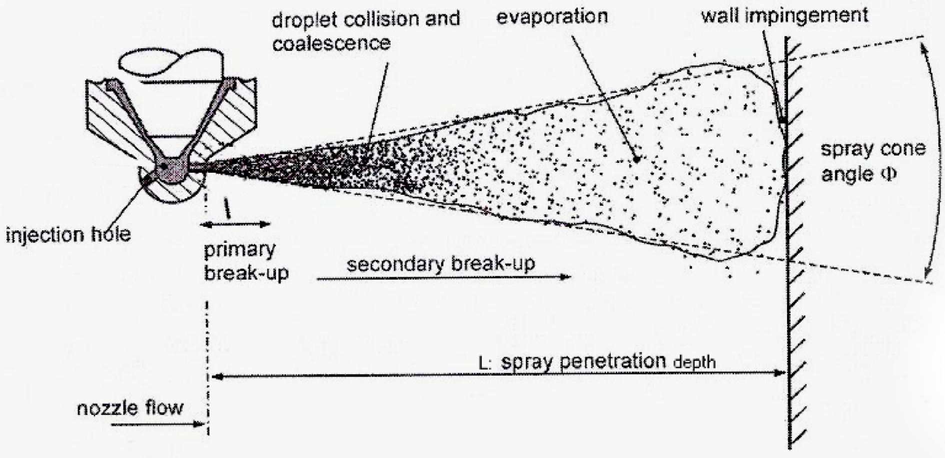


figure ( ) full cone spray