CHAPTER II
BACKGROUND AND LITERATURE SURVEY

2.1 Atomization

Atomization is defined as the disintegration of a liquid into small drops or droplets. The atomization process may be classified into two major categories in terms of relative velocity between the liquid being atomized and the surrounding ambience. In the first category, a liquid at high velocity is discharged into a still or relatively slow-moving gas (air or other gases). The processes in this category include, for example, pressure atomization and rotary atomization. In the second category, a relatively slow-moving liquid is exposed to a stream of gas at high velocity. This category includes, for example, two-liquid atomization and whistle atomization. This research is focused on pressure atomization in diesel engines.

Pressure atomization is one of the most commonly used techniques in general application areas. In pressure atomization of a liquid, pressure is converted to kinetic energy to accelerate the liquid to a high velocity relative to the surrounding ambience. Pressure atomization in diesel engine is called pressure jet atomization, which uses a plain-orifice atomizer as a pressure atomizer.

For steady injection of a liquid through a single nozzle with a circular orifice into a quiescent gas (air), the mechanisms of jet break up are classified into four primary areas (Figure 2.1) due to the relative importance of inertia, surface tension, viscous, and aerodynamic forces. Ohnesorge proposes the most common criteria for the classification. Each area is characterized by the magnitudes of two dimensionless numbers, which are the Reynolds number, Re_L and the Ohnesorge number, Oh:

$$Oh = We_L^{0.5} Re_L^{-1} = \frac{\mu_L}{(\rho_L \sigma d_o)^{0.5}} \tag{2.1}$$

$$Re_L = \frac{\rho_L U_L d_o}{\mu_L} \tag{2.2}$$

Note: Summarized from Liu (2000). *Science and Engineering of Droplets*

$$We_L = \frac{U_L^2 \rho_L d_o}{\sigma} \tag{2.3}$$

where U_L is the liquid velocity at the nozzle exit. We_L is the dimensionless number called the Weber number. Oh is the Ohnesorge number or stability number or viscous group. It represents the ratio of an internal viscosity force to a surface tension force. And ρ_L, μ_L and σ are the density, viscosity and surface tension of the liquid, respectively, and d_o is the diameter of the thin circular tube.

From these equations, the properties of the liquid that affect the atomization are surface tension, density and viscosity, which can be called atomization characteristics of the liquid.

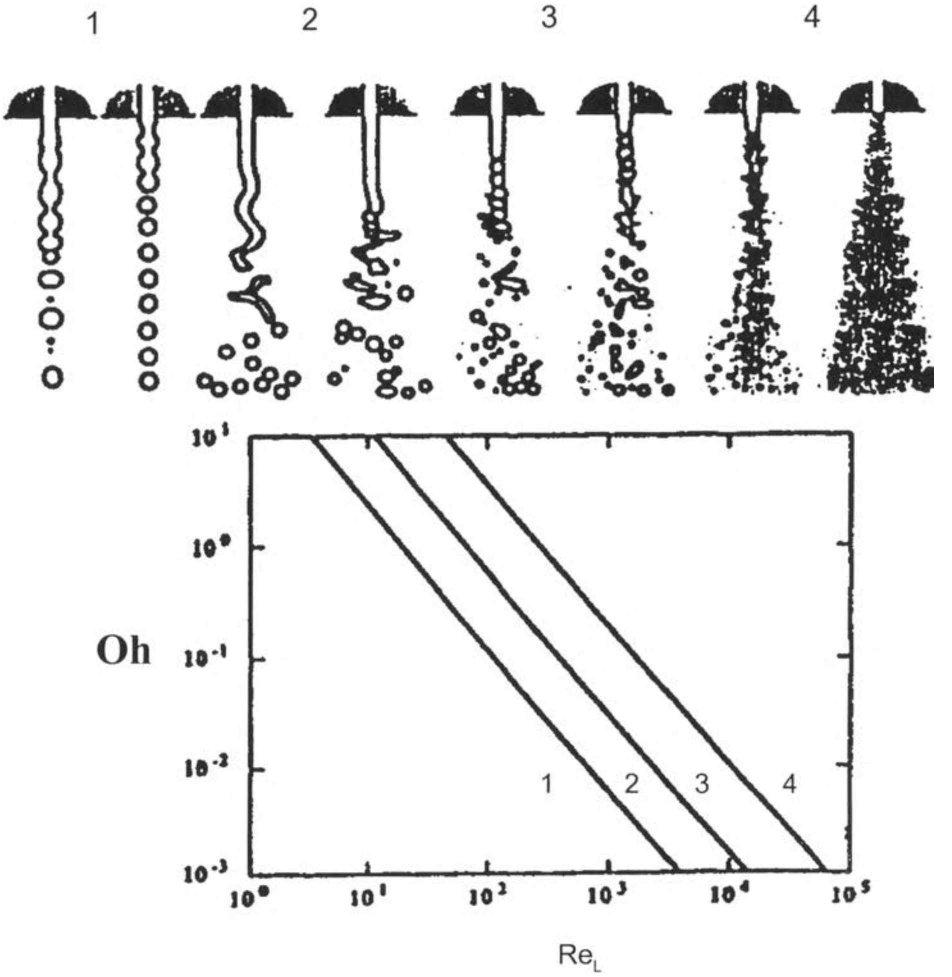

Figure 2.1 Break up regimes of round liquid jets in quiescent air.

Note: Summarized from Liu (2000). *Science and Engineering of Droplets*

From Figure 2.1, the regimes are:

1. Rayleigh jet break up
2. First wind-induced break up
3. Second wind-induced break up
4. Atomization

2.2 Alternative Fuels for Diesel

Alternative fuels for diesel that have been used in Thailand are those derived from biomass, e.g. vegetable oils, because of their availability. There are two methods in which vegetable oils can be used (Polabut, 2002). The first method is to use vegetable oils directly without adding any additives or changing their properties. In the second method, vegetable oils must be first converted to a fatty acid methyl ester (FAME) by transesterification. Then, FAME can be used directly or blended with diesel. Direct uses of vegetable oils have not been widely practiced because of their high viscosity that adversly affects the atomization characteristics. The interesting alternative diesel fuel is FAME because its properties are closed to those of diesel fuel (Allen and Watts, 2000). There are several investigations on the atomization characteristics of FAME being reported.

Allen and Watts (1999) analyzed viscosity and density of methyl ester from peanut, rapeseed, canola, olive, coconut, corn, palm, safflower, sunflower, soybean, sunola, cottonseed oils, beef tallow, butterfat and lard using equations (2.4)-(2.6):

$$\ln \mu_m = \sum_{i=1}^{n} y_i \ln \mu_i \tag{2.4}$$

$$\sigma_m = \sum_{i=1}^{n} w_i \sigma_i y_i \tag{2.5}$$

$$w_i = m\sigma_i + c \tag{2.6}$$

where μ_m is the mean dynamic viscosity of mixture (Pa•s), μ_i is the dynamic viscosity of pure i^{th} component (Pa•s), y_I is the mass fraction of the i^{th} component (-

), n is the number of components (-), σ_i is the mean surface tension of the mixture (N/m), σ_m is the surface tension of the i^{th} component (N/m), w_i is the surface tension weight factor for the i^{th} component, m is the slope of the surface tension linear, weight-function line, and c is a constant of the surface tension linear, weight-function line.

The authors found that the carbon chain length affects the surface tension of those fifteen biodiesel fuel types but not as dramatically as for viscosity.

The studies of kinematic viscosity and specific gravity of commercially available biodiesel (NOPEC Corporation, Lakeland, FL) blended with No. 1 or No. 2 diesel in various ratios show that the kinematic viscosity sharply increases as the temperature decreases (Tat and Gerpen, 1999). Moreover, the kinematic viscosity of the blends varies between that of biodiesel and the diesel fuels according to their percentages. For the specific gravity of the blends, it was found that the specific gravity linearly decreases as the temperature increases and can be predicted by the equation:

$$SG_{Blend} = \sum_{i} SG_i \times m_i \tag{2.7}$$

where SG_{Blend} is the specific gravity of the blend, SG_i is the specific gravity of component i, and m_i is the mass fraction of component i.

Polabut (2002) has reported some negative sides of FAME, which include high production cost and corrosion so the diesel producers avoid using it as fuel directly. But FAME has better lubricating properties than hydrocarbon-based lubricants because its polar structure can provide effective boundary lubrication and acts as a barrier to metal-metal contact. That makes FAME more interesting to be used as a lubricating additive in low sulfur diesel as some researchers have already presented (Anastopoulos *et al.*, 2001).

Masjuki and Maleque (1996) studied the anti-wear characteristics of palm oil methyl ester (POME) blended with diesel engine oil using a four-ball tribometer test. They concluded that the blend of 5% POME resulted in the best lubricity property.

The study of lubrication properties of low sulfur diesel in the presence of biodiesel from sunflower, olive, corn and used fried oils, lauric diethylamide and palmitic dibutylamide was carried out (Masjuki and Maleque, 1996; Haseeb, 2000). It was found that the addition of four types of biodiesel at low concentration around 0.15 to 0.50 vol% resulted in a significant decrease of the wear scar diameter value. Moreover, the examination of two tertiary amides showed that both compounds improved the lubricity of the low sulfur diesel.

The use of refined palm oil blended with high-speed diesel in truck was also studied (Akarapanjavit, 2002). It was found that the mixture can improve lubrication properties and decrease sulfur content and smoke. The refined palm oil can be added in the diesel around 10 vol% without any effect on the indirect injection engine but it causes the reduction of power and acceleration rate and increased carbon monoxide, total hydrocarbon and particulate emissions. Most properties of the mixtures are acceptable except the kinematic viscosity, which is too high.

The study of using high-speed diesel mixed with crude palm oil in 10 and 20 vol% was investigated (PTT, 2002). It was found that some physical properties such as kinematic viscosity and water and sediment content are outside the standard range. Moreover, they cause wax and injector deposit but do not affect the power, fuel consumption and amount of smoke of the engine.

Katpan and Leelatanamongkol (2001) studied fuel properties of coconut, palm and soybean oil. They found that the blends between the oils and high-speed diesel can be used as an alternative diesel but the vegetable oils fraction must be less than 40 vol%.

The study on chemical properties of coconut oil blends as fuel and its emission was carried out by Siribangkeadpol *et al.* (2001). It was found that the blends have higher specific gravity and viscosity than standard diesel. The use of the blends causes the decrease of some emissions. The fuel consumption and heating value are higher than the high-speed diesel.