Multi-Jet Spray Generation for Small Droplet Production

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Abstract

There is an increasing need for the production of very small droplets, using spray generators. Such a need exists, for example, in the field of combustion engines where droplets with Sauter-diameters below 10 microns are favored for direct injection engines. The presentation shows that normal injector sprays are limited regarding the achievable size of the Sauter-diameter by the mass flow that needs to be injected through the jet-nozzle. Jet nozzles with small holes are required to produce small spray particles and large holes are needed to introduce the required mass flow rate through the nozzle. Simple ad hoc explanations are given to explain these counter acting influences of the jet hole diameter. The influence of the fluid viscosity and its surface tensions are also discussed, although their utilization to control the droplet size are limited.

To overcome the limitations of jet type spray generators investigations were carried out for two jet and multi jet sprays. Fundamental investigations were fulfilled to understand the spray generation mechanisms. General outcomes of these investigations are summarized in the presentation. Experimental investigations were carried out to verify some results of theoretical considerations for two interacting fluid jets. Results of the experiments are presented and the obtained particle diameter distributions are briefly described. It is shown that the two-jet-sprays can be utilized as a basis for spray generators to yield particles with Sauter-diameters around 10 microns in size, to reach the required mass flow rates through the nozzle and to guarantee a specific distribution of the spray in the combustion chamber which is needed for a homogenous fuel-mixture generation.

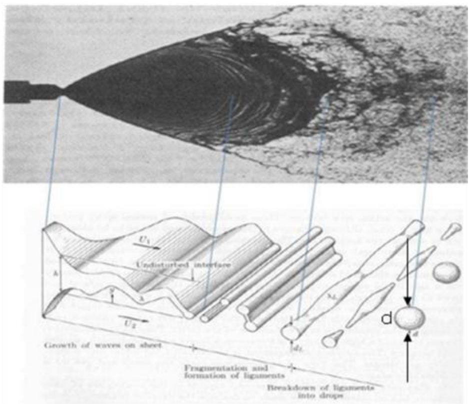
Some practical applications of multi jet spray generators are given during the final part of the presentation. The needs for further developments are outlined for some of the technical realizations of two-jet injectors.

Content of the lecture

The presentation introduces various methods to generate sprays. Methods for monodispersed droplet size distributions are mentioned but the main parts of the presentation are concentrating on polydispersed sprays. The spray productions by cylindrical liquid jets are outlined and it is shown that the demand for high mass flow rates through nozzles contradicts the requirement for small droplet productions. Theoretical considerations are presented to support experimental findings.

Spraygeneration by instable liquid films

The droplet formation by instable very thin liquid films is presented and again theoretical results are used to guide experimental investigations.



Resultant droplet diameter d:

$$d \approx \sqrt[3]{\frac{3\pi}{\sqrt{2}}} \cdot \delta \qquad (1)$$

$$\delta = 0{,}56 \cdot \frac{1}{\alpha_L} \cdot \sqrt{\frac{\rho}{\Delta p}} \cdot D^{0{,}75} \qquad (2)$$

Figure 1. Example of a thin liquid film and its break-up into droplets [1]

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Liquid jets are set up to impinge onto flat discs of a few mm in diameter, the resultant thin films are shown to become instable, when they reach the edge of the discs. The instability mechanism is considered and final relations are derived to correlate the resultant droplet diameter with fluid and film parameters to provide the basis for experimental studies.

Spraygeneration by the interaction of liquid jets

The interaction of two inclined liquid jets is looked at as a basis for spray production. Between the jets a thin lamella forms that becomes instable some small distance away from the jet interaction region. A spray is generated in this way, which can again be treated theoretically, at least in some respect. Some of the deduced results are explained. Experiments were carried out to verify that interacting jets can be employed to yield droplets of very small diameters. Sauter diameters of 10µm and smaller can be reached for water droplets, even smaller droplets for gasoline and Diesel fuels.

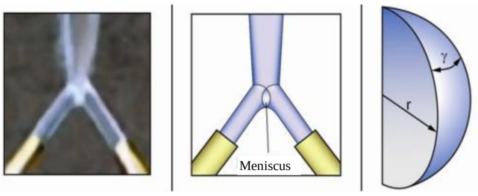

Figure 2. Interaction of two inclined jets and formation of a meniscus at the hitting point

Analytical considerations show, that there exists no back flow of droplets (Figure 2) if the surface tension is larger than the inertia forces of the back flow. At a certain critical angel α a meniscus is formed at the hitting point and avoids the backflow.

$$\sin\alpha = 1 - \frac{8\sigma}{D\rho U^2} \tag{3}$$

Application of spray generators

The lecture summarizes, at the end, various products that employ liquid sprays, like humidifier, sprinklers, paint spray nozzles, injectors for combustion engines, medical inhalers, etc. It is indicated that spray generators are needed that employ different mechanisms for generation of small droplets in order to cover the entire range of applications of liquid sprays.

Figure 3. Products that employ liquid sprays (f.l.t.r.:Monodisperse Droplet Generator, Injectors for combustion engines, air humidifier, inhalator)

Nomenclature

d	droplet diameter [m]
δ	thickness of liquid film [m]
αL	nozzle coefficient [-]
ρ	density [kg·m-3]
Δp	pressure difference [Pa]
D	nozzle diameter [m]
σ	surface tension [N/m]
U	jet velocity [m/s]

References

[1] Brodkey, Robert S., *The Phenomena of Fluid Motions*, New York, Dover Publications, 1967.