Experimental and theoretical investigations of Twin-Jets

F. Durst[1], Y.Han, A.Handtmann, M.Zeilmann
FMP TECHNOLOGY GMBH, Albert Handtmann Holding GmbH & Co. KG
info@fmp-technology.com, y.han@fmp-technology.com, info@handtmann.de, m.zeilmann@fmp-technology.com

Abstract

Twin-Jet sprays have been extensively studied and numerous publications exist that document their properties. This yields to the finding that the theoretical treatment, forwarded by Dombrowski & Johns [1], is often used to provide an insight into the physics of Twin-Jet sprays. The theory in [1] deals, however, with an aerodynamically stretched and excited plane liquid lamella, a spray production process that does not apply to the Twin-Jet sprays. The authors forward the theoretical treatment of Twin-Jet sprays. Based on experimental observations, a theory applicable to high pressure Twin-Jet sprays is developed that is also extended to low pressure Twin-Jets by experimentally based correlations using dimensional analysis, to yield the Sauter-mean-diameter and the liquid jet lengths, which agree well with the experiments. The results are generalized by providing them as Oh-Re-correlations. The latter can be used to lay out Twin-Jet sprays for different applications, i.e. for designing Twin-Jet injectors for Otto- and Diesel-engines.

The liquid sheet formed by two identical impinging jets breaks down due to two principal mechanisms. Firstly, the interaction between liquid and ambient air produces super-imposition of aerodynamic waves. When the wave length is greater than the jet radius, the sheet will break up into liquid ligaments and further into fine droplets. Secondly, the impact of two jets results in hydrodynamic waves starting from the impinging point. These waves cause the sheet to disintegrate into bands of drops, particularly at high jet velocities. The detailed mechanism for hydrodynamic breakup has not been clarified until now. However, it can be determined that both mechanisms of disintegration of a sheet are dependent upon the jet parameters like impinging angle, liquid density, viscosity, surface tension, jet velocity and jet diameter. Therefore, the mechanism of disintegration can be summarized in a function of Reynolds number, Ohnesorge number and impinging angle.

Starting with the assumption that the region of drop formation by two inclined, interacting jets decreases to the periphery of a small ellipse, the mass flow of the two impinging jets are set to be equal to the mass flow out of the periphery. This yields to an equation for the thickness d_L of the lamella by assuming that the velocity of the fluid in the lamella is equal to the initial jet velocity

$$d_L \approx \frac{D}{3/2(1 + 1/\sin\theta) - \sqrt{1/\sin\theta}}$$

A ligament is only formed out of the liquid lamella if the fluid momentum exceeds the surface tension force. By taking also the viscosity into account one can derive

$$f_3\left(\frac{d_{32}}{D}\right) \geq f_1(\theta)\, f_2(Oh, Re)$$

Finally, by applying a dimensional analysis, the Sauter-mean-diameter of the resultant spray droplets can be obtained as

$$\frac{d_{32}}{D} = C \cdot f_1(\theta) \cdot f_2(Oh, Re)$$

Reference

[1] Dombrowski N. and W. R. Johns, The aerodynamic instability and disintegration of viscous liquid sheets, Imperial College, London, S.W.7.

[1] Corresponding author: info@fmp-technology.com