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Summary of:

BREAK-UP AND ATOMIZATION OF A ROUND WATER JET BY A HIGH-SPEED ANNULAR AIR JET

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Break-up and atomization of a round water jet by a high-speed annular air jet

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This paper focuses on the experimental investigation of the droplets in the coaxial flow system that involves air as the gas flow while water is the liquid coming out from the jet. The visualization carried out using the phase doppler particle sizing (non-intrusive laser diagnostic) provides a detailed information on the primary and secondary breakup mechanisms involved in the spray in the near-field and far-field from the nozzle for a case with the gas flow velocity (U_g) ranging from $10^4 < Re < 10^5$.

For the primary breakup region that is caused due to the high shear forces at the gas-liquid interface, the unstable waves are produced that break into fragments, which then contracts to ligaments. A critical shear We_c is defined above which there will be a breakup from these lumps. Based on the study by Hinze, We_c is of the order 10 for a water droplet. For the turbulence near the nozzle, it is reported that the $Re \geq 10^3$. Similarly, the area ratio (ratio of area of annular gas nozzle to the area of jet nozzle), mass flux ratio (ratio of mass flux of liquid to gas) and the momentum flux ratio (ratio of momentum flux of gas to liquid) are equally important.

Near-field atomization is characterized by the breaking off of the fiber-type ligaments through Rayleigh type capillary breakup mechanism. If the air velocity is increased for the given water flow, the momentum flux as well as We increases. There are larger lumps that are seen downstream for the mass flux ratio greater than 5. To analyze the liquid intact length before the pinch-off, an entrainment model is applied considering the fact that the liquid is entrained or carried away due to the gas flow. When the air momentum is dominant, the ligaments are entrained into the airstream.

As the liquid moves downstream from the nozzle, the viscous liquid layer gets accelerated which leads to formation of eddies. At a higher mass and momentum ratio, these eddies will cut-off the central cone of the spray, leading to the secondary breakup.

A statistical description is provided using a distribution function dependent on diameter of the drop(d),spatial range about the vector position(x), velocity range about(v),time(t) : $f(d, x, v, t)$. In a turbulent flow region, the turbulent dissipation K.E (ε) plays a vital role in the droplet breakup. For a highly turbulent case, the maximum drop size that will withstand breakup is reported to be $\varepsilon^{-\frac{2}{5}}$. Also, it is observed that the value of ε is greater in the near-field so, the droplet breakup is dominant, whereas in the far-field because of the lower ε, the coalescence of drops is found to be a dominating behavior.

In the far field, the mean size of the droplet is minimum at the jet centerline and it increases as it moves away from the centerline. For the analysis, the study is carried out assuming that the flow is free of any event such as evaporation. The drop size depends on the relative velocity of the flow, droplet acceleration, turbulent dispersion and the droplet evaporation are mentioned.

1) Relative velocity dependence is such that the value of the minimum diameter will decrease with the increasing gas velocity.
2) Droplet acceleration causes the increase in the mean droplet size.
3) Turbulent dispersion that is caused due to the eddies, lead to the increase of the mean droplet size.
4) Droplet evaporation occurs since the entrained air is not saturated with water vapor, so downstream of the flow, evaporation assumption cannot be neglected, and will cause the decrease in the mean diameter.

Overall, this paper provides a detail overview of the formation of drops in the near-field as well as the far-field. The analysis is carried out for the coalescence as well as evaporation of the secondary drops.