Flow characteristics and turbulence analysis of a large-scale pressure-atomized spray

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Abstract

The purpose of this study is to characterize the atomization of a jet of water sprayed into the air at high velocity through a commercial nozzle widely used for sprinkler irrigation. Atomization in sprinkler irrigation is wished to be as gradual as possible. Inefficiency of the atomization process is needed in order that water jets keep a sufficient range to irrigate large areas of farming parcels. As a consequence, the jets involved in sprinkler irrigation are very different from usual sprays. On the contrary to usual liquid sprays, sprinkler jets have a very long core of liquid, which can reach up to 210 nozzle diameters. The surface of this liquid core is very turbulent and on it are present very thin liquid ligaments, which give raise to the first small droplets. Further, the flow is composed of three-dimensional liquid fragments, which are still breaking up and whose surface is very complex. A large variety of scales are present in this flow as the ratio of the large turbulent scales over the smallest liquid length is about 10^4.

The typical diameter of the droplets present in the spray is in the range of several tens of micrometers to several millimeters. They are visualized by ombroscopy. A specific Droplet Tracking Velocimetry (DTV) technique is developed to estimate the size and velocity of these highly polydispersed droplets that are distinctly non spherical. This analysis is performed from the rupture of the liquid core region (distance of about 550 nozzle diameters) to the dispersed zone (distance of about 900 nozzle diameters). With this technique, we obtain joint size-velocity measurements that are rarely produced. Especially two velocity components and also a large diameter range are characterized at the same time; while with other techniques, such as Particle Doppler Anemometry (PDA), the diameter range is quite reduced and requires specific settings. Additional measurements of the liquid volume fraction are performed using a single mode fibre-optic probe. In the light of our experimental data, it appears that the turbulence of the liquid phase in the spray is strongly anisotropic, with the ratio of radial to longitudinal velocity variances which can be as small as 0.1. This ratio (or anisotropy factor) significantly depends on both the droplet size and their circularity parameter R ($R = P^2/4\pi A$ where P denotes the droplet perimeter and A their area, with typically $0.8 < R < 2.2$ on the jet axis). This anisotropy is quite unexpected because other studies on sprays (generally concerned with engine applications) show a relatively low anisotropy. We attribute this increase of anisotropy to the fact that, for this type of spray, the droplet relaxation time is long in comparison to the characteristic time of the turbulence. This strong anisotropy is responsible for the poor radial dispersion of the spray.

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