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CFD study of a corrugated hollow cone for enhanced dew yield

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Dew condensation is the result of cooling by radiative deficit between a substrate and the atmosphere. The yield is limited by the latent heat of condensation and the heat flux between the substrate and the atmosphere, which increases with wind speed. Then dew yield can be enhanced in hollow structures like hollow cones where the influence of wind is lowered. Passive dew collection involves in addition the shedding of small droplets by gravity, which increases with the angle of the structure with horizontal. However, radiative cooling diminishes with this angle. A good compromise is a tilt angle of 30° with horizontal. Hollow cones with 60° half-angle give thus good results for dew condensation and dew collection.

Another process improves the dew drop collection efficiency: On edges or other singularities, dew drop grow faster thanks to a solid angle of vapor collection larger than in the middle of the substrate (Phys. Rev. E 90, 062403 (2014).). Then edge drops detach sooner and act as natural wipers. In addition, corrugation increases the local tilt angle with horizontal, thus increasing locally the gravity forces acting on the drops.

In order to combine all positive effects (hollow structures, edge effects), a corrugated, w-shaped hollow cone is compared to the same, smooth structure by Computational Fluid Dynamics. Two softwares were used: ANSYS CFX for detailed aerodynamics where the computational domain is modelled to obtain a fully developed wind profile assuming an unobstructed inlet and COMSOL Multiphysics for heat flux, including radiative exchange surface-to-sky and surface-to-surface. Local temperatures are obtained, which can be related to the dew yield within some assumptions that will be discussed.

The cone dimensions are 4.635 m upper radius, 0.2115m lower radius, 2.554 m height with upper part at 8 m above the ground. The cone external sides and the lower hole are thermally insulated. Air temperature is set at 15°C and wind speed is varied from zero to 5m/s (CFX) or at two typical values, 0.0001 and 2 m/s (COMSOL).

Turbulence is seen at all speeds but stagnation of the flow is also observed, which limits the convective heat exchanges and facilitates dew formation. For 0.0001 m/s windspeed, mean cone cooling is found to be 5.8 K (smooth) and 6.5 K (corrugated), and for 2 m/s windspeed, 5.5 K (smooth) and 5.2 K (corrugated). Corrugation increases radiative and convective heat exchange. At low speed, convective heat exchange is however similar for both smooth and corrugated surfaces, and corrugation increases cooling. At higher air flow velocities, convective heat exchange is larger for the w-cone and cooling is smaller than found on the smooth cone. However, the difference (0.3 K) remains small, which makes the w-cone in general a better dew condenser.