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Application of Computational Fluid Dynamics to Design High Performance Drip Irrigation Emitters

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The emitters with labyrinth channels are widely applied in drip irrigation system for their simply structures and low manufacturing cost compared with pressure compensating emitters. The pressurized water in pipes drops into the soil slowly and uniformly through emitter's labyrinth channels. The fluid inside emitters is expected to be turbulent so that it can weaken the influence on flow rates due to the fluctuation of operating pressure and improve the irrigation uniformity [1]. Because of its small geometry and opaque channel, it is not easy to observe the flow state of the fluid. Computational Fluid Dynamics (CFD) offers the possibility to investigate the fluid inside channels not always accessible using experimental techniques.

By using CFD technique, we can visualize the flow field inside labyrinth channels including the fluid velocity and pressure, and can also find the critical Reynolds number from laminar flow to turbulence [2]. If a three-dimensional numerical model of emitter is build up, the flow rates of emitters can be quickly calculated at different pressure heads [3]. From a series of flow rates and pressure heads of emitters obtained by CFD, the relationship can be regressed as $Q = k \cdot H^x$, where Q is the flow rate (l/hr), k is an emitter constant, H is the pressure head (kPa), and x is the emitter flow rate exponent. The constants k and x are always used to evaluate emitter's hydraulic performance. Therefore, the structure can be optimized according to the evaluation parameters till reaching a satisfied result.

On the other hand, emitter clogging has been considered one of the most annoying problems inhibiting the popularization of drip irrigation; it can be caused by physical, chemical or biological contaminants [4-5]. Regardless of which kind of the clogging, it can be ascribed to the deposition of particles with different diameters (sand, indissolvable carbonate, bacteria etc.) in emitters. Usually, we conclude the drip irrigation whether is clogged or not based on the flow rate at the same pressure head. We are not sure why and how emitter's discharge is reduced? CFD can simulate the motion and trajectories of particles and visualize the single particle's stagnation position by using stochastic trajectory model. In addition, by means of Eulerian-Eulerian model, potential deposition regions of plenty of solid particles can be obtained, which can be used to explain the clogging mechanism of emitters [6]. These simulation results are good criterions for structural optimization of emitters.

CFD is an effective technique to discover the flow behavior of the fluid in labyrinth channels which is important for the micro-characteristics of the emitter. The researchers and manufacturers can design serials of high-performance emitters by using CFD.

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