Research on the flow of water in flexible tubes could make irrigation technology more sustainable and cost-effective

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Ruo-Qian Wang (left) worked with engineers at Jain Irrigation Systems in Jalgaon, India, to understand the design requirements for high-efficiency irrigation technology. Credit: Massachusetts Institute of Technology

A team of MIT engineers has described a novel way of controlling the flow of water in flexible tubes, a finding with implications for agricultural systems worldwide. Their research, published in the Journal of Mechanical Design, could reduce the energy demands of pulsating sprinklers used for irrigation.

"Food and its relationship to water is one of the biggest problems in the world," says Ruo-Qian Wang, a former postdoc at the MIT Tata Center for Technology and Design who is now a postdoc at the University of California at Berkeley. "There is a clear need for efficient irrigation technologies that save money and conserve resources."

Wang co-authored the paper with three researchers in MIT's Department of Mechanical Engineering: graduate student Teresa Lin, PhD candidate and Tata Fellow Pulkit Shamshery, and Assistant Professor Amos Winter.

The model they propose could be especially useful in developing countries, where many farmers cultivate small plots of land without reliable access to the electricity grid. These farmers rely on solar or diesel power to draw water for irrigation.

"If you bring down the energy requirements of the irrigation system, that means a farmer can buy a smaller solar panel, or use less diesel," Wang says. "Everything gets cheaper and more accessible."

Compensating for pressure

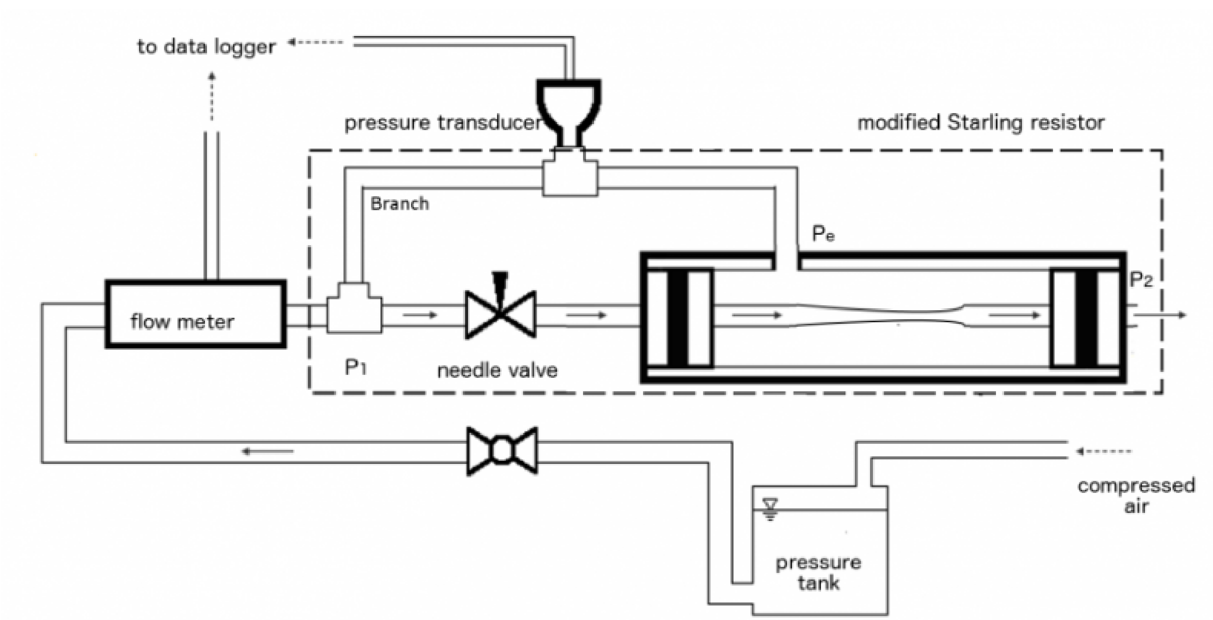
The researchers focused on a device called a Starling resistor, which is a flexible tube that collapses as pressure is applied. This device is noted for its similarities to human respiration, and has been used to model flow in the lungs and airways.

"But," Wang says, "it has never been applied to a pressure-compensated flow control system for agriculture."

The team created an experimental Starling resistor architecture that introduces a needle valve, which allows for independent control of two key variables: activation pressure and flow rate. The goal is a phenomenon called pressure compensation, in which a steady flow rate can be maintained no matter the pressure differential.

"Activation pressure is key to energy consumption," Wang says. "A traditional resistor has to achieve a high level of activation pressure, about 1 bar, to activate the pressure compensation mechanism. That takes a lot of pumping power."

The team's experiment showed that using a rubber tube to replace the diaphragm of the existing Starling resistor design can reduce the needed activation pressure by 90 percent.



The MIT team's novel design of a Starling resistor includes a needle valve to control the rate of water flow through the system. Credit: Massachusetts Institute of Technology

"As a result, Wang says, "farmers can use smaller pumps and smaller solar panels to provide the activation pressure."

They placed the needle valve at a critical juncture in the system, where, together with the rubber tube, it acted as part of a series of resistors to water flow. Using different tube lengths and thicknesses, they discovered that adjusting the needle valve changed the flow rate, but did not change the minimum pressure needed to "activate" the system. Their paper describes the first mathematical model that quantitatively predicts this decoupling of the two variables.

This means their device could make it easier to optimize irrigation systems for a variety of settings.

"We can design the activation pressure using a given tube material and geometry, and by adjusting the needle valve, water can be applied to different crops at different flow rates," Wang says.

This new Starling resistor can be optimized for a high flow rate—necessary for pulsating sprinklers—while the pressure compensation phenomenon also causes the tube to oscillate, which gives it a natural pulsating quality.

Wang explains that "a traditional sprinkler uses a spring-loaded arm to impact the flow rate. That wastes energy, and energy has a cost. This device provides pulsation by itself."

Leveraging global expertise

The project has grown out of the team's partnership with Jain Irrigation Systems, a multinational company headquartered in Jalgaon, India, that provided funding, technical knowledge, and market expertise. Researchers in Winter's GEAR Lab have collaborated with Jain on a number of projects related to water and agriculture.

"Jain is a $1 billion revenue company with small-scale farmers comprising 80-90 percent of their clients," says Wang. "They can commercialize agriculture projects in that space better than any other company."

He notes that Jain's guidance and ability to field-test prototypes helped keep the Starling resistor project on the right track.

"Being able to test this architecture with Jain helped us determine that it had potential in sprinkler systems. Now we have a great opportunity for our work to make an impact."

More information: Ruo-Qian Wang et al. Control of Flow Limitation in Flexible Tubes, *Journal of Mechanical Design* (2016). DOI: 10.1115/1.4034672