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基于模糊控制的肥液自动混合装置设计与试验

Design and experiment of automatic mixing apparatus for liquid fertilizer based on fuzzy control

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中文关键词: 肥料,模糊控制,自动,混合,液体,肥液浓度,电导率

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作者	单位
李加念	1. 昆明理工大学现代农业工程学院，昆明 6505002. 华南农业大学工程学院，广州 510642
洪添胜	2. 华南农业大学工程学院，广州 5106423. 南方农业机械与装备关键技术教育部重点实验室，广州 5106424. 国家柑橘产业技术体系机械研究室，广州 510642
冯瑞珏	2. 华南农业大学工程学院，广州 5106425. 华南理工大学广州学院，广州 510800
倪慧娜	2. 华南农业大学工程学院，广州 510642

中文摘要:

为提高混肥精度，该文在基于脉宽调制的文丘里变量施肥装置的基础上，对其结构进行了改进，并利用电导电极设计了一个电导率测量仪用以实时反馈肥液浓度，构成一个闭环控制的自动混肥装置。该装置采用粗细2级调节的控制策略，首先根据检测的入口水压调用对应的函数关系，自动调节电磁阀PWM（pulse width modulati 控制的占空比进行混肥；然后以电导率测量仪实时反馈混肥浓度，并采用模糊控制算法进一步细调PWM的占空比，使混肥浓度尽量逼近目标浓度。试验结果表明，电 测量仪的有效测量范围为0~12.64 mS/cm，它所测量的电导率与肥液浓度呈显著的线性关系，其决定系数R2为0.997。对混肥装置进行了实测验证，结果表明混肥时的最 度误差为0.04%，控制装置达到稳态的响应时间为7.8～10.4 s，能满足实际应用的要求。

英文摘要:

Abstract: Fertigation is an irrigation technology of integration of water and fertilizer, and has been widely used in micro-irrigation systems, because of uniform fertilization, hig utilization of water and fertilizer, and effectively reducing the pollution of soil and environment. The venturi fertilizer injector has become one of the main means and important equipment to achieve fertigation due to its simple structure, economy, and practicability, but the liquid fertilizer concentration could not be easily adjusted automatically. In order realize variable rate fertilization with a venturi fertilizer injector, a variable fertilizer apparatus based on PWM (pulse width modulation) technology has been developed, but the apparatus belongs to open-loop control from the perspective of automatic control, and its accuracy and stability is difficult to guarantee. Therefore, a closed-loop control automat fertilizer-mixing device was developed to improve the liquid fertilizer concentration mixing accuracy and stability, by improving the structure of the variable fertilizer apparatus and adding a conductivity meter that was employed to feedback the real-time fertilizer solution concentration indirectly. The conductivity meter was designed based on a conductivity electrode, and a square signal whose amplitude is ±3.5 V was determined as the excitation signal of the conductivity meter through experiments, to weaken or even eliminate polarization effects and capacitance effects of the conductivity electrode in the measuring process. In order to further improve measuring accuracy, temperature compensation ha been applied to the conductivity meter, the measuring range had been divided into several small-scale ranges which could be switched by a multiplexer ADG1408 controlled by a microcontroller, and the corresponding divider resistor and square signal frequency of each small scale range were determined by experiments. By comparison with a standard conductivity meter, whose model is sension 156, the effective measuring range of the conductivity meter designed was 0-12.64 mS/cm, and the conductivity meter designed was calibrated according to the data measured in the effective measuring range. It was known that the conductivity of the fertilizer solution measured by the conductivity meter has a significant linear relationship (the coefficient of determination R2 is 0.997) with the fertilizer solution concentration, based on conductivity testing of a series of different concentra fertilizer solutions prepared in the range of 0.1%-1.0%. In order to improve the control performance of the automatic fertilizer mixing device, a kind of control strategy of two-step regulating with coarse adjustment and fine adjustment was employed: first, the device adjusted the duty cycle of PWM for controlling the solenoid valve to mix fertilizer automatic by calling the corresponding function based on the detected inlet water pressure; then the device uses a fuzzy control algorithm to regulate the duty cycle of PWM finely, accord the real-time fertilizer solution concentration measured by the designed conductivity meter, in order to make the mixed fertilizer concentration get close to the target concentration much as possible. An actual test and verification had been undertaken for the fertilizer mixing device, and the results showed that the maximum error of the mixed fertilizer concent was 0.04% and the response time of the control device for achieving steady-state was 7.8-10.4 s, and it is now known that the device can meet the requirements of practical applica in agriculture.