

Development and Evaluation of an Automatic Surge Flow Irrigation System

BEHROUZ MOSTAFAZADEH-FARD¹, YASSIN OSROOSH AND SAEED ESLAMIAN

Irrigation Department, College of Agriculture, Isfahan University of Technology, Isfahan, Iran

¹Corresponding author's e-mail: behrouz@cc.iut.ac.ir

ABSTRACT

Surge flow irrigation can reduce the irrigation water losses and improve irrigation performance. In this study attempts have been made to design, manufacture and evaluate an automatic surge flow irrigation system. The system includes an automatic surge valve, which can be programmed by user based on field conditions such as soil infiltration characteristics changes during the irrigation season. The surge valve is inexpensive, portable and wireless and its energy is supplied by a chargeable battery, which the battery can also be recharged by a solar panel for a long duration uses. To evaluate the performance of the system, the surge valve including constant head water delivery system to the furrows were installed in an furrow irrigation experimental farm and based on input data given to the system the furrows were irrigated automatically by surge method with cycled inflow of 10 min on and 10 min off. The results showed that the system is able to accurately and automatically irrigate the furrows by surge method based on information given to the system. For the same discharge and volume of water applied to the furrows the water advance along the furrows were faster for surge flow as compared to the continuous flow.

Key Words: Furrow irrigation; Surge flow irrigation; Automation

INTRODUCTION

Furrow irrigation is one of the oldest methods of irrigation in which soil surface is used to convey and infiltrate water. This method of irrigation as compared with sprinkler or trickle methods is inexpensive. Therefore, more attention is being paid to improve the efficiency of this method of irrigation. For instance runoff recovery, cutback technology and surge flow irrigation have been studied to reduce losses and save labor (Walker, 2003). One of the newest surface irrigation methods is surge flow irrigation in which water applies intermittently to the furrows (Yonts *et al.*, 1996). Soil infiltration plays an important role in performance of surface irrigation (Osman *et al.*, 2003). Previous studies have shown that the intermittent application of water changes soil intake rates, because a surface seal layer is formed in the wetted portion of irrigated furrow during the off time that causes the water to move down the furrow more quickly at the subsequent on time (Samani *et al.*, 1985). Previous studies have shown that surge flow irrigation helps to improve surface irrigation efficiencies and uniformities and have several advantages over conventional irrigation method (Bishop *et al.*, 1981; Izadi *et al.*, 1991; Yonts *et al.*, 1996; Fekersillassie & Eisenhauer, 2000). Surge flow irrigation reduces the total amount of irrigation water by reducing deep percolation and runoff water losses. Also, it allows for automation without requiring a high pressure water supply to apply water to the furrows.

Following some efforts to develop a system to reduce furrow inflow after the completion of the advance phase,

Stringham and Keller (1979) introduced the concept of surge flow irrigation. They noted that automatic irrigation valves act better in either completely open or close form than in semi-open status and it would be simpler to cycle the valves to reduce the average flow rate instead of partially closing the valves. In early 1981, surge irrigation trials were conducted at the Utah State University. A surge controller connected to the gated pipe was developed to operate the valves. The surge controller was able to provide variable cycle times (on time plus off time) ranging from 1 to 60 min and cycle ratio (on time divided by the cycle time) of 0.5. Switching solenoid valves were controlling the two set of furrow pneumatic valves. Actuating any valve was causing a diaphragm to inflate and blocking the flow (Walker & Skogerboe, 1987). Research also on surge flow irrigation at the U.S. Department of Agriculture, Agricultural Research Service, concentrated to design and evaluates valves to be used in gated pipe for automatic surface irrigation systems. The valves manufactured for use in the gated pipe were operating either with water or air pressure (Walker & Skogerboe, 1987).

There are mainly two types of surge valves, mechanical or bladder valves. The mechanical valve is a butterfly disk valve located either across the tee junction (single butterfly) or in each branch of the tee junction (double butterfly). The most common valves used in surge flow irrigation are butterfly valves coupled with a controller. The disk valves are powered by electricity (or batteries), air pumps, or water pressure. Most controllers utilize solar cells to keep their batteries charged. The controllers allow the farmers to irrigate the field based on desired cycle time or

cycle ratio.

It is nearly three decades since the surge flow idea has been introduced, but challenges for introducing appropriate and less costly equipments to apply surge flow irrigation for field conditions still exist.

The objective of this study is to design, manufacture and evaluate a low cost and simple surge flow irrigation system, which can be used for various furrow irrigation field conditions.

MATERIALS AND METHODS

The developed automatic surge flow irrigation system as shown in Fig. 1 mainly consists of a constant head water delivery system to the furrows, controller (Fig. 2), single butterfly valve (Fig. 3) and gated pipe. The combination of the butterfly valve and controller that is commonly called "surge valve" may be programmed by the user for specified field conditions and cycle time based on factors such as soil infiltration variations over the irrigation season. The surge valve is placed at the middle of the gated pipe switching water from one side of the field to another side. The controller is wireless and powered by a battery that can be recharged by solar panel. The whole set including the controller and butterfly valve has dimension of 40 x 40 x 40 cm and weight about 25 Kg.

Controller. The controller has three main parts, electronic board (Fig. 4), motor and gear and power supply (battery). The electronic board is made up of two 89C55 microcontrollers, a static memory (IC 24C16), five relays, two triacs (MOC3010 & Z00607MA), an A/D chip (ADC0808), two micro switch, a LCD display and a keyboard. The controller can be programmed by user interface (keyboard & LCD, as shown in Fig. 5), which allows the user to enter number of cycles, cycle time, cycle ratio and irrigation time. The butterfly valve is activated by the controller through running a 12 volts DC small motor. Since the surge valve is used in the field, where there is no electricity, the controller is powered by a 12 volts chargeable battery.

Butterfly valve. The butterfly valve is a three way T type valve. It takes water from water supply and switches it either to the right or left as receive information from controller. Commercial valves manufactured are generally cast iron or stainless steel for high pressure proposes. Due to low pressures required for the surge flow irrigation, the butterfly valve was made from Teflon sheet and the frame was assembled by welding iron plates to reduce the costs. The sphere shape was used for the frame of the butterfly valve and disk shape was used for the butterfly valve.

Gated pipe. A PVC gated pipe with outside diameter of 160 mm was used. Plastic belts were used to connect the ball valves to the gated pipe at 60 cm spacing. The ball valves can be adjusted to handle the desired inflow rate to the furrows at constant pressure head provided by the water supply reservoir. The gated pipe was placed at the up-stream

Fig. 1. Automatic surge flow irrigation system installed in the experimental field



Fig. 2. Controller of the butterfly valve

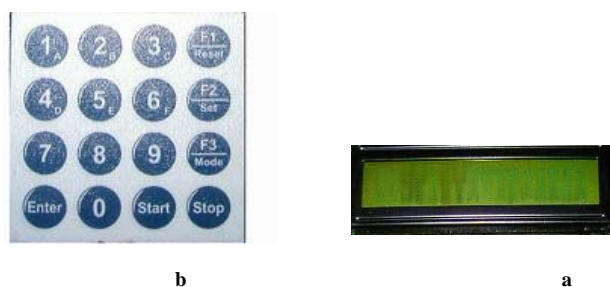


Fig. 3. Butterfly valve



end of the furrows such that each ball valve be located in front of one furrow.

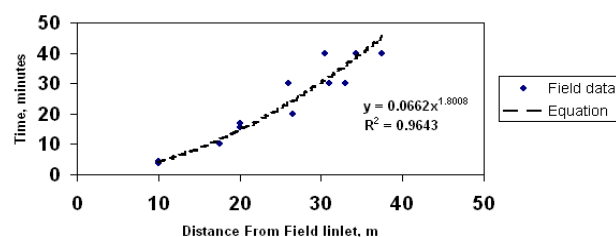
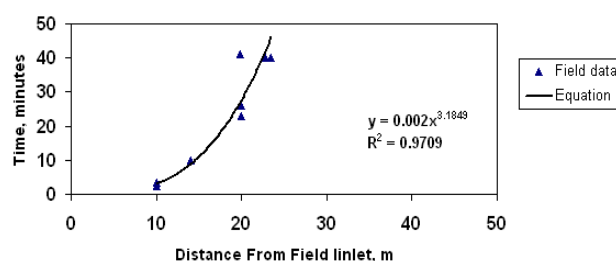
Water supply. A 220 L cylinder tank was used as reservoir. Flow into the tank was greater than the volume of the water needed for the tests and the excess water was delivered outside of the tank through a weir placed near the top of the tank. Therefore the water pressure remains constant during the experiment.

Fig. 4. Electronic board of surge valve**Fig. 5. LCD monitor (a) and keyboard (b)**

Field test. The surge flow irrigation system as described above was installed in an experimental furrow irrigation field (Fig. 1). The experimental field having sandy clay loam soil with slope of 0.3% was located in Isfahan University of Technology. The ball valves connected to the gated valve were used to adjust the furrow inflow rate at non-erosive discharge rate of 1.2 L per second. The field was irrigated for the first time with no plant. Advance time was measured at 5 m intervals along the furrows for both surge and continuous methods. Three replications were used for each measurement and inflow discharge was the same for both methods. One portion of the field was selected for surge flow tests and another portion of the field was selected for the continuous flow tests. The furrows were irrigated automatically by the surge valve with cycled inflow of 10 min on and 10 min off based on input data given to the system. For continuous flow irrigation the above system was used but the controller was programmed such that the furrows are irrigated continuously.

RESULTS AND DISCUSSION

To ensure that the developed surge flow irrigation system functions satisfactory, several trials were carried out both in workshop and field to evaluate the surge valve performance and improve its capability. Then, the system was installed at the top of a furrow irrigation experimental field located at Isfahan University of Technology and based on field conditions the input data was given to the controller

Fig. 6. Advance curve for the surge flow irrigation**Fig. 7. Advance curve for the continuous flow irrigation.**

and tests started for surge flow irrigation. Similar approach was also used for the continuous flow tests.

Fig. 6 shows the results of the advance tests for the surge flow irrigation. Fig. 7 shows the results of the advance tests for the continuous flow irrigation. The comparison of Fig. 6 with Fig. 7 show that for the same furrow inflow rate and volume of irrigation water the advance of water is faster for surge flow as compared to the continuous flow. The results presented in Figs. 6 and 7 also show that the surge valve is able to monitor surge and continuous flow automatically for actual field conditions based on information given to the system. Faster water advance for surge flow irrigation as compared to the continuous flow irrigation will result in more uniform distribution of the water along the furrows, which consequently the result is less irrigation water losses especially as deep percolation at the upper end of the field. The runoff also can be decreased by changing the cycle ratio when the water reaches to the end of the field. The system can be programmed to change the cycle ratio and cycle time when the water reaches to the end of the field in order to reduce losses. The system is wireless and portable and can be placed at different locations in a field to irrigate a larger area. The area that can be irrigated by the surge valve mainly depends on the capacity of water supply reservoir and the number of gated pipe sections connected to each other. A solar panel can also be added to the set to recharge the battery automatically when the system is going to be used for a long duration.

CONCLUSION

Automation of surface irrigation reduces water loss and improves the irrigation performance. The results showed that the developed surge valve can irrigate furrow

irrigation field automatically for both surge and continuous flow. The system is simple to operate by the local farmers, portable, wireless and inexpensive and can be placed anywhere in the field to irrigate the desired number of the furrows.

Acknowledgment. This research was funded by Isfahan University of Technology, which is appreciated.

REFERENCES

- Bishop, A.A., W.R. Walker, N.L. Allen and G.J. Poole, 1981. Furrow advance rates under surge flow systems. *J. Irrig. Drain. Div. ASCE*, 107: 257–64
- Fekersillassie, D. and D.E. Eisenhauer, 2000. Feedback-controlled surge irrigation: I. Model development. *Transaction of ASAE*, 43: 1621–30
- Izadi, B., D. Studer and I. MaCann, 1991. Maximizing set-wide furrow irrigation application efficiency under full irrigation strategy. *Transaction of ASAE*, 34: 2006–14
- Osman Saleem, M., A. Muhammad, S. Imran and A. Saqib, 2003. Adoption of Kostikov model to determine the soil infiltration for surface irrigation methods under local conditions. *Int. J. Agric. Biol.*, 5: 40–2
- Samani, Z.A., W.R. Walker and L.S. Willardson, 1985. Infiltration under surge flow irrigation. *Transaction of ASAE*, 28: 1539–43
- Stringham, G.E. and J. Keller, 1979. Surge flow for automatic irrigation. Presented at the July, 1979, *ASCE Irrigation and Drain. Division, Special Conference, ASCE, Held at Albuquerque, N.M.* Pp: 132–42
- Walker, W.R., 2003. "SirmodIII: Surface Irrigation Simulation, Evaluation and Design." Software Engineering Division, Biological and Irrigation Engineering Department, Utah State University, Logan, Utah, U.S.A
- Walker, W.R. and G.V. Skogerboe, 1987. "Surface Irrigation: Theory and Practice," P: 386. Prentice-Hall Inc., Englewood Cliffs, New Jersey
- Yonts, C.D., D.E. Eisenhauer and D. Fekersillassie, 1996. Impact of surge irrigation on furrow advance. *Transaction of ASAE*, 39: 973–9

(Received 12 May 2006; Accepted 19 June 2006)