A Novel Universal Water-Saving Irrigation System Based on Cam and Throttle Design

Siwei Zhang, Huan Yang, Jianhang Si, Lei Kang, and Xuesong Liu
Northwestern Polytechnical University, Xi'an, China
Email:{ 1226237819, 2496834052,1178933269,1484597921,2925548729}@qq.com

***Abstract*—Making precise watering in horticulture development is becoming an inevitable trend for the lack of water resources in China. In order to solve the wasting problem, a new water-saving irrigation system with novel mechanical design is proposed to do accurate irrigation under different circumstances. As for various shapes of flower beds, we establish the watering model and calculate one specific shape as an example. The results provide a theoretical proof for the availability of watering system.Precise irrigation is an inevitable trend for gardening development in the serious situation of water shortage. With a gradual increase in private custom flower beds, this invention has great value in application and market prospects.**

***Index Terms*—precise watering, new irrigation system, various shapes**

I. The Application Background

With more and more green areas are built to meet the need of higher living condition, the need of watering is always growing during these years. In addition, the trend of private custom flower bed also makes the consumption of water increased year by year. Usually, people used to water their flowers beds through randomly spraying systems, which absolutely waste amount of water. However, the lack of water source is the urgent situation that we must face today: according to the survey on nature sources of 2011 in China, more than 300 cities lack water, which result from the fearful pollution of groundwater. Out of resource security considerations, to carry out multi-precision watering is imperative, and a new irrigation system is needed to save water when satisfying various watering tasks.

II. The Basic Principle of Watering Devices

The new universal water-saving irrigation system is put forward schematically by dividing the whole system into three parts [1].

A. Cam Gear

By using the cam profile surface to control the pitch angle of water pipe, different spraying distance is achieved to meet the need of alterable spray shapes, which is shown in Fig. 1.

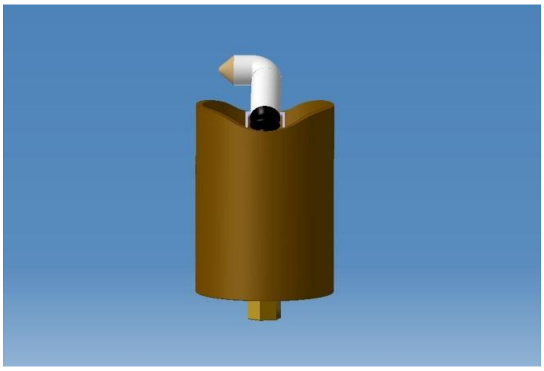

Figure 1. A schematic view of a cam gear

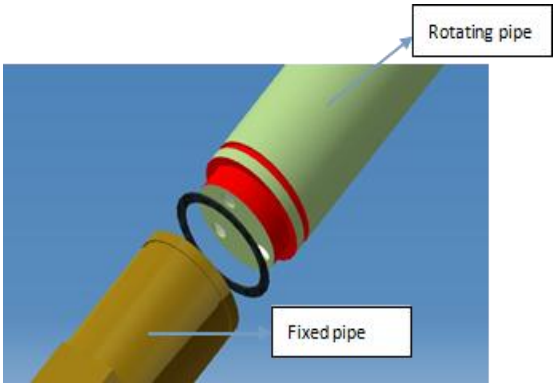

Figure 2. The two parts of the pipe

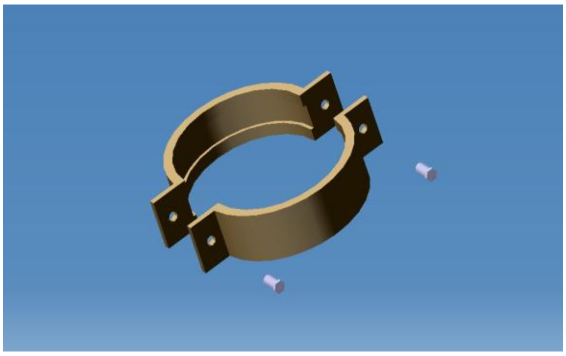

Figure 3. The coupling

B. Throttle

As shown in Fig. 2, the pipe is divided into two parts, with each edge inserted with a throttle valve. It includes the fixed part and the rotating part: the former is connected to ground, with the three-hole throttle plate

Manuscript received July 5, 2014; revised September 19, 2014.

doi: 10.12720/joaat.1.2.147-150

positioned on its top; the latter has another piece of throttle place on the bottom, also with the same number of holes. Besides, the coupling is used to make the two parts screwed together. There is an O-rings as drainage grommet. Only when the holes of the two parts meet each other, the water can go through the whole pipe and spray regionally, which is shown in Fig. 3.

Figure 4. The overall pattern of the irrigation system

Figure 5. The simulation irrigation effect

C. Mechanical Construction Program [2]

When water flows into the nozzle, the torque caused by the reaction force makes it rotate to spray. As mentioned above, the throttle makes watering within a designated range; and the cam changes the pitch attitude of the nozzle in time, which all contributes to the accurate spraying distance. The overall pattern is shown in Fig. 4, while the simulation effect is shown in Fig. 5.

III. Precise Watering Model

Water-saving devices can realize irrigating regionally, when positioned at the edge area of a quadrilateral playground, which verifies the possibility of "limited scope spraying"; then the pentagon, six tulip-shaped flower beds were all simulated, with the given result of "pitch angle - angle" relationship, proving the realizability of multi-shaped spray. As for more complex situations with alterable shapes and a determined position, the design can be cut into different parts, each parts of which can be researched individually. As an example, the calculation of clover-shaped flower bed is described in detail, indicating that the device drivers can indeed overcome the friction force and the system is powerfully universal, water-saving, and realizable.

A. Universality Proof

To establish the suitable irrigation system to water the clover-shaped flower bed, the basic parameters is set in Table I [3]:

By using the throttle, when two holes of the two parts meet each other, water can be sprayed within a specific range. Three orifices are set in each valve plate, with the corresponding central angle of 30 degrees. Clover is presented as a centered symmetrical shape, and so only the heights of one-sixth of cam need to be designed. Fig. 6 shows the designated heights with the corresponding pitch angle of the nozzle. And firstly, in the coordinate system, the triangle side length is assumed as 9 meters and the radius semicircle is 4.5 meters, which aims at easier calculation.

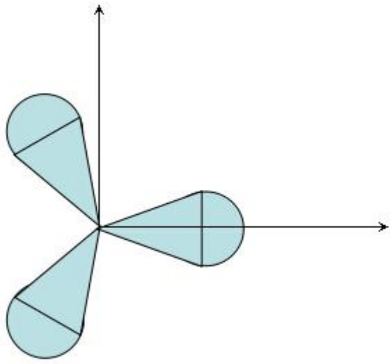

Figure 6. The coordinate system

The positive direction and angle of the shaft (nozzle angle) is shown in Fig. 6: since the clover is centrosymmetric, the calculated angles just range from 0° to 30° and the computing spacing is 5°, and then $\alpha = \{0°,5°,10°,15°,20°,25°,30°\}$. In corresponding to the cam edge height, the nozzle pitch angle values can be symmetrical.

TABLE I. The Basic Parameter of the Irrigation Systems

Jet range/m	Pressure /kPa	Flow /(m^3/h)	Nozzle diameter/mm	Vents thickness/mm	Pipe height/mm	Cam radius/mm	Cam height/mm	Spout length/mm
15	150	4.58	18	3	125	40	125	50

According to the formula (1), corresponding to different α, values of the arc edge points along the x-axis can be released, as shown in Table II.

$$(x-1.5\times4.5)^2+(x\cdot\tan\alpha-2.25\times\sqrt{3})^2=4.5^2 \quad (1)$$

TABLE II. The Arc Edge Point with Different α

α/°	30	25	20	15	10	5	0
x /m	10.65	10.00	9.17	8.17	7.04	5.8	4.50

Along the y-axis, the coordinate point of arc edge can be computed by $y = x \cdot \tan\alpha$, and the result is shown in Table III.

TABLE III. THE Y-AXIS COORDINATE WITH DIFFERENT α

α/°	30	25	20	15	10	5	0
l /m	12.29	12.21	11.98	11.55	10.95	10.13	9.00

TABLE IV. THE JET LENGTH OF THE CLOVER SHAPE

α/°	30	25	20	15	10	5	0
y /m	6.15	7.01	7.69	8.17	8.39	8.30	7.79

The distance between the origin point and the arc is the jet length, which can be calculated by $l = \sqrt{x^2 + y^2}$, the result of which is shown in Table IV.

The relationship between jet length and the cam height is based on formula (2).

$$L = \frac{V^2\cos\theta\sin\theta}{g} + V\cos\theta\left(\frac{V^2\sin^2\theta}{g^2} + \frac{2H}{g} + \frac{2b\sin\theta}{g}\right)^{\frac{1}{2}} \tag{2}$$

Let $l = L$, and calculate the pitch angle α of the nozzle, corresponding to the angle β (θ is in the formula). The result is shown is Table V.

TABLE V. THE CORRESPONDING α AND β

α/°	30	25	20	15	10	5	0
β/°	54.65	55.18	56.61	30.65	27.99	24.86	21.10

And $\tan\theta = \frac{H-h}{R-r}$, so the corresponding cam height H can be calculated, as shown is Table VI.

TABLE VI. THE CAM HEIGHT

α/°	30	25	20	15	10	5	0
h/m	0.18	0.18	0.19	0.15	0.15	0.14	0.14

Based on the above calculation, the design on the cam of clover flower bed is completed, as shown in Table VII.

TABLE VII. THE DESIGNING RESULT

Clover (a petal)		Cam radius 40mm		Side 9m	Height 125mm	Leaf is an equilateral triangle+semicircle	
Num	7	6	5	4	3	2	1
x	4.50	5.81	7.04	8.17	9.17	10.00	10.65
α/°	60/180/300	55/175/295	50/170/290	45/165/285	40/160/280	35/155/275	30/150/270
β/°	21.10	24.86	27.99	30.65	56.61	55.18	54.65
h/m	0.14	0.14	0.15	0.15	0.19	0.18	0.18

Spraying a specific shape can be realized through the application of the cam gear. There is no water sprayed in the non-determined part. The specific data analysis is shown in Table VIII.

TABLE VIII. THE REPRESENTATION OF THE WATER-SAVING EFFECTS

Shape	Side /m	Area /m^2	Circumcircle area/m^2	Water saving area/ %
Square	15	225	353.43	36.34
Pentagon	15	487.14	706.86	31.08
Six petal-shaped	9	401.30	474.85	15.49

B. Feasibility[4]

The torque required to overcome the friction is

$$T = I\varepsilon + F\mathrm{r} \tag{3}$$

here T is the torque, I is the moment of inertia, ε is the angular acceleration, F is the friction, r is the distance from the center of rotation to the friction.

The torque provided by water reaction is

$$T = \mathrm{m}\varepsilon\mathrm{r}^2 \tag{4}$$

here $m = Q \times \rho$, and ε is set to 10rad/s.

Assuming the moment of inertia of the horizontal pipe is I_1,the moment of inertia of the vertical pipe is I_2, the whole moment of inertia is calculated as:

$$I_1 = \frac{1}{3}ml^2,\ I_2 = \frac{1}{2}m(\mathrm{r}_2{}^2 - \mathrm{r}_1{}^2) \tag{5}$$

The moment of inertia is shown in Table IX

As for the friction, it contains two parts: one is between the two pipes, and the other is between horizontal pipe and cam gear [5]. And the friction from the weight of water is the dominate one. As the size mentioned before, we get:

$$F = 0.5228 \times 9.8 \times 0.25 + 0.49455 \times 9.8 \times 0.1$$

According to the above, the friction torque is $T_1 = 0.03$

The friction torque test:

$T_2 = 1.13$ (when pressure=200kpa) or $T_2 = 0.08$ (when flow= $5.5\mathrm{m}^3/h$)

So $T_2 > T_1$,the scheme is feasible.

From the formula (5):

$$T_1 = T_2 \tag{6}$$

the minimum pressure and flow can be concluded: $P_{\min} = 75.481kPa$ $Q_{\min} = 3.102m^3/h$.

As the city water pressure is defined as about 150kpa. From the formula (6):

$$Q = CA\sqrt{\frac{2P}{\rho}} \tag{7}$$

the flow is achieved:Q= $4.58m^3/h$

Therefore, $P > P_{\min}$ and $Q > Q_{\min}$, so that the city water pressure can make irrigation system rotate normally, which prove that the scheme is feasible

TABLE IX. THE MOMENT OF INERTIA

	Vertical Tube	Horizontal pipe
I /m^3	2.23*10^{-5}	3.18*10^{-4}
Moment of inertia of the water column in the tube/m^3	2.54*10^{-6}	9.42*10^{-5}

IV. CONCLUSION

A. Innovation

In this paper, through the design and calculation of water-saving devices, the actual situation of precise irrigation in various lawn are analyzed. It has a high practical significance in application, which laid the foundation for the popularity of this water-saving device and water-saving ideas.

The water-saving device is equipped with a throttle valve which controls the water within a predetermined range. Besides, there is a cam gear outside so that the spray distance can be adjusted. With these two special structures, the lawn with any shape and any range can be precisely watered. Therefore, it comes to the conclusion that this irrigation system has good generalization.

B. Evaluation of Irrigation Systems

Precise irrigation is an inevitable trend for gardening development in the serious situation of water shortage. And the situation "private custom flower beds" is in the ascendant. Therefore, it is conducive for the concept about water-saving deeply welcomed by people and provides a broad market prospect for the design scheme.

The water-saving device has an ingenious mechanical design, low material and processing costs, which are key factor for the acceptance of operators. The post-maintenance is also cost-effective, which is the performance of market competitiveness.

REFERENCES

[1] G. Y. Li and H. Lv, “garden lawn sprinkler design basis,” China Agricultural University.

[2] B. Red, S. Y. Xie, and Z. Y. Qiu, “Variable range of spin injection nozzle design water core,” Southwestern University.

[3] Z. Y. Chen, Z. M. Wu, and L. Q. Zhao, "Lawn sprinkler system hydraulic parameter adjustment," College of Engineering and Technology, Shanxi Agricultural University, 2005.

[4] Society of Controllable Variable Spray Nozzle and Sprinkler Irrigation Fields Precise Technical Research NWAFU, 2003.

[5] Facilities are Bright, Positioning Sprinkler Sprinkler Systems Design Strength, "Sprinkler Technology," Feb. 1980.

Siwei Zhang, a student of Northwestern polytechnical university, born in 1.4.1993 in China, studying the aircraft design and program in his university. I'm good at scientific research and have great ability of organization. And I get school ship for two times in my school. I have finished the college students' innovative practice project and has published two papers.

Huan Yang, 21 years old, a senior student from Northwestern Polytechnical University, majoring in Aircraft Design and Engineering. A warm, generous and diligent man is good at professional knowledge. I always have high standard requirements for myself, which makes me having a great grades in most of courses. I’ve done assistant work in Institute of Aviation for two years, whose work gets the praise of teachers and students for the cautious and responsible working attitude. Additionally, I like running, reading and painting. Study and physical exercise is equally important for me.

Sijianhang, born in Yulin, Shan Xi Province on October 1, 1992. Major in aircraft design, Sept. 2008—Jul. 2011 Shan Xi YuLin Middle School Student.Sept.2011—present Northwestern Polytechnical University Student. He is a senior student in Northwestern Polytechnical University, presently. Having Earned Nationnal Scholarship for Encouragement for many times during the three years of college life

Kang Lei, male. 21 years old. College student from school of aeronautics, NPU, Xi’an, Shaanxi, China. Major in aircraft design and engineering.

I always study hard, I got ‘merit student’of school and university. In my spare time, I like to listeng to English songs, watching English movies or TV programs. In my summer holiday last year, I play a role as leader of practicing team. In that time, we visit some wind tunnels and know much about local conditions and customs of Sichuan.

Liu Xuesong, a senior college student in NWPU of China. In the last years, I have courage to challenge many contests and activities, and have made many friends with different academic background and characteristics. In this process, I have shown my powerful ability in learning new things, as well as in thinking logically and reasonably when faced difficulties. I have won national scholarships in two consecutive years, have been sponsored to study in France by CSC and have been to the USA in “Rainbow Bridge” exchange program as the representative of our school. I am good at making speech and writing, have won the “honorable mention” in MCM/ICM, and have published a SCI paper in Corrosion Science. I would like to cooperate with my teammates to do the most cost-effective things, which, I hope, can improve our career to some extent and develop ourselves in an upward trend.

dehydration and poor water quality were important issues in rice-fish farming. Karami *et al*. [26] noted that Discriminant function derived from integrated model could suitably categorize adopters and non- adopters of RFF. The most important variables, which differentiated RFF adopters and non-adopters, were access to information, knowledge of fish fingerlings, aquaculture management, and plot preparation for aquaculture and knowledge of fish harvesting. In addition, fuzzy analysis in study of Noorhoseini *et al*. [35] showed that most important agro-economics benefits of integrated rice-fish farming were more accessible to villagers to white meat through the production of fish, optimal and dual use of rice fields, pollution reduction and environmental sustainability by reducing the use of pesticides and chemical fertilizers, fish production as an additional product and increase revenue rice farmers, dual use from water irrigation resources, increase soil fertility of rice field by fish farming, biological control of weeds and pests

IV. Conclusions

In this study, important agro-economic factors influencing the adoption of integrated rice-fish farming were application of chemical fertilizers, application of herbicides, especially quantity using Diazinon, yearly income from agricultural activities, number animals and accessibility to agricultural organs. This result was recommend that the first agricultural extensional must display essential resources for adoption of integrated rice-fish farming among farmers. Second, developers of integrated rice-fish farming must increase benefit ably of fish farming. Secondly, the agronomic knowledge of using rice-fish farming should be disposed of farmers to adopt it more consciously and with a positive viewpoint. Finally the promotion of integrated rice-fish farming should be paid more attention for following enormous numbers of adopters of this technology.

References

[1] C. H. Fernando, “Rice field ecology and fish culture - an overview,” *Hydrobiologia*, vol. 259, pp. 91-113, 1993.

[2] A. Rothuis, “Rice-fish culture in the Mekong delta, Vietnam: constraint analysis and adaptive research,” thesis Submitted for the Award of the Degree of Doctor of Science, Department of Biology, Laboratory of Ecology and Aquaculture, Katholieke Universiteit Leuven, Vietnam, 1998, pp. 113.

[3] S. A. Noorhosseini and F. Bagherzadeh-Lakani, *Ecology of Integrated Rice-Fish Farming*, Haghshenass Publication, 2012, pp. 104p.

[4] T. Larsen, S. H. Thilsted, K. Kongsbak, and M. Hansen, “Whole small fish as a rich calcium source,” *British Journal of Nutrition*, vol. 83, pp. 191–196, 2000.

[5] N. Ahmed and T. S. Garnett, “Integrated rice-fish farming in Bangladesh: Meeting the challenges of food security,” *Food Security*, vol. 3, no. 1, pp. 81-92, 2011.

[6] S. A. Noorhosseini and M. N. Safarzadeh-Vishekaei, “Effective factors on adoption of integrated rice and fish farming in Tavalesh Region of Guilan,” Young Researchers Club, Islamic Azad University, Rasht Branch, Rasht, Iran, 2009, pp. 94.

[7] S. A. Noorhosseini and F. Bagherzadeh-Lakani, “Ecological and biological effects of fish farming in rice fields,” *Persian Gulf Crop Protection*, vol. 2, no. 2, pp. 1-7, 2013a.

[8] D. H. Giap, Y. Yi, and C. K. Lin, “Effects of different fertilization and feeding regimes on the production of integrated farming of rice and prawn Macrobrachium rosenbergii (De Man),” *Aquaculture Research*, vol. 36, pp. 292–299, 2005.

[9] P. Dugan, M. M. Dey, and V. V. Sugunan, “Fisheries and water productivity in tropical river basins: enhancing food security and livelihoods by managing water for fish,” *Agricultural Water Management*, vol. 80, pp. 262–275, 2006.

[10] H. Berg, “Rice monoculture and integrated rice-fish farming in the Mekong Delta, Vietnam-economic and ecological considerations,” *Ecological Economics*, vol. 41, pp. 95–107, 2002.

[11] M. Halwart and M. V. Gupta, *Culture of Fish in Rice Fields*, FAO and the World Fish Center, 2004, pp. 83.

[12] A. Hilbrands and C. Yzerman, *On-Farm Fish Culture*, Printed by: Digigrafi, Wageningen, Netherlands, 2nd ed., pp. 67, 2004.

[13] S. A. Noorhosseini, “Ecological and biological effects of fish farming in rice fields,” Regional Congress of Sustainable Management Science-based in Agriculture and Natural Resources. Gorgan University of Agricultural Sciences and Natural Resources, Iran, May 21-22, 2011, pp. 244-250.

[14] S. A. Noorhosseini, “Fish farming in rice fields toward sustainable agriculture: The case study in guilan province,” in *Proc. First National Conference on Sustainable and Cleaner Product*, Esfahan of Iran, Nov. 10-11, 2010, pp. 529.

[15] S. A. Noorhosseini and R. Radjabi, “Decline application of insecticide and herbicides in integrated rice-fish farming: The case study in North of Iran,” *American-Eurasian Journal Agriculture & Environment Science*, vol. 8, no. 3, pp. 334-338, 2010a.

[16] S. A. Noorhosseini and R. Radjabi, “Reduce pesticide and herbicide use in integrated fish - rice farming: A case study in west guilan province,” in *Proc. 4th Conference and Exhibition on Environmental Engineering*, Tehran University, Iran, 2010.

[17] S. A. Noorhosseini and N. Mohammadi, “Environmental and social benefits of fish farming in rice fields,” in *Proc. 4th Conference and Exhibition on Environmental Engineering*, Tehran University, Iran, 2010.

[18] D. R. Das, M. A. Quddus, A. H. Khan, and M. Nur-e-Elahi, “Farmers participatory productivity evaluation of integrated rice and fish systems in transplanted aman rice,” *Pakistan Journal of Agronomy*, vol. 1, no. 2-3, pp. 105-106, 2002.

[19] S. T. Hossain, H. Sugimoto, G. J. U. Ahmed, and M. R. Islam, “Effect of integrated rice-duck farming on rice yield, farm productivity, and rice-provisioning ability of farmers,” *Asian Journal of Agriculture and Development*, vol. 2, no. 1, pp. 79-86, 2005.

[20] S. A. Noorhosseini and M. S. Allahyari, “Problems of fish farming in rice fields: the case study in guilan province,” in *Proc. First National Conference of Aquatic Sciences*, Islamic Azad University, Booshehr Branch, Iran, Feb. 24-25, 2011, pp. 15.

[21] S. A. Noorhosseini, “Problems of fish farming in paddy fields,” *Indian Journal of Fundamental and Applied Life Sciences*, vol. 3, no. 3, pp. 268-272, 2013.

[22] K. Li, “Rice-fish culture in Asia: A review,” *Aquaculture*, vol. 71, pp. 173–186, 1988.

[23] D. C. Little, P. Surintaraseree, and N. I. Taylor, “Fish culture in rain fed rice fields of northeast Thailand,” *Aquaculture*, vol. 140, pp. 295–321, 1996.

[24] S. A. Noorhosseini, “Production of fish varieties in rice fields simultaneously,” in *Proc. National Conference on Food Industries*, Young Researchers Club, Islamic Azad University, Quchan Branch, Iran, 2012.

[25] S. A. Noorhossein and F. Bagherzadeh-Lakani, “Production of fish varieties in paddy fields simultaneously (the case study in Iran),” *International Journal of Farming and Allied Sciences*, vol. 2, no. 15, pp. 464-469, 2013b.

[26] E. A. Karami, K. Rezaei-Moghadam, M. Ahmadvand, and M. B. Lari, “Adoption of rice- fish farming (RFF) in Fars Province, Iranian,” *Journal of Agricultural Extension and Education*, vol. 2, no. 2, pp. 31-43, 2006.

[27] S. A. Noorhosseini and M. S. Allahyari, “Effective socio-economic factors for adoption of integrated rice and fish farming in the Guilan Province,” *Journal of Agricultural Extension and Education Research*, vol. 3, no. 3, pp. 35-51, 2010.

[28] S. A. Noorhosseini and M. S. Allahyari, “Factors influencing the adoption of rice-fish farming system in Talesh Region, Iran,”