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NUMERICAL CALCULATION OF TRIANGLE CIRCULATION DRIP IRRIGATION EMITTERS

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ABSTRACT

Based on the hydraulic characteristics of triangle circulation, sudden-expansion pipe and sudden contraction pipe, Construct a drip irrigation emitter with strong turbulent flow, large over-current cross-section and strong anti-clogging ability. Triangular circulation flow path emitters for the key structural parameters for the factors, application of computer numerical fluid dynamics CFD software FLUENT6.3, simulate triangular circulation flow channel structure, analyze the influence of various structural parameters on hydraulic performance of emitters, flow index, flow rate and the anti-clogging ability. The results show that increase unit cusp, unit chamfer, the flow index increased, but the effect to varying degrees; inlet dimension increase, flow index reduced; flow channel depth and flow channel width increases, the discharge increases. Increase unit cusp, unit chamfered, can improve the anti-clogging performance of emitters. Based on the above results, to design an emitter structure with good performance, and its numerical simulation analysis, the flow index, flow rate and anti-clogging ability have met the requirements of drip irrigation. Provide a theoretical basis for the triangle circulation emitter structure design and quantitative analysis. The research has a positive meaning for energy conservation.

Keywords: emitter, triangle circulation, parameter, simulation, hydraulic performance

INTRODUCTION

Emitter is one of the core components of the drip irrigation system, the performance and quality directly determines of the work performance of the irrigation system, its main function is to consume the energy of water pressure, so water droplets flow out evenly. For some time, the flow channel structure of emitter develops slowly, constrain the diversity development and application of drip irrigation emitters product, difficult to adapt to the development and promotion of drip irrigation applications. In this paper, a new type of triangle circulation drip irrigation emitters was simulated by computational fluid dynamics（CFD）based on the turbulent model established, which provided some visual and direct evidences for predicting the hydraulic performance of drip emitters, by changing the structural parameters to study the hydraulic performance of emitters and the influence of structural parameters on flow rate and the anti-clogging ability. Establish a new type of emitter channel with the best structure parameters, provide theoretical basis and reference for the systematic design of emitters channel structure.

1.Emitter channel structure

A new development trend of emitter flow path is to build a good flow channel structure, and reduce the flow index, to improve the stability of emitter outflow, increase flow channel cross-section dimensions, narrow the flow channel length, to increase the flow velocity and turbulence intensity, and increase anti-clogging capability, while reduce the work pressure and the cost of emitters, to reduce energy consumption and construction investment of drip irrigation systems.

1.1 The structural characteristics of flow channel

Fluid flowing in the sudden expansion and sudden narrowing channel flow is a common phenomenon. Due to fluid inertia and the boundary conditions of the sudden expansion or sudden narrowing, fluid divorces the wall between the corner and the main beam. The lower velocity in the corner and the larger velocity near the axis flow, results from the stratosphere to form a recirculation zone, cause pressure drop and energy loss. Triangle circulation emitter is a new type of drip irrigation emitters which combine hydraulic characteristics of bypass flow and the two kinds of flow sudden expansion and sudden contraction flow.

1.2 geometry model of flow channel

Flow unit is a triangle ring cylinder channel composed of two nested similar triangles, its structure shows in Figure 1. Where, α is flow channel unit cusp, º ; l is inlet dimension, mm; W is channel width, mm.

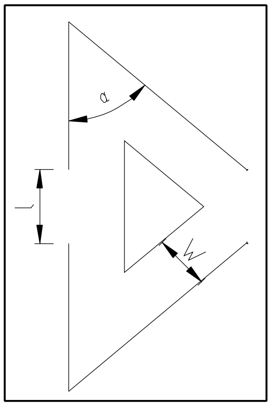


Fig.1-Structure of flow unit

Establish model of emitter through the PRO / E software. Emitter structure is controlled by a number of months of triangle ring cylinder units with the same inlet dimension, structured the way connected end to end, the outlet of a flow unit as the next inlet. Inlet part uses the single-mode import. According to the selected parameters, the model of triangle circulation emitter shows in Figure 2.

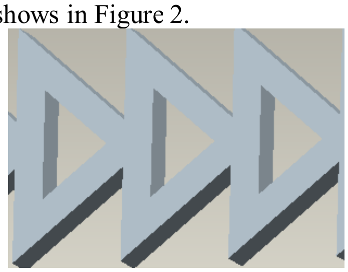


Fig.2-Schematic diagram of flow channel

2 Experiment design and methods

2.1 Experimental Design

Consult to the dimensions of labyrinth emitters, initially identified the structure of triangular circulation emitters. Flow channel unit cusp α = 45 º, inlet dimension ι =0.8mm, flow channel width W = 0.5mm, flow channel depth D=0.8mm. Given the current research results on the emitters, the flow channel length of the emitter made a weak effect on flow index, only affect the flow. Channel length of the emitters take a fixed value of L = 64mm or so. Change the value of each parameter in the range to study the influence of the changes of the parameters on hydraulic performance, flow and anti-blocking ability of emitters and get the optimal parameter combination.

2.2 Numerical calculation

Use PRO/E establishing the emitter channel model with different dimension, import the model to GAMBIT which was the preprocessor of FLUENT6.2, through GAMBIT carried out on different forms of emitter flow channel grid, meshing with the basic size of 0.09mm of hexahedral grid, the grid number is about (10.1 ~ 18.3) × 10^4. Secondly, according to the internal fluid flow channel properties, select the simulation models. Select the current common criteria k-ε model as CFD numerical simulation of turbulence model.

For the continuous phase, an operating pressure of 10m H^2O was applied on the inlet of emitter channel, and a zero pressure on the outlet. Emitter flow channel of imports set to the pressure inlet conditions, flow channel outlet pressure set to atmospheric pressure. Use standard wall function method convection Road wall for processing. The pressure items such as use of second-order upwind scheme, mixed standard is set to 1 × 10^{-4}, speed coupled with SIMPLE algorithm.

3 Results and discussion

In the free outflow condition, the flow discharge and flow index depends on the flow channel geometry dimension, the relationships between discharge and working pressure as the following equation:

$$q = kh^x \qquad (1)$$

Where, q is the emitter flow rate, L / h; k is the flow coefficient; h is the working head, m; x is the flow index.

Fluent software applications for different emitters with different structural parameters, simulate under the working head from 1 to 10 m, obtain the discharge q. Fit flow - pressure function relationship from equation (1), obtain flow pattern index x, flow coefficient k.

3.1 Simulating results with α changing

Simulate the four groups of emitters with different cusps between 45 º ~ 60 º ,Sharp corners of the unit were from the of numerical simulation analysis of irrigation emitters, obtained the discharge under the working head from 1 to 10m, and the flow index values fitting out of each group emitters, the results shows in Table 1.

Table 1-Numerical Results (α)

α	45°	50°	55°	60°
q_5/L • h^{-1}	1.501313364	1.698897348	1.959943572	2.206669068
q_{10}/L • h^{-1}	2.10607074	2.383144812	2.76215184	3.12397218
x	0.4955	0.4978	0.5087	0.5201

Table 2 shows that cell cusp increases, the flow index x increases even greater regularly. Thus, according to data in the table to make the factor - indicator diagram about α and flow index x, Figure 3, and fit out of the relationship expression equation (2), correlation coefficient R^2 = 0.9914, shows a better expression of the relationship between the two.

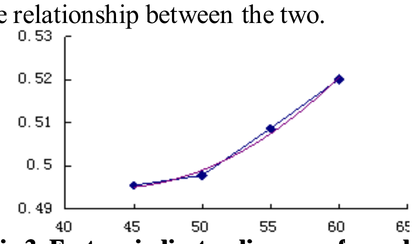


Fig.3- Factor - indicator diagram of α and x

$$x = 9.1E^{-5}\alpha^2 - 0.0079x + 0.6646 \qquad (2)$$

The results shows that with unit cusps increase, the discharges of emitters increase, flow index values have also increased. For the emitter, the discharge of the smaller, the more water-saving; flow index of smaller, the better hydraulic performance. Therefore, emitters have better performance with the smaller unit cusp. Taking into account the processing precision and anti-clogging ability, and other factors, ultimately determine the unit emitters to take cusp corners designed to take 45 º.

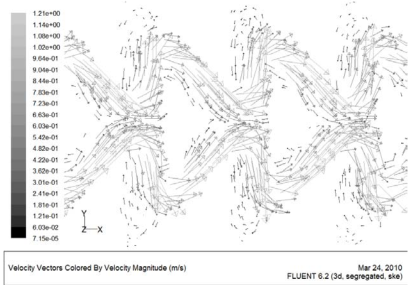


Fig.4- Velocity vector of part of the flow channel in the 45 º cusp

Figure 4 is the velocity vector of part flow channel for the 45 º cusp corners under 5m head. As can be seen from the diagram, there is a large number of dead zones and speed vortex area in the unit angular area on both sides, easily form a clogging of the emitter is very negative. Therefore, considering fillet the both sides of the cusp, to optimize the structure of the emitters in order to try to eliminate dead zones and speed vortex.

3.2 Simulating results with *r* changing

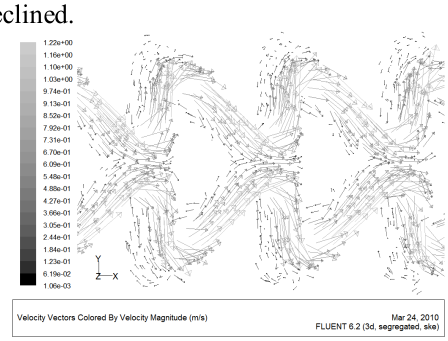
Optimize the structure of emitters, change the Chamfers in the range of 0.3 ~0.6mm, take 4 emitters with different radians *r*. The numerical results show in Table 3.

Optimize the structure of emitters, change the Chamfers in the range of 0.3 ~0.6mm, take 4 emitters with different radians *r*. The numerical results show in Table 3.

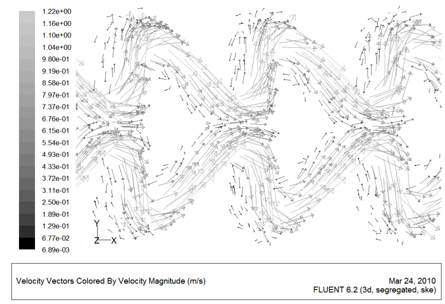
Table 2-Numerical Results (*r*)

a	0.3	0.4	0.5	0.6
q_5/L • h^{-1}	1.496319336	1.516670892	1.536705108	1.40728014
q_{10}/L • h^{-1}	2.098523664	2.1338469	2.172159108	1.9926621
x	0.4945	0.4995	0.508	0.5116

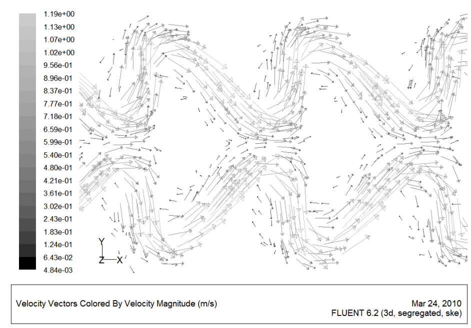
The above figures show that right after emitters structure for structural optimization, compared to the structures when not to optimize of 45 º cusp sharp corners, discharge changes are not obvious; as the radians increases, the flow index increased, indicating radian increases, the hydraulic performance of emitters declined.



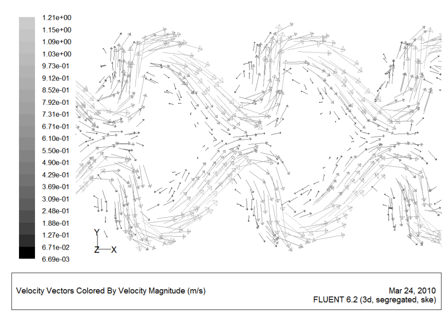
r=0.3mm



r=0.4mm



r=0.5mm



r=0.6mm

Fig.5- Velocity vector in different radians

Figure 5 is the velocity vector diagram with different radians. As can be seen from the figure, the greater the radian, the smaller dead zone on both sides of unit, in more than 0.4mm, the dead zone eliminate almost. That structural optimization of emitters improved anti-clogging properties. Comprehensive consideration the changes in discharge and water properties, take optimal radian of 0.4mm.

3.3 Simulating results with *l* changing

Simulate the four groups of emitters with different inlet dimension, the numerical results show in Table 3.

Table 3-Numerical results (*l*)

l	0.6	0.7	0.8	0.9
q_5/L • h^{-1}	1.449368424	1.513078632	1.51667089	1.499719032
q_{10}/L • h^{-1}	2.045428092	2.133125208	2.1338469	2.10694392
x	0.5051	0.5024	0.4995	0.4975

Table 3 shows, l increases, the flow index x decreases, and there is a certain pattern. Make the factor - indicator diagram about *l* and the flow indices *x*, Figure 6, and fit out of the relationship between the two as expression equation (3), correlation coefficient R^2 = 0.9945, shows a better expression relationship.

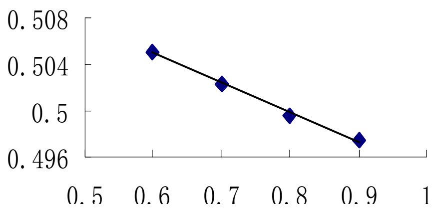


Fig.6- Factor - indicator diagram of l and x

$$x=-0.0257l+0.5204 \quad (3)$$

From Table 3, combined with (3)-type, the discharge of emitters with different inlet dimension did not change significantly, and no definite change in the law; inlet l increases, the flow index decreases, hydraulic performance improved. In the actual design, you can improve the hydraulic performance of emitters by increasing the inlet dimension. Integrated all the data, take the inlet dimension of 0.8mm for structural design.

3.4 Simulating results with *W* changing

Simulate the four groups of emitters with different channel width, the numerical results show in Table 4.

Table 4-Numerical results (*W*)

W	0.5	0.6	0.65	0.7
q_5/L • h^{-1}	1.516670892	1.629135612	1.726562772	1.944823032
q_{10}/L • h^{-1}	2.1338469	2.285268048	2.42407342	2.738295252
x	0.4995	0.4884	0.4895	0.4952

Flow channel width of the larger emitters for over-current cross-section, the more beneficial impurities passed, anti-clogging performance, the better emitter. However, the flow discharges of emitters will be even greater. According the results of numerical analysis in Table 4, the selected four flow channel width emitters, flow discharge is increased, making the curve about q_5 and channel width W, and fit out of the relationship, as equation (4), correlation coefficient R^2 = 0.9928, shows a better expression of the relationship between the two. In the triangular circulation emitters design applications, you can obtain the required flow discharge by changing the flow channel width.

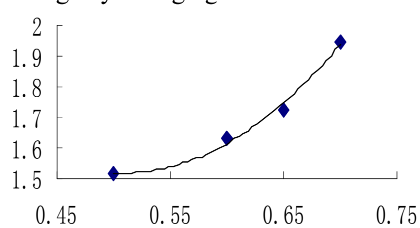


Fig.7- Curve of q_5 and W

$$q_5=11.434W^2-11.631W+4.4763 \quad (4)$$

Table 4 shows the changes of index has no obvious pattern. Take into account the processing precision and hydraulic performance, and such factors as over-current and eventually to take the flow channel width of 0.6mm design

3.5 Simulating results with *D* changing

Simulate the four groups of emitters with different channel depth, the numerical results show in Table 5.

Table 5 -Numerical results (*D*)

D	0.7	0.8	0.9	1.0
q_5/L • h^{-1}	1.420939188	1.629135612	1.837416888	2.045687724
q_{10}/L • h^{-1}	1.993059828	2.285268048	2.577501216	2.869699824
x	0.4888	0.4884	0.4881	0.4879

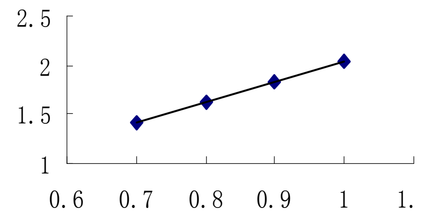


Fig.8- Curve of q_5 and D

Fig8 is the factors - index map of flow discharge under 5m head and flow channel depth. Fit out the relationship between the two, as equation (5) shows, the correlation coefficient R^2 = 1, shows a better expression of the flow and flow channel depth of relationship.

$$q_5=2.0825D-0.0369 \quad (5)$$

Flow channel depth of the larger emitters for over-current cross-section, the more beneficial impurities passed, anti-clogging performance, the better emitter. However, the flow discharges of emitters will be even greater. See from Table 5, flow channel depth increases, the flow index of emitters has no significant changes. That the changing of flow channel depth play the role of weak on the hydraulic performance of emitters. Thus, in the design of triangular circulation emitters, you can obtain the required flow emitters by changing the flow channel depth.

4 Conclusions

(1) In this paper, numerical computing software FLUENT6.2 was used to analysis the hydraulic performance of triangular circulation with multiple factors. The triangular circulation emitters have the characteristics of sudden expansion and sudden narrowing vertical section. Triangular circulation flow channel drip irrigation emitters compared to the same type of emitter flow channel, a significant increase in cross section, easy passage of water and impurities that can effectively enhance the anti-clogging capacity of emitters. The numerical results of the analysis shows that flow index value of triangular circulation emitters is 0.5 or so, the hydraulic performance is good.

(2) The impact of the selected five main structure parameters on performance is different: unit cusp α increases, the flow index increased, the flow discharge has increased, the hydraulic performance of emitters for the negative, according to numerical results, α = 45 º, the flow rate and flow index values are more desirable, therefore, the unit cusp defined as 45 º; when the structure unit take sharp corners, there are obvious speed dead zones and vortex area on both sides, easily result in blockage of the emitters for anti-blocking is very negative, by taking chamfer on the emitters to optimize the structure, then the flow discharge has no significant change, while the flow index x increases, when r=0.4mm, the speed dead zone almost eliminated, and the flow discharge and flow indices are relatively good; inlet dimension l larger the hydraulic performance of emitters for the better, but discharge has been no great change; the greater width and depth of flow channel, flow discharge higher, but the hydraulic performance of emitters but no obvious changes.

（3） Fit out the relational expression of unit cusp a, inlet dimension l and flow index and the relational expression of channel width W, flow channel depth D and flow discharge under 5m working head with a high linear correlation. The establishing of regression formulas guides the design of triangular circulation emitters, has a positive significance, and provides a theoretical basis for the design of triangular circulation flow path emitters.

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