HYDRAULIC STUDY, DESIGN & ANALYSIS OF DIFFERENT GEOMETRY OF EMITTER LABYRINTHS USED IN DRIP IRRIGATION FOR CLOG FREE PERFORMANCE

ÉTUDE HYDRAULIQUE, CONCEPTION ET ANALYSE DE GÉOMÉTRIE DIFFÉRENTE DE LABYRINTHES D'ÉMETTEUR UTILISÉ DANS IRRIGATION GOUTTE À GOUTTE POUR SABOT PERFORMANCE GRATUIT

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ABSTRACT

Water is becoming more and more a scarce and valuable resource as population and consumption rise. Agricultural use of water accounts for nearly 70% of the water used throughout the world, and the majority of this water is used for irrigation. In order to solve the problem of water shortage in agriculture, it's necessary to develop water-saving irrigation. Drip irrigation is the most effective way and its utilization rate can reach up to 90%. In drip irrigation, water emitting source is emitter which must be clog resistant. In the design of emitter structure, we use SolidWorks Software to design labyrinth emitter. According to emitter's hydraulic performance and its requirement for anti-clogging, we can design new channel structures by changing those dimensions. In order to analyze the hydraulic behavior and anticlogging performance of these emitters, rapid prototype development (RPD) was used to fabricate the experimental samples. Then the visualized experiments were conducted to perform the analysis of the hydraulic behavior and anti-clogging performance. The structural parameters of the emitter were then analyzed and optimized.

RÉSUMÉ

L'eau est de plus en plus une ressource rare et précieuse que la population et de la consommation en hausse. L'utilisation agricole de l'eau représente près de 70% de l'eau utilisée dans le monde entier, et la majorité de cette eau est utilisée pour l'irrigation. Afin de résoudre le problème de pénurie d'eau dans l'agriculture, il est nécessaire de développer l'irrigation économes en eau. irrigation goutte à goutte est le moyen le plus efficace et le taux d'utilisation peut atteindre jusqu'à 90%. Dans irrigation goutte à goutte, source d'émission de l'eau est l'émetteur qui doit être résistant à obstruer. Dans la conception de la structure d'émetteur, on utilise à la conception du logiciel SolidWorks labyrinthe émetteur. Selon les performances hydrauliques de l'émetteur et son exigence pour l'anti-colmatage, nous pouvons concevoir de nouvelles structures de canal en changeant celles développement dimensions.Le prototype rapide (SPR) utilisé pour le comportement hydraulique et anticlogging évaluation de la performance. Ensuite, les expériences ont été menées visualisées pour effectuer l'analyse du comportement et de la performance hydraulique anti-colmatage.

Keywords: Drip Irrigation, discharge, pressure, velocity, anti-clogging behaviour, flow simulation, Labyrinth design

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1. INTRODUCTION

A successful uniform application through drip irrigation system depends on the physical and hydraulic characteristics of the drip tubing (Al – Amoud, 1995). In surface drip irrigation systems, uniformity can be evaluated by direct measurement of emitter flow rates. The emission uniformity (EU) criterion is used largely to design micro irrigation laterals. The EU is affected by the variation of pressure head due to elevation changes and head losses along the lines, as well as by water temperature, manufacture's variation, grouping of emitters, clogging, variability in soil hydraulic characteristics, and emitter spacing (Wu, 1997). Introduction of emitters along a drip irrigation line modifies flow streamlines, inducing local turbulence that results in additional head losses, friction losses and local losses due to the presence of emitters in the pipe are must be considered (Bagarello and Pumo, 1992; Al Amoud, 1995; Provenzano *et al.,* 2003).

The most important properties in drip tubing irrigation systems are uniformity; anti-clogging unregulated dripper varies with inlet water pressure rather than friction losses along the laterals, both in designing the desired emitter flow path. Computational Fluid Dynamics (CFD) numerical technique was applied to investigate the flow, heat and mass transfer for many years. CFD technique has many advantages compared with other numerical calculation methods. The simulation can maintain a stable boundary condition while CFD modeling can be easily simulated with the change of the structure specification (Lee and Short, 2000). The numerical calculation results can help researcher analyze the hydraulic performance of the emitters and modify the geometries of the flow path, thus reducing time and cost for producing new emitter designs (P. Salvador et al, 2004).

2. STRUCTURE DESIGN AND FLOW RATE PREDICTION OF MICRO CHANNEL

The drip emitter is an important device in water-saving agriculture, and it characterizes all development of modern agriculture. The use of dripper emitter is fundamental in arid regions or where rain begins to decrease. The task of this component is to dissipate pressure and to deliver water at a constant rate by lowering the pressure energy. Shapes may vary with different shapes. Usually dimensions are very small, and the water flow crosses through micro-orifices like a labyrinth channels which make the pressure drop. Discharge rate is usually 1 to 8 L/h and is linked to the small width and depth of the flow path which is about 0.5 to 1.5 mm high.

3. HYDRAULIC DESIGN PROCESS OF EMITTER

The research is focused on drippers design and production. Companies define the exact shape of drippers on the base of specifications and then design and produce injection molds for their realization. Usually they sell the product, but sometimes only molds. Above all, they provide a specific dripper design service. Dripper production follows the mass customization paradigm, today highly diffused in the modern globalization. The dripper is not a standard product and customers are represented by pipe producers. These firms buy drippers which are Inserted in the pipeline during the extrusion process. Every customer requires different specification based on the specific irrigation application and the technologies being used to manufacture the pipeline. When a new order comes, it specifies some overall dimension requirement, a specific flow rate, a certain intake pressure, specific environmental working conditions and other functional requirements. All these variables lead to the necessity of a new design which often may be similar to a previous one. However this does not mean that the design process can be fully recovered. Currently the time for designing and realizing of the final prototype of a drip emitter is quite long (almost 3 months) and it includes four steps:

1. Design of the emitters,
2. RPD development & CFD analysis of emitters,
3. Assembling emitter on setup,
4. Experimental set-up of the emitters pipelines

An initial wrong design could highly increment the cost of all the realization process. For instance, negative results from the experimental set-up require a product revision and the repetition of all the design and manufacturing steps. Moreover, drippers are usually designed and produced by a firm while they are assembled by pipe producers. That means the overall time for iteration is long and the all design process could span for months. The first design step is the most complex because engineers must considerate at least four fundamental aspects: fluid dynamics, geometrical and dimensional constraints, influence of geometry into molding process and the choice of materials. A new project begins with the analysis of the geometrical constraints. Overall dimensions depend on different extruding machines which include drippers in pipeline.

Each of them makes use of a particular track to convey the emitters: so it is not possible to standardize product geometrical limits. Secondly, the designer must fulfill customer fluid dynamics specifications. In particular, every dripper has its own characteristic discharge rate, linked to a particular agricultural application. This parameter is very critical. There are no rules or methods to analytically compute this value due to the complexity of the geometry. CFD simulation may be employed but there are many parameters influencing the results. It is important to know them precisely in order to come out with good results.

4. EXPERIMENTAL SETUP

For achieving the required experimental and the experimental setup included one water tank, pump to lift the water, filters, Pressure regulator valves, digital pressure gauges, and different types of procedures, an experimental setup was designed and installed at Jain Plastic Park, Jain Irrigation Systems Pvt. Ltd., Jalgaon (Maharashtra, India) and the experimental setup included one water tank, pump to lift the water, filters, Pressure regulator valves, digital pressure gauges, and different types of experimental emitters.

4.1. Flow Testing of Prototypes: For estimation of discharge from the emitter

4.2. Clogging Tests: For evaluation of anti-clogging behaviour

4.2.1. Clogging test with Clay as impurity:

4.2.2. Clogging test with Aluminium Oxide as impurity

5. RESULTS AND DISCUSSION

This chapter deals with the results obtained from the experimental studies carried out on different types of geometries, emitter prototypes at various operating pressure head. Firstly different emitter geometries are prepared and analysed in software (SolidWorks 2012 / 2008). Then selected emitter prototypes were prepared for experimental analysis.

Table 1: Boundary conditions for pressure flow profile

Condition 1:		**Condition 2:**	
Faces	**Inlet Face**	**Faces**	**Outlet Face**
Value	Environment Pressure: 151325.00 Pa	Value	Environment Pressure: 101325.00 Pa
	Temperature: 293.20 K		Temperature: 293.20 K

Table 2: Flow profile results

Sr. No.	Name	Max. Velocity (m/s)
1	Model Emitter 1	6.487
2	Model Emitter 2	8.07
3	Model Emitter 3	6.568
4	Model Emitter 4	6.839
5	Model Emitter 5	2.294

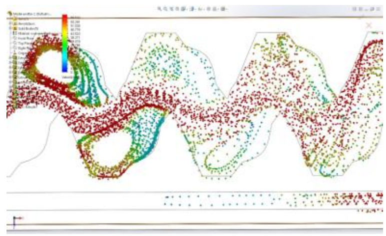

Fig. 1: Mass Flow Profile for Model Emitter 1

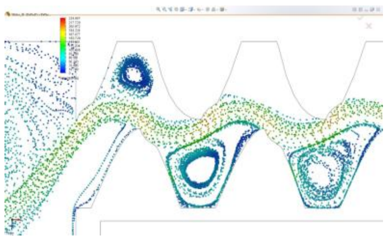

Fig. 2: Mass Flow Profile for Model Emitter 2

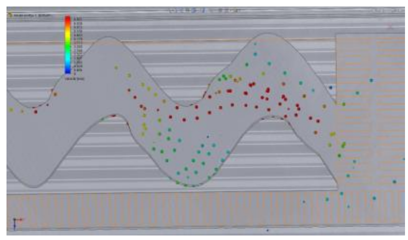

Fig. 3: Mass Flow Profile for Model Emitter 3

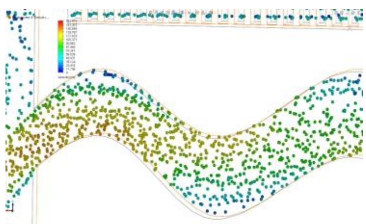

Fig. 4: Mass Flow Profile for Model Emitter 4

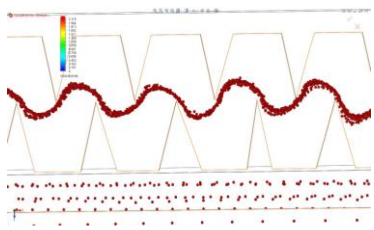

Fig. 5: Mass Flow Profile for Model Emitter 5

6. SUMMARY AND CONCLUSION

By considering the above objective different emitter models were designed and analysed in computer based software (SolidWorks) as well as analysis did experimentally. The drip emitter is an important device in water-saving agriculture, and it characterizes all development of modern agriculture. The task of this component is to dissipate pressure and to deliver water at a constant rate by lowering the pressure energy. Shapes may vary with different shapes. Usually dimensions are very small, and the water flow crosses through micro-orifices like a labyrinth channels which make the pressure drop. The most important properties in drip tubing irrigation systems are uniformity, anti-clogging capacity and lifespan of all components. A well designed dripper device should maximize these aspects and ensure a good hydraulic performance. Under different dentate structure, there were different intensities of turbulent whirlpools within the path. The flow resistance patterns and energy dissipation patterns were also different. This paper utilised the CFD technology to analyse the flow process within the flow path of emitter and revealed the correlation relationship between the dentate flow path structure and energy dissipation, meanwhile the anti-clogging analysis was conducted. The rear of dentations and dentate tip were the primary regions for energy dissipation. Selecting reasonable boundary structure could produce intensive turbulent whirlpools and increase the internal energy dissipation. The good hydraulic property could also improve the scouring effect along the boundary and the anti-clogging effect of emitters.

By considering anticlogging behaviour of drip irrigation emitter we have designed five different geometries in SolidWorks software. These models were analysed in the software. The CFD analysis shows that Emitter model 1, Emitter model 2, Emitter model 4 & Emitter model 5 shows better performance. But Emitter model 3 shows drastic change in velocity for mass flow profile even at higher rate of discharge from emitter, velocity of water is much lesser as compared to other emitter models. These Emitter model prototypes were prepared, firstly flow of emitter is checked for confirmation of design and then further samples were prepared. We observed more variation in Model emitter 4 which is calculated as 24.58% as compared to other emitter models.

This may happen because of either variable cross section labyrinth design or pipe material intrusion in emitter labyrinth while manufacturing. In Model emitter 5 variation is less (4.4 %) in comparison with proposed model. These emitter models were further tested for their behaviour of risk of clogging. In clogging test results we observed that Model emitter 4 & Model emitter 5 has better performance than other emitters.

By considering clogging test results we may propose Model emitter 4 or Model emitter 5 for use it in drip irrigation system. But by considering discharge variation in Model emitter 4 is more as compared to Model emitter 5. Even the discharge of emitter is less only one emitter is plugged in Clay clogging test, hence we propose Model emitter 5 has feasible drip irrigation emitter labyrinth.

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