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The Development and Implementation of New Technologies in Agri-Food Systems: The Case Study of Modularized Solution for Water Filtering Equipments

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The Development and Implementation of New Technologies in Agri-Food Systems: The Case Study of Modularized Solution for Water Filtering Equipments

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Abstract. The outcomes of the evolution in the area of informatics, sensory science, data processing or non conventional technologies started to be transferred and successfully used in the field of the agro-industrial equipments and applications. The new generation of water filtering equipments is among them and the importance of the self-cleaning filtering battery is obvious. The system has to answer both to the requirements of industrial users as well as private users. A lot of work was done to improve the existing solutions with a new model which accomplishes the needs of the small users. The work is focused on this sector in the view of designing a modularized solution with a simple geometry which is able to incorporate the back-flushing valve, the filter and all the associate pipelines. Simultaneous these modules have to be easily connected for materializing the filtering batteries with two, three or more filters. The study presented in this paper is conducted in order to solve the problem of a part included in a hydraulic system – a self cleaning filtering battery prototype. Further research has to be done in order to provide reliable information for long run strategies.

1. Introduction

Industrial agriculture is a variety of up to date farming that refers to the industrialized production of livestock and crops. The techniques of industrial agriculture are technical, scientific, economic and political. They consist of innovation in agricultural machinery and farming methods, genetic technology, techniques for achieving economies of scale in production, the establishment of new markets for consumption, the application of patent protection to genetic information, and global trade. These methods are well-known in developed nations and increasingly common international. Most of the food products available in supermarkets are produced using these methods of industrial agriculture.

Micro-irrigation systems are among the technical – scientific approaches. They are designed to deliver water and nutrients in precise amounts and at controlled frequencies directly to the plants root zone. With micro-irrigation systems, an extensive network of pipe is used to distribute water to emitters that discharge it in droplets, small streams, or through mini-sprayers^{1,2}. The major cause of failure in micro-irrigation systems is emitter plugging. Emitter plugging may cause severely degradation of irrigation system performance and application uniformity. It is important to understand the filtration and maintenance requirements of these systems and be proactive to prevent plugging because the emitters are small and can easily plug. The basic components of a typical micro-irrigation system are shown in Fig.1.

Emitter plugging may occur from physical, biological, and chemical causes when one is using micro-irrigation. It is important to prevent plugging problems before they occur. The best prevention plan includes an effective filtration, water treatment, and maintenance strategy. A water analysis is vital for the proper design and operation of the micro-irrigation system³.

To assess irrigation system performance and to ensure that components like filters are correctly working flow meters and pressure gauges must be properly installed to provide feedback to the system operator. Monitoring flow meters and pressure gauges over time can reveal system performance anomalies that may require attention.

Filtration equipment is the item with the greatest cost when installing a micro-irrigation system. Good filtration will pay for itself by avoiding the costs and extra effort required to repair a damaged system.

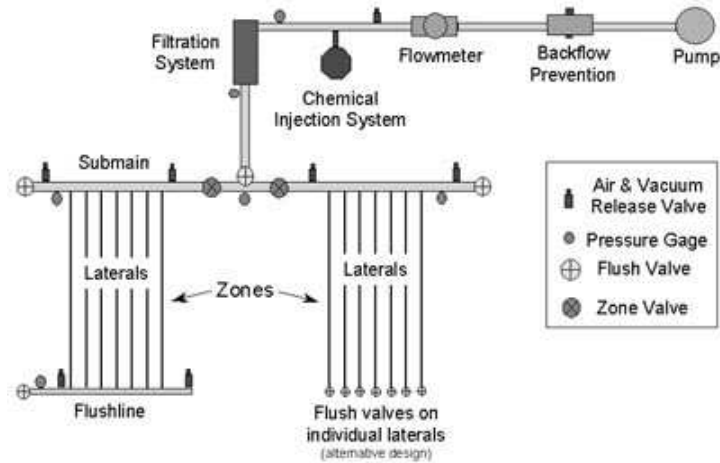


Figure 1. Diagram of micro-irrigation system

No matter how well designed your filtration system is, some "contaminants" will find their way into the system. To prevent the accumulation of those contaminants and the resulting emitter plugging, the system has to be periodically flushed. Regular flushing is critical to system health and longevity⁴.

If the micro-irrigation system is equipped with a method for chemically treating the water source (most will be), backflow protection, and other safety provisions, are necessary.

2. General specifications

2.1. Theoretical background

The crossing capacity through the filter is defined as :

$$q = \alpha \cdot \frac{\Delta p}{\eta} ; \left[\frac{m^3}{s \cdot m^2} \right] \quad (1)$$

Where :

- α is a proportionality coefficient which defines the fluid crossing capacity through the filter unit surface, at a pressure gap of $1 Pa$ for a liquid which has the viscosity

$$\eta = 1 \frac{N \cdot s}{m^2} ;$$

- p is the pressure gap on the filter [Pa] ;

- η is the dynamic viscosity coefficient $\left[\frac{N \cdot s}{m^2} \right]$.

The maximum flow which crosses the filter is:

$$Q = q \cdot A \quad (2)$$

where A is the filtering surface [m^2]

The pressure gap on the filter is calculated as :

$$\Delta p = \frac{q \cdot \eta}{\alpha} = \frac{\eta \cdot Q}{\alpha \cdot A} \quad (3)$$

In practice, the equation (3) is used to calculate the pressure gap :

$$\Delta p = \xi \cdot \frac{\rho \cdot v^2}{2} \quad (4)$$

The Reynolds value is calculated as:

$$Re = \frac{d \cdot v}{\nu}$$

The ξ coefficient when $Re > 400$ is determined as:

$$\xi = 1,3 \left(1 - \frac{A_0}{A} \right) + \left(\frac{A}{A_0} - 1 \right)^2 \quad (5)$$

The ratio K:

$$\frac{A_0}{A} = K .$$

A_0 – is the surface of crossing mesh

Being $Re < 400$, ξ coefficient is corrected as following:

$$\xi_0 = c \cdot \xi \quad (6)$$

where : c takes values between 1 and 1,44 when Re is included in the interval [50; 400].

The filter design begin with calculus of filtration surface that the lost pressure in the filter not exceed: $\Delta p = 0.05 - 0.1$ bar (0.75 – 1.5 psi). The maximum accepted speed in the filtering holes is: $v = 0.01 - 0.02$ m/sec.⁵

The filtration surface can be calculated with the formula:

$$S_{filter} = \frac{Q}{6 \cdot v} \quad (7)$$

Practical, the filtration surface must be:

$$S_{filter} = (40 \div 60) \cdot S_{pipe} \quad (8)$$

The surface for 2'' pipe is:

$$S_{pipe} = \frac{\pi \cdot d^2}{4} = 19,6 \text{ cm}^2$$

therefore, the filtration surface must be :

$$S_{filter} = 800 - 1200 \text{ cm}^2$$

(2'' filter for: $Q = 360 \text{ dm}^3/\text{min}$)

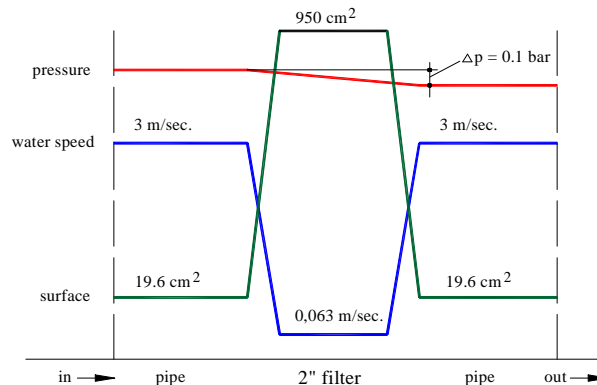


Figure 2. The evolution of pressure through the filter

It is necessary to assure enough kinetic energy, incorporated in the cleaning water jet and enough debit for assure an efficient cleaning operation for the self flushing phase. These conditions are synthesized on the following diagram^{6,7}.

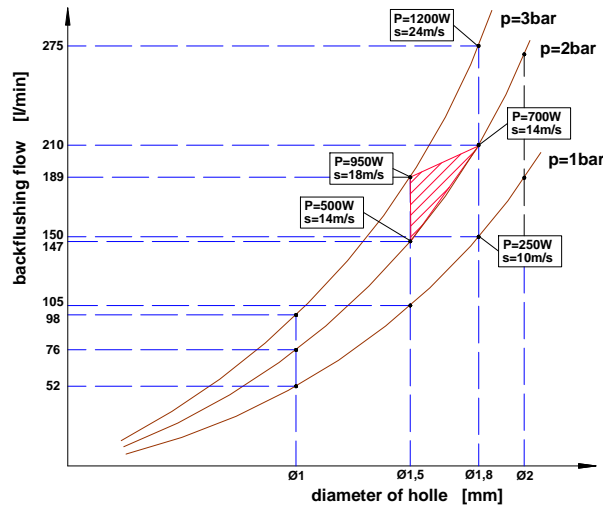


Figure 3. Kinetic energy diagram

The prototype requires a 1,4 mm diameter of the cleaning holes, posted on four columns and the distance between two holes is 15 mm. The minimum recommended pressure for an efficient cleaning is 2,5 bar. On these conditions, the speed of water jet is 15-16 m/sec and the cleaning flow is 140 l/min, around. (500 – 800W).

2.2. Object and motivations

The self-cleaning filter batteries are designed following the hydraulic diagram as such is illustrated in the figure 4.

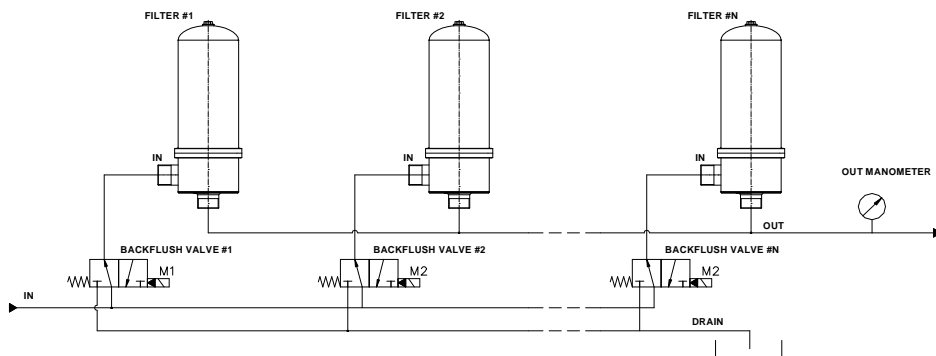


Figure 4. Hydraulic diagram of a self cleaning filters battery

All the self-cleaning filter batteries produced nowadays and used in the micro-irrigation systems, are made up of two or more filters, an equivalent number of flushing electro-valves and air exhaust valves joined together by pipes and fittings so as to form a self-cleaning filtering battery (Fig. 5.).

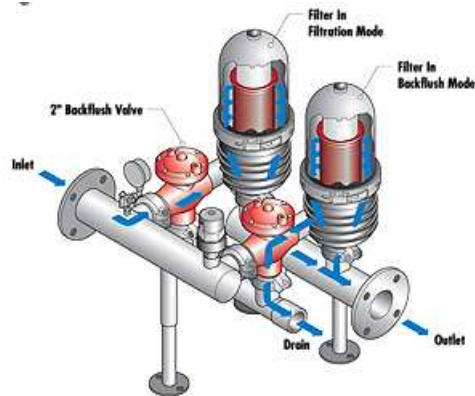


Figure 5. The classical structure of a self cleaning filters battery

The first type of filter which was designed was almost similar with all the filtering batteries offered by the majority of manufacturers. Its promotion in the market was very difficult.

Because of these negative aspects it was necessary to find a new solution (idea) able to bring the economical and functional advantages relative to the actual similar products. It was done a study which analyzed the technical solution for the self-cleaning filtering systems offered by a big number of manufacturers and was remarked that all of them were focused upon the parts of the system (filters, valves, pipes, etc.) and neglected to optimize functional and economically, the assembly.

Similar analysis in other industrial domains, where was studied the evolution of several products concluded that the solution is to modularize the filtering system.

3. The modularized solution

Returning at the hydraulic diagram, showed in figure 4, it was remarked that one can select a sector that is multiplied for creating the self-cleaning filtering batteries⁸. This sector contains a self-cleaning filter, a back-flush valve, an air-flushing valve, pipes and fitting for connecting it, as such is showed in figure 6.

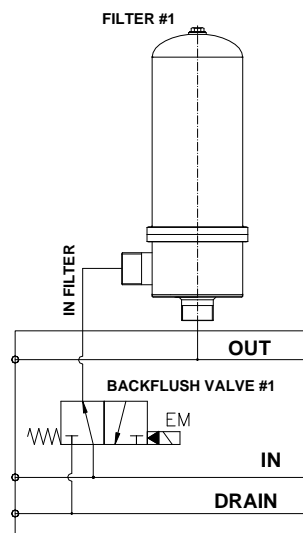


Figure 6. The hydraulic diagram of a module

The work was focused on this sector with a view to design a module with a simple geometry able to incorporate the back-flushing valve, the filter and all the associate pipelines. Simultaneous these modules must be able to be easily connected to materialize the filtering batteries with 2, 3 or 4 filters.

3.1. First solution - cubical module

It was opted for a reasonable dimension of the module in concordance with the dimension of the filter. Thereby, for 3m/sec. water speed, was chosen the IN/OUT tube section of 100 cm².

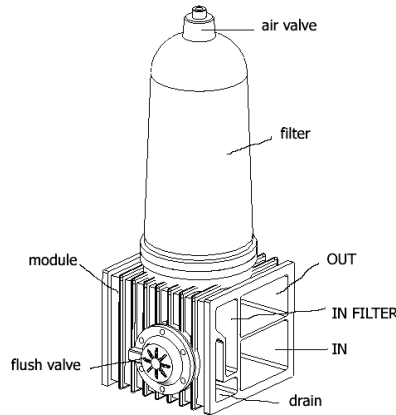


Figure 7. The physical structure of a modularized self flushing filter

Starting with this section, it is possible to couple up to 4 self-cleaning filters and the batteries are able to deliver from 700 l/min (42 m³/hour) till 1400 l/min (84 m³/hour).

For verifying the rightness of this concept was designed, in SolidWorks, a module. Because its geometry was sophisticated, there was very difficult to manufacture it by using the classical technologies (i.e.: by welding faces and parts)^{9,10}.

The optimal solution for manufacturing this module was by injection but, because the price for such a big and sophisticated mold is high and the risk for possible error is high was decided to manufacture first, a prototype using the rapid prototyping technology (SLS method)^{11,12,13}.

3.2. The test and the changes

It was used a hydraulic stand (Fig.8.) for testing the filters battery. In order to verify if the filters correctly function it is required to increase the pressure at minimum 2,5 bar. These minimal pressures are necessary, especially, for the self-cleaning operation: for decompressing the discs and for assuring enough speed for the jet of water for an correct cleaning of the discs.



Figure 8. The modularized self flushing filter battery on test

On this moment, when the pressure increased, the module crashed, on the bottom face, exactly at the soldered line. First, that was happen at around 0,8 bar. After I reinforced the bottom part of the module on repeat the test but when on increased the pressure the bottom part crashed again at around 1,3 bar.

Due to the weak results it was necessary to change the design of the module and flushing valve in order to solve the problems previously presented. This new cylindrical design keeps integral the new concept exposed in the patent proposal¹⁴.

It was made a new verification, with the finite element method, for the cylindrical body and the result confirmed that these new geometry supported very well the pressure effect¹⁵.

It was proved that the first design of the module, the cubic version, did not accomplish the maximum deformation requirement.

The new version is recommended to be implemented. Future work will be done for the development of self cleaning batteries filters. The modular idea is a new one in their construction, generating decrease in cost, production time and simplifying the maintenance aspects.

4. Comment and conclusions

The cost of manufacturing is lower in comparison with the similar self-cleaning filters nowadays manufactured. This fact is due to the reason that the quantity of material is less in comparison with the actual solutions and the assembling is easier and faster.

The filtering battery is more compact and easy to be transported and handled. The number of parts is significantly reduced with the new module.

This model of the self-flushing batteries is a good offer for the farmers with 1 to 15 ha of field.

Applying the finite element method were analyzed two versions of a module from a hydraulic system. It was proved that the first design of the module, the cubic version, did not accomplish the maximum deformation requirement.

The new version is recommended to be implemented. Future work will be done for the development of self cleaning batteries filters. The modular idea is a new one in their construction, generating decrease in cost, production time and simplifying the maintenance aspects⁹.

The patent was registered and the procedure for it is running. Future information can be obtained from the authors.

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