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DIFFERENTIAL PISTON INJECTION DEVICE WITH CONTROL MECHANISM WITH PILOTED HYDRAULIC VALVES

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Abstract: The realization of the fertigation equipment of agricultural crops practiced on sandy soils, in arid, semi–arid, dry sub–humid climate, is the subject of component project 5 within the complex project "Innovative technologies for irrigations of agricultural crops in arid, semi–arid and dry sub–humid climate", contract 27 PCCDI / 2018– PN III. The differential piston injection device for fertilizing solutions in localized watering installations, which is the main component of the equipment, had as a reference model the DOSATRON D3 Green Line device. Compared to reference model, in which the direction of movement of the drive piston – piston injection pump with simple effect mobile assembly is achieved with the help of a spring tilting mechanism, an innovative solution was designed and implemented in the device realized within the project of mechanical–hydraulic mechanism with spring and piloted valves.
Keywords: fertigation, injection device, differential piston

INTRODUCTION

The methods used to reduce the action of stressors for agricultural crops practiced on sandy soils, in arid, semi–arid or dry sub–humid climate conditions (atmospheric, pedological and agricultural drought, strong burns and major precipitation deficit, with uneven distribution during the vegetation period of plants), (Lăcătuş V., 2016), are:

≡ Selection of species with short vegetation period (potato, melons);
≡ Selection of tolerant and drought resistant varieties based on physiological criteria (rate of transpiration, rate of photosynthesis, water forms);
≡ Management of agrotechnical factors in order to increase the efficiency of plant metabolism (irrigation, fertilization, disease control and pests).

Irrigation and fertilization of crops on sandy soils, in arid climatic conditions is achieved by the phase application with reduced norms of water and fertilizer, in order to avoid their evaporation and percolation under the root layer, taking into account the high temperatures during the vegetation period and the reduced sand soil capacity of water retaining.

Under these conditions, fertigation is the most efficient method of water and fertilizer administration (Biolan I. et al, 2010).

MATERIAL AND METHOD

The differential piston injection device made by DOSATRON, Figure 1, (*www.dosatron.com – Dosatron: Water–powered proportional dosing pumps) can be located both on the main hydraulic circuit of the irrigation system (full flow), and on a circuit parallel to it (by–pass), and it uses irrigation water as a drive fluid.

The device consists of two functional subassemblies: the subassembly acting as linear hydraulic motor and the subassembly acting as single–effect piston volumetric pump. The motor subassembly consists of two bodies, assembled together by threading and sealed with O–ring.

The lower body consists of two concentric tubes: in the inner tube, of cylindrical form, the part of diameter d1 of the drive piston is displaced, while the outer liner is provided with the inlet connections for the water used as a drive fluid and the discharge connections for the fertilizing solution (formed by mixing the primary solution with water).

The upper body is of cylindrical shape inside; inside of it the drive piston part with large diameter moves.

Figure 1. Schematic presentation of the injection device with DOSATRON differential piston

Inside the motor assembly, Figure 2, three work chambers are made: chamber A, delimited by the outer surface of the inner cylindrical tube, the inner surface of the liner of the lower body, the inner surface of the upper body and the lower part of the drive piston, in the area of large diameter; chamber B, delimited by the upper part of the drive piston in the area of large diameter and the inside of the upper body; chamber C, delimited by the lower part of the drive piston in the zone of small diameter and the inside of the cylindrical tube of the lower body.

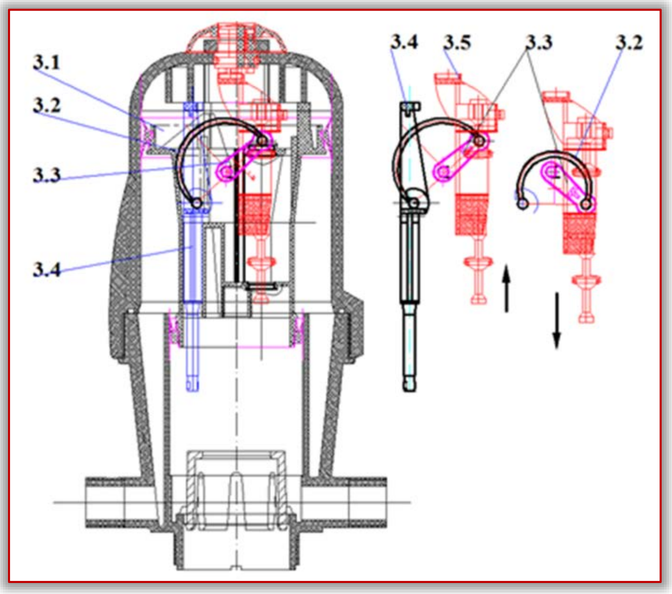

Figure 2. Cross section through the motor assembly of the injection device with DOSATRON differential piston. Section to the left of the axis of symmetry–ascending stroke of the drive piston; Section to the right of the axis of symmetry–descending stroke of the drive piston

The pressurized water supply connection pipe communicates with chamber A, and the fertilizer solution discharge connection pipe – with chamber C.

The subassembly of the volumetric pump with piston is connected by threading to the lower part of the body 1.

During operation, the drive piston and the volumetric pump piston (which form the mobile assembly of the injection device) move in the same direction, as they are joined by a rod.

The water acts on the drive piston of the injection device. The change of direction of movement of the mobile assembly is controlled by the tilting mechanism, located in the drive piston, which by actuating two blocks of valves on the cone allows the access of water acting as drive fluid below or above the piston.

Pressurized water enters through the inlet connection in chamber A. If the valve train 2.4 in the drive piston 2.1 is moved up (see the left side of Figure 2) then the valves 2.2 close the connection between the chambers A and B and the valves 2.3 open the connection between the chambers B and C. Between A and B the liquid forms a pressure difference that acts on the annular surface of the drive piston and produces an upward movement of it. The fluid from chamber B is evacuated through the open valve 2.3 in chamber C where it is mixed with the primary solution arrived from the dosing area and then directed to the discharge. If the valve train is moved down (see right side of Figure 2), the valves between the chambers A and B are opened and the valves between the chambers B and C are closed. The pressure in the chambers A and B is uniformed; the pressurized fluid passes into the chamber B, and acts on the cylindrical surface of the drive piston between B and C and moves the piston down.

The tilting mechanism, located in the drive piston 3.1, controls the valve train; it has the following structure:

≡ the probe 3.4, which moves in a fit in the drive piston 3.1;
≡ a plastic spring 3.2 hinged to the probe, forming the probe–spring joint;
≡ the other end of the spring is hinged to the oscillating rod 3.3, forming the spring–rod joint;
≡ the oscillating rod 3.3 is connected to the drive piston 3.1 through the rod–piston joint.

Approaching the ends of the stroke, the probe 3.4, by leaning on the housing, changes the position of the spring–probe joint, with respect to the drive piston 3.1, respectively the positions of the rod–piston and spring–rod joints.

Under the action of spring 3.2, the joint assembly is unbalanced, tilting the mechanism up or down, depending on the displacement of the probe relative to the drive piston. By tilting, the mechanism hits the valve train 3.5, which it pushes up or down, closing or opening the connections between the chambers A, B, C.

The change of the displacement direction of the drive piston is made mechanically, the stroke being fixed (preset, in terms of construction, by the geometrical dimensions of the tilting mechanism).

RESULTS AND DISCUSSIONS

In the constructive version of the drive piston made by INOE 2000–IHP, the valves on the cone, actuated by the tilting mechanism with spring were replaced by hydraulic piloted valves (Anghel S. et al, 2019), which establish the connections between the chambers A and B, respectively between the chambers B and C.

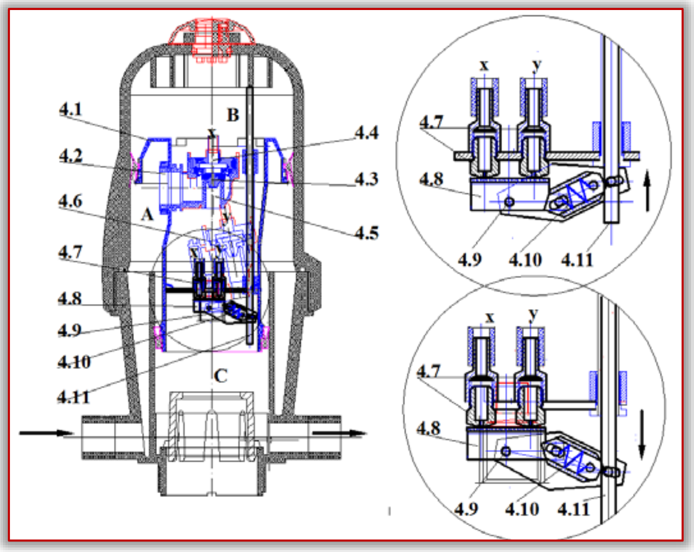

Figure 3. Constructive variant of the drive piston made by INOE 2000–IHP

The piloting is done with the help of a piece 4.8 (on the surface of which a rubber tape is applied by gluing), which by tilting around the shaft 4.9 alternately closes one of the two nozzles 4.7, thus piloting the two hydraulic valves through the connections x–x or y–y.

The hydraulic valve consists of the tubular part 4.5, which in the inactive state is closed by membrane 4.3. The membrane, the surface of which is larger than the surface of the tubular part, is mounted in the valve housing.

The water enters behind the membrane through the port 4.2 and closes the pilot chamber 4.4, acting on the active surface formed from the sum of the cross–sections of the tubular part 4.5 and annular section delimited by the outer diameters of the membrane and the tubular part.

In the membrane there are ports (nozzles) that establish the communication between the inlet port 4.2 and the pilot chamber. If the tilting device 4.8 closes the nozzle 4.7 related to the valve, then the pilot chamber 4.4 is closed, the pressurized water from the entrance entering the pilot chamber through the ports in the membrane; under the action of the water, the membrane presses on the tubular part 4.5 and closes the path between the chambers A and B. The pressure in the pilot chamber acts on the whole surface and creates a force greater than the same pressure exerted only on the annular surface.

By tilting the pilot device at the stroke end (through the probe 4.11, which drives the compression spring–guide assembly 4.10 and tilts the part 4.8 on the nozzles 4.7), the pilot chambers of the two valves are opened alternately; by opening the ports of the pilot chambers the pressure in the chambers decreases, the membranes are raised and the communication between the chambers A and B (for the upper valve) and B and C (for the lower valve) is established.

At the ascending stroke of the drive piston–dosing piston assembly (joined together by a special construction rod), the dosing piston provides access to the primary solution beneath it and drives the volume of primary solution above, existing inside the dosing cylinder from the previous stroke, inside the drive fluid – primary solution mixing chamber (the cylinder in the lower body component of the motor subassembly).

In the downward stroke, the dosing piston allows access to the volume of primary solution already introduced in the dosing cylinder to the previous stroke above it, through the longitudinal slots practiced on the outer generators of the connecting rod; by continuously changing the volume of the mixing chamber, in order to reduce it, the fertilizing solution is injected through the connection of the injection device discharge into the irrigation system.

RESULTS

The laboratory tests, carried out on the test stand for devices and equipment that use water as working fluid, from the infrastructure of the Environmental Protection laboratory of INOE 2000–IHP (Șovăială Gh. et al , 2019), have demonstrated the functionality of the injection device in the version designed and developed under the component project 5 "Innovative fertigation technology in fruit and vine plantations specific to arid and dry sub–humid climate" within the complex project "Innovative technologies for irrigation of agricultural crops in arid, semi–arid and dry sub–humid climate – SMARTIRRIG", contract no. 27PCCDI / 2018.

To highlight the way in which the pressure varies, during a functioning cycle, in the connection points of the device to the localized irrigation system, its installation on a circuit parallel to the main circuit of the system (bye–pass) was done. The pressure sensors, located at the mentioned points, were connected to a programmable logic controller which, based on dedicated software, allowed real–time monitoring of the investigated parameters and data acquisition.

Figure 4 shows the stand for conducting tests on the device in laboratory conditions, and Figure 6 depicts a screen instance of the computer with which data acquisition was made.

Figure 4. Testing the injection device with differential piston under laboratory conditions

Figure 5. Acquisition of data regarding the variation of pressures in the connection points of the device to the main pipe of the stand (the equivalent of the main pipe of the localized irrigation system)

Figure 6. Drive piston (DOSATRON–left variant; INOE 2000–IHP right variant)

The tests were performed with both constructive variants of the drive piston. DOSATRON original version, with valve train on cone and spring tilting mechanism, Figure 7 left, respectively the INOE 2000–IHP variant with hydraulic valves controlled by a miniaturized spring tilting control mechanism, Figure 6 right.

In Figure 7 and 8 are presented screenshots of the software application panel, which highlights the variation of pressure at the connection points of the device, for the two constructive variants of drive piston.

In Figure 8 shows the variation of the pressures in the connection points for the piston with valve train on mechanically operated cone of the DOSATRON D3 Green Line 3 m³ / h device, and in Figure 8 for the driven piston with hydraulic piloted valves.

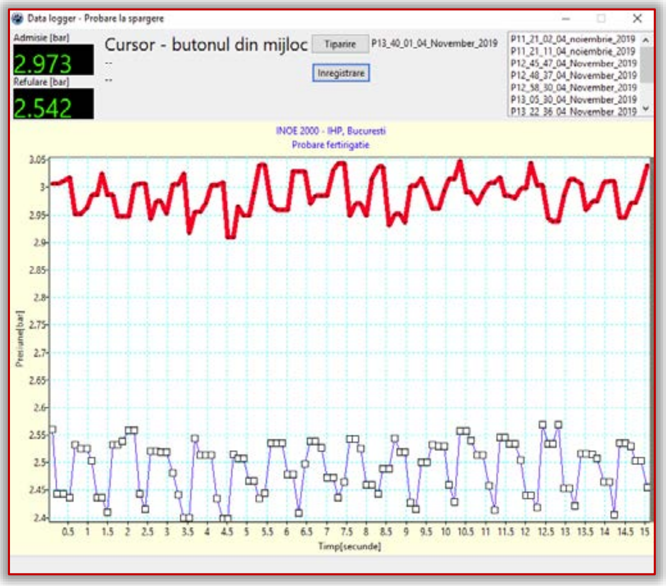

Figure 7. Variation of pressures at the connection points for the drive piston with valve train on mechanically operated cone

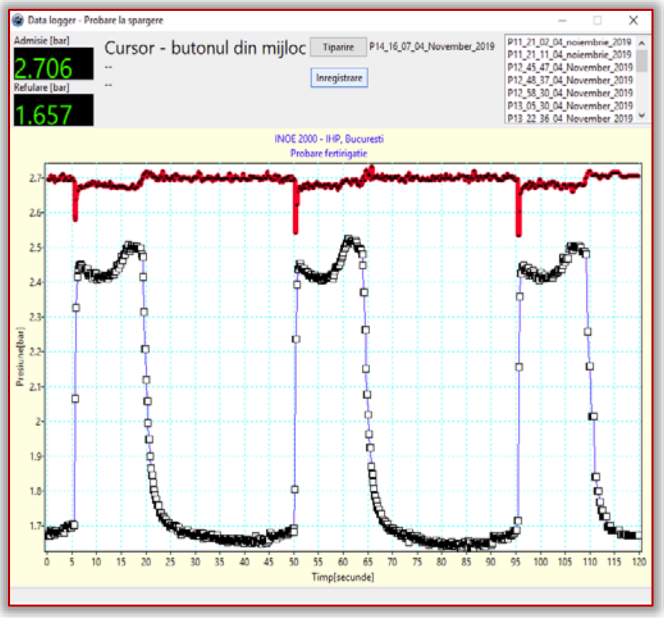

Figure 8. Variation of pressures at the connection points for the drive piston with hydraulic piloted valves

CONCLUSIONS

- The laboratory tests have demonstrated the functionality of the primary solution injection device developed under the component project 5 "Innovative fertigation technology in fruit and vine plantations specific to arid and dry sub–humid climate" within the complex project "Innovative technologies for irrigation of agricultural crops in arid, semi–arid and dry sub–humid climate – SMARTIRRIG", contract no. 27PCCDI / 2018.
- The flow of fertilizing solution (mixture of water used as drive fluid and primary solution is between 10 l / h and 3000 l / h, for dosages (injection rates between 1: 100 and 1: 10 – volumes of primary solution) / volume of drive fluid);
- The injection rate of the primary solution (with a concentration of 1... 10%) is between 300 and 0.1 l / h;
- For similar working pressures (around 3 bar upon the device inlet port), the frequency of drive piston, in variant developed by INOE 2000–IHP it is 4 times smaller than that of the DOSATRON piston, this aspect favouring the administration of very small doses of microelements;
- The switching frequency of the drive piston can be adjusted through the diameter of the nozzles 4.7 (Figure 3).
- The tilting mechanism of the drive piston injection device with piloted valves requires an actuating force 5 times smaller than that of the mechanically actuated drive piston device;
- The injection device realized within the project responds to the requirements of the fertilization of agricultural crops on sandy soils under arid climatic conditions, having the possibility of administering fertilizer norms in accordance with the agricultural technologies practiced on this category of soils.

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