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AGRICULTURAL FIELD IRRIGATION SOLUTION BASED ON VENTURI NOZZLE MODEL

Abstract: *There are situations when the agricultural field irrigation requires water retrieved from the medium or deep groundwater reserves. For this solution submersible pumps are needed in order to take over the water from a certain depth and carry it to the surface to be stored in a tank or distributed directly to the irrigation plant. An alternative solution is represented by using a pumping system that can achieve a continuous water transport on a vertical direction from the source depth to the surface that comprises a centrifugal pump and a VENTURI nozzle positioned inside the well. In order to achieve this model a fluid driving circuit is required and special construction of the VENTURI tube by means of which the water is accelerated toward the surface. A 3D model of the VENTURI nozzle was built and analyzed with ANSYS CFX in order to highlight the operating parameters depending on the initially declared conditions. The obtained results are presented from the conducted analysis on the virtual model.*

Key words: *fluid actuation, VENTURI effect, nozzle model, experimental modeling, CFD*

INTRODUCTION

In agriculture in order to achieve high yields that can ensure the investments recovery, made by farmers, irrigation must be done especially in terms of the lasting drought in some arid areas.

The water needed for irrigation can be taken from the rivers located near land or transported over long distances through the channels.

In generally in every country it was established an extensive channel network that provide water needed to irrigate agricultural lands.

But there are situations where the land is located at a considerable distance from an irrigation canal and in that case some solutions must be found for providing water. The solution could be taking water directly from the underground area.

To do this water well drilled in the ground is required and the use of submersible pumps that can take water from a certain depth and carry it toward the surface. There are different kinds of submersible pumps, but some type of pump can perform the pumping operation using the VENTURI effect.

It is a system model that uses a special pump for conveying a fluid circuit and a VENTURI to drive water from the depths toward the surface. The process known as the VENTURI effect can be described by an increase of the fluid velocity within a region of reduced diameter and a decrease in static pressure value.

2. THE VENTURI TUBE FLOW PRINCIPLE

In figure 1 is presented the VENTURI tube model, having different diameter values between the main regions.

The three main regions are as convergent, narrow and divergent region.

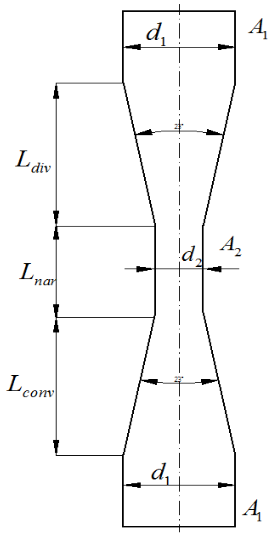


Fig. 1 Schematic representation of VENTURI tube

The inlet section at the VENTURI tube is represented by the area A_1 through which the fluid flows to the convergent region of length L_{conv}, reaching into the narrow region, of area A_2 and length L_{nar}, following then the divergent region of length L_{div}, and finally back in the region of maximum sectional area.

The continuity equation describing the fluid flow between the inlet section of area A_1 and output section of area A_2 can be written as 0:

$$v_1 A_1 = v_2 A_2 = Q \qquad (1)$$

where:

Q – fluid flow rate;

v_1, v_2 - fluid velocities.

For the two points 1 and 2, positioned inside the fluid region at the inlet of the convergent region (1) and also at the inlet of narrow region (2), according to the Bernoulli relationship, can be assumed 0:

$$\frac{p_1}{\gamma}+\frac{v_1^2}{2g}=\frac{p_2}{\gamma}+\frac{v_2^2}{2g} \qquad (2)$$

The fluid motion in the narrow region of area A_2 corresponding to point 2 is registering a decrease in the value of static pressure while increasing the flow velocity value.

The difference between the pressure values between the two points is proportional to the flow rate of the fluid circulated 0:

$$\frac{p_1-p_2}{\gamma}=Q^2\frac{1}{2gA_2}\left(1-\frac{v_1^2}{v_2^2}\right)=mQ^2 \qquad (3)$$

3. VENTURI NOZZLE THREE-DIMENSIONAL MODEL

A three-dimensional nozzle model that is using the VENTURI effect was built using Solid Edge V20 program, shown in Figure 2.

This device model uses a fluid circulation driven by an external pump to extract water from an underground well, working at wide range of depths, depending on the underground water reserve depth at which is executed the well.

The centrifugal pumps are usually used for circulation of the working fluid which is introduced from the exterior into the well through a supply line at well depth.

Once inside the fluid enters the narrow section of the VENTURI nozzle where is registered a decrease in the value of static pressure in the same time with an increase in fluid velocity. Due to this, the existing water in the well is driven towards the surface so that the water flow rate at the outlet has a higher value than the inlet flow rate.

Thus through the circulation of water from surface within a circuit is driven and exploited the groundwater. This type of system can be used at reduced inlet diameters ranged at 2-5 cm, the water flow rate achieved is up to 200 l/min, the circuit pressure is between 3-6 bar, and the minimum power of the driving motor is from 1.5 kW 0.

In figure 2 is presented the VENTURI nozzle three dimensional model, having the diameter values at the inlet of 2 cm and at the outlet of 4 cm.

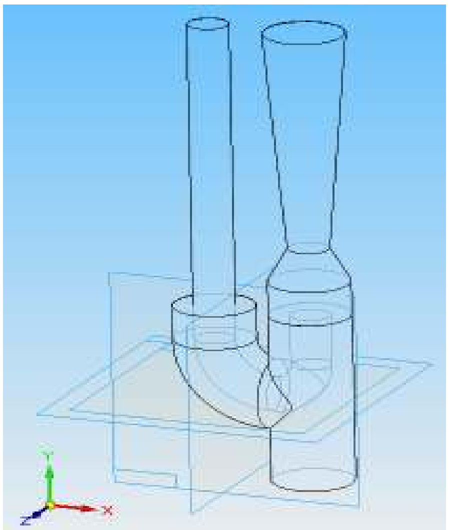


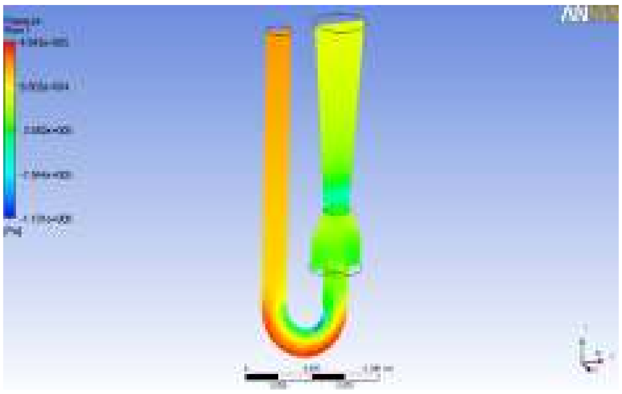
Fig. 2 The three-dimensional model for the Venturi nozzle

4. CFD ANALISYS FOR THE VENTURI NOZZLE MODEL

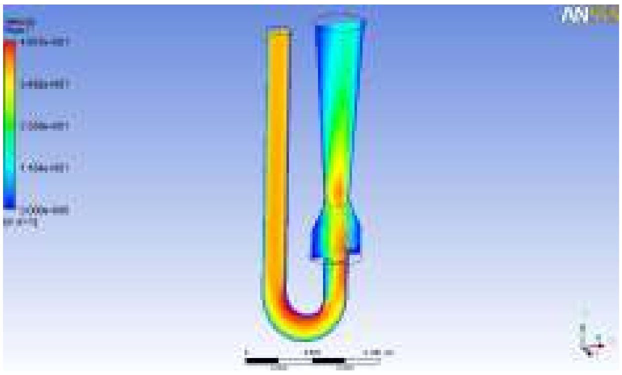
Using the nozzle three-dimensional model numerical analysis using ANSYS CFX software was performed for highlighting the working fluid dynamics inside the body. Because the model is intended to provide water from underground it has been declared water as the working fluid. A water pumping circuit from the exterior provides a pressure range between 3-5 bar. Thus at the inlet was declared the pressure value while the water was directed through the nozzle interior channel where the pressure decreases while the velocity value increases.

The analysis results shown in the following are being represented by the pressure and velocity values of the working fluid inside the fluid region calculated in relation to the declared inlet pressure. Three cases were analyzed for three different values of pressure within the range 3-5 bar: case 1 - inlet pressure value of 3 bar, case 2 - inlet pressure value of 4 bar, and case 3 – pressure value of 5 bar at the inlet.

In figure 3 are presented the obtained results for the case 1.



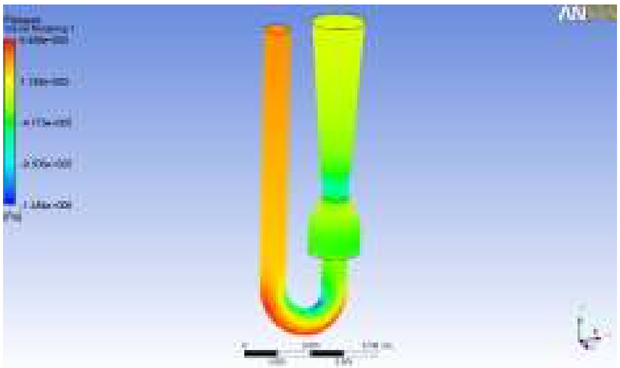
a) pressure values



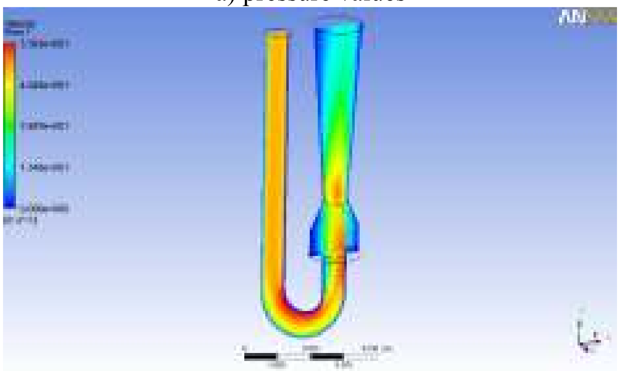
b) velocity values

Fig. 3 The obtained results for case 1, (3 bar)

In figure 4 are presented the obtained results for the case 2.

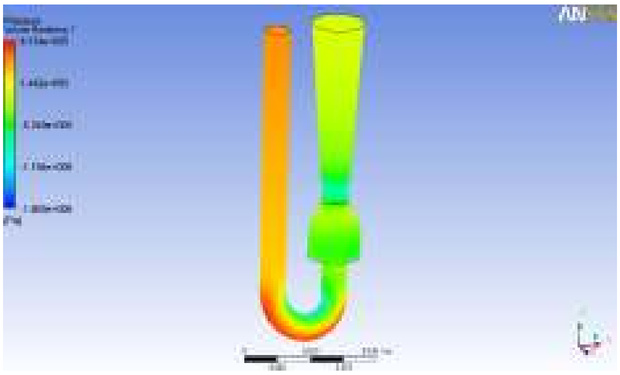


a) pressure values

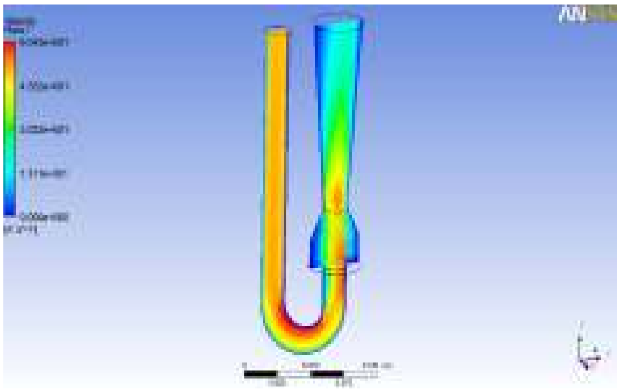


b) velocity values

Fig. 4 The obtained results for case 2, (4 bar)



a) pressure values



b) velocity values

Fig. 5 The obtained results for case 3, (5 bar)

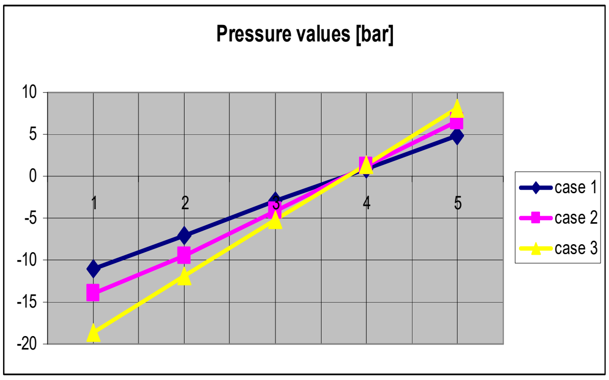
In figure 5 are presented the obtained results for the case 3.

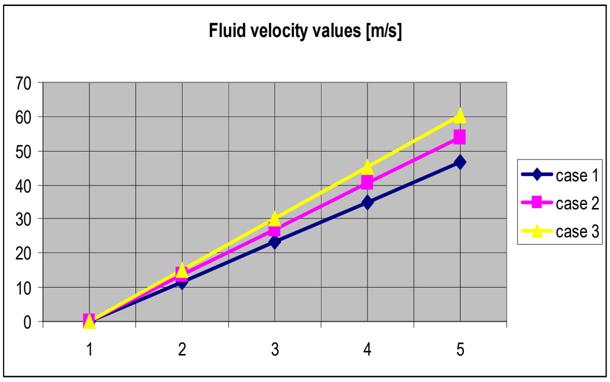
For the three analyzed cases the corresponding values of pressure and velocity were obtained regarding the working fluid transport on the main vertical direction of motion. The maximum pressure values inside the fluid region are in the range of 4-8 bar, while the maximum fluid velocity is ranged between 40-60 m/s.

Schematic representations of the results obtained are presented in Table 1 for both for the pressure and fluid velocity values for the three analyzed cases.

Table 1

The numerical results obtained





According to the obtained results, the low pressure value corresponding to the nozzle inlet area is observed for all the three cases. This means that in this region takes place the water entrainment and its transport towards surface along with the continuously circulated water inside the circuit. The water from the well is ensuring the required flow rate for the circulation through a larger diameter nozzle at high velocity values. The values for the total water flow rate circulated through the VENTURI nozzle model are presented in table 2.

Table 2

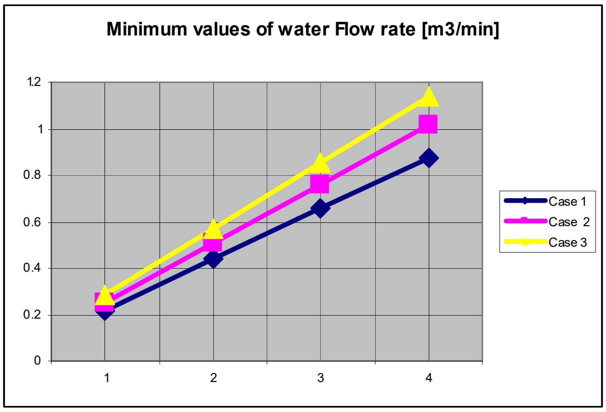
The water flow rate values

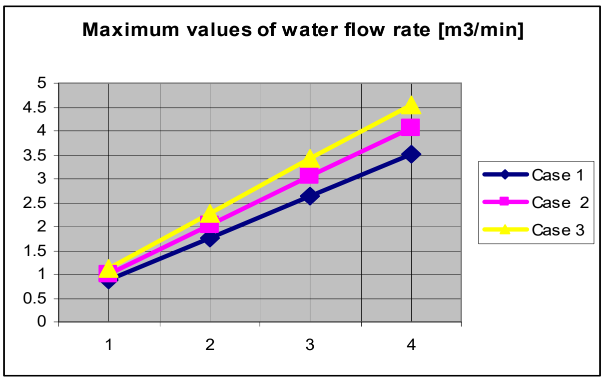
Q_{min} $[m^3 / min]$	Q_{max} $[m^3 / min]$
Case 1	
0.219298	0.877609
0.438595	1.755219
0.657893	2.632828
0.877379	3.511192
Case 2	
0.253963	1.016662
0.508115	2.034077
0.762078	3.050739
1.016041	4.067401
Case 3	
0.284672	1.139596
0.569345	2.279192
0.853829	3.418034
1.138501	4.557631

Table 3 shows the diagrams on the minimum and maximum water flow rate values.

Table 3

The diagrams for water flow rate values





5. CONCLUSIONS

A model for a pumping system component was described and analyzed in this paper. This component is represented by a nozzle having the shape of a VENTURI tube and working after the same principle.

This type of device can be used to extract water from drilled wells in connection with a surface pump that transports water in a circuit.

The proposed solution is efficient for small farmers who need to take water from underground to perform irrigation for the established field crops in small and medium surfaces.

A numerical analysis on the virtual model of VENTURI nozzle was performed for three different cases for which they were declared the values of the working pressure range used by a water pumping system which transports water from wells drilled into the ground.

The analysis results clearly show the principle of circulation of water through the nozzle, being registered high velocity values within the tube narrow region while the pressure has a low value.

Also, very low pressure values have been registered at the inferior nozzle part showing that in this fluid region takes place the water takeover from the drilling well and transported to the surface.

In this way, a pumping system comprising a VENTURI nozzle can be easily used by farmers, having the advantage of not need to insert a submersible pump at a specific depth into the well.

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