Fanel Dorel SCHEAUA

THEORETICAL FLOW MODEL THROUGH A CENTRIFUGAL PUMP USED FOR WATER SUPPLY IN AGRICULTURE IRRIGATION

Abstract: *Today the climate conditions are generally averse for practicing a competitive agriculture because in areas with little precipitations during the summer some solutions are needed to be adopted in order to supplement the distributed water volume amount on cultivated areas through intensive irrigation process. For this practice specialized installations are needed that able to take water from natural or artificial sources, such as irrigation channels, realizing convey and transport to the irrigation specialized installations.*

The main component within these installations is represented by a pump, which is usually a centrifugal pump having an profiled impeller inside by which it can take water and send it forward due to the rotary motion of the rotor. A theoretical model for calculating the flow of the working fluid through the interior of a centrifugal pump model is presented in this paper as well as the numerical analysis on the virtual model performed with the ANSYS CFX software in order to highlight the flow parameters and flow path-lines that are formed during centrifugal pump operation.

Keywords: *centrifugal pump, fluid flow, three-dimensional model, CFD*

1. INTRODUCTION

Agriculture represents a primary component within a country economy and for obtaining the optimal results in field cultivation is necessary that all the conditions are met for maximum performance values.

This involves the use of large water amounts for the irrigation of the cultivated areas through the specific methods applied at regular intervals of time.

Therefore it is necessary that water considered as a primary resource to be delivered using specialized installations that include a power source represented by a thermal or electric engine, a pump which performs the water aspiration directly from the river or irrigation canal and send it to the discharge pipe connected with the final consumer or installation which distributes the water on the cultivated land surface.

According to expert studies conducted aiming the trend analysis in the seasonal rainfall variance show significant quantity increases during the autumn season, which directly reflect trends of increasing water flows from rainfall this season detrimental to spring and summer seasons.

Also have been recorded precipitation amount decreases occurred especially during the winter and spring seasons, which normally affects directly the field agriculture branch due to insufficient water quantities required for crops normal development.

In these conditions, where the precipitation regime shows the changes of water flow rates recorded in time, during the spring and summer season in order to obtain the desired optimum results for the branch of plant cultivation in agriculture intensive irrigation methods are needed to be used on the cultivated land using the specific installations.

2. THEORETICAL ASPECTS FOR FLOW MODEL CALCULATION OF A CENTRIFUGAL PUMP

A centrifugal pump constitutes a hydrodynamic unit that transfers the mechanical energy, taken over from the energy source represented by an electric or thermal motor, to the working fluid used in the system. Basically a centrifugal pump converts the mechanical energy into kinetic energy of the fluid characterized by mass flow rate and flow velocity.

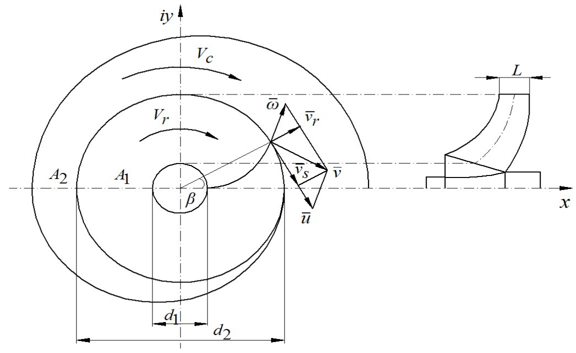


Fig. 1 Calculation model for the fluid flow inside a centrifugal pump.

The model of working fluid flow through the interior of a centrifugal pump is described using a fluid flow rate aspirated through the orifice of a certain diameter, being taken through the impeller located within the pump casing and having a rotational motion with a rotation velocity.

Inside the pump housing is formed a fluid vortex of intensity V = const> 0, located in the rotor axis which has a rotation motion relative to the fluid rotation direction through the rotor and the absolute rotation through the pump casing.

These movements can be described by means of complex potentials applied for the impeller and pump casing relative to the Oz axis:

$$f_r(z)=\left(\frac{Q}{2\pi}-i\frac{V_r}{2\pi}\right)\ln z;\ f_c(z)=\left(\frac{Q}{2\pi}+\frac{V_c}{2\pi}\right)\ln z \quad (1)$$

where:
Q - fluid flow rate;
V_r, V_c - flow turbulence intensity for rotor and pump casing;

For the working fluid flow model through the rotor blades of a centrifugal pump it is considered the tangential fluid movement to the blades profile. So in relation with the *Oxy* reference system which is integral with the rotor, the reference trajectory of fluid particles are represented by the blade profile and due to the continuous movement of the rotor fluid stream flow lines are formed.

The movement is described as a function of complex variable having the velocity potential (φ) and the stream function (ψ):

$$f(z)=\varphi+i\psi=\left(\frac{Q}{2\pi}-i\frac{V_r}{2\pi}\right)\ln z=\left(\frac{Q}{2\pi}-i\frac{V_r}{2\pi}\right)(\ln r+i\beta) \quad (2)$$

The relations describing the velocity potential (φ) and the stream function (ψ) can be written as follows:

$$\varphi=\frac{Q}{2\pi}\ln r+\frac{V_r}{2\pi}\beta;\ \psi=\frac{Q}{2\pi}\beta-\frac{V_r}{2\pi}\ln r \quad (3)$$

The relationship for the circulated flow rate inside the centrifugal pump can be written taking into account the main flow sectional regions *A1* and *A2* and the recorded values for the flow velocity within each section separately:

$$Q=A_1v_{r1}=A_2v_{r2}=\pi d_2Lv_{r2} \quad (4)$$

3. DESIGN ELEMENTS FOR A CENTRIFUGAL PUMP ASSEMBLY MODEL

Water pumping within the specialized supply circuits for field irrigation requires an equipment with axial or centrifugal pumps on which the energy transfer is realized by the existence of the interaction between the profiled rotor located inside the pump casing and the working fluid in which it is immersed.

The parameters of functionality characterizing the operation of these hydraulic machines are represented by the discharged fluid flow rate (Q), the height where the fluid is pumped out (H_p), the absorbed power, (P), the yield of use (η), and rotor velocity (n).

The centrifugal pump operation is accomplished within a specific installation based on the functional relationship between the parameters describing the operating principle:

$$f\left(Q,H_p,P,\eta,n\right)=0 \quad (5)$$

A three-dimensional model of a centrifugal pump assembly designed with Solid Edge V20 software is shown in Figure 2.

The assembly contains the pump housing, the impeller located within the housing, the mounting elements on the base support at the working point and the fastening systems to the aspiration and discharge boundaries of the pump as welded flange type with a number of orifices for bolt and nut necessary to achieve connections.

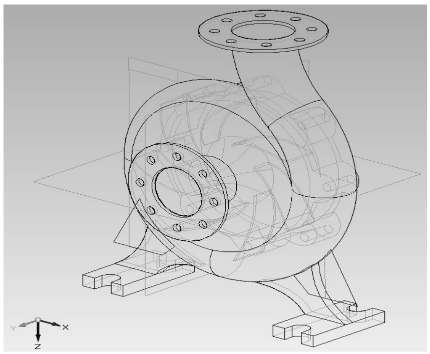


Fig. 2 Assembly model of centrifugal pump.

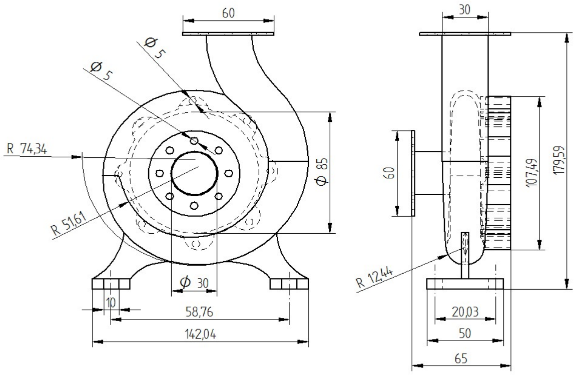


Fig. 3 Design elements and dimensioning details of the centrifugal pump assembly (dimensions in mm).

4. COMPUTATIONAL FLUID DYNAMICS FOR THE CENTRIFUGAL PUMP MODEL

The three dimensional model of the centrifugal pump assembly was introduced in numerical analysis conducted with ANSYS CFX software in order to perform a virtual operation analysis for the model.

In order to be assured an optimal aspiration, the aspiration orifice diameter was set to 50 mm, while the discharge orifice has a diameter of 30 mm. The other overall dimensions of the analyzed model are shown in Figure 3.

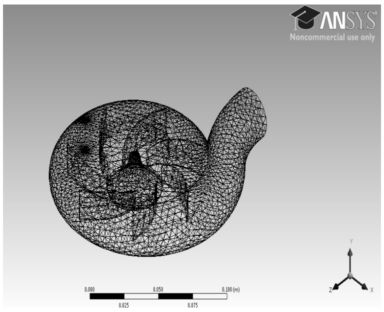


Fig. 4 Mesh model.

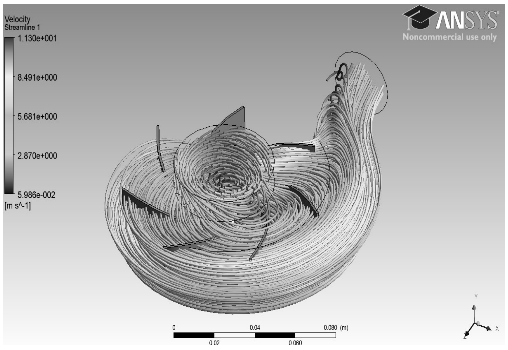
The meshing network was made for triangular shape elements having 11845 nodes and 58 589 elements.

The working fluid contained within the pump housing was water and the impeller positioned inside of the pump casing is fully immersed being declared as solid in rotation motion with a velocity of 2300 rev / min.

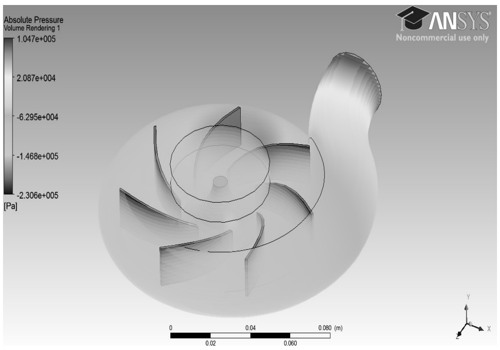
For the fluid region have been declared the fluid inlet and outlet. In each examined case in part it has been declared the value of water velocity at the inlet and values are as follows: for the case I - v = 1 m / s, the case II - v = 3 m / s and in case III - v = 5 m / s.

An increase in the fluid velocity it is expected due to the impeller rotational motion of the inside the pump housing, as well as an increase in pressure in the housing up to the outlet region with a progressive velocity decrease in this area.

The obtained results from the carried out analysis for the three cases considered are presented in the following.

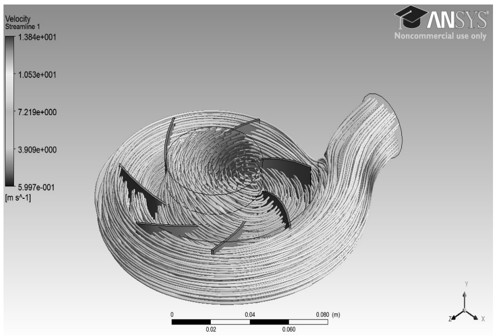


a) Flow velocity values on fluid streamlines

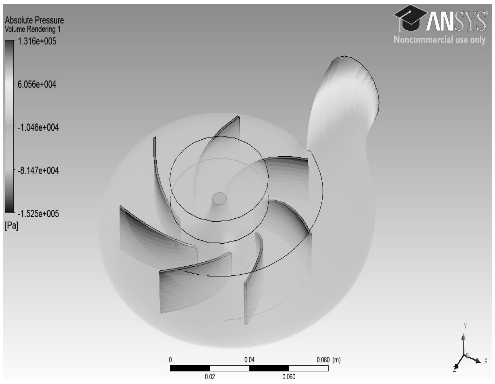


b) Absolute pressure values (volume rendering)

Fig. 5 Case I - Velocity value at the inlet of 1 m/s.

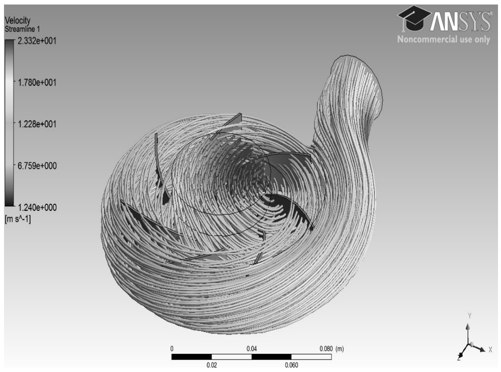


a) Flow velocity values on fluid streamlines.

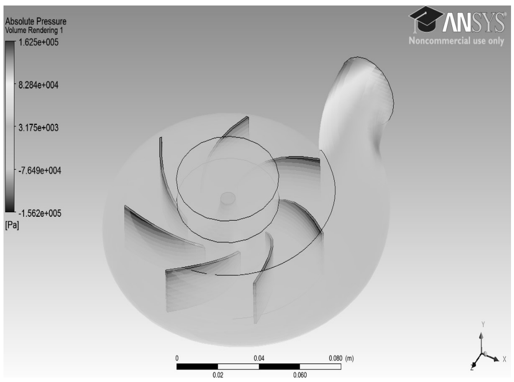


b) Absolute pressure values (volume rendering)

Fig. 6 Case II - Velocity value at the inlet of de 3 m/s.



a) Flow velocity values on fluid streamlines



b) Absolute pressure values (volume rendering)

Fig. 7 Case III - Velocity value at the inlet of 5 m/s.

Analyzing the obtained results from the analyzes performed on the three cases it can be seen that in the inlet region of the pump housing are reported very low rate of water movement which changes gradually as the fluid is advancing within the pump housing being entrained in a circular motion by means of the impeller blades.

Due to the limited space between the rotational blade and the pump housing wall the water is taken up from the inlet region and transported instantaneously due to the centrifugal forces to the outlet region where it is released from the impeller blades space and being continually entrained into the discharge pipe.

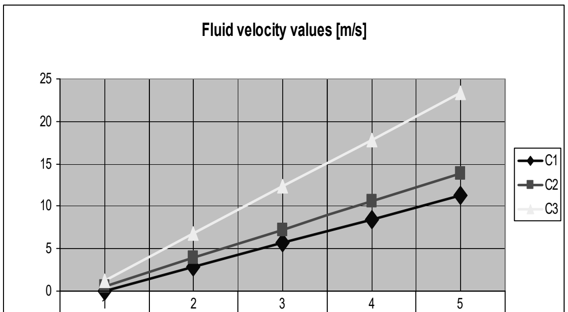
Initially, inside the pump casing, the water has a considerable velocity and a relatively low pressure, while as it reaches the outlet region it is registered a progressive velocity decrease while a pressure value increase occurs that can be explained by the fact that the fluid kinetic energy is converted in the pressure potential energy.

Thus it can be seen that the results confirms this overall trend for all three analyzed cases and the values are proportional to the declared velocity values at the pump housing inlet, corresponding to the start moment of operation.

The diagrams for the result values obtained for the three cases are presented in table 1 for fluid velocity and in table 2 for absolute pressure values.

Table 1

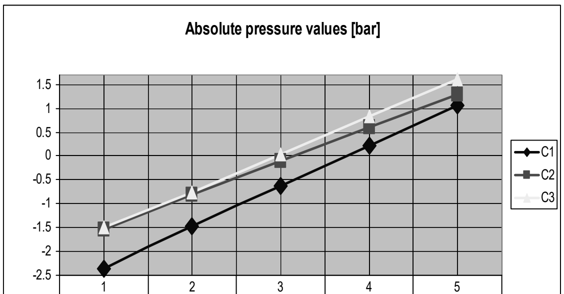
The diagram for the fluid velocity values



	1	2	3	4	5
C1	0.05	2.8	5.68	8.49	11.3
C2	0.6	3.9	7.2	10.53	13.84
C3	1.24	6.76	12.3	17.8	23.32

Table 2

The diagram for the absolute pressure values



	1	2	3	4	5
C1	-2.36	-1.47	-0.63	0.21	1.05
C2	-1.53	-0.815	-0.1	0.605	1.3
C3	-1.5	-0.77	0.03	0.828	2

5. CONCLUSION

In this paper it is presented a centrifugal pump three dimensional assembly model built with Solid Edge software.

The centrifugal pump is considered as a main component within an installation which is intended to achieve water absorption from a river and transport at a required height the necessary flow rate for the irrigation of agricultural land, having the possibility of providing a constant water flow rate during operation.

Such centrifugal pump patterns represent hydrodynamic models capable of converting the mechanical energy received from a thermal or electric motor into fluid kinetic energy, characterized by mass flow rate and flow velocity.

By rotating motion of the rotor within the pump housing the fluid is taken from the input or absorption region and transported to the outer walls of the pump casing then being sent to the outlet or discharge side.

Thus the kinetic energy of the fluid is gradually transformed into potential energy characterized by output pressure. This is visible also on the results of analysis conducted with ANSYS CFX software on the centrifugal pump virtual model.

If initially at the pump inlet the values recorded for fluid velocity and pressure are relatively low as the fluid is driven by impeller within the pump housing the velocity increases and then on the exit region the pressure values are high, so that the fluid is driven by means of hydrostatic forces of pressure directly to the discharge pipe.

REFERENCES

[1] Axinti, A., S., Scheaua F., D., (2015). *Introducere în hidraulica industriala,* ISBN 978-606-696-032-8, Editura Galati University Press, Galati

[2] Arghirescu, C., L., Nedelcut F., Arghirescu D., C., (2013). *Mecanica Fluidelor - Culegere de probleme*, ISBN 978-973-720-475-2, Editura AGIR, Bucuresti

[3] Bojariu, R., Birsan, M., V., Cica, R., (2015). *Schimbarile climatice – de la bazele fizice la riscuri si adaptare*, Editura Printech ISBN 978-606-23-0363-1, Bucuresti, available at: http://www.meteoromania.ro/clima/Schimbariclimatice2014.pdf, *Accessed at 2017-03-15*

[4] *Trasarea curbelor caracteristice ale pompelor centrifuge*, available at:https://www.termo.utcluj.ro, *Accessed at 2017-03-10*

Author:

Lecturer Eng. Fanel Dorel SCHEAUA, Dunarea de Jos University of Galati, Engineering and Agronomy Faculty in Braila, Department of Engineering Sciences and Management, Member of Machine Mechanics and Technological Equipments - "MECMET" Research Center, E-mail: fanel.scheaua@ugal.ro, Phone: 00407498437.