Possibilities for Agricultural Farms of Adopting and Applying Optimal Energy Recovery Solutions from Nearby Water Flows

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Abstract: *Today, must be highlighted the increase of energy needs according to continues population growths worldwide. That is why it should be increasingly used the possibilities of energy obtaining by optimizing the resources at hand. These clean resources that do not have a major impact on the environment, are represented by water falls and flows. These resources are among the most advantageous in terms of obtaining the electrical energy by converting the mechanical energy obtained by the flowing water from a river. A method of obtaining electric energy based on the water flow power is presented in this paper. It is about a mini-hydroelectric power system that can be achieved and mounted on a water body with a lower water flow rate, with the ability to supply power for a nearby agricultural farm. Based on the continuous water stream flow a rotational motion is carried out at the helicoidally rotor shaft which is connected to a power generator thereby achieving the mechanical energy conversion into electrical energy with optimal results for producing continuous electric energy. The water intake assembly system consisting of water channel and the helicoidally rotor it has been modelled as a three-dimensional model, on which an flow analysis has been made in order to highlight the distribution of fluid flow from the inlet to the outlet of the supply channel of the hydroelectric plant model. The obtained results are presented in terms of fluid velocity across regions and specific pressures appearing on the fluid region in which the helicoidally rotor of the system is immersed.*

Keywords*: Hydro power, hydraulic energy, water resource, agricultural farm, rotor model, fluid flow, 3D modelling, computational fluid dynamics (CFD)*

1. Introduction

It can be observed today worldwide that the population living standard is steadily increasing. In order to support this growth, it is necessary for the production of goods and services to be supplied continuously with the necessary resources. The primary resource is the energy, without which the proposed activities can not be performed. This can highlight the major role of energy in the development of human communities over time.
If initially for power generation fossil fuels were used mainly, now it needs to be implemented more and more the handy solutions for power production that implies a minimum impact on the environment.
These solutions are represented by the power recovery from the water flows in rivers, seas and oceans waves force, wind force or capture energy from the sun. Throughout the world, these power generation processes are being used, and are being constantly developed.
For a lower water flow, a mini hydropower solution is available that can be built relatively easily and used on an agricultural farm to produce the electricity needed in order to meet internal needs.
The proposed solution consists in the construction of a special channel with a certain inclination degree, inside which is mounted a helical rotor which is driven in rotational motion based on the water flow force.
For the construction of this mini hydroelectric power model, a river near the farm can be used, thus enabling the generation of electricity through a generator mounted on the rotor shaft.
Such mini hydropower solutions can be the optimal solution for obtaining electricity for farms that have nearby flowing water, where the collector channel and the rotor can be easily mounted.

2. General aspects regarding the hydro power plants

The operation of a hydro power unit can be described based on the available water stream flow rate. Depending on this key parameter the total power can be calculated referring on the hydraulic

head, expressed as the energy amount on the water weight unit, for the static head or water stream velocity for the dynamic head.
For a water stream can be calculated the available power that can be obtained if we know the rotor efficiency and the water flow rate. In the equation enter also the water density, gravitational acceleration and the total head. The relation can be written as follows: [5]

$$P = \rho \cdot g \cdot h \cdot \eta \cdot Q \tag{1}$$

Based on the power relation presented can be aproximated the potential power values for a small water stream.

Table 1: The power diagrams based on water volumetric flow rate and rotor yield

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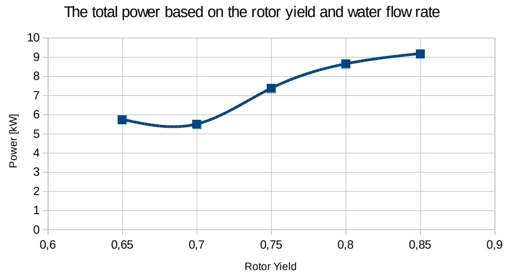
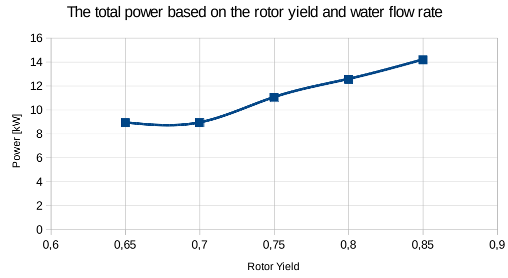
<tr><td>
</td><td>
</td></tr>
<tr><td>a) case I - Water flow rate between 0.4 an 0.6 m3/s</td><td>b) case II - Water flow rate between 0.7 and 0.85 m3/s</td></tr>
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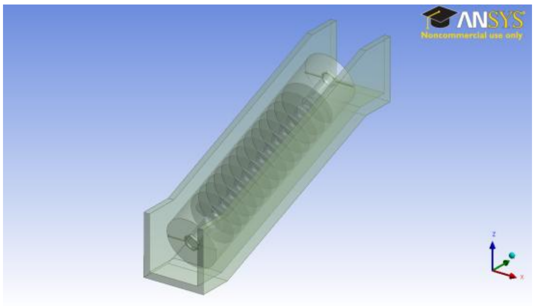
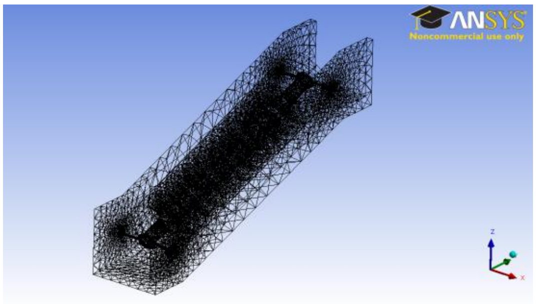
It is possible to estimate the total energy amount that can be obtained by means of a hydropower plant model at which the difference level is relatively low (2 m) and the water flow is considered between 0.4 and 0.85 cubic meters per second. Thus, it can be seen that the total values of the obtained energy amount is from about 6 kW to over 9 kW for the first case and between 9 kW and 14 kW per hour of operation of the hydropower plant for the second case.

3. CFD analysis for the Hydro Power Flow System

In order to illustrate the working process of a micro hydro power plant, an overall model of the adduction system has been built, which is in fact a three-dimensional model that includes the channel and helical rotor. For this model a computational fluid dynamics (CFD) analysis was carried out that can achieve the water trajectory calculation across the channel, describing the water flow from the upstream inlet region to the downstream exit region. The overall model of the adduction channel is shown in Figure 1a, along with the triangular shape mesh network with 39072 nodes and 173354 elements, Figure 1b.



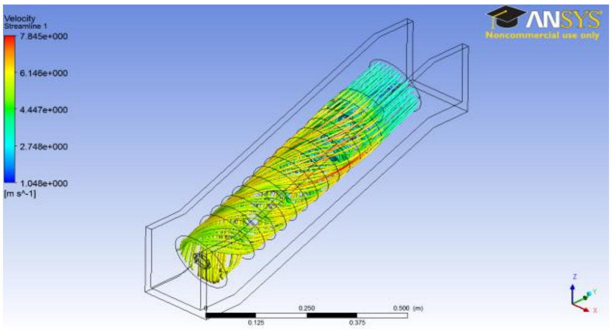
a) Overall adduction channel model



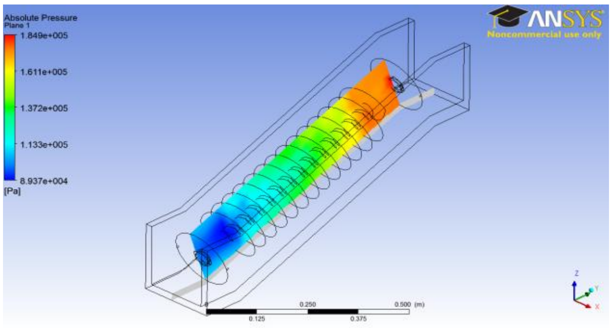
b) Mesh network

Fig. 1. Mini-hydropower water supply channel assembly

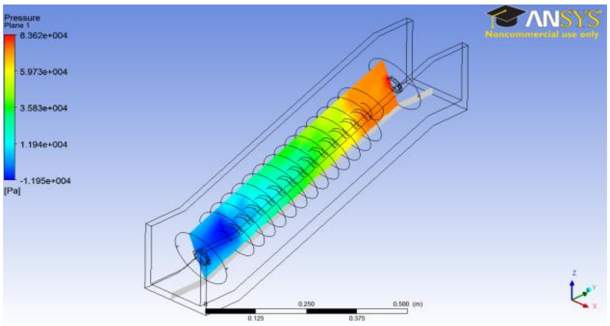
For the fluid region, the chosen fluid was water at the reference pressure of 1 atm, having a temperature of 25 degrees Celsius. An entry fluid velocity of 1 m / s was adopted. The helical rotor is considered as solid, being firmly immersed in the fluid, having a rotation movement of 60 rpm.



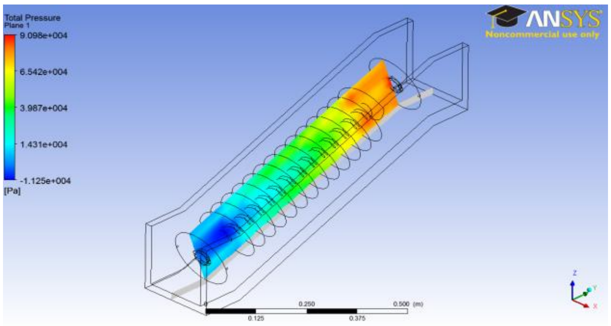
a) water velocity streamlines



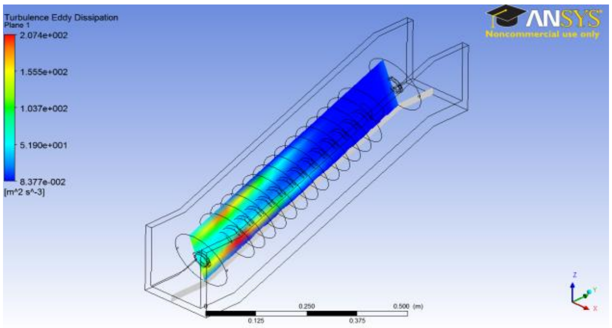
b) absolute pressure values



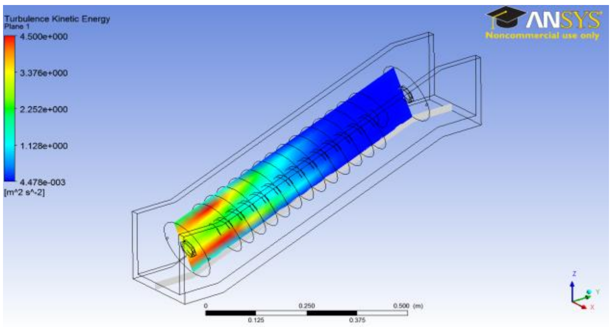
c) static pressure values



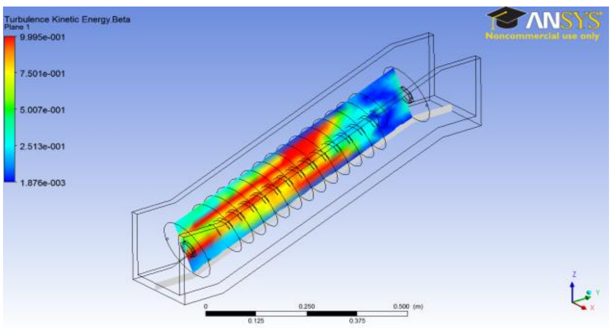
d) total pressure values



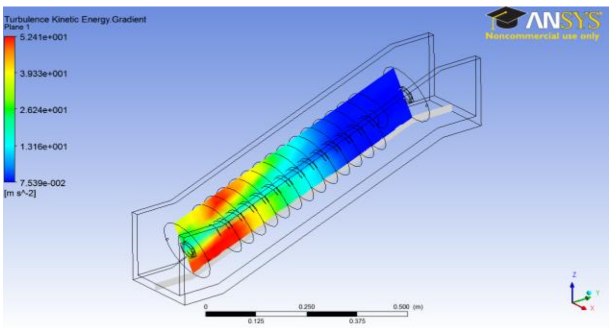
e) turbulence eddy dissipation values



f) turbulence kinetic energy values



g) turbulence kinetic energy beta

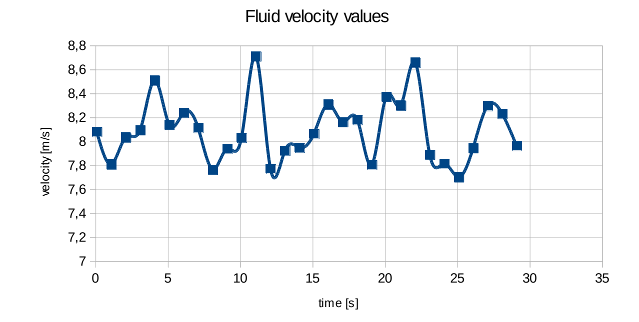


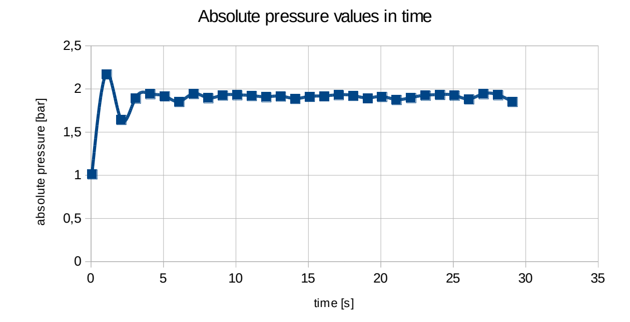
h) turbulence kinetic energy gradient

Fig. 2. The result obtained from the flow analysis

The results are shown in Figure 2, illustrating the main flow parameters such as fluid velocity, static pressure, total and absolute pressure, turbulence kinetic energy and turbulence eddy dissipation rates. Also, the values for the created turbulences as a result of the kinetic energy dissipation on the fluid mass unit engaged in the turbulent flow, the energy dissipation rate or the energy amount loses of the fluid during the flow between the inlet and the outlet region are also highlighted.

Table 2: The diagrams for fluid velocity and absolute pressure values in time





In Table 1 are presented the results diagrams for the fluid velocity values and absolute pressure values in time.
The flow pattern is that of turbulent flow (Re> 2300), as can be seen from the fluctuations of the pressure and velocity values of the fluid over the analyzed region over time due to the ratio of the inertia forces to the viscous friction forces between the fluid particles.
Energia potențială acumulată a apei din amonte determină formarea energiei cinetice la curgerea prin canalul de aducțiune a apei care antrenează în mișcare rotorul elicoidal al centralei.
Acest proces este de fapt o conversie a energiei hidraulice a fluidului în mișcare în energie mecanică de mișcare a rotorului, conectat cu un generator care produce energie electrică.
The accumulated potential energy of upstream water determines the formation of kinetic energy when flowing through the water intake channel that drives the helical rotor of the plant in motion.
This process is in fact a conversion of the hydraulic energy of the moving fluid into mechanical rotational motion energy of the helical rotor shaft, connected to a generator that produces electrical energy.

4. Conclusions

This paper presents a mini-hydroelectric model designed for the production of electricity based on the water flow.
This model can be adopted for electric power production within an agricultural farm located in the vicinity of a flowing stream that meets the conditions of construction and operation of such hydropower plant.
Once built, such a hydropower plant unit can provide the farm's electricity demand, with medium and long-term economic benefits.
An adduction channel assembly pattern has been built and analyzed in terms of fluid flow in order to highlight the velocity and pressure values that occur in the analyzed fluid region.
Fluctuating values of absolute pressure and velocity of the fluid in the turbulent flow motion, as well as values obtained for energy dissipation rate or turbulence kinetic energy were presented.
All results show the particulars of the water flow through the fluid region of the adduction channel according to the input data originally considered.

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