

ENERGY CONVERSION UNIT FROM WATER STREAMS FOR USE IN AGRICULTURAL RURAL REGIONS

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Abstract: *The natural water circuit is of vital importance for maintaining life on our planet. The waters flowing from the mountain heights form important water courses that feed underground aquifers by infiltrations that occur directly from their riverbed but also the oceans that receive the optimum water flow rates initially released by evaporation. In addition to other utilities offered by the rivers, the high potential for obtaining energy from the water flow, which is currently insufficiently exploited, must be shown. A turbine model by means of which energy can be produced based on the water flow is presented in this paper. It is a simple model that can be easily mounted directly into the river bed in order to obtain energy in a particular agricultural rural area that is far away positioned from the centralized electrical network. A complete turbine model has been developed and analyzed in terms of its operation principle in a CFD analysis.*

Keywords: *fluid flow, water stream, impeller, energy conversion, CFD*

1. Introduction

The uninterrupted water flow in nature has ensured the perpetuation of life and offered multiple benefits to flora, fauna and human communities over time.

A continuous water movement in nature has determined man's intervention through constructions designed to capture the moving water energy and transform it into another form of energy, namely electricity, needed to ensure the industry needs but also the optimal comfort in human communities as well.

It has to be remembered that man has used the water power since the earliest times when the first mills located on the course of the fast mountain waters were conceived.

For the power generation, the first power plants were designed at the end of the 19th century, being designed to supply energy to a small number of consumers, but with the passage of time, many hydroelectric power units have been placed on the most important courses of flowing water in the world. Thus the largest hydro-power unit in the world is located in China with a total of 22500 MW installed capacity when working at full capacity.

When energy is needed in a more isolated area adjacent to a flowing stream with a considerable flow rate, it can be considered a solution to generate energy by means of a special construction unit with turbine that can be located directly in the riverbed, meant to take over the potential energy from water flow, converting it into mechanical rotational energy and through a generator into electricity.

This constructive solution is a mobile version of a power plant that uses water to provide electricity, which can be used in specific agricultural applications located in rural areas that do not have an electrical network in the immediate vicinity.

2. Theoretical aspects on water stream flow in nature

The river flow phenomenon in nature can be described using the Navier-Stokes equation system. These equations characterize the movement of the fluids in general and can be considered as a continuation of Newton's fluid movement second law, which for Newtonian compressible fluids can be written: [4]

$$\rho \left(\frac{\partial v}{\partial t} + v \nabla v \right) = -\nabla p + \nabla \left(\mu \left(\nabla v + (\nabla v)^n \right) - \frac{2}{3} \mu (\nabla \cdot v) I \right) \quad (1)$$

where:

v - fluid velocity;

p - pressure;

ρ - fluid density;

μ - dynamic viscosity.

The equation balances the inertial forces represented by the left-hand term with the fluid pressure and viscosity forces in the right-hand term. These equations representing the mass conservation equations are solved together with the continuity equation constituting the conservation of the moment: [4]

$$\frac{\partial \rho}{\partial t} + \nabla \cdot (\rho v) = 0 \quad (2)$$

The mathematical modelling of a river's water flow can be achieved using a system of equations deduced from the Navier-Stokes equation system called the Saint-Venant system: 0

$$\begin{cases} A_t \frac{\partial v}{\partial x} + v \frac{\partial A_t}{\partial x} + \frac{\partial A_t}{\partial t} = Q_l \\ \frac{\partial v}{\partial t} + v \frac{\partial v}{\partial x} + \frac{g}{A_t} \frac{\partial (h A_t)}{\partial x} + \frac{v Q_l}{A_t} = g (\alpha - \alpha_r) \end{cases} \quad (3)$$

where:

A_t - river transversal section area;

v - water velocity;

Q_l - the affluent per length unit;

t - time;

g - gravitational acceleration;

α - river slope;

α_r - hydraulic gradient;

h - the depth between the water section gravity center and the surface.

3. Power unit with turbine assembly model

An overall model of a mobile power unit with turbine has been built. The model is a simplified constructive solution by means of which the water potential energy it can be converted into mechanical rotational energy at the turbine shaft on which electric power can be obtained within a generator. Such simplified solutions can be handy for obtaining energy in areas where there is no electricity network from farms rural areas.

Figure 1 shows the schematically operation principle for the presented constructive solution of power unit with turbine for energy conversion.

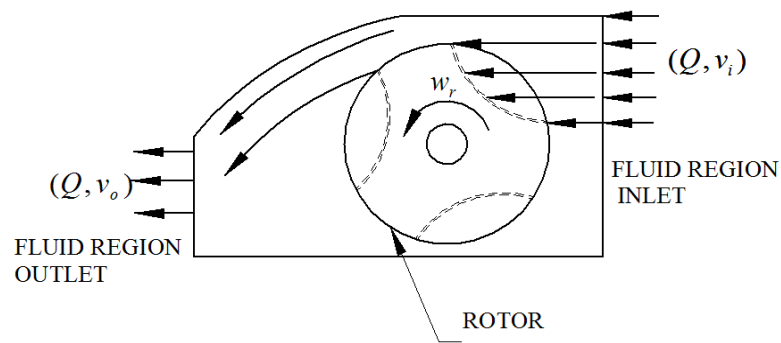


Fig. 1. Schematic representation for the turbine assembly model

The assembly operation consists of introducing into the water so that the water flow rate exerts a force on the propeller blade which causes its rotation movement around the turbine shaft. Due to the continuous water flow, this force is applied sequentially on each blade providing a permanent rotation motion to the turbine shaft.

4. Functional analysis for the turbine model

An analysis describing the turbine virtual model operation was performed using the ANSYS CFX program. Thus, a fluid region having a water working fluid has been defined, inside which the turbine model is placed, being declared as immersed fluid.

A water flow rate of 3 cubic meters per second was declared at the fluid region inlet. The results are presented in terms of fluid velocity and pressure of working fluid inside the analyzed region.

A meshing network having 12774 nodes and 61314 triangular shaped elements was achieved for the analyzed model. Figure 2 shows the analysed virtual model and the results obtained.

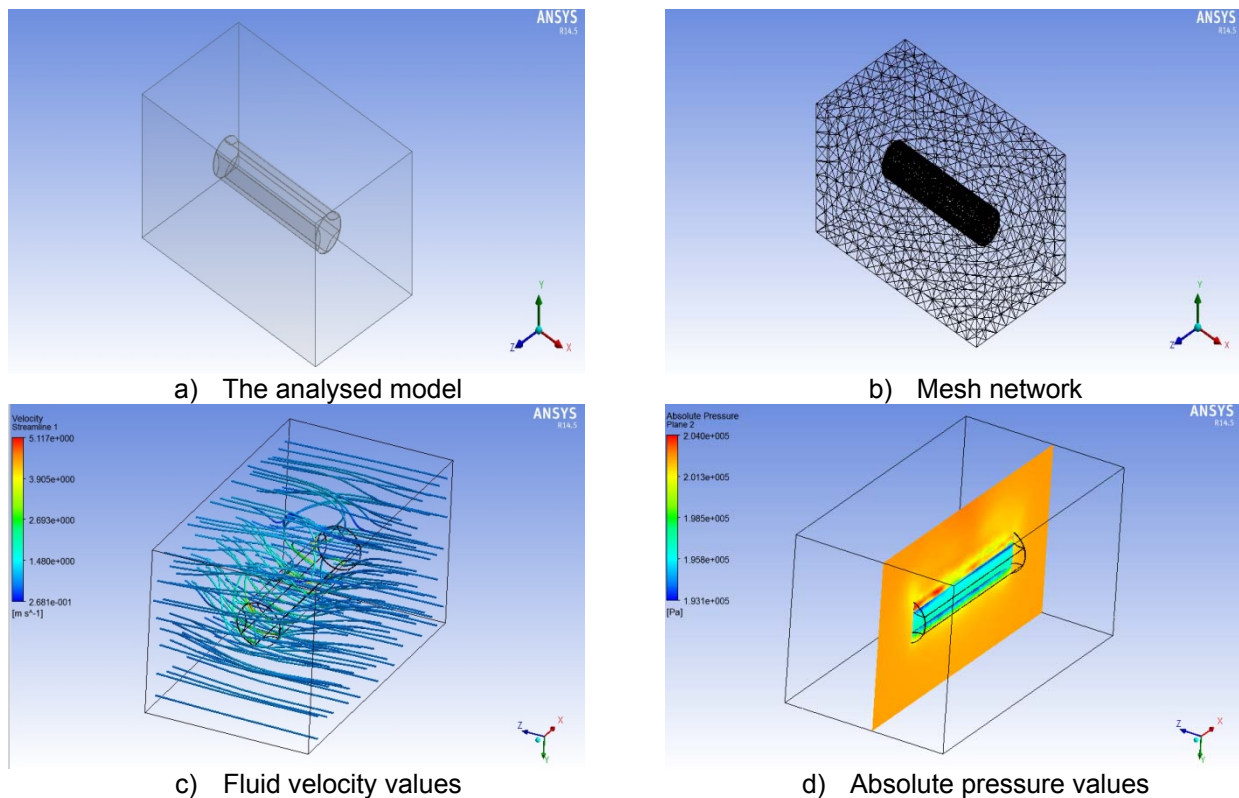


Fig. 2. The analyzed virtual model and the results obtained

5. The results obtained from the conducted analysis

Table 1: Fluid velocity and absolute pressure values and diagrams

Fluid velocity values [m/s]	Absolute pressure [bar]
0.09	1.01
1.33	1.07
1.47	1.09
1.58	1.23
1.89	1.44
2.43	1.57
2.85	1.63
3.32	1.72
3.89	1.81
4.07	1.89
4.24	1.95
4.89	1.98
5.37	2.01
5.6	2.03

A line graph with 'Absolute pressure values [bar]' on the y-axis (ranging from 0 to 2.5) and 'Fluid velocity values [m/s]' on the x-axis (ranging from 0 to 18). The data points are connected by a blue line with square markers, showing a steady increase in pressure as velocity increases.

A line graph with 'Fluid velocity values [m/s]' on the y-axis (ranging from 0 to 6) and 'Absolute pressure values [bar]' on the x-axis (ranging from 0 to 18). The data points are connected by a blue line with square markers, showing a steady increase in velocity as pressure increases.

Table 1 shows the values obtained from the analyzed model and corresponding diagrams for the fluid velocity and absolute pressure variation inside the fluid region.

The results obtained show a pressure increase and fluid velocity higher values near the blade region necessary for the blade rotational movement.

6. Conclusions

This paper presents a turbine model that can be used to convert the water flow potential energy into mechanical energy as propeller rotational motion and further into electrical energy by means of a generator.

The model is intended for use on low depth water courses but with a high flow velocity and a relative constant water flow rate.

From the analysis on the virtual model the obtained results reveals that higher values of fluid velocity and pressure are recorded in the fluid region near the blade area. This shows the possibility of achieving rotation movement of the blades around the axis of the turbine.

Such devices can be easily used because they do not require a complex installation solution inside the river bed, but only a mounting by anchorage.

References

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