A HELICAL TURBINE SYSTEM FOR WIND AND HYDRAULIC ENERGY RECOVERY

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Abstract: *The engineering complex study of the triad "gear-technology-transmission" has permitted to The main objective of this work is to elaborate and investigate the conversion devices for non-conventional energies (wind and hydraulic energy), easy to be stocked and available to a greater number of consumers.*
The utilisation of aeolian units and hydraulic mini-plants will provide rural consumers with the benefit from partial supply of electrical energy, mechanical energy for the irrigation of their fields, and thermal energy for home heating in cold weather. This will help to reduce the import of fossil fuels for electrical energy production and the emission of polluting gases.
Keywords: turbines, coefficient of wind, water mass

1.Introduction

The Government of Moldova launched a strategic plan for the improvement of local and regional environment and for the diversification of energy sources. According to the Action Program of the National Agency for Energy Conservation and the Governmental Program of Action (2000) the focus is on the utilisation of alternative energy sources and implementation of new low energy consumption technologies. The proposed work is in line with these priorities. The main objective of this work is to elaborate and investigate the conversion devices for non-conventional energies (wind and hydraulic energy), easy to be stocked and available to a greater number of consumers.

The Republic of Moldova is an overpopulated country (approximately 140 habitants/km^2). Environmental issues (atmosphere, aquatic basins and soil pollution, forest clearing) with which the country is confronted are quite serious. At the same time, Moldova has no traditional energy sources (coal, oil, gas, etc.) of its own. Currently, about 95 percent of electrical energy production in Moldova depends on imported sources of fossil fuel.

Thus, development and utilisation of wind turbines and hydropower mini-plants will ensure the reduction of expenses for fuel import and the reduction of gas emission. Hence, its energy security is being jeopardized.

The development of small agricultural farms and processing enterprises in Republic of Moldova demands reliable low cost energy sources. In this respect it is obvious that the proposed project corresponds to the national priorities of the Republic of Moldova (as well as to global priorities): environment improvement and utilization of alternative non-polluting renewable energy sources.

The climate conditions in Moldova allow a large utilization of the wind and water energy. The "reserve" of the aeolian energy on the territory of the Republic of Moldova reaches nearly 5450 million kW.

In the case of Republic of Moldova, large-scale hydro-electric power utilisation is not appropriate as it could lead to an environmental unbalance. Small-scale hydro-electric power facilities without a need for dams are therefore quite favourable for Republic of Moldova from different points of view, including the fact that generation of one exajoule of electric energy requires a surface of only 170 km^2 as compared to requirements from biomass (125000 km^2), large-scale hydro-electric power plants (8300km^2), photovoltaic plants (1700 km^2), wind (300 km^2) and natural gas turbines (200 km^2).

The utilisation of aeolian units and hydraulic mini-plants will provide rural consumers with the benefit from partial supply of electrical energy, mechanical energy for the irrigation of their fields, and thermal energy for home heating in cold weather. This will help to reduce the import of fossil fuels for electrical energy production and the emission of polluting gases. The utilisation of wind and hydro-energetic resources of rivers will reduce the poverty level of rural population and will support rural producers of agricultural products.

In such a case, it is important to design conversion devices for non-conventional sources of energy that is available to a greater number of consumers. Such challenges can be partially satisfied by conversion systems utilizing wind and river's water hydraulic energy.

In the Republic of Moldova, due to the high density of the population and to the low speeds of the wind, small and medium sized aeolian stations (wind units) are preferable. The wind turbines can be installed taking into account the practical characteristics of the landscape in all Moldova regions. In conditions of permanent energy shortage in the Republic of Moldova, the farms and micro-production enterprises (especially in the country side) demand wind units to produce energy. In this context, potential producers may develop the market for these products.

The utilisation of hydraulic mini-plants will allow rural consumers to benefit from the partial supply of electrical energy, mechanical energy for the irrigation of their fields, and thermal energy for house heating in cold weather. This will help to reduce the import of fossil fuels for electrical energy production and the emission of polluting gases. Next, the utilisation of hydro-energetic resources of rivers will reduce the poverty level of rural population and will support rural producers.

The suggested hydraulic mini-plants: demand small surface (practically only for the construction on the river bank of the bed on which it will be assembled); do not require construction of dams that could lead to aquatic unbalance, and demand low fabrication and maintenance expenses. Having reasonable dimensions (total palette surface is approximately 20 m^2 and the flowing water speed V=1.5-2.5 m/s) the mini-plant power can reach P=100 kW. The annual energy potential of a hydraulic mini-plant is approx. 750 MWh. Simple manufacturing and maintenance of hydraulic mini-plants will produce low cost electrical energy.

2. Description of the helical turbine

The analysis of the scientific papers and patents in the envisaged domain shows that efficiency increase of the wind unit and hydropower plant can be ensured by increasing the coefficient of wind and water energy utilisation. The issue is very important for the Republic of Moldova, where the annual average wind speed is not more than 3-5 m/s, and water speed is 1.5-2.5 m/s. According to the undertaken analysis, the utilisation of wind units with a capacity of 1.5-2.5 kW is considered to be profitable for the Republic of Moldova.

For many years we collaborated with the Production Scientific Association ***NPO "Vetroen***" from Istra, Moscow region. The cooperation focused on the development of an electro wind unit multiplier with **P = 8 – 16 kW** for high wind speeds. There are no organizations in the Republic of Moldova to carry out research in the field of wind energy utilization. During the last 20 years the team patented about 20 inventions in this field.

Recently, the research team from the Technical University of Moldova started the improvement of the helical turbine concept (Fig. 1) for the aeolian units and the hydropower mini-plants. The preliminary results of this research are very encouraging.

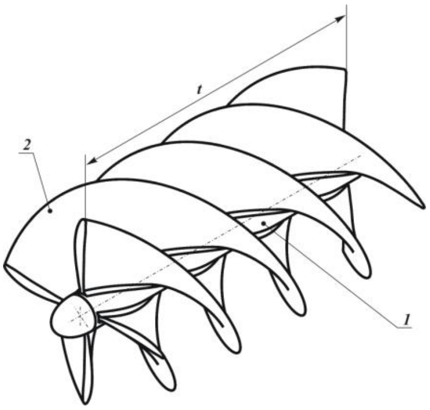

Fig.1.

To obtain definitive results it is necessary to ascertain the influence of many geometric and flow kinematic parameters upon the coefficient of wind and water energy utilisation. It is also necessary to study air and water mass characteristics driving the turbines. This research demands ample mathematical and physical modelling. Detailed analysis of construction of the existing turbines demonstrated a lack of fundamental research in the area of helical turbine efficiency.

The absence of updated assessment methods and the absence of required equipment and software prevented us in the past from optimizing the functional parameters of the working units of the aeolian stations and hydropower mini-plants. To utilize widely the helical rotor concept for turbines and to optimize their functional parameters it is necessary to carry out additional research. Specifically, we propose to:

-estimate the energetic potential of wind and water;
-optimise of the helical turbine profile in normal section;
-determine the speed field for a 3-D helical rotor blade,
-simulate analytically or numerically the air and water flow around the helical rotor;
-undertake aerodynamic analysis for the wind turbine helical rotor;
-determine the aerodynamic forces and performances for the helical rotor;
-perform optimization of the helical turbine geometrical parameters;
-study air mass characteristics driving the turbine;
-study the influence of the geometrical parameters upon the coefficient of wind and water energy utilisation;
-elaborate the fabrication technology for the helical rotor and other components.

We envisage to increase the coefficient of wind (water) energy utilization based on additional ejection of air (water) mass. To obtain final results we propose to ascertain the influence of the following parameters upon the coefficient of air (water) flow utilization:

- number of turbine blades,
- radial variation of the geometric parameters of the rotor blades,
- axial variation of the geometric parameters of the rotor blades and the duct radius,
- optimum axial length of the helical turbine rotor and the duct, and
- angle of turbine location concerning air or water current.

To utilize widely wind (water) helical turbines and to optimize their functional parameters it is necessary to carry out additional research in the following directions to:

- optimise the helical turbine blade section profiles;
- determine the three-dimensional fluid velocity field for helical rotor blades;
- determine the aerodynamic forces and performances for the helical rotor;
- perform the optimization of the helical turbine geometrical parameters;
- study air and water mass characteristics driving the turbine,

- study the influence of the geometrical parameters upon the coefficient of turbine utilisation;
- elaborate the fabrication technology for the helical and multi-blade turbine.

The optimized helical turbine will ensure high efficiency over a range of operating conditions and will become a realistic candidate for the consequent industrial utilization.We have defined the basic geometrical parameters of the profile as:

- relative thickness of the profile;
- relative camber of the profile;
- profile contour characterised by the flexure angle of the mean line.

The position of the profile concerning the air current is characterized by the angle of approach, that is, the angle between the vector of angular velocity and the tangent at the profile mean line. The pressure difference among various sections was defined by Bernoulli equation. The force of the ideal gas upon the profile was defined by Joukovsky equation. We envisage an increase in the coefficient of wind utilization based on additional ejection of air mass.

3. Certain views regarding the geometry of the helical turbine.

Let's analyze haw the internal fiction of an incompressible gas reacts on all force results which react on the profile in the net. From the equation of the motion quantity we will obtain the relation for the axial and frontal components of the current reaction on an integrated profile of the net

$$P_Z = (p_1 - p_2)t$$

$$P_U = -\rho w_Z t (w_{1U} - w_{2U}).$$

Taking account of the internal friction, the Bernoulli equation for section 1 and 2 will be:

$$p_1 - p_2 = \frac{\rho}{2}\left(w_{2U}^2 - w_{1U}^2\right) + \Delta p,$$

where Δp are the abstract loses of the overall pressure that appear because of the internal friction.So,

$$\Delta p = p_1 + p_2 - \frac{\rho}{2}\left(w_{1U}^2 - w_{2U}^2\right),$$

$$R_Z = (p_1 - p_2)t = -\frac{\rho t}{2}\left(w_{1U}^2 - w_{2U}^2\right) + \Delta p \cdot t.$$

Let's compare the relation for the lifting force projection at the motion of a perfect gas will the similar relation at the motion of the semi fluid gas.

For a perfect gas we have:

$$P_U = -\rho G w_Z,$$

$$P_Z = -\rho G \frac{w_{1U} + w_{2U}}{2}.$$

For a perfect semi fluid gas:

$$R_U = -\rho G w_Z, \qquad R_Z = -\rho G \frac{w_{1U} + w_{2U}}{2} + t \cdot \Delta p \cdot$$

The additional component $t \cdot \Delta P$ expresses the projection of the resistance force $\vec{R}'$, on the net axis. The projection of the force on the axis is equal to zero, that is parallel to the net axis. We introduce the overage geometry speed $\vec{w}_m = (\vec{w}_1 + \vec{w}_2)/2$ and obtain the relation $R = \rho G w_m$, which formally does not differ from the one of the perfect gas. But here, both w_m and G are determined according to real velocities $\vec{w}_1$ and $\vec{w}_2$.

The resultant interaction force R of the semi fluid gas current with the profile of the net is equal to:

$$\vec{R} = \vec{P} + \vec{R}'$$

As $P_U = R_U$, the resistance force does not influence on the torque moment of the profile net.

We take apart R into components:

$$\vec{R} = \vec{R}_X + \vec{R}_Y$$

where R_X is the frontal resisters force;

R_Y – the lifting force.

The frontal component of the resultant force R_X characterizes the power effect of the air course on the working wheel, but the axial, component R_Y determines the loading force of the turbine bearing.

We will name the profile quality: $K = R_Y / R_X = ctg\varepsilon$

the lifting force relation of the profile to the frontal resistance force.

These dimensionless coefficients of the integrated profile force or of the net depend on the geometry profile and of the net, angle of adjustment i, backpressure $\rho w_m^2 / 2$ and other additional agents.

The resultant force for the net made up of n profiles with integrated height is determined according to: $R = C_R n b \rho w_m^2 / 2$,

but the components for the integrated profile:

$R_Y = C_Y b \rho w_m^2 / 2$; $\quad R_X = C_X b \rho w_m^2 / 2$,

here C_R, C_Y, C_X are aerodynamic force coefficients, and also frontal resistance coefficients.

The coefficient $C_Y = \frac{2t}{b}(ctg\beta_1 - ctg\beta_2) sin\beta_m$ allows the determinations of the lifting force according to the known characteristics of the profile nets.

As a results of some mathematical modeling made on computer it was possible to establish the variation limits of R_Y lifting force characteristics parameters.

We elaborated also the model of the multi-blade turbine (Fig. 2) for the hydropower mini-plant. To verify the theoretical results the team will design and execute the experimental sample of the helicoids and multi-blade water turbines.

They will be tested in the Laboratory of Experimental Testing, Department of Theory of Mechanisms and Machine Parts at the Technical University of Moldova. Based on the theoretical and experimental results recommendations on the implementations of aeolian system and hydraulic mini-plants with helicoids or multi-blade turbine and electrical generator with permanent magnets and precessional multiplicator will be elaborated and the results will be disseminated. In this respect we rely much on the assistance of the U.S.A. research team.

The results of this research will contribute to the partial solutions of energetic, industrial, environmental or security-related problems. Research results will permit to elaborate new helical and multi-blade turbines of high performance that could be utilised in the aeolian units for wind energy recovery and in the hydropower mini-plants.

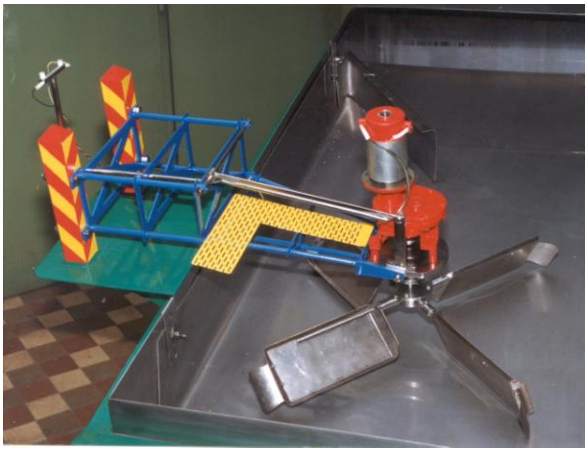

Fig. 2. The hydropower mini-plant.

4. Conclusions:

1. The helical turbine efficiently functions at low wind velocity (4-6 m/s).
2. Theoretical and experimental researches proved the existence of the peripheral injection of air courses, agent which allows:
   - to increase the wind power coefficient of utilization.
   - to reduce the weather change dependence of the air course direction.
3. The suggested helical turbine allows the use of kinetic energy of river running waters at speed (2-3 m/s) without building barrages and without the negative impact on the environment.

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