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NEW DESIGNS OF ROTORS WITH VARIABLE GEOMETRY PARAMETERS IN DYNAMICS AND THEIR EFFECTIVE USE IN AVIATION AND WIND ENERGY

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Abstract: *This article presents the investigation results upon the dynamics of the working model of rotors with variable geometry parameters. Through aerodynamic and economic calculations, the effectiveness of use of such designs for powerful wind stations is proved. It is presented the analysis of various designs and methods of selection designs for various conditions of operation of wind installations in wide range of the wind speed change. Also quite effective method regarding the costs of the accumulation of wind energy will be suggested, that being the topical world problem for which development hundreds of millions of US Dollars are spent annually.*

Key words: *blade, setting angle, blades twist, wind energy.*

Recently, in conditions of the abrupt increase of the growth tempo of global thaw and considerable deterioration of the ecological stat, the acquisition of power energy by traditional methods becomes a serious threatening to the mankind. In connection with this, especially developed countries are in difficulty due to their annually quick tempos of increasing the volume of industrial products and accordingly the quantity of consumed power.

In this case it must especially be noted the risk factors that are characterizing the atomic power stations and the dissatisfaction of population that reached its peak during the disaster in Fukushima that happened in Japan in 2011.

It is recognized internationally that these processes were the basis of the solutions proposed by the authorities of all countries for caring out operative steps in direction of changing the atomic energy with some less dangerous energy types able to improve the energy balance of the countries.

By these processes it is preconditioned the fact that in the last 10−15 years almost in all countries of the world special attention is paid to updating of the existing and creation of new non-traditional methods of the energy acquisition and maximal use of the existing potential in the country.

Furthermore, the governing bodies of the international community elaborate special encouraging measurements for those countries and firms that effectively work on the development of ecological pure and non-dangerous methods of acquiring energy.

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First of all, wind and solar energy refer to such kind of energy. Therefore, the designs of wind stations and solar panel technology are extensively updated.

The extensive works in both directions are conducted at the Georgian Technical University.

For increasing the effectiveness of wind stations, several designs of rotors with the ability of changing of basic geometry parameters have been created. Such parameters are the rotor diameter, i.e. length of blades, setting angle of each blade and law of their twist.

The preliminarily conducted aero-dynamic and economic calculations prove that as a result of use of the designs elaborated by authors, the annual volume of output of each wind station can be increased by min 100%.

Despite multiple work of well-known companies and scientists of various countries, the variable geometry rotor – VGR problem has not been solved yet. There are patents that have not materialized in real applications, mainly due to their complexity and insufficient reliability of technical solutions.

It must be noted that all these companies were focused mainly on a single parameter. For example, Sikorsky Company was involved in changing only the rotor diameter and the Boeing Company only in the blade twist change.

Georgian Technical University (GTU) proposed a combination of changes in the diameter and twist at the same time dynamics.

Initially, in the phase of analysis, because of separation of the investigation object, the model of the rotor with variable diameter and then the model of the rotor with variable blade twist have been designed and manufactured. After laboratory tests of their main units in the phase of the synthesis, the rotor with variable diameter and blade twist (Fig. 1) and the testing stand has been created [1].

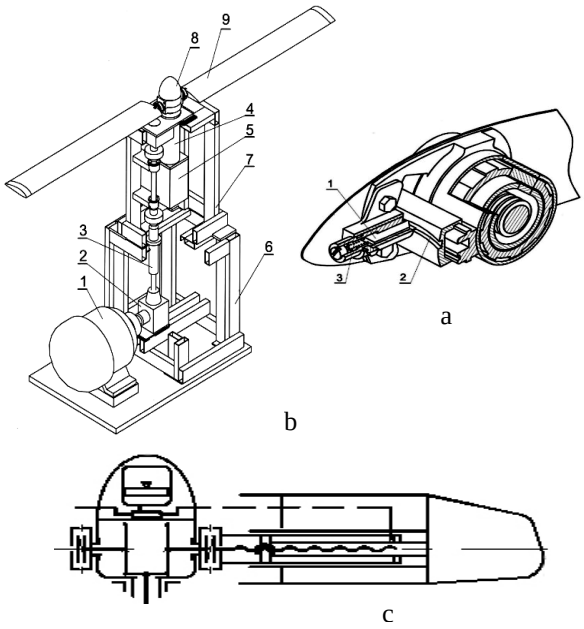

Fig. 1. Mechanisms for management of parameters of the VGR and testing stand: *a* – mechanism of the twist change; *b* – stand for dynamic tests; *c* – mechanism of the diameter change.

The conducted tests on stand of the VGR have shown that at high rotational speed significant centrifugal forces arise that influence the blade movable part. They are taken up by the jackscrew. The jackscrew is the most loaded element of the rotor design and also the weakest unit. The reduction of harmful influence of these forces is the very actual problem.

Therefore, a system was developed to compensate for centrifugal forces. The technical approach was transferred in the model experiment in which the stand is stationary fixed in place. At the rotor running in the fan mode, the thrust measurement was done depending on the change of the rotor rotational speed and diameter. According to the principle of reversibility, this imitates the conditions of the hover mode of the aircraft. From the possible principles of compensation (mechanical, electrical and hydraulic) the hydraulic one was chosen (Fig. 2) as the most flexible in control [1, 2, 3].

For the design of this version of the VGR, an European Patent has been achieved, Application №/Patent 08737551.5-2422 PCT/IB2008001041. At present, it follows the process of patenting in the USA. All the financial costs were assumed by the European Union.

The safety of the VGR dynamic tests was provided by the reliability of the VGR units with the compensation system. For evaluation of the reliability it was designed and manufactured the stand for static tests (Fig. 3) on which experimentally were imitated the loads acting at various rotor rotational speeds. The blade elasticity lines were determined depending on imitated rotational speeds at retracted and extended blade and dependence of forces on the control lever of the stand from imitated rotational speeds.

The experiments on the stand for dynamic tests (Fig. 4) were conducted by the measuring method of the airflow speed with a revolving-vane analyzer, which for this task was characterized, with a sufficient iteration of measuring results.

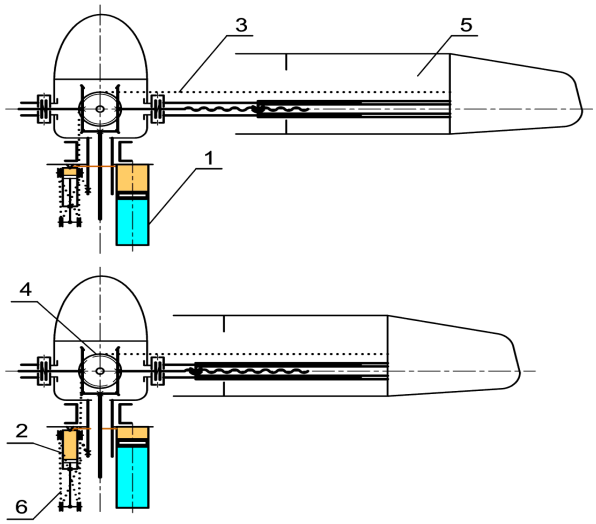

Fig. 2. Schematic arrangement of the VGR with position of the hydro-pneumo-accumulator and hydro-cylinder below the rotor hub (1– hydro-pneumatic accumulator, 2 – hydro-cylinder, 3 – cable, 4 – roller, 5 – blade, 6 – pulley block).

Fig. 3. Experimental set-up: *a* – stand for static tests; *b* – blade with flexible elements and rib.

It has been established that in case of increase of the rotor diameter of 1.4 times and the change of the blade twist within 16÷18° the increase of the thrust force is of approximately 1.6 times.

The effectiveness of the compensation system is proved by multiple retraction-extension of the rotor blade in all range of change of the rotational speed. It conditioned the synchronism of the VGR functioning.

Results of repeated and comprehensive dynamic investigation of the working model of air screws with changeable geometrical parameters were recorded. The example shown in Figs. 5–8 presents the values of changing the rotor diameter from maximum to minimum in a large range of the rotational speed.

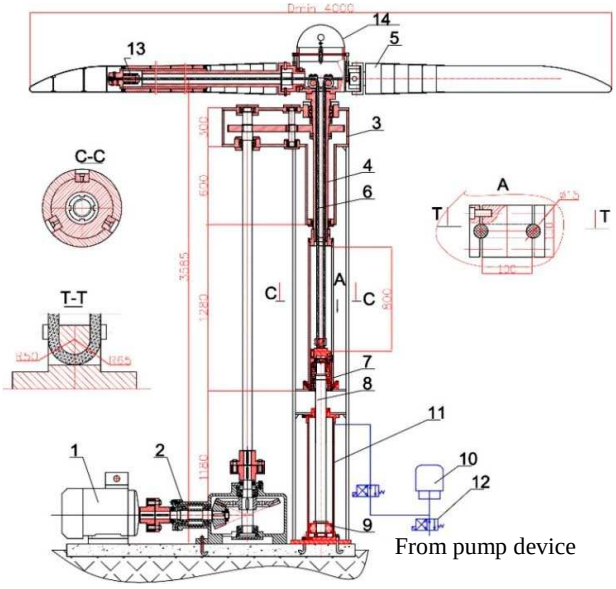

Fig. 4. Stand for dynamic tests and photo of the stand: 1 – Electrical engine of direct current, 2 – conical reducer, 3 – cylindrical reducer, 4 – spindle of cylindrical reducer, 5 – blade with flexible elements, 6 – cable, 7 – unit of bearings with body, 8 – rod, 9 – piston, 10 – hydro-pneumo-accumulator, 11 – hydro-cylinder, 12 – hydro-distributor, 13 – UNIT of the cable mount, 14 – hub.

As a result of manufacture and dynamic test of a functional model of the rotor with variable geometry parameters one has proved that for wind energy installations, especially for big powers, the use of VGR will enable extending the scale of efficiency of the setting during the change of the wind speed in a large scale from 3 to 20−22 m/sec and also will provide the workability of the setting during those high speeds of wind (22–35 m/sec) (Fig. 9), at which the existing installations are unable to work [4].

At present negotiations are being held with an important German firm for creation of a joint venture or its subsidiary on the territory of Georgia and manufacture of standard rotors along with new designs.

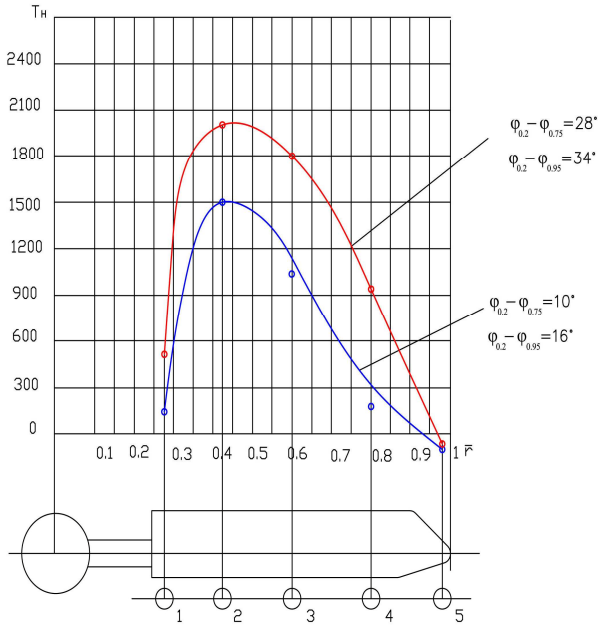

Fig. 5. Diagram of dependence of the VGR thrust from the blades twist change for the minimal diameter $D_{\min}$ of the rotor, rotational speed $n = 300$ RPM and setting angle $\varphi = 5^0$.

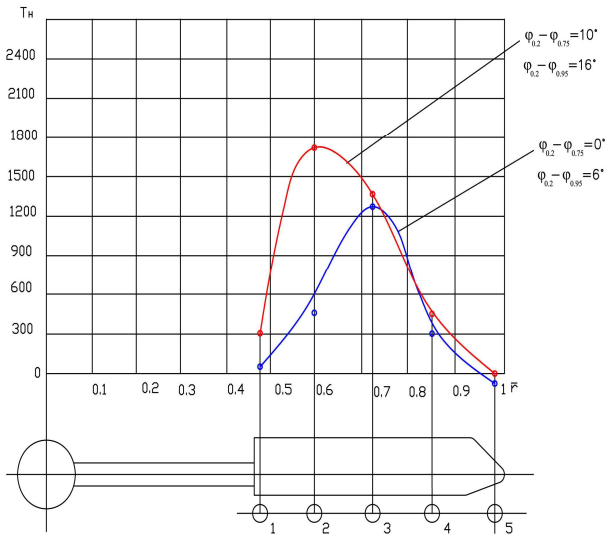

Fig. 6. Diagram of dependence of the VGR thrust from the blades twist change for the maximal diameter $D_{\max}$ of the rotor, rotational speed $n = 200$ RPM and setting angle $\varphi = 5^0$.

Also, negotiations with a firm specialized in production of solar panels are conducted.

Implementation of this project in Georgia is expediently for some large enterprises for microelectronics. Therefore, the Georgian scientists have very interesting offers for separating operations of production of plates from a silicium monocrystall, from the principles of selection of places for installation of ready solar modules and creation of designs of the corresponding mechanisms whose implementation will further increase the efficiency of solar modules in operation.

In particular, installation of these panels, for example over vineyards in advance calculated parameters, using special mechanisms allowing to change angular position of panels in large range, will give the chance along with

obtaining electric energy, to protect plantations to hail, and also against drying of grapes and soil when air temperature constantly is within the range 35–40º and above. It should be noted that such situations in Georgia are very frequent and if it happens before the process of grape harvesting, it strongly influences the crop size, especially the production of grape juice.

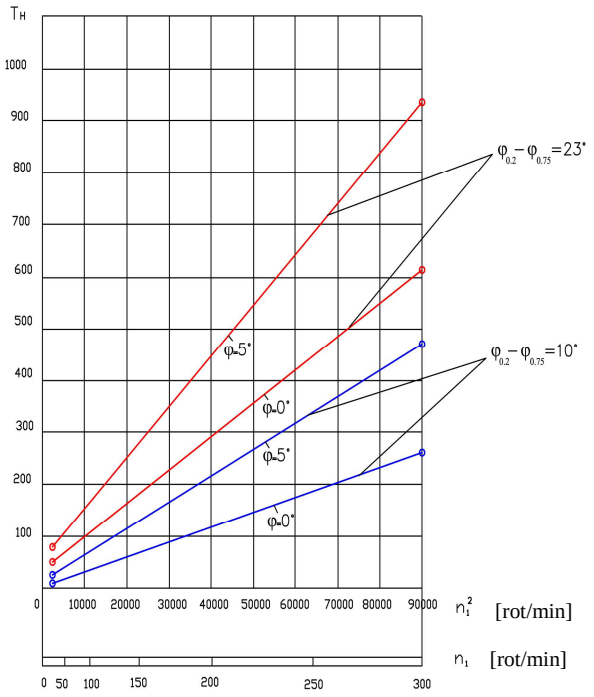

Fig. 7. Diagram of dependence of the VGR thrust from the rotor rotational speed for the minimal diameter $D_{\min}$.

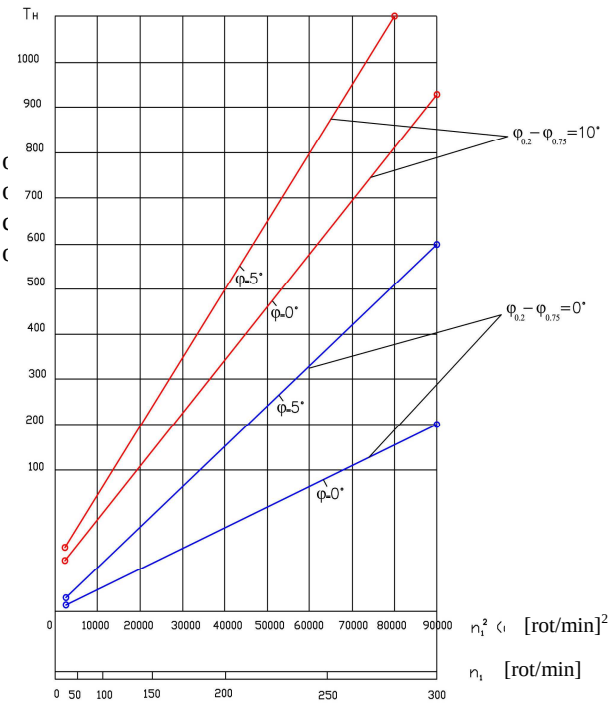

Fig. 8. Diagram of dependence of the VGR thrust from the rotor rotational speed for the maximal diameter $D_{\max}$.

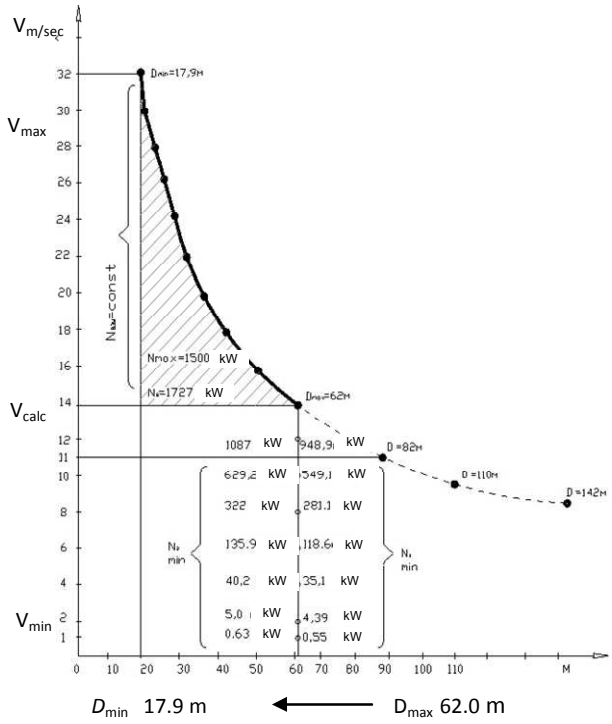

Fig. 9. Necessary combination of the rotor diameter and wind speed for acquisition of the planned power of wind station.

Both protection of plantations against hail, and control of the process of grape drying before harvesting is a burning issue not only for Georgia, but also for all other countries where there are similar plantations.

Therefore, we intensively work on development of methods of optimization of schemes of installation of solar panels over vineyards.

In Fig. 10 one of versions of schemes of installation of such panels is shown.

At present, it undertakes researches related to the optimum sizes of panels, schemes of their arrangement and improvement of mechanisms for adjustment of their angular orientation in wide range for the different periods of time. Also, different options of mechanization and automation of these processes are developed.

Fig. 10. Solar panels over vineyards.

Fig. 11. Approximate option of composition of aggregates and system of their management for accumulation of the received wind and solar energy.

On the basis of consultations with skilled peasants it was established that the use of such schemes of installation would increase significantly the volume and quality of a crop that finally will have notable economic effect.

The presented idea contains also scientific novelty developed together with the German experts for proposing in the near future an European Patent.

Now it was obtained the consent of our partners for gratuitous transfer of 200 m^2 of solar panels for the purpose of organizing in Georgia of a skilled site where prototypes of solar panels will be installed, all necessary researches being done for that.

It still remains a very actual problem studied by important scientists of many known scientific centers of the world. However, unfortunately the effective solution of this problem has not been found. This concerns a method of the solar and wind energy excess storage for whose research hundreds of millions of US dollars are annually spent.

We have in our opinion the interesting solution of this problem for those countries where there are hydroelectric power stations with average and big capacities, i.e. where there are already built high dams and reservoirs.

It is known that all such power plants have big deficiency of water. The water volume, which is gained generally in the spring, is gradually decreasing the whole year being used economically according to a special schedule.

The essence of our method consists in mounting as many as possible wind stations and solar panels around a reservoir. When there is an order for electric energy, they will work for its development and when orders are not present, they work for water pumping from the lower reservoir back to the upper one. It will give the opportunity for all power sources to work constantly and efficiently 24 hours, the whole year.

Figure 11 shows the approximate scheme of configuration of such constructions where one small group of wind-driven generators and solar modules are mounted. It is also visible that around a reservoir it is yet possible to place other such groups.

The consultations with leading experts in power show that after creation of equipment and systems, the improvement of the separate knots and system management will be successfully and effectively done on wide scale with the perspective to be used in many countries of the world.

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