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Electric Generator Model Research (Stage Efficiency of Electromechanical Part)

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Abstract. **The article presents interim results of an ongoing continued study (https://doi.org/10.17770/etr2023vol3.7261). At this stage, measurements are made on a model in which two cavities for magnets and coils are already provided in the turned-wing impeller. The cavities contain mounted magnets that rotate with the impeller around to the housing stationary mounted coils. We already have two independent power generators. In the initial stage, these two generators were selected with coils of different inductance and the voltage and current generated by them were measured. The goal is to find out the possibilities of efficiency using a comparative method, as well as the dependence of the parameters of the generated energy on the speed of the air flow. In the experiments, the speed of the air flow, the area of the air inlet and the area of the air outlet were varied. A rather large amount of data was received, the processing of which will still have to be worked on, but the general trends of the dependence of the extracted electricity parameters not only on the air flow speed, but also on the geometric parameters of the ducts (in this case, the areas of the openings) became apparent. The general parameters of the generated current are already obtained at values suitable for practical use, because in the previous stage of research these values were insufficient to achieve the level of the practical efficiency factor. The article discusses the results of the experiments, observed trends, presents generalizations and conclusions, and predicts directions for further research.**

Keywords: robotic system, electricity generator, regeneration, electricity, wind.

I. INTRODUCTION

The configuration of the model impeller selected for research was determined by the results of previously conducted and published research and experiments [6], [7]. The last article presents interim results of an ongoing study was https://doi.org/10.17770/etr2023vol3.7261 [5]. At this stage, measurements are made with a model in which two cavities for magnets and coils are already provided in the turned-wing impeller. The cavities contain magnets that rotate with the impeller around the in housing stationary mounted coil. We already have two independent power generators as shown in Fig. 1.

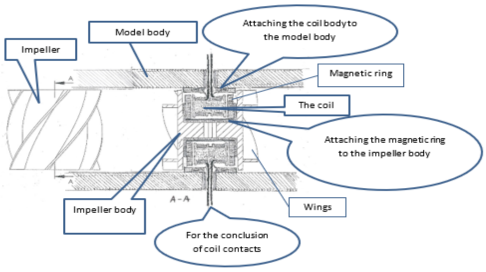

Fig. 1. Airfoil top view and section AA showing internal structure configuration.

In the initial stage, these two generators were selected with coils of different inductance and the voltage and

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current generated by them were measured [2]. In the oscillograms presented below in the text, the voltage dependences generated by one coil are delayed in red, while the others are already in blue. In this way, they can be compared with each other and the perspectives of their combination and possible utility effect can be studied [1]. The inductance of the oscillogram coil displayed in red color was 14.2 mH and the inductance of the oscillogram coil displayed in blue color was 12.8 mH.

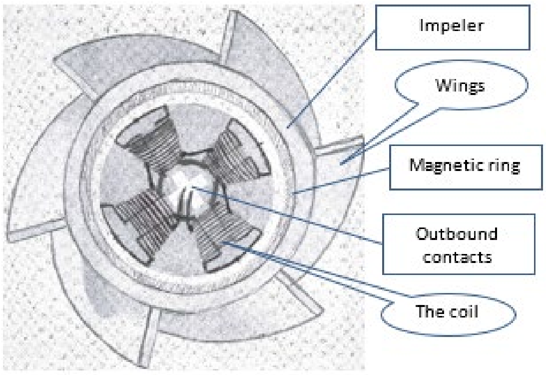

Fig. 2. Side view of the impeller, section showing the configuration of the internal structure.

Next, Fig. 2 shows a side view of the impeller and is analogous for both left and right views. The coils are permanently attached to the body of the model. When improving the layout, it is necessary to provide additional measures allowing to change the mutual position of the coils (phase difference of the generated voltage) and to compare the obtained oscillogram after the measurements.

Using this impeller with two sets of coils, experimental studies were carried out measuring the dependence of the generated electricity on the speed of the air flow, the dependence of the generated electricity on the mass of the air flow (with the height width of the inlet), and the dependence of the generated electricity on the mutual position of the coils (phase difference) when inlet remaining constant.

II. MATERIALS AND METHODS

In Figures 3, 4 and 5, we see the oscillograms of the generated electricity when the air flow speed is 50 km/h, respectively; 65 km/h and 72 km/h and, also the generalized dependence of the generated voltage on the air flow speed in Fig. 6 which shows the general trend obtained by connecting the measurement points to each other.

In Fig. 3, we see the oscillogram of the voltage of the generated electricity, from which we can record that the maximum amplitude of voltage fluctuations is only about 3.7 V. This is not a big value, but it is already significant for practical use, although the air flow speed here is about 50 km/h.

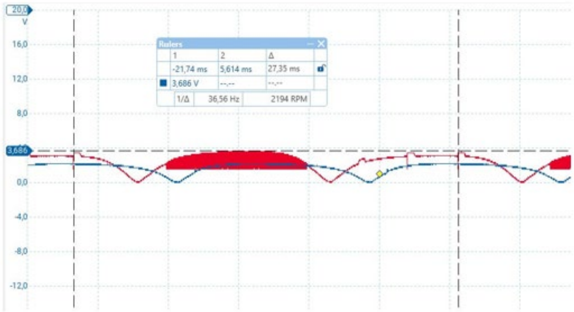

Fig. 3. Oscillogram when the inlet air flow speed is about 50 km/h.

In Fig. 4, we see the oscillogram of the voltage of the generated electricity when the speed of the air flow is already about 65 km/h. As we can see, the maximum amplitude of voltage fluctuations rises to 9.02 V. Such a change is significant for practical use.

Fig. 4. Oscillogram when the inlet air flow speed is about 65 km/h.

In Fig. 5, we see the oscillogram of the voltage of the generated electricity when the speed of the air flow is already about 72 km/h. Here again, an increase in the amplitude of the maximum voltage fluctuations is observed up to 12.55 V. All these changes are already quite significant for practical use, as they already allow the use of the electronic part. In practically all measurement cases, the current values of the generated electric power already reach from tenths of amperes to amperes.

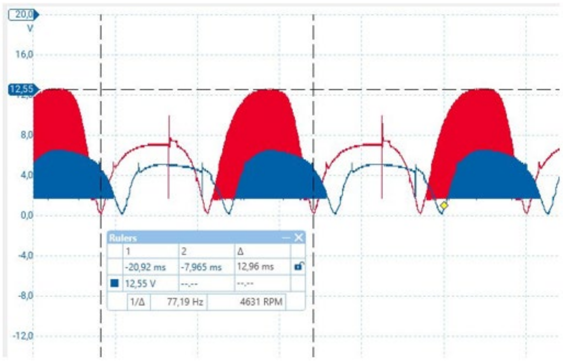

Fig. 5. Oscillogram when the inlet air flow speed is about 72 km/h.

Figure 6 shows the generalized dependence of the generated voltage on the air flow rate, which shows the general trend obtained by connecting the measurement points to each other.

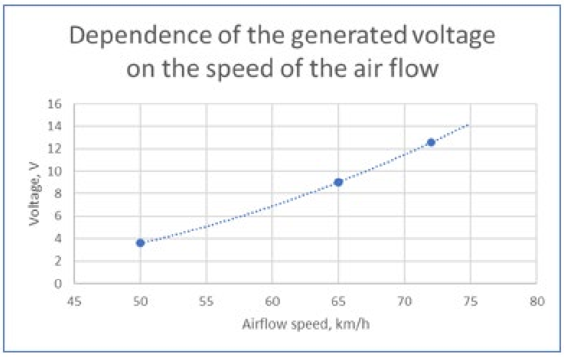

Fig. 6. Generalized dependence of the generated voltage on the air flow speed.

Such a generalized analysis of the dependence of the generated voltage on the air flow rate allows us to assume that at this stage we have not yet used all the resources for improving the efficiency factor. This gives hope and the need for further research. Here we are only talking about the kinetic energy component of the air flow [4].

The theoretical foundation of wind turbines uses two basic assumptions, that the energy is equal to the product of mass and velocity squared ($E=mv^2$) and that the mass of the air flow is equal to the product of the area (through which the air flow passes) times the cubic meter ratio (consisting of the air flow the product of speed per unit of time and air density), in other words, the mass of the air flow is a function of the air flow speed ($m=f(v)$, where v is the air flow speed). In theory [1], [3], the energy carried by an airflow is a function of the cube of the velocity of this airflow:

$$E = f(v^3) \quad (1)$$

The possible losses during energy transformation should not affect the dependence itself, but in our case, the dependence is obtained only on the square of the speed, which makes to assume additional possibilities for improving efficiency.

The presented measurements were obtained in laboratory conditions using the layout described in the introduction, so only characteristic measurements were chosen for the presentation of the measurement results.

In the experiment, further measurements were made by changing the height of the air flow inlet at a constant air flow speed. In this way, the dependence of the generated energy on the mass of the air flow passing the model is obtained.

As it was already mentioned, changing the air flow mass is one of the dependencies of the air flow speed. However, its own specifics appear here, as it depends both on the geometry of the selected impeller and on the structural features.

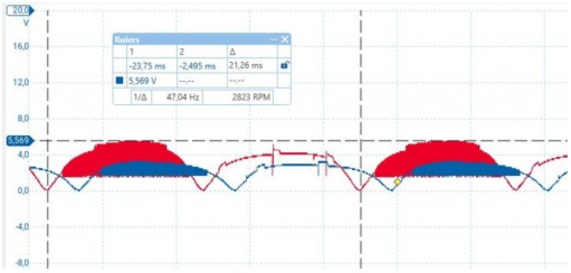

Fig. 7. Oscillogram when the height of the inlet air flow opening is equal to half the height of the airfoil.

In the picture Fig. 7 we see the oscillogram of the voltage of the generated electricity when the opening of the incoming air flow is geometrically the smallest. From the pictures revealing the structure of the impeller in Fig. 1 and Fig. 2, we can easily see that the blades of the impeller make up approximately one third of the radius of the entire impeller. The width of the air flow inlet is limited by the walls of the mock-up body, and the height in this mock-up (the design of the mock-up as shown in the article published in 2023; https://doi.org/10.17770/etr2023vol3.7261) [5] is adjusted by an insert plate and had four provided locking positions which relatively can be metered by wing heights. This delivery method was chosen this time.

The lowest height of the entrance hole means that the smallest amount of air flow mass passes through the impeller per unit of time, compared to other heights of the entrance hole. Naturally, the air flow acting on only half of the wing area cannot ensure a sufficiently efficient transformation of energy from the kinetic energy of the air flow into electrical energy. We can also see this in Fig. 7, where the maximum amplitude of voltage fluctuations generated by one of the coils reaches only about 5.6 V.

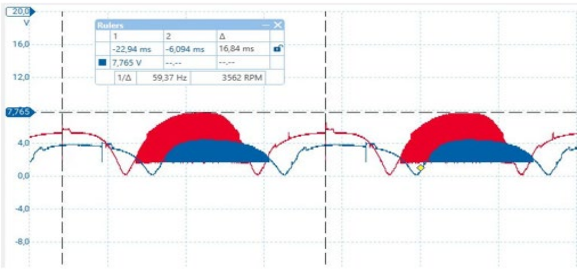

Fig. 8. Oscillogram when the height of the inlet air flow opening is equal to the height of the wing.

In Fig. 8 and Fig. 9, where the height of the air flow inlet is increased to the height of one wing and to the height of two wings, respectively, we can see an increase in the amplitude of the voltage fluctuations of the generated electric power from 5.6 V to 7.77 V and to 12.87 V, respectively.

Fig. 9. Oscillogram when the height of the inlet air flow opening is equal to two wings.

Experiments were conducted with the number of impeller blades and their geometric parameters: tilts, turns, etc. based on that was selected design of impeller. The rotated aerofoils of Fig. 1 absorb quite efficiently the energy of the air flow of two wings heights due to their vectorially rotated absorption angle.

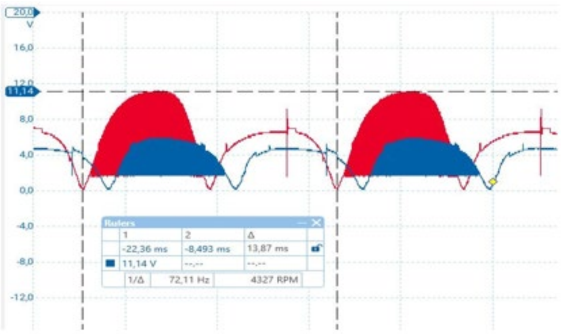

Fig. 10. Oscillogram when the height of the inlet air flow opening is equal to the height of the three wings.

In Fig. 10, where the height of the air flow inlet is increased to the height of three wings, a decrease in the amplitude of the voltage fluctuations of the generated electric power is observed from 12.87 V to 11.14 V. Well, here the influence of the interference caused by the air flow hitting the impeller body on the efficient energy conversion process is already manifested.

We can clearly see this in the summarized graph of these measurements in Fig. 11, where a clear trend of this effect emerges when the measurement points are connected by a curve.

In all oscillograms, we see two curves each, because the voltage fluctuations of the electricity generated by both coils were measured, but at this stage, attention was not paid to the possibility of summing up these two energy flows and their mutual influence on each other and for the overall process.

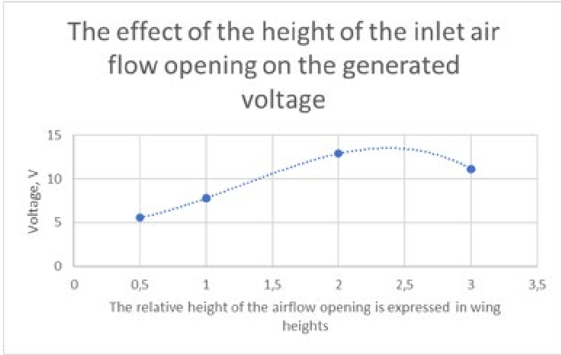

Fig. 11. Effect of Inlet airflow hole height on generated voltage when relative airflow hole height is expressed in airfoil heights.

III. RESULTS AND DISCUSSION

When reviewing the results of the obtained experiments and analysing them, it was noticed that under the same conditions: air flow speed, height of the entrance hole; different parameters of oscillograms are obtained.

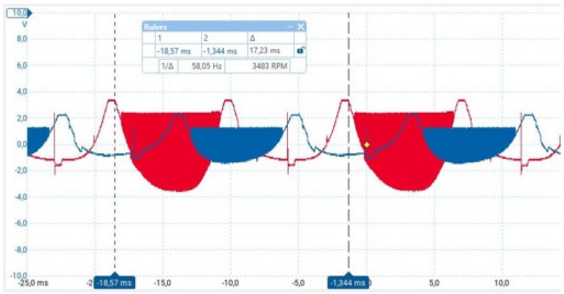

Fig. 12. The oscillogram of the voltage of the generated electric energy when the mutual positions of the coils differ by 90 degrees (phase difference π/2).

The main difference observed was that when the phase position of the coils is shifted, the maximum amplitude of the voltage fluctuations of the generated electricity also changes. This is perfectly illustrated by the mutual comparison of the presented pictures Fig. 12 and Fig. 13. In these images, we also see changes in parameters such as the speed of rotation of the impeller or the frequency of fluctuations in the voltage of the generated electricity.

This type of measurement was not prearranged with this model, so there was no possibility to adjust the relative position of the coils. Between the measurements, the model had to be re-collected several times, so apparently during one of these re-selections, the mutual position of the coils was changed by about 90 degrees, which corresponded to a phase shift close to π/2. Of course, it is difficult to expect that the position of the coils would remain the same when the model was re-collected, but apparently the deviations were so insignificant that they did not pay attention to the changes in other parameters, so they went unnoticed.

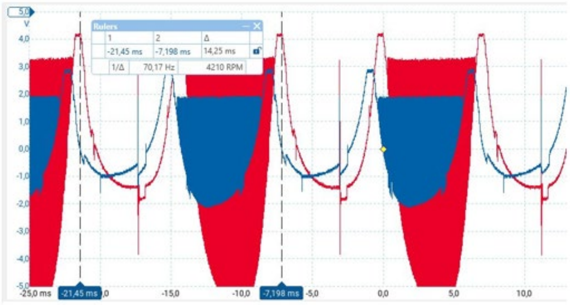

Fig. 13. The oscillogram of the voltage of the generated electricity when the positions of the coils almost coincide (the phase difference is close to 0).

This observation provides us with additional material for planning the design of an improved layout for the next round of experiments. It will be necessary to provide for the possibility of conducting experiments by changing the relative position of the coils, when other conditions remain almost the same, i.e., the speed of the air flow and the geometry of the inlet air flow opening. This part of the experiment would help us find out how to efficiently use the dependence of the generated electricity on the position of the coils. It would also help to plan how to combine these two electricity flows efficiently.

IV. CONCLUSIONS AND SUGGESTIONS

It turns out that the dependence of the amount of electricity generated in the ducts does not reach the theoretical dependence on the speed cube (*E ~= f(v3)*). In our case, the squared dependence of the velocity is the best so far. This means that there is still room for improving the efficiency of resources.

The mass of air passing through the impeller is also limited by the geometry of the impeller itself. The conducted studies show that the efficiency of energy transformation starts to fall after exceeding a certain limit. More detailed research is needed.

It has been observed that the amount of generated energy also depends on the mutual position of the coils, which determines the phase difference between the voltages of the generated energy. Proposal: when improving the layout for further experiments, consider the possibility of changing the mutual position (phase) of the coils and allocate a separate cycle of measurements for this.

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