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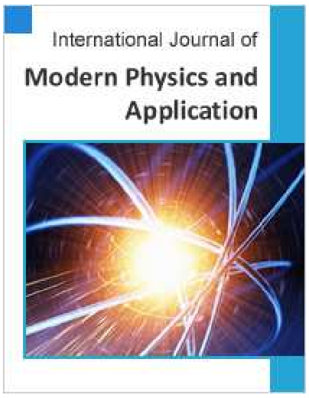

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Generation of Airflow by Means of Electrically Charged Microdroplets (A Way to Develop a New Type of Flying Vehicles)

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Abstract
Conversion of dc electric energy into the kinetic energy of airflow without recourse to mechanically moving elements has been studied experimentally. The mechanism of air propulsion exploits molecular and atomic ions, or, alternatively, charged microdroplets moving in a constant electric field and pushing air ahead. The experiments show that the electric energy required to create airflows can be reduced by a factor of several tens if only charged microdroplets are used as charge carriers instead of molecular and atomic ions.

1. Introduction

Gas flows are used in numerous technical devices. As a rule, the working gas is accelerated by rotating blades.

An alternative to these traditional devices are devices in which air is entrained by atomic and molecular ions arising in a corona discharge and moving in air in a stationary electric field. From the practical standpoint, this mechanism offers a major advantage over traditional devices because of absence of mechanical components.

A physical phenomenon which is used here called electric wind or ionic wind. The interest in this phenomenon increased considerably after the publication of the works of M. Robinsona [1, 2]. In [1], the author described the entire history of the study of ion wind. In [2], the author developed the theory linking the electrical characteristics of corona discharge with gas-dynamic characteristics of the emerging air flow. From this theory it follows that the efficiency of conversion of electrical energy into kinetic energy of the air flow is very low, close 0,005.

Therefore, these devices are used where there is no requirement for high efficiency. For example, they are widely used to create and study air flows in aerodynamics [3, 4].

In [5], the design of the device was modified to enhance efficiency, and the efficiency was doubled, but it remained too low in comparison with the efficiency of devices using moving mechanical elements.

In [6, 7], the authors proposed a new version of the method described above. In this version, electrically charged microdroplets (CMDs) are used as charge carriers instead of ions. Theoretically, the efficiency of electro-kinetic energy conversion in this case can be close to 1.

A direct conversion of electrical energy into the energy of the airflow by using electrically charged microdroplets moving in an electric field may be of great practical significance, as it provides a possibility of generating an air flow with the use of a hydrogen fuel cell battery. The battery is a very efficient (efficiency~0, 8, theoretical limit 1 [8]) chemical source of electric energy, and water is the end product. The water is suitable for a production of microdroplets.

Let's call a device generating the airflow using CMDs and intended to set a vehicle in motion an ELDROPS engine.

The flying vehicles with ELDROPS engine would be more energy efficient, noiseless and would not pollute the environment. They would be more reliable due to the absence of elements exposed to high temperatures and pressures.

Clearly, the implementation of such novel flying vehicles calls for experimental investigations demonstrating the feasibility of the mechanism proposed. The main purpose of the present work was to devise and carry out experiments under the conditions that allow the conversion of dc electric energy into the kinetic energy of airflow by means of charged droplets. Simultaneously, another problem was also solved. The experimental device was designed in such a way that it could be used to carry out experiments with both CMDs and ions. Such experiments allow one to compare the efficiencies of both methods

2. Experimental Device

For correct comparison of these two methods, it is important to ensure that the CMDs and ions move in identical electric fields. This condition is fulfilled in our experimental device (Fig. 1).

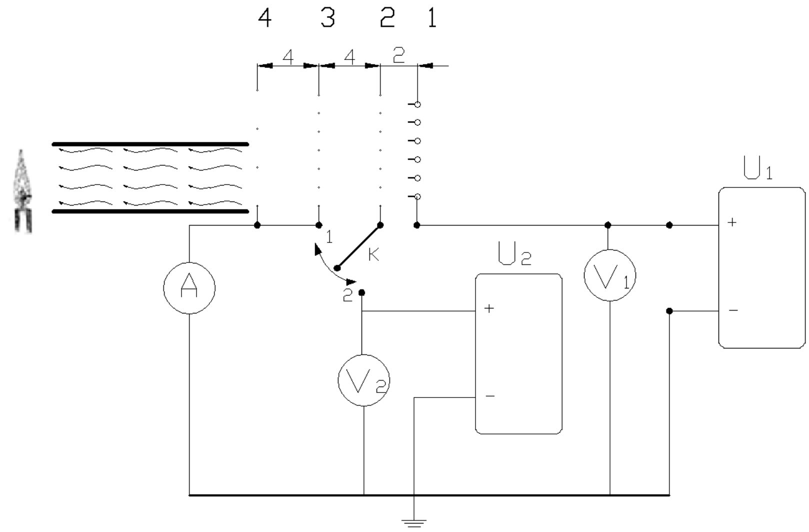

Figure 1. *Diagram of the experimental device.*

The numbers 4,3,2,1 at the top of the figure are the numbers of the electrodes on the diagram below. The numbers 4, 4, 2 above the arrows are the distances in centimeters between the neighboring electrodes 4, 3, 2, 1 respectively. The switch K can be closed either in position 1 or in position 2.

The atomic and molecular ions were produced by a corona discharge near the points of a high-voltage needle electrode1. The CMDs were formed at the same points, to which a liquid was delivered through narrow channels inside the needle**.**

Figure 2 shows a photograph of the electrode1 with 10 lines of hollow needles (capillaries). The capillaries are arranged in a grid consisting of 10 parallel metal pipes of length 10 cm and of diameter 4 mm. A distance between the pipe axes is 1 cm. Twenty capillaries are soldered in the pipe at regular intervals. The inner diameter of each capillary is 200 µm, its outer diameter is 330 µm, and its full length is ~7 mm. Each capillary tube is inserted into the pipe to a depth about half its full length. The pipes are positioned horizontally. One end of each pipe is closed, whereas the other end is connected with the vertical pipe through which liquid from an external reservoir is delivered into capillaries. The level of liquid in this reservoir is maintained at a height *h* ~ 15 cm above the lowermost pipe. The capillary unit was mounted on a square metal frame of side 20 cm.

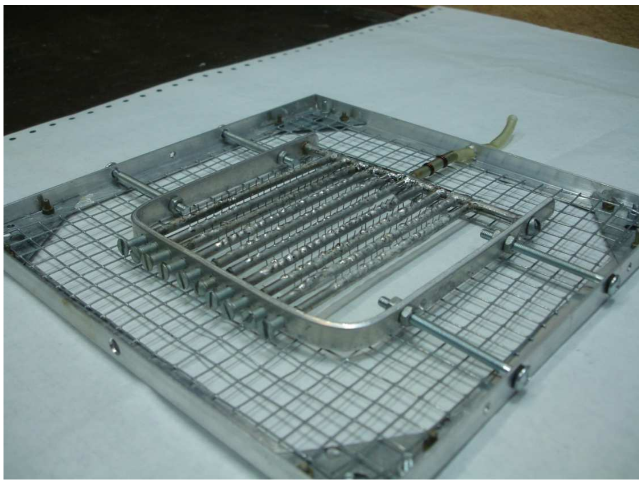

Figure 2. *Electrode with capillaries.*

Electrode *2* is opposite to electrode *1* and is positioned in a parallel plane at a distance of 2 cm. This electrode consists of a grid of horizontally positioned metal rods 2 mm in diameter that are spaced at intervals of 1 cm. The rods are framed similarly to electrode *1*. Electrode *3* is identical in design to electrode *2*. These two electrodes are placed 4 cm apart. The grids *2*, *3* are shifted in height with respect to the grid *1* by 0.5 cm to make the grids *2*, *3* permeable to particles, because the trajectories of particles emitted from electrode *1* pass through these grids without touching the rods. The last electrode *4* is positioned at a distance of 4 cm behind electrode *3*. This electrode consists of a grid with 6 metal rods 2 mm in diameter that are spaced at intervals of 2.5 cm.

The Coulomb repulsive forces between CMDs and their electrical image in the metal of the grid electrode *3* and *4* should provide the precipitation of microdroplets on the surface of electrodes *3* and *4*.

The end element of the experimental device is a horizontal duct of height 5 cm, width 10 cm and length 70 cm. The duct is connected to electrode *4* in such a way that the airflow produced by emission of charged particles from the lower 5 pipes of electrode *1* enters the duct.

When going from the upper pipe of elektrode1 to the lower one, the height of a liquid column, which produces hydrostatic pressure at the capillary inlet, increases by 1 cm. This involves an increase in the quantity of emitted droplets and the intensity of their action on the adjacent air mass. The effect of an initially nonuniform distribution of droplets on the output airflow is smoothed out because the length of the output tube is much larger than its cross-section dimension. Such a long narrow tube has a high aerodynamic resistance which slows down the generated airflow.

The average velocity of the outflow was measured with the help of a torch positioned at the end of the tube. The velocity was measured from verticality deviation of the torch exposed to airflow.

A relation between the deviation angle and airflow velocity was determined by preliminary calibration.

During the experiments, the electrodes were supplied with different voltage and electrode currents and the airflow speeds were measured. The measurements were made in two comparative modes of experiments, i.e., when the capillaries were fed with the liquid or they remained empty. All the measurements were carried out at such potentials, when corona discharge could exist at the tips of the capillaries. When applying the liquid into the capillaries, the emission of microdroplets from the tips of the capillaries could be observed.

The internal radius of the capillary channel and the electric field E_k at the tip of the capillary determined the radius and charge of a microdroplet. In the conducted experiments the radius of microdroplets was equal to ~ 10^{-4} m, and the electric charge was equal to ~ 3.10^{-12} C. The energy received by a drop depended on the magnitude of the hydrostatic pressure in the capillary and the potential difference of the emitter of microdroplets and their collector. To reduce a portion of energy apart from the energy received by a drop from the electric field, it is necessary to minimize hydrostatic pressure.

The liquid pressure that is capable to overcome the force of surface tension is minimal, if the liquid has minimum surface tension. Considering all these facts, ethyl alcohol, whose coefficient of surface tension is 0.022 N/m, 3.2 times less than that of water, was chosen as the working liquid.

With the hydrostatic pressure and electric fields used in the experiments, the total force pushing the liquid out of the capillaries could overcome the force of surface tension only in the five lowest tubes.

Elementary charge of $1.6.10^{-19}C$ is equal to one electron (proton) charge. It means that a droplet with a charge ~ 3.10^{-12} C carries as many as ~ 20. 10^6 elementary charges.

The gas-kinetic cross-section of a droplet with a radius of $10^{-4}m$ is $S=3.14 \cdot 10^{-8}\ m^2$; if we divide it by the number $20 \cdot 10^6$ of elementary charges, we find a specific value of ~ $1.5 \cdot 10^{-15} m^2$ per elementary charge. On the other hand, the gas-kinetic cross-section of a free ion carrying one elementary charge is ~ 10^{-19}m^2 and is 10 000 times less than that of an ion on a droplet.

Both the free ions and the ions on a drop are in the same electric field *E*, and are exerted by the same force f_E. Under the action of this force the ions continue to accelerate in airflow unless force f_E is fully balanced by the air resistance force $f_A= f_E$. In this case the force f_E applied to the ions is applied to the air mass and pushes it ahead. I.e. the force propelling the air mass is equal to f_E and is the same for both the free ions and ions on droplet. For charged microdroplets, the balance of forces is attained at a relative velocity V_d, for atomic and molecular ions it is attained at a relative velocity V_i. The cross-sectional area of ions on a droplet is10000 times larger than that of free ions, therefore, $V_d \ll V_i$.

As the velocity V_d is significantly less than V_i, the usage of electrically charged microdroplets requires significantly less energy to exert the same pressure on air mass.

3. Experimental Results, Discussion

With a switch K closed in the position 1 (see Fig. 1), the electrodes *2*, *3*, *4* become electrically connected between one another and are grounded through an ammeter A, so that $U_{12}= U_1$. Operation in these conditions allowed us to find out how the emissive ability of electrode *1* depends on the voltage U_{12}.

The ammeter currents were 4; 12,5; 37 μA in the absence of liquid and the currents were 2; 9; 27 μA when the liquid was fed into the capillaries at voltages U_{12} = 8, 9, 10 kV, respectively.

Thus, the electric current, emitted by electrode 1, decreases when the liquid was fed into the capillaries.

This result suggests that the main current curriers are atomic and molecular ions generated in corona discharge, whereas the appearance of microdroplets only disturbs somewhat the discharge. A disturbing effect of microdroplets is easy to understand. The electric field of the droplet directed toward the capillary is opposite in sign to the electric field between the electrodes.

The emission of droplets is sufficient to reduce the field near the point of a capillary while a microdroplet leaves the capillary and moves away over distance equal to one or two its diameters.

As a result, the quantity of ions leaving the point of the capillary in a unit time decreases, but the contribution from CMDs to the current is very small and cannot compensate the reduction in the current carried by ions.

Certain of the droplets emitted from electrode *1* did not reach electrodes *3* and *4* but fall on electrode *2*. These droplets impinging on the rods of electrode *2* produced a thin liquid film on their surface. This film is unstable against an onset of the Tonks-Frenkel instability [9, 10]. In some cases, smallest drops detached from electrode *2* were moving in the opposite direction, i.e., toward electrode *1*.

In the second part of the work, the switch K was set in the position 2 (Fig. 1). Electrodes *3* and *4* were grounded through the ammeter A. The total potential difference through which the particles (both ions and CMDs) are moved is equal to the sum of the potential difference U_{12} = 8 kV in the path between electrodes *1* and 2, and the potential difference U_2 between electrodes *2* and 3.

The value of U_{12} remained unchanged when changing U_2. When the U_2 was changed, U_1 was also changed, so that the potential difference U_{12} remained equal to 8kV. When the voltage U_2 was equal to 4, 6, 8,10 kV, the current measured by ammeter was equal to 1; 2; 2,7; 4.2 μA in the absence of liquid and it was 1,1; 2; 2,8; 4,2 μA in the presence of the liquid. The electric field, generated by U_2 at the rods of the electrode 2, increases a portion of charged particles, which can pass through the grid of electrode 2. Therefore, the current increases with increasing U_2. In addition, as U_2 increases the Tonks-Frenkel instability develops on the wet surface of the electrode 2 facing the electrode 3 and liquid micropoints appear with corona discharge at their tips, thus producing the emission of ions. This emission compensates the decrease in emission of free ions from capillaries of electrode 1 in the presence of liquid. As a result, the currents to the electrodes 3, 4 change but little, when the liquid is fed into the capillaries of electrode 1.

The air flow velocity was measured simultaneously with the measurement of the currents arriving at the electrodes 3, 4. The results are presented in figure 3. Curve 1 is for the case, where liquid is not supplied. Curve 2 is for the case, where liquid is supplied. It follows that the flow of liquid into the capillaries involves a strong increase of the air flow. Interestingly, the current emitted by electrode 1 decreases, but the airflow increases.

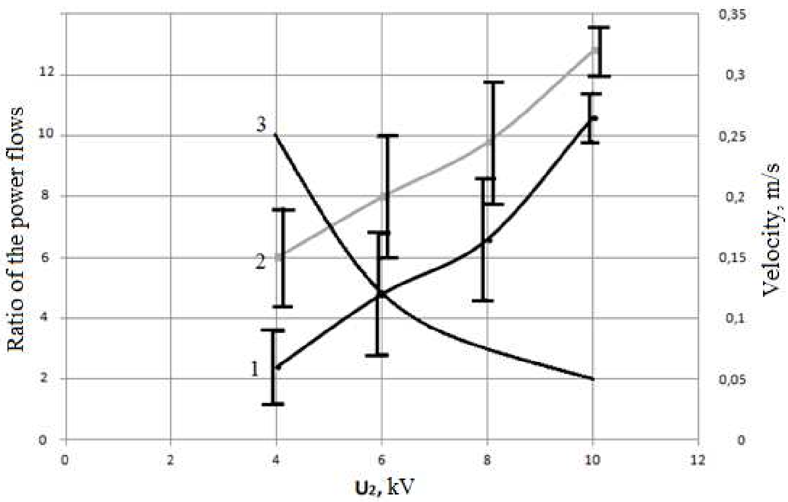

Figure 3. *Air velocity as a function of U_2. Curve 1 is for the case where the liquid is not fed into the capillaries, curve 2 - the liquid is fed into the capillaries, curve 3 is the ratio between P_2 (the power of air flow for the case where the liquid is fed into the capillaries) and P_1 (the power of air flow corresponding to the case where the liquid is not fed into the capillaries). The potential difference between electrodes 1 and 2 is 8 kV.*

The efficiency of energy transfer by means of CMDs becomes all the more evident if we are reminded that the kinetic energy of airflow is proportional to its velocity V raised to the third power (the quantity of air carried away in a unit of time is proportional to V, and the kinetic energy of a unit of air mass is proportional to V^2).

Figure 3 (curve 3) shows the cubic ratio of the airflow velocities measured when liquid was fed/not fed into capillaries.

The obtained results allow us to assert that the use of microdroplets is energetically more favorable than the use of free ions. Indeed, from these results, it is seen that even less intense current which is emitted from electrode1 and partly is due CMDs, creates a much more powerful airflow in comparison with the case, where the emitted current is carried by only free ions.

When the switch K is in position 1 and U_{12} = 8кV, capillaries in the presence of the liquid emit half as large current.

If the assumption is made that the total current is carried by only CMDs, then one-half the current, but carried by only microdroplets results in an airflow ten times more powerful.

This suggests that the efficiency of conversion of the electric energy into the kinetic energy of the airflow by means of microdroplets is no less than twenty times higher than that for molecular and atomic ions. Actually, the current carried by CMDs makes up only a fraction of the emitted current. It is not unreasonable consequently to think that the ratio between the efficiencies of the CMD and ion methods is more than 20.

The ratio decreases with increasing U_2, but even for U_2 = 10 kV it is twice as large as the power of the airflow transferred by only ions.

This decrease from 10 to2 times may be explained by the fact that corona discharge current increases with E_k more rapidly than the current carried by CMDs.

Electric field strength E_k increases somewhat with increasing U1 and U2. The reason is that the rods of electrode 2 are widely separated and cannot serve as a good electrostatic screen.

4. Conclusion

The results of theoretical and experimental investigations allow us to conclude that the efficiency of the novel method is a factor of several tens higher than the efficiency of the method using ions. It is necessary to continue research and find out what efficiency can be obtained while using only CMD in practice. Besides it is necessary to determine the magnitude of the reactive force per unit area of the emitter of droplets and per unit weight of the Eldrops engine.

The ability to create high voltage sources based on hydrogen fuel cells and satisfying general requirements to flying vehicles, namely, the ratio of the electric power to the weight of the battery is extremely important in creating flying vehicles. Here, a preference might be given to a battery in form of a thin, plane disk or a thin, plane ring rotating round its axis. In this case, the weight of the battery per unit of generated electric power would be less than that of conventional fuel cells. There would be no need to pump in fuel and pump out products of the electrochemical reaction because of the centrifugal force. There would also be no need in cooling devices. The large surface of the battery serves as a radiator. Thus the flying vehicles could take the form of a disk.

A new type of electrical discharge called ERE discharge was investigated in [11]. This type of discharge can be excited in the system of electrodes called the ERE system. In the ERE system, both poles of the DC power source serve as the emitters, which emit equal currents. The polarity of the emitted particles is the same as the polarity of their emitter. When the ERE system is in outer space, a mode is possible in which all the emitted particles do not arrive at the electrodes of opposite polarity, but go away into space, thereby creating a reactive force.

A scheme of flying vehicles with an ERE systems was proposed in [11]. The ERE systems of these devices emit positively charged microdroplets of water. Negative particles are electrons.

The temperature of the droplets should be close to 0^0 C at the time of emission.

The potential difference between the poles of high-voltage power supplies of the ERE systems of these devices should be such, that the kinetic energy obtained by the droplet in the electric field of the device be equal to the electrical energy generated by fuel cells when forming water contained in the droplet.

The substance emitted by this device remains cold. This means that you are saving energy that is uselessly spent by modern rockets on the heating of the emitted mass to a temperature of~3000°K.

From this article, it follows that the efforts dedicated to creation of high-voltage, light, powerful DC power supplies based on hydrogen fuel cells batteries, as well as efforts to create and study devices generating an air flow through the acceleration of electrically charged microdroplets, can lead to the development of new types of flying vehicles capable of moving in air and space and superior to the existing devices in many aspects.

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References

[1] M. Robinson, AIEE Trans. 80 (1961) 143.

[2] M. Robinson, Am. J. Phys. 30 (1962) 366.

[3] Grech N., Leyland P., Peschke Ph., Ott P. Progress in flight physics Knight D. D., Lipatov I. I., Reijasse Ph. Ser. "EUCASS advances in aerospace sciences" Moscow, 2015. pp. 191-210.

[4] E. Moreau, G. Touchard, Journal of Electrostatics. 66(2008)1, 39.

[5] J. Pons, E. Moreau and G. Touchard, J. Phys. D: Appl. Phys. (2005) 38, 3635.

[6] G. S. Luk'yanchikov, T. R. Khaziev, Phys. Lett. A. 375(2010). 73.

[7] G. S. Luk'yanchikov, T. R. Khaziev, Prikl. Fiz. 1(2012). 116(in Russian).

[8] I. L. Knunjanc, Abridged Chemikal Reference Book, Sov. Encycl, Moscow, 1967 (in Russian).

[9] L. Tonks, Phis. Rev. 48(1935) 562.

[10] J. I. Frenkel, Zn. Eksper. Teor. Fiz. 6(1936) 347. (in Russian).

[11] G. S. Luk'yanchikov, Phys. Lett. A. 342(2005). 1.