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A METHOD AND SYSTEM FOR BRAKING OF FLYING OBJECTS

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ABSTRACT

A patent presentation is proposed, details of which are given in (Triger *et al*., 2017). The basis of the device is a stub (made in the form of a cable with a metal sheath) released at the time of braking. The stub develops the force of aerodynamic drag in dense layers of the atmosphere. This force is created due to the interaction of atmospheric ions with a charged stub. The strength of this interaction is regulated in dependence on the speed of the satellite and the altitude of the flight. Thus, this allows maintaining the permissible overload from impact when entering the dense layers of the atmosphere. The design is such that the kinetic energy of the satellite is converted into the kinetic energy of the interaction of atmospheric ions with a charged stub. In addition, a description of a ground-based experiment that can prove the existence of the physical effect on which the invention is based, has been described. The authors of the patent invite firms with the appropriate capabilities to participate in this experiment for a certain share of patent rights.

Keywords: Air vehicle braking; safe landing; space vehicles.

INTRODUCTION

The following is a brief description of the patent. The requisites of the patent are indicated in (Triger *et al*., 2017). The present invention relates in general, to the field of aviation and in particular, to a method and system that supports air vehicle braking for supporting safe landing. In addition, a description of a ground-based experiment that can prove the existence of the physical effect on which the invention is based, has been described.

Composition of the Project

It is proposed that project is comprised of the following :

- Patented device,
- Physico-mathematical justification of its efficiency,
- Programs for calculating various device options,
- Programs for calculating the trajectories of the aircraft during the braking process.

Main Advantages

The proposed project may have the following advantages:

- A significant reduction in the mass of the satellite due to:
- Reduction of thermal protection weight,
- A significant fuel reduction for the brake jet engines,
- Safety:
- Entrance to the dense layers of the atmosphere without creation of a shock wave.
- Without additional heating of the satellite
- Without loss of communication
- Overload does not exceed 5G, where G = 9.81 m/s^2. This is relevant for private future flights.
- As a consequence, probability of a destruction during landing is negligible and
- The experimental results on the satellite are preserved,
- Crew's health is preserved.

Some Economic Assessments

For reusable space vehicles, the application of the proposed system can significantly reduce the amount of fuel for the operation of brake motors. This means that the payload mass increases. On average, it can be assumed that the payload mass increases by 35%. Thus, an increase in the payload by 10% due to the installation of the proposed system allows the increase of the total payload by 35%. It can be assumed that the installation of the proposed system allows increasing the payload by 25%. The cost of sending a payload into space is currently estimated at $50,000-80,000 per 1 kg.

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Operating Principle
The method based on THE GENERATION OF combined Electrodynamics and Aerodynamic braking forces BY THE SAME STRUCTURE (STUB).
The basis of the device is a stub released at the time of braking. The stub develops
• The force of electrodynamics inhibition in a rarefied atmosphere,
• The force of aerodynamic drag in dense layers of the atmosphere.

Electrodynamics braking force is created due to the interaction of atmospheric ions with a charged stub. The strength of this interaction is regulated by the special design of stub (see Appendix 1) depending on the speed of the satellite and the altitude of the flight. Thus, this allows maintaining the permissible overload from impact when entering the dense layers of the atmosphere. The design is such that the kinetic energy of the satellite is converted into the kinetic energy of the interaction of atmospheric ions with a charged stub.

Electrodynamics braking force is generated by interaction between stub charges and atmospheric charges due to the kinetic energy of the satellite, see Appendix 2.

MATERIALS AND METHODS

Method and Program of Calculation
Essentially, an integral part of the invention is the method and program of calculation
• the forces of electromagnetic braking necessary to keep the acceleration within the given limits at a known speed (in magnitude and direction) and the altitude of the satellite,
• the value of the capacitor charging current, depending on the known electromagnetic braking force.
An example of the result of such a calculation is given in Appendix 3.

Composition of the Device
The device contains:

- Brake stub, see Appendices 1 and 2,
- Battery,
- Source of constant high voltage (by about 1,000 V),
- Control unit.

The total weight of the device is not more than 5% of the weight of light satellites and decreases with an increase in the weight of the satellite.

For example, Appendix 3 shows the calculation for a satellite weighing 5 kg. In this case, the braking device must have the following mass of elements:
Braking stub ≈ 0.15kg,
Battery ≈ 0.05 kg,
High voltage converter ≈ 0.05kg.
Thus, total weight of the device is equal approximately 5% of the satellite weight.

Control
To control the device, height and speed meters must be installed. Based on these measurements, the control unit calculates the charging current of the stub, on which the electrodynamic braking force depends. This supports the permissible overload and hit when entering the dense layers of the atmosphere. Appendix 3 shows the trajectory of a certain satellite, obtained with a certain control of the braking device.

Proof of Operability and Conclusion
The physical effect underlying the invention was found theoretically and substantiated mathematically. However, an undeniable proof can only be an experiment. The experiment in space is very expensive and it can stop a potential investor. However, it is possible to offer an inexpensive ground-based experiment that proves the existence of this effect. Such an experiment can be performed independently of the authors of the patent. This experiment is described in Appendix 4.

The authors of the patent invite firms with the appropriate capabilities to participate in this experiment for a certain share of patent rights.

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Appendix 1. Dielectric Stub

Dielectric stub negatively charged is attached to the satellite. It receives its charge from an electric generator installed on the satellite. The stub during the flight stretches and flies with great speed after the satellite. The stub is a flat wire with a metal coating and high-voltage insulation, coiled - see details in Appendix 2. The stub is connected to an internal high-voltage generator, see Figure 1, where

S - Shell of the satellite,
G – Generator,
L - Stub (material – dielectric),
W –Wire (material – metal),
M – Metal coating,
e - Electrons on the stub surface,
p – Positive ions.

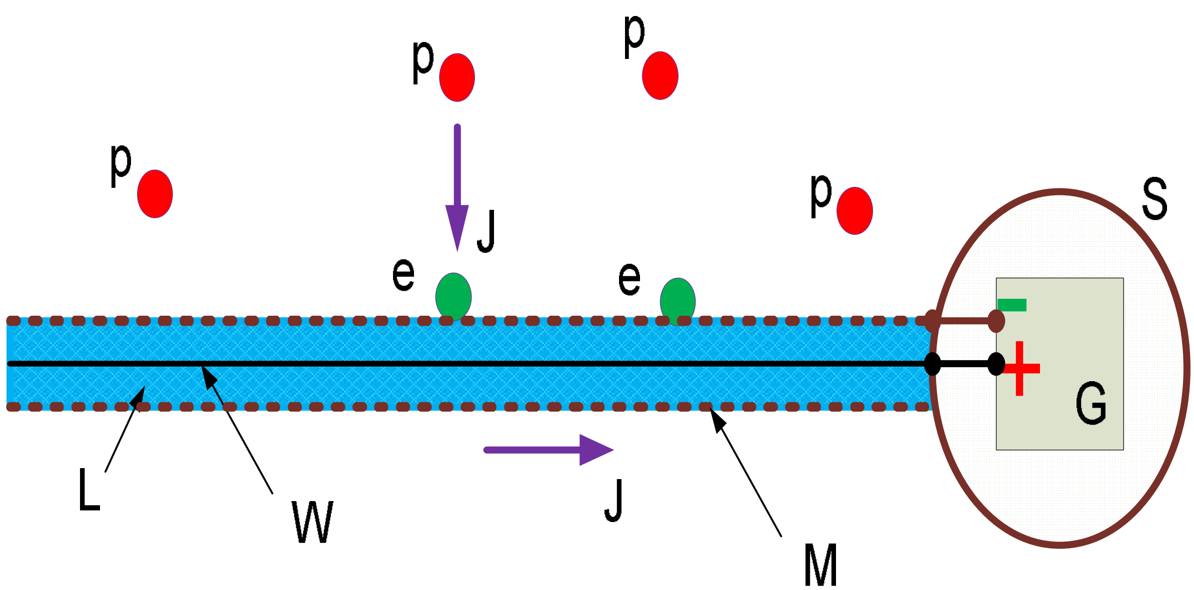

Fig. 1. The stub is connection to the generator.

Let us consider in more detail the principle of electromagnetic braking

The stub is a long condenser moving at high speed. The existence of moving electric charges can create a convection electric current. This current was shown at the beginning of the last century by Eichenwald (1928). In the other applications of this effect can be found (Khmelnik, 2017). The electric current creates a magnetic field around the stub. Negative charges on the surface of the stub create a negative electric field in the vicinity of the stub. This field repels negative ions and attracts positive ions. Falling from all sides on the stub positive ions create an electric current directed to stub. This current interacts with the magnetic field of stub directed perpendicular to this current (around stub). The current of the ions is shifted by the Ampere force that arises with this (as in a DC motor). The ions move as move of stub. The energy of this motion is the kinetic energy of stub. Spending energy on the motion of ions, the stub along with the satellite loses kinetic energy, i.e. is inhibited. Calculations show that the braking force is proportional to the speed of the satellite plume.

Positive ions, incident on the capacitor, discharge it. The constant high voltage generator set on the satellite generates the capacitor charge current. Thus, the force of electromagnetic braking depends on the current of the recharging. Note that another method of slow decline of satellite can be implemented on the basis of a patent by Khmelnik (2013).

Appendix 2. The Stub is Aerodynamic Brake

Figure 2 shows the stub as an aerodynamic brake. Figure 2a shows the stub in assembled form and Figure 2b shows the stub in the half-opened form. The form of a fully-opened spiral for the stub is shown in Figure 2c.

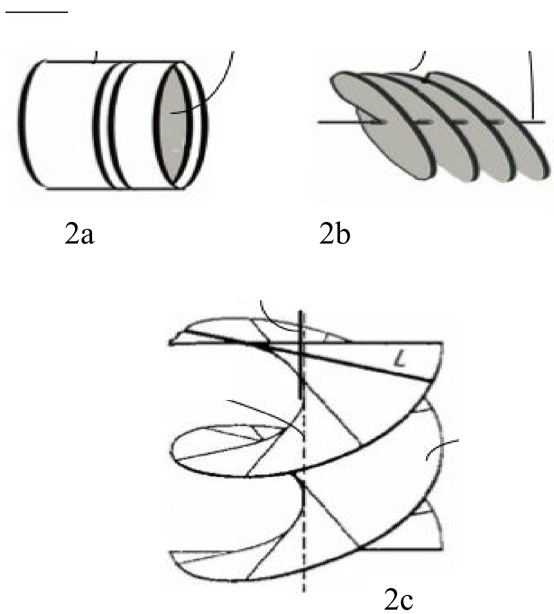

Fig. 2. The stub is aerodynamic brake: (2a) the stub in assembled form; (2b) in the half-opened form; (2c) in the form of a fully-opened spiral.

Appendix 3. Flight Trajectories

For illustration, the results of calculating the trajectory for a satellite with the following characteristics are shown here:

- mass – 5 kg,
- initial velocity – 8,000 m/s,
- initial altitude – 500 km.

The following trajectory characteristics are obtained:

• deceleration < 50 m/s,
• landing velocity < 5 m/s,
• speed of entry into the dense layers of the atmosphere < 160 m/s at an altitude of ≈ 100 km.

The following notations are used:
V(*t*) is the absolute total velocity,
W(*t*) is the vertical velocity (dotted line),
a(*t*) is the absolute acceleration,
F(*t*) is the total force,
Fad(*t*) is the aerodynamic force
H(*t*) is the height,
L(*t*) is the distance.
Figure 3 shows the entire trajectory of *H*(*L*).

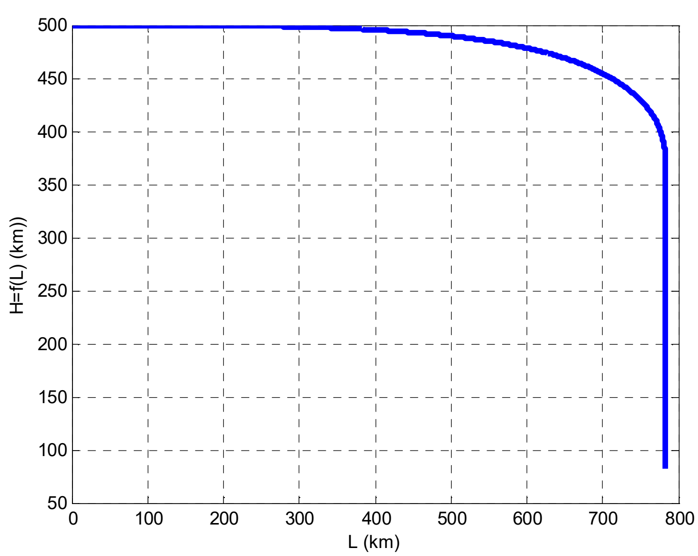

Fig. 3. The entire trajectory.

Figure 4 shows the initial segment of the trajectory (first 2,000 seconds):
in the upper right window 2 are shown $V(t)$, $W(t)$ (dotted line),
in the right lower window 4 $a(t)$ is shown,
in the upper left window 1 are shown $F(t)$, $Fad(t)$ (dotted line),
in the lower left window 3 are shown $H(t)$, $L(t)$ (dashed).

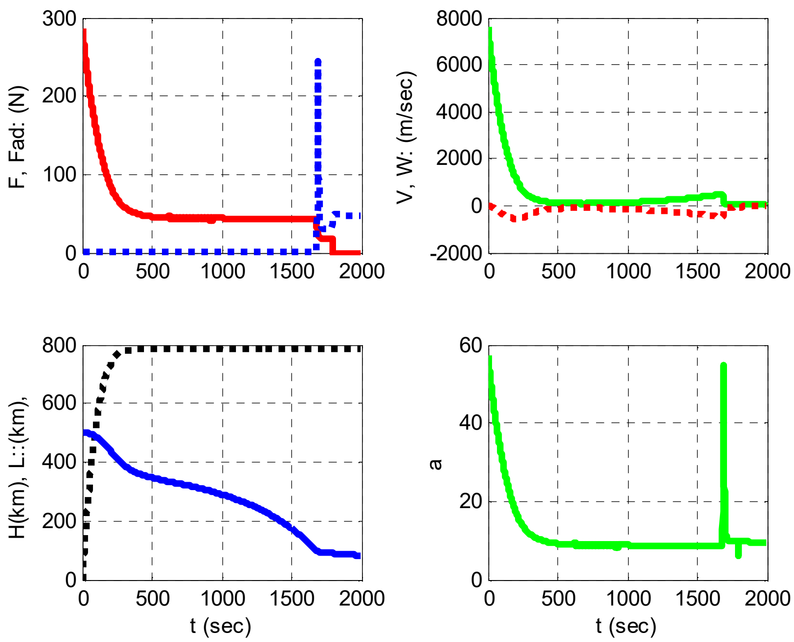

Fig. 4. The initial segment of the trajectory.

Figure 5 shows the final segment of the trajectory (from 2,000 seconds to 12,000 seconds)
in the left window 1 are shown $V(t)$, $W(t)$ (dotted line),
in the left window 2, $H(t)$ is shown,
in the left window 3 are shown $F(t)$, $Fad(t)$ (dotted line),
in the right window the trajectory $H(L)$ is shown.

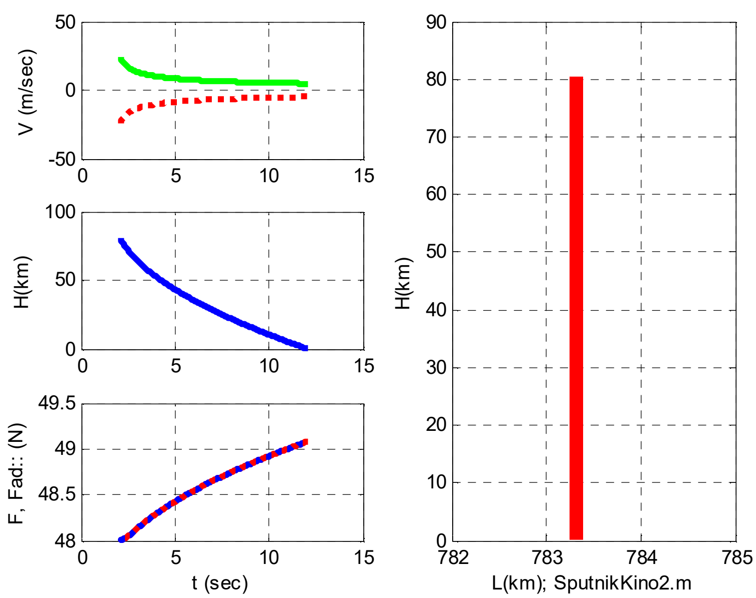

Fig. 5. The final segment of the trajectory.

Figure 6 shows the last section of the trajectory (last 400 seconds),
in the left window 1 are shown $V(t)$, $W(t)$ (dotted line),
in the left window 2, $H(t)$ is shown,
in the left window 3 are shown $F(t)$, $Fad(t)$ (dotted line),
in the right window the trajectory $H(L)$ is shown.

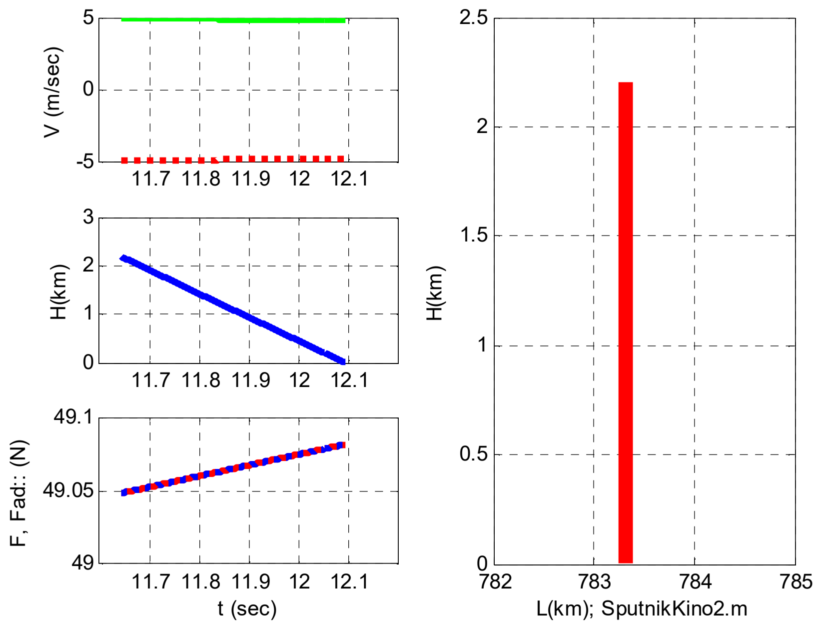

Fig. 6. The last section of the trajectory.

Appendix 4. Ionic Brake

(i) Description of the Physical Effect

Let's consider the scheme which is shown in Figure 7, where the wire 1, covered with insulation 2, and the insulation is covered with a metal sheath 3. A current 'J' flows along the wire 1, and a constant voltage 'U' is between the wire 1 and the sheath 3. Thus, the wire 1, the insulation 2, and the sheath 3 form a capacitor.

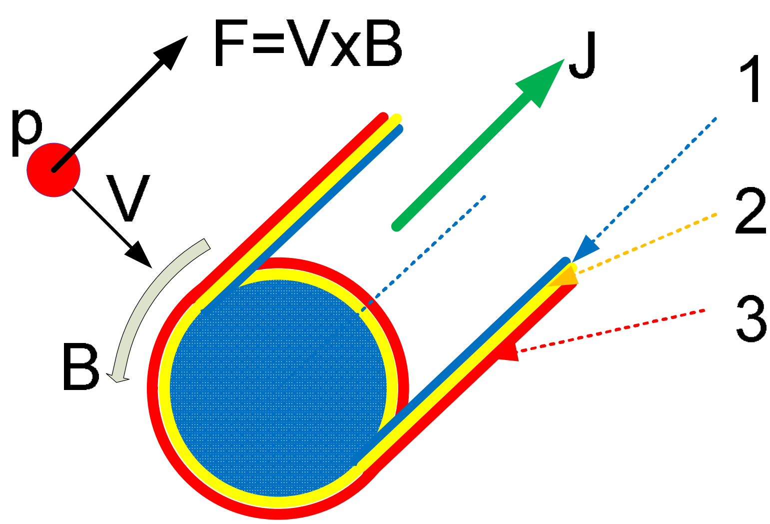

Fig. 7. Schematic of a device.

Let's assume that the negative charges (electrons) are on the sheath 3 of this capacitor, and the wire as a whole is in a cloud of positive ions 'p'. Then the ions will be attracted to the negatively charged sheath and move perpendicular to the wire axis with a certain (not constant) velocity 'V'. Around the wire with a current 'J' there is a magnetic field in which the induction vector 'B' is tangential to the wire circumference. Consequently, the ion 'p' is acted upon by the Lorentz force

$$F = V \times B \tag{1}$$

The force 'F' is directed towards the current 'J', i.e. the current 'J' by the Lorentz force 'F' pulls the ion 'p' in the direction of motion of current 'J'. In other words, a pulse is applied to the ion 'p' on the side of the wire with current J'. This impulse is directed towards the current 'J'. According to the law of conservation of momentum, from the side of the ion 'p' at the wire acts the same impulse directed towards the current 'J'. If the wire is not fixed, then it will start moving towards the current J.
This effect can be called as **an ion brake**.

(ii) Experiment
Now we consider an experiment to check the existence of this effect and its quantitative estimation. Scheme of the experiment is shown in Figure 8.

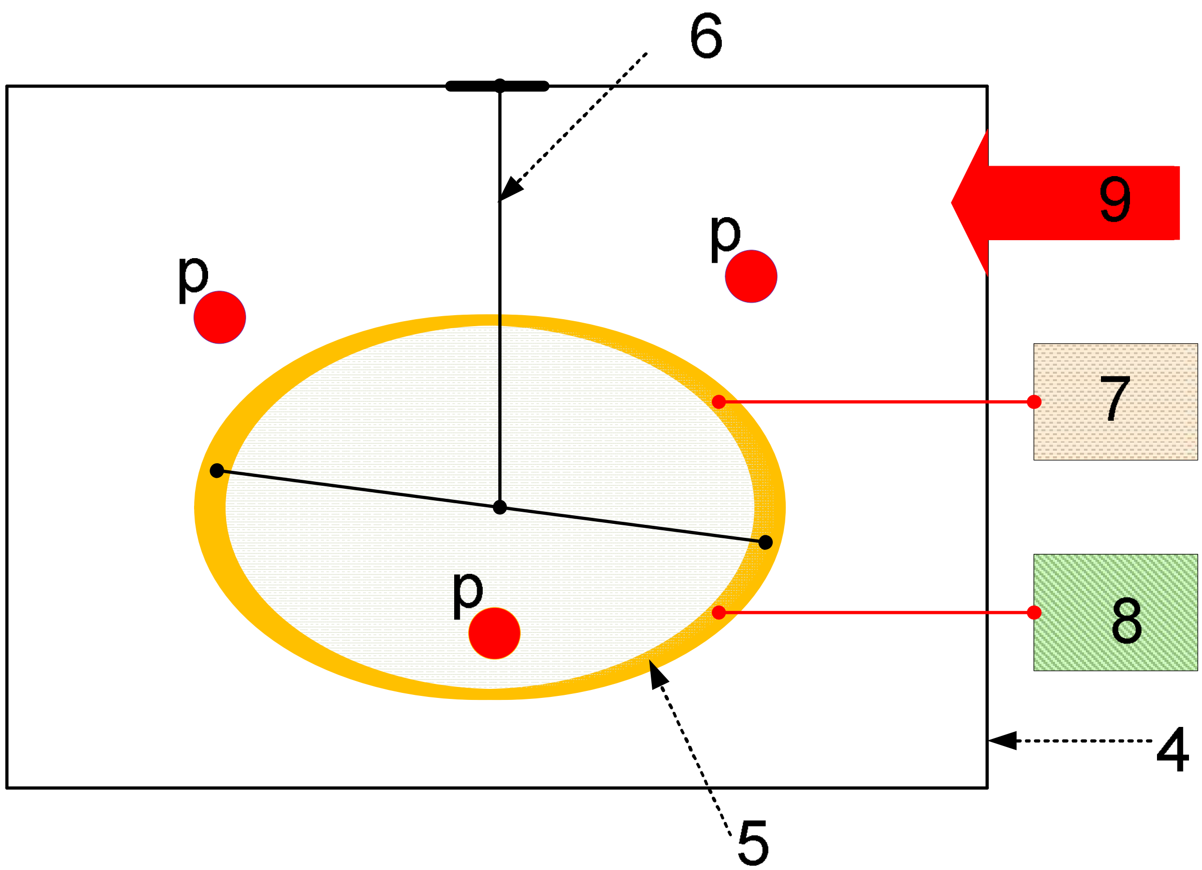

Fig. 8. The scheme of a proposed test rig.

In Figure 8 there are:
4 - a vacuum chamber,
5 - folded by a ring wire,
6 - a torsion balance on which the wire 5 hangs,
7 - current source '*J*',
8 - voltage source '*U*',
9 - injector of positive ions '*p*'.

Measuring instruments of current, voltage, pressure, ion density, and torque must also be provided.
The design of the wire and its connection to the current and the voltage sources are shown in Figure 9.

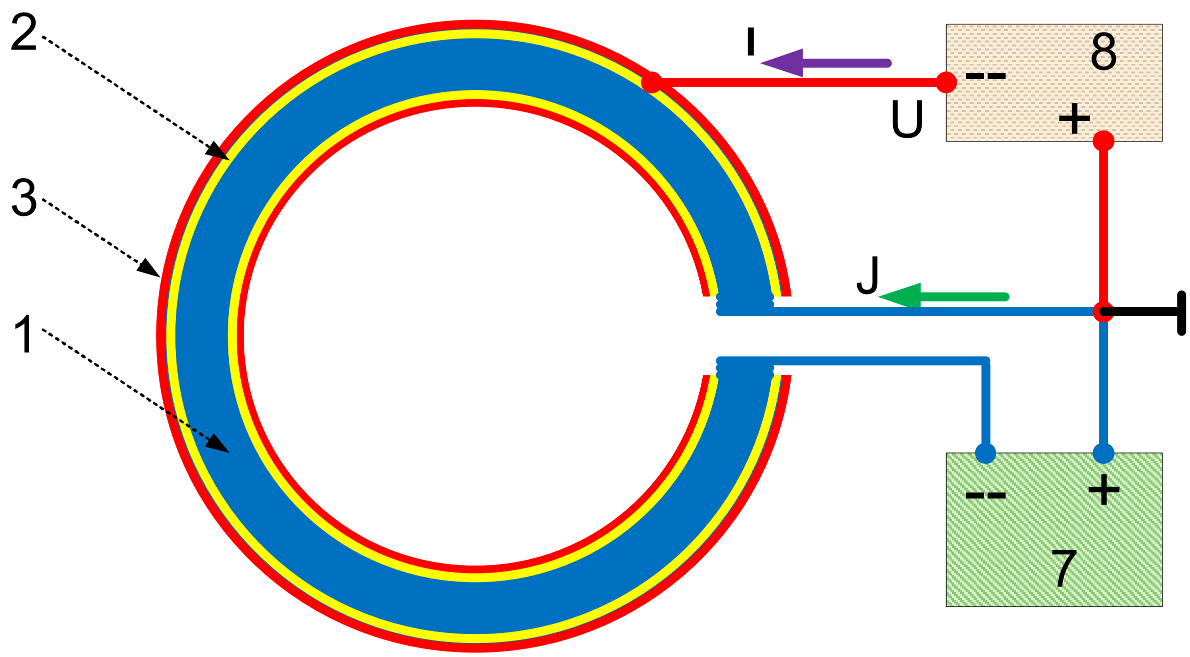

Fig. 9. The wire design.

It follows from section 1 that the ring of wire 5 must turn under these conditions. This effect must be fixed by the torsion balance 6.

(iii) Conditions of the Experiment

The following conditions should be carried out:

(1) Pressure in the vacuum chamber $P \approx 2 \cdot 10^{-9}$ N/m^2.

(2) Strength of current $J = 200$ A

(3) The density of ions $\eta \approx 10^{11} / m^3$. The density should be kept constant as the ions are neutralized when they come into contact with the sheath.

(4) Surface charge density on the sheath $Q = 5 \cdot 10^{-4} C / m^2$.

(5) First, the high-voltage source should charge the capacitor to the specified density Q, and then to add the charge value till initial value as it will decreases due to the discharge by the current of the ions. This process is observed as the capacitor charge current I, see Figure 3.

(iv) Required Measurements and Range of Parameters

It should be possible to change the values of $x = \{D, J, \eta, Q\}$ within the range

$$x = (0.1 \div 3) \cdot x_o \tag{2}$$

where x_o relates to the initial conditions specified above.

It is necessary to receive the following measurements values

• **force '*F*'** acting on the wire - by the torsion balance

• **charging current '*I*'** from the voltage source U as functions of the parameters (2).