Experimental study on the factors affecting the performance of wire-plate Biefeld-Brown thrust unit

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Abstract. Biefeld-Brown effect (B-B effect for short) refers to the phenomenon that when a high voltage is applied to an asymmetric capacitor, the capacitor generates an additional force. In order to explore the influencing factors and series characteristics of the B-B effect of wire-plate asymmetric capacitors in atmospheric pressure, a set of experimental devices with adjustable parameters was designed. Based on this device, the effects of different wire-plate lengths, power supply types and electrode application modes on the thrust and efficiency of B-B effect are studied. At the same time, the optimal parameters are selected to study the series characteristics. The research shows that the thrust generated by B-B effect is directly proportional to the length of the wire plate. The thrust generated by applying positive emission voltage to the copper wire and grounding the aluminum plate is the largest, and the two-stage series connection can achieve multiple increase of the thrust, with better performance.

1. Introduction

Biefeld-Brown effect[1](hereinafter referred to as B-B effect) refers to the phenomenon that when a high voltage is applied to an asymmetric capacitor, the capacitor will produce an additional force. This phenomenon is named after its discoverers, physicists Paul Alfred Biefeld and Thomas Townsend Brown. Because it can directly convert electricity into thrust, it should have a broad application prospect in the aerospace field, but because of the lack of a reasonable and feasible scheme, it has not been really applied in engineering. In recent years, with the development of new structure, new scheme, high-performance integrated power supply and other technologies, the application of B-B effect in aerospace field has been paid more attention.

A series of researches have been made on Brown-B effect, and some patents have been applied [2-6]. One of the models is a pair of asymmetric arc electrodes with a dielectric rod placed between them. When high voltage is applied, a force pointing to the positive electrode will be generated. De Seversky[7]studied that the electrode structure area is 0.1 m2, the distance between electrodes is 5cm, and the thrust force is 50mN under 20kV voltage and 0.5 mA current, and pointed out that the thrust efficiency is related to atmospheric pressure and humidity. The early B-B effect is mostly used in the power demonstration device of the floating lift, and the thrust force level is mN[8-14], so the electric thrust conversion efficiency is low. Since then, Bedolla, Tajmar and Cabanas et al[15-18] have carried out a lot of theoretical analysis and experimental measurement research on the B-B effect based on the structure of the floating elevator. In 2018, Nature introduced the pure electric propulsion aircraft based on B-B effect in MIT atmosphere[19]. The aircraft adopted the structure of four levels in parallel up and down and two levels in series, with a wire board length of about 40m and a wingspan of about 5m, which produced a thrust of 3.2N and achieved an autonomous flight of 60m. Undefined Technology Company of the United States designed a new type of silent UAV prototype by using B-B effect[20,21]. The prototype realized the miniaturization and integration of power supply, and could take off vertically with its own power supply, at the same time, it significantly improved the electric-thrust conversion efficiency and thrust level of B-B effect.

Comparatively speaking, there are few researches on B-B effect in China. Jiang Xingliu of Beijing University of Aeronautics and Astronautics[22-26] studied the B-B effect, and thought it was related to vortex dynamics and torsion field theory. Wang Liying[27] made an experiment on the length and spacing of wire-plate structure, and simulated the model based on Maxwell software, and compared it with the experimental data. Cheng Xiangyu[28] made research and analysis on various electromagnetic propulsion devices, made theoretical calculation and related structural design of the B-B effect lift, and carried out experiments. Hefei Institute of Material Research, Chinese Academy of Sciences [28] increased the thrust of B-B effect to 5.2N through a large number of series and parallel connection methods of asymmetric electrodes with wire and plate layout, and made a certain breakthrough.

Throughout the research at home and abroad, there are relatively few researches on B-B effect at present, the experimental data are not comprehensive and detailed enough, the research on the influencing factors and laws

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of B-B effect is not deep enough, and there is a lack of research on the series structure that can obtain greater thrust.

In this paper, a new experimental device with adjustable structural parameters is designed. Under atmospheric pressure, based on the line-plate asymmetric capacitor, the influences of line-plate length, power supply type and electrode application mode on the thrust and efficiency of B-B effect are studied, and the reasons for the changes are analyzed. At the same time, the optimal structural parameters are selected for the series structure experimental study, which provides a reference for the subsequent research and design of B-B effect.

2. Experimental system and measurement method

2.1 Experimental system

The experimental system of B-B effect in this paper consists of a high-voltage power supply, a balance of measuring equipment, a self-designed line-plate B-B effect experimental device, etc., as shown in Figure 1. Among them, the high-voltage power supply is the DC high-voltage generator of Shanghai Shenggao Electric Technology (model ZJF-60kV/5mA), which outputs high voltage through the high-voltage cylinder and applies it to one pole of the line-plate asymmetric capacitor.

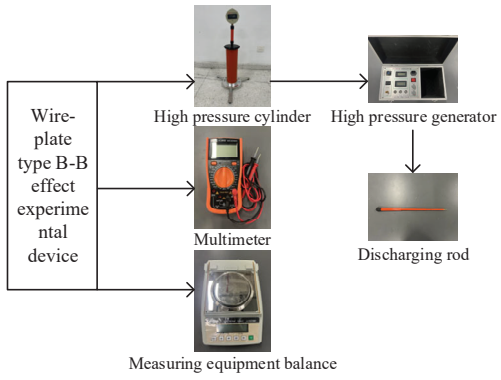


Fig. 1 Experimental system

At present, the experimental devices for testing the B-B effect mostly adopt the structure of floating machine, which is triangular or polygonal. In order to adjust various structural parameters more conveniently and improve the experimental efficiency and accuracy, a line-plate type B-B effect experimental device shown in Figure 2 is designed, which consists of a bracket, a saw-tooth frame, a copper wire component and an aluminum plate component. Among them, the copper wire component and the aluminum plate component are convenient to replace copper wires with different diameters and aluminum plates with different sizes, so that they are in the same plane, forming an asymmetric capacitor. At the same time, it is installed on the saw-tooth frame, and the distance between adjacent saw-teeth is 1cm, which is convenient to adjust the distance between the wire boards. The length of the saw tooth determines the length of the wire board.

The saw-tooth frame is installed on the pallet and put on the balance of measuring equipment for experiment. All components are made of insulating materials, and the main dimensions of the device are shown in Figure 3.

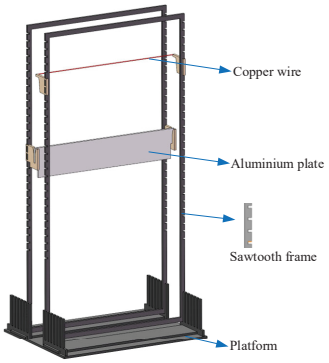


Fig. 2 Line-plate type B-B effect experimental device

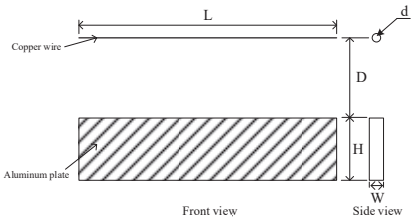


Fig. 3 Main dimensions of line-plate type B-B effect experimental device

2.2 Measurement method

The control box of DC generator adjusts the output voltage, and applies it to one pole (such as copper wire pole) of the experimental device through the high-voltage cylinder, while the other pole (such as aluminum plate pole) is grounded to form a potential difference. Micro-ammeter on the high-voltage cylinder displays the loop current in real time. The experimental device is placed on a measuring device balance (model JJ1023BF of Shuang Jie Balance, measurement accuracy is 0.1mg), and the thrust generated by B-B effect is the indicator change of the balance. Under atmospheric pressure, the B-B effect is mainly the ion wind effect. The high-voltage electrode ionizes the surrounding air to form electric charge, and the electric charge moves to drive the air to flow to form ion wind. In order to avoid the interference of ion wind and high-voltage environment on the measurement and reading of the balance, the measuring device balance is wrapped with aluminum foil and grounded together with the metal weighing plate. At the same time, a wind shield is added between the experimental device and the balance. After testing, the experimental device is suspended above the balance, and the applied voltage has no effect on the balance readings, so the balance readings are stable during the experiment. Fig. 4 is the circuit connection diagram of the experimental device.

Change the wire board length, power supply type and electrode application mode, etc. The voltage starts from 10kV, and the voltage and current and balance weight reduction indicator are recorded every 2kV until the breakdown voltage.

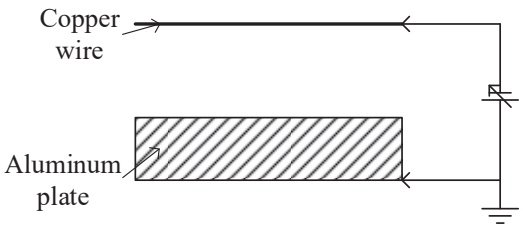


Fig. 4 Circuit connection mode 1

3. Experimental results and discussion

3.1 Characteristics of B-B Effect under Different Length of Wire Plate

The distance between fixed wires and boards is D=8cm, the diameter of copper wire is d=0.1mm, the width of aluminum plate is W=3mm, and the height is H=40mm. The circuit connection mode is connection 1 shown in Figure 4. The line length L varies between 10 and 20 cm, and every 2cm is a group. Fig. 5 shows the variation of thrust force of B-B effect with voltage under six groups of different wire board lengths. As shown in the figure, the force generated by the B-B effect is proportional to the voltage. Under the same voltage, the greater the length L of the wire board, the greater the thrust of the B-B effect. If the experimental phenomenon is analyzed from the angle of ion wind effect, ion wind effect refers to the strong electric field generated after the electrode is applied with high voltage, which ionizes the surrounding air and generates positive and negative charges. Under the action of electric field, the charges move and collide with air molecules to exchange momentum, and the air flow makes the asymmetric capacitor also have a "relative movement" and generate thrust. Therefore, the longer the length of the wire plate, the more the total charge generated by ionization, thus causing more air molecules to move, which makes the relative motion effect of the asymmetric capacitor stronger, and finally shows that the thrust of B-B effect increases.

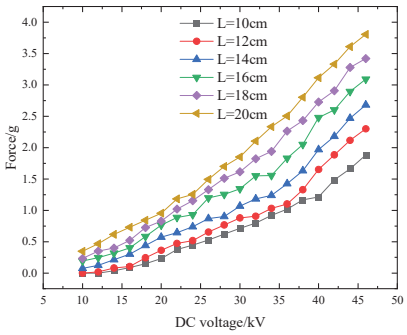


Fig. 5 Thrust force under different length of wire plate

3.2 Characteristics of B-B Effect under Different Power Supply Types and Electrode Application Methods

The above experiments are all based on the circuit connection method (A) shown in Figure 6. Different power emission polarities and electrode application modes also have influence on the B-B effect. There are two types of power sources: positive emission and negative emission; There are two ways to apply electrodes: copper wire to electrode, aluminum plate to ground, copper wire to electrode and aluminum plate to electrode, so there are four ways: (a) copper wire to negative high voltage, aluminum plate to ground; (b) Copper wire is grounded, and aluminum plate is connected with negative high voltage; (c) The copper wire is connected to positive voltage, and the aluminum plate is grounded; (d) Copper wire is grounded, and aluminum plate is connected to positive voltage.

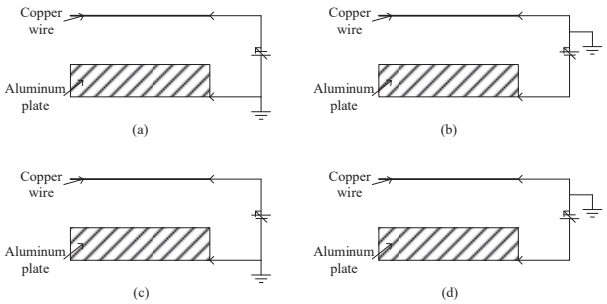


Fig. 6 Different power supply types and electrode application modes

Fig. 7 shows the thrust of B-B effect with voltage under different power supply types and electrode application modes. Under different forms, the thrust of B-B effect is still proportional to the voltage, and changing the polarity of the electrode will not change the thrust direction, but will only affect the thrust. Under the same voltage, the thrust generated by aluminum foil grounding and copper wire connecting to high voltage pole is greater, and the thrust generated by positive polarity transmitting power supply is greater than that of negative polarity transmitting power supply, so the B-B effect thrust generated by copper wire connecting to positive voltage and aluminum plate grounding in mode (c) is the largest.

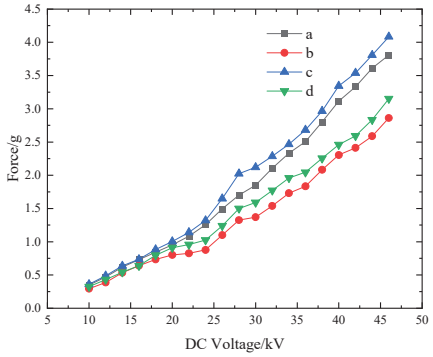


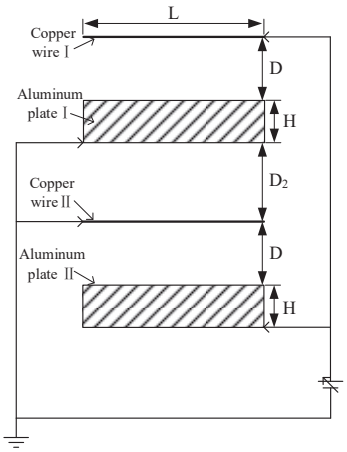
Fig. 7 Thrust force under different power supply types and electrode application modes

3.3 B-B effect characteristics of multistage series structure

In order to obtain better performance, to study the reason why MIT adopts the B-B effect of two stages in series, it is necessary to conduct experimental analysis on the multi-stage series structure. Select single-stage wire board length L=20cm, wire board spacing D=4cm, copper wire diameter d=0.1mm, aluminum plate height H=4cm, aluminum plate width W=15mm, power supply type and electrode application mode: the first-stage copper wire is connected to positive high voltage and aluminum foil is grounded. At the same time, in order to prevent breakdown, adjacent poles of different stages adopt the same polarity.

Fig. 8 is a schematic diagram of two-stage and three-stage series structure. Two-stage series connection is copper wire I-aluminum foil I-copper wire II-aluminum foil II, in which copper wire I and aluminum foil II are connected with positive high voltage, and aluminum foil I and copper wire II are grounded; The three-stage series connection is copper wire I-aluminum foil I-copper wire II-aluminum foil II-copper wire III-aluminum foil III, in which copper wire I, aluminum foil II and copper wire III are connected to positive high voltage, and aluminum foil I, copper wire II and aluminum foil III are grounded. The variables studied are the series distance D2 between single-stage line board modules and the series number. The series distance D2 is 2, 4, 6 and 8cm.

In addition to the thrust, the electrical efficiency and geometric efficiency are also analyzed. The electrical efficiency is defined as the ratio of thrust to consumed power, i.e. F/P, P=UI(U is the voltage, I is the corresponding current at this voltage). The higher the electrical efficiency, the less electric energy is needed to generate the same thrust. Geometric efficiency is defined as the ratio of thrust to geometric size, that is, F/(L*(D+H)). The higher the geometric efficiency, the smaller the device size will be when the same thrust is generated.



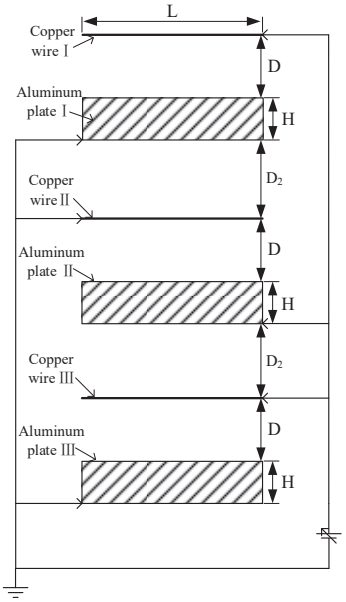


Fig. 8 Two-stage and three-stage series connection

Fig. 9 is a diagram of the thrust of the series structure B-B effect with voltage. In the series structure, the B-B effect thrust is still proportional to the voltage. Under the same voltage, the thrust generated by three-stage series is larger than that of two-stage series, and the single-stage thrust is the smallest, but the thrust generated by two-stage series exceeds twice that of single-stage, while the thrust generated by three-stage series is three times lower than that of single-stage, so the multiple increase is not realized. At the same time, the series distance D2 between single stages does not affect the thrust of B-B effect.

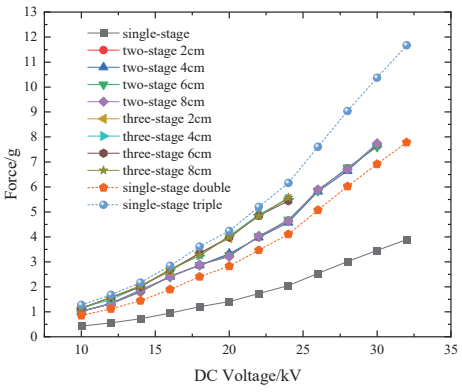


Fig. 9 Thrust force under series structure

Fig. 10 is a graph of the change of current in series structure with voltage. It can be seen that the current in the series structure is proportional to the voltage. Under the same voltage, the current consumed by the three-stage series is greater than that of the two-stage series, and at the same time it is greater than that of the single stage, that is, the more series stages, the greater the current consumed. Whether two or three stages are connected in series, the larger the series distance D2, the smaller the current consumed.

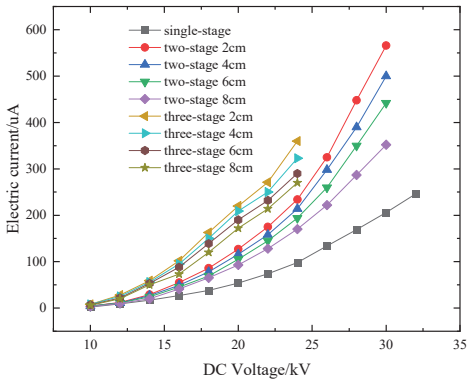


Fig. 10 Electric current under series structure

Fig. 11 is a graph showing the change of electrical efficiency of series structure with voltage. As can be seen from the figure, the electrical efficiency of the series structure is inversely related to the voltage. At a lower voltage (< 20kV), the electrical efficiency of two-stage series is greater than that of three-stage series, and it is basically greater than that of a single stage. Similarly, the electrical efficiency tends to be consistent at a high voltage. In the same voltage and series number, the greater the series distance D2, the greater the electrical efficiency.

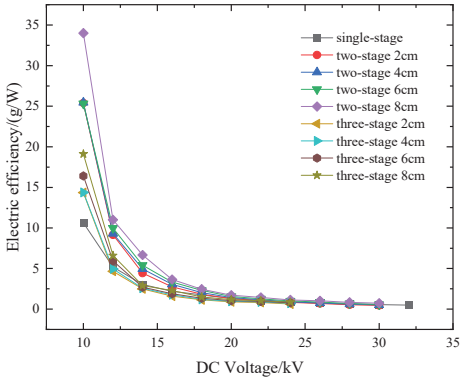


Fig. 11 Electric efficiency under series structure

Fig. 12 is a graph of the geometric efficiency of the series structure as a function of voltage. In the series structure, the geometric efficiency is still directly proportional to the voltage. Under the same voltage, the geometric efficiency of two-stage series is greater than that of three-stage series, but both are smaller than that of single stage, that is, the more series, the smaller the geometric efficiency. At the same time, in the same voltage and series number, the larger the series distance D2 is, the smaller the geometric efficiency is.

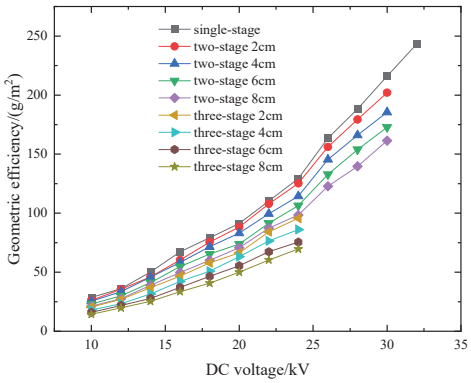


Fig. 12 Geometric efficiency under series structure

To sum up, the thrust generated by two-stage series connection achieves the multiple growth of a single stage, and at the same time, it consumes less current, and has higher electrical efficiency and geometric efficiency, which is more advantageous than three-stage series connection. Perhaps this is the reason why MIT ion propulsion aircraft adopts the front and back two-stage series connection structure. For the series distance D2, the distance will not affect the thrust, but the larger the distance, the smaller the current consumed, the greater the electrical efficiency and the smaller the geometric efficiency. Therefore, in the actual design of the aircraft based on the B-B effect, it is necessary to make a reasonable choice according to the application objectives whether to consume less energy or have a smaller and more compact structure.

4. Conclusion and prospect

In this paper, an experimental system of Biefeld-Brown effect is designed under atmospheric pressure. The length of the wire plate, the type of power supply and the way of applying electrodes are adjusted for experiments, and the characteristics of B-B effect under different parameters and series structures are studied. Research shows that:

(1)The Biefeld-Brown effect of wire plate is directly proportional to the length of wire plate. The longer the length of the wire, the greater the thrust generated.

(2)Different power supply types and electrode application methods will not change the thrust direction, but will only affect the thrust. The thrust generated by the positive emission power supply is larger than that generated by the negative emission power supply, and the thrust generated by the copper wire connected with high voltage and the aluminum plate grounded is larger and the electric efficiency is higher.

(3)The series structure can increase the thrust, and the two-stage series connection can realize the multiple increase of the thrust. At the same time, the two-stage series connection consumes less current and has higher electrical and geometric efficiency, which is better than the three-stage series connection. Series spacing does not affect thrust, but only electric efficiency and geometric efficiency.

The research object of this paper is the line-plate thrust unit, and the follow-up research will be carried out in the full-scale prototype. The optimized structure and series parameters obtained in this paper will provide an important reference for the next full-scale prototype research.

References

1. Thomas T B. How I Control Gravitation[J]. Science and Invention, 1929:374.
2. Thomas T B. A Method of and an Apparatus or Machine for Producing Force or Motion[P] .UK:300311 ,1928-11-15.
3. Thomas T B. Electrostatic motor[P] .US:1974483 ,1934-09-25.
4. Thomas T B. Electrokinetic apparatus[P] .US:2949550 ,1960-08-16.
5. Thomas T B. Electrical thrust producing device:[P] .US:2958790 ,1962-01-23.
6. Thomas T B. Electrokinetic apparatus[P] .US:3187206 ,1965-06-01.
7. SAP De. Ionocraft:[P] .US:3130945 ,1964-04-28.
8. Bahder T B, Fazi C. Force on an Asymmetric Capacitor[R]. Physics, 2002.
9. Tajmar M. Biefeld-Brown Effect: Misinterpretation of Corona Wind Phenomena[J]. Aiaa Journal, 2004,42(2):315-318.
10. Stephenson G V. The Biefeld Brown Effect and the global electric circuit[J]. Aip Conf Proc, 2005, 746(1): 1249-1255.
11. Musha T. Explanation of dynamical Biefeld-Brown effect from the standpoint of ZPF field [J]. Jbis-J Brit Interpla, 2008, 61(9): 379-384.
12. Wang W, Yang L J, Gao J, et al. Experimental study on the thrust and the ratio of thrust to power of multi-points/grid ionic wind exciter [J]. Acta Physica Sinica, 2013, 62(7): 292-298.
13. Einat M, Kalderon R. High efficiency Lifter based on the Biefeld-Brown effect [J]. Aip Adv, 2014, 4(7):201-220.
14. Wang W, Yang L J, Liu S, et al. Theoretical and experimental study of thrust produced by corona discharge exciter in wire-aluminum foil electrode configration [J]. Acta Physica Sinica, 2015, 64(10): 151-157.
15. Bedolla P O, Vorlaufer G , Sequard-Base P , et al. Altitude dependence of electrohydrodynamic flow in an electrostatic lifter[J]. Journal of Electrostatics, 2017, 87:32-44.
16. Tajmar M , Schreiber T . Put Strong Limits on All Proposed Theories so far Assessing Electrostatic Propulsion: Does a Charged High-Voltage Capacitor Produce Thrust?[J]. Journal of Electrostatics, 2020, 107:103477.
17. P. Huang, Z. -y. Xie, P. Liu, at el . Ionic Wind Simulation of Wire-Aluminum Foil Electrode Structure Lifter in 2-D Space[J] . Transactions on Plasma Science, 2022,50(3):566-573.
18. Cabanas M F, Gonzalez F P, Gonzalez A S, et al. Analysis of the Efficiency of the Electrohydrodynamic Propulsion Based on the Biefeld-Brown Effect for Manned and Unmanned Aircrafts [J]. Appl Sci-Basel, 2022, 12(6):512-521.
19. Xu H, He Y, Strobel K L, et al. Flight of an aeroplane with solid-state propulsion [J]. Nature, 2018, 563(7732): 532-535.
20. TECHNOLOGIES U. https://www.undefinedtechnologies.com/. 2020.
21. TECHNOLOGIES U. The US VTOL Ion Thruster Drone for Urban Cargo Delivery [M]. https://www.youtube.com/watch?v=uFtBdMm26Tk. 2020.
22. Lei Jinzhi, Jiang Xingliu. Kasimir effect and zero point energy extraction [J]. Science and Technology Herald, 1999(04):10-12.
23. Lei Jinzhi, Jiang Xingliu, Zhang Jiangang, et al. Electrochemical Anomalies and the Theory of Deflection Field [J]. Science and Technology Herald, 2000(06):3-5.
24. Jiang Xingliu, Yi Lizhi, Rui Liu, et al. Research on Corona Discharge Hoist [J]. Journal of Aviation, 2005(06):28-31.
25. Jiang Xingliu. The 21st century is the century of zero point energy [J]. Frontier Science, 2010,4(03):15-20.
26. Ren Junxue, Liu Yu, Jiang Xingliu, et al. Study on the lift mechanism and efficiency of electric floating machine [J]. journal of aerospace power, 2010,25(06):1395-1400.
27. Wang Liying. Experimental study of Biefeld-Brown effect in fluid [D]. Beijing: Beihang University, 2007.
28. Cheng Xiangyu. Exploration and pre-research of space electromagnetic propulsion system [D]. Hefei: University of Science and Technology of China, 2018.