Control of Propulsion in Horizontal Direction for EHD and Electrostatic Propulsion Device

Taku SAIKI
(3-3-35 Yamate, Suita, Osaka 564-8680, JAPAN)
Department of Electrical, Electronic, and Information Engineering, Faculty of Engineering Science, Kansai University, Japan

E-mail: tsaiki@kansai-u.ac.jp

Abstract

Electro hydro dynamic (EHD) and electrostatic propulsion devices has no moving parts and, in the air, operates on electrical energy. It is expected to develop electric propulsion systems without future moving parts of airplanes and helicopters propellers in the future.

When a high voltage is applied to the EHD device, levitaion force is generated and the EHD device levitates. I have already revealed the levitation property of the EHD device in the gravitational direction. I had also demonstrated a control method for hovering, ascent, and descent by applying pulse voltage to the EHD propulsion device. However, the method for horizontal propulsion was not yet demonstrated. In this time, with the object of controlling propulsion in the horizontal direction perpendicular to the direction of gravity, I proposed a method of dividing the upper wire electrode of the double ring electrodes, or adding a new single-pole capacitor composed of multiple electrodes to the lower part. Experiments had been conducted to proof that the two methods actually work.

1.Introduction

It is expected to develop electric propulsion systems without future moving parts of airplanes and helicopters propellers in the future. The advantage of this propulsion system is that 1) there are no moving parts, easy to maintain and 2) the propulsion efficiency may exceed the conventional engine.

There is a report that the principle of ion craft considered as a part of a series of thrust generation experiment by Brown effect using high voltage is propulsion by the imbalance of electrostatic force, attraction by space charge. We also think so from many experimental results other than that paper. It is considered that the propulsion principle is determined not by the ion wind but by the external electric field (applied voltage) and the amount of electric charge accumulated in the electrode. Much research has been done on the principle of lifters.

I have already conducted research on the remarkable specificity of the levitation characteristics of the EHD propulsion device, that is, the levitation characteristics in the direction of gravity. Also, I have previously demonstrated the differences in flight characteristics of EHD propulsion devices compared to conventional helicopters and drones. When a high voltage is applied to the EHD device, levitation force is generated and the device levitates. I had clarified the levitation property of EHD devices. I had also demonstrated how to control the altitude to a certain level by applying pulse voltage to the propulsion device, and how to ascend and descend at a reduced speed. However, a method for horizontal propulsion has never been demonstrated. In order to make the device propel freely in space like a drone, it is essential to demonstrate not only vertical movement in the direction of gravity but also horizontal propulsion.

In this paper, in addition to the principle of levitation, I also describe the principle of how to generate thrust in the horizontal direction, and present specific strategies. For the purpose of horizontal propulsion perpendicular to the direction of gravity, we demonstrated a method of dividing the upper part of the double ring structure, the upper thin wire part, or adding a new single-pole capacitor composed of multiple electrodes to the lower part. Furthermore, I performed experiments to demonstrate that the EHD device work by using two methods. In the discussion, I showed the advantages and disadvantages of lateral movement of the device compared to drone control methods.

2. Principle

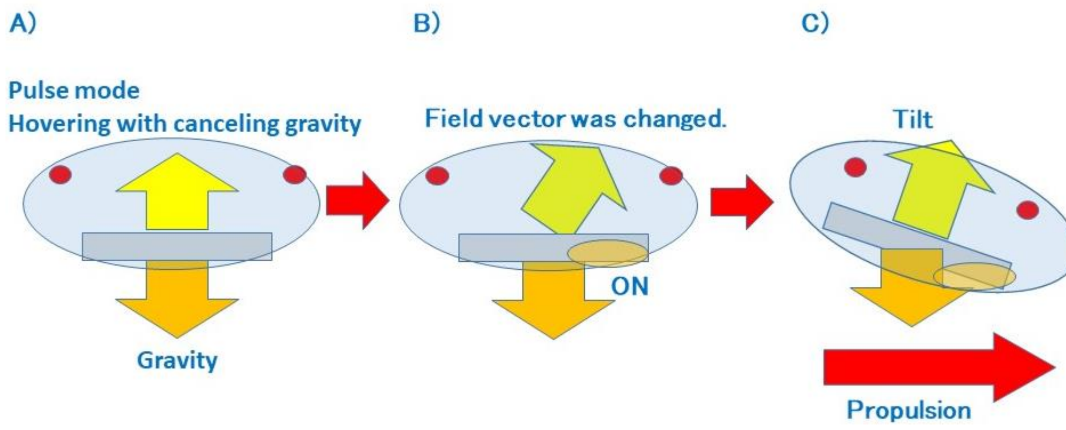


Fig.1. Concept of propulsion in the horizontal direction for EHD propulsion device.

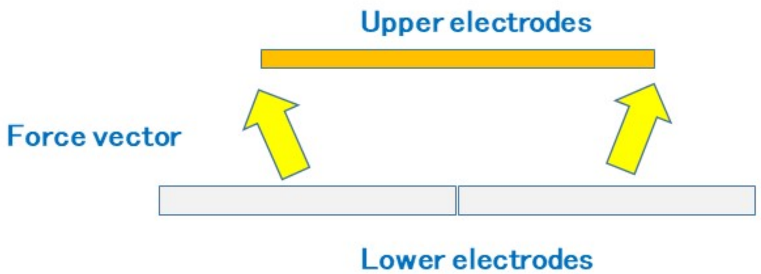


Fig.2. Example of upper and lower electrodes for EHD propulsion device.

Here, we discuss the control related to the lateral propulsion of the EHD propulsion device. In principle, this device exhibits the strange behavior of levitating as if repelling gravity, so consider using this to propel the device diagonally. That is, by changing the direction of this repulsion from vertically upward to obliquely, a lateral force is generated. Figure 1 shows the concept of its propulsion principle. Furthermore, an example of a simple double-ring electrode structure for the device is shown in Fig. 2. As a precondition, in Fig. 1, the EHD device is in a floating state due to the application of a pulsed high voltage, and is kept at the same height by repeatedly rising and falling. At this time, it is assumed that some kind of field is formed around the EHD device. So, if you stop applying voltage to a part of the wire, the field in that part weakens. Further, an additional capacitor is placed on the lower electrode, and charges are stored in the unipolar electrode. In this case, the field will become stronger. The situation shown in Fig. 1 B) corresponds to these conditions. Next, it is assumed that the state changes to the state shown in Fig. 1 C). In the state shown in Fig. 1 A), the object floats up to repel the field from below, but the fields repel each other in diagonal directions. Explaining this in terms of force vectors, in addition to the levitation force, a new force to move in the right direction is generated.

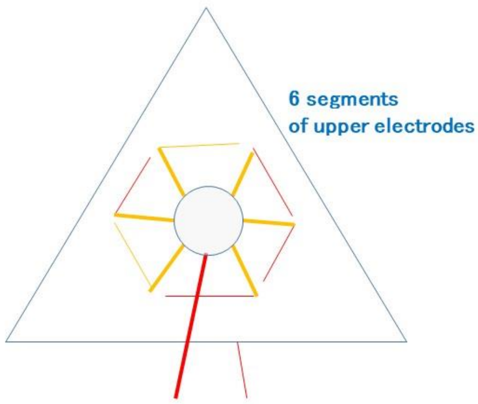
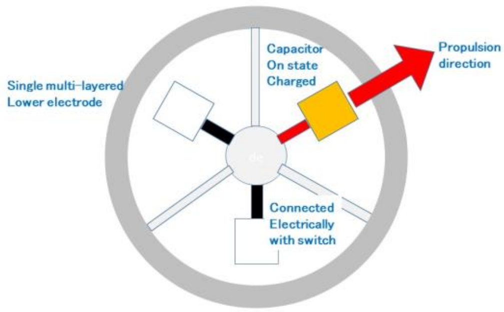
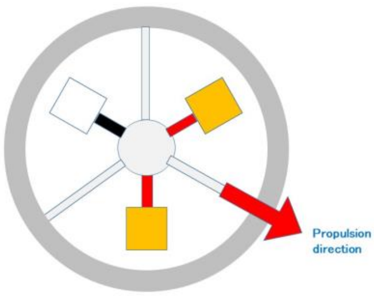


Fig.3. Dividing upper wire electrode.

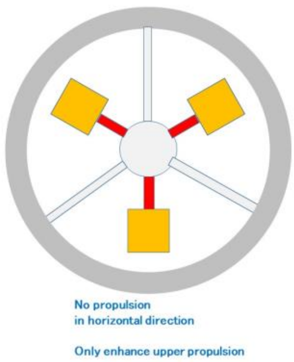
Fig. 3 shows a specific example of a propulsion method using division of the upper wire regarding control of the propulsion direction. Specifically, this is accomplished by spatially cutting off a certain portion of the wire, or by turning off electrical continuity in that portion of the wire. Here, the wire is divided into 6 parts. Charge is supplied from a single high-voltage power supply. Propulsion direction is controlled by connecting or disconnecting these six switches.



(a)



(b)



(c)

Fig.4. Configuration of single pole capacitors added at under electrode (a)1 ON state, (b)2 ON state, (c)3 ON state.

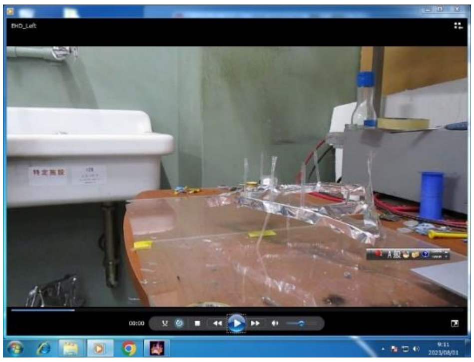
Fig. 4 shows a control method for the propulsion direction based on the arrangement of multiple single-pole capacitors added to the bottom of the EHD propulsion device. This uni-pole capacitors refer to a multilayer single-pole capacitor with improved storage efficiency. These capacitors are connected together with the switch, and is placed at a distance that does not create a complete capacitive coupling with the lower electrode when the switch is not turned on, that is, so that no charge is accumulated due to electrostatic action. Use the switch to turn the charge ON/OFF. It is assumed that the charge disappears when the switch is in the OFF state. Here, the capacitors are composed of three pieces. It is not limited to just 3, but it is also possible to use multiples of 3. When one capacitor is turned on, a propulsive force is generated from the center toward the capacitor. When two capacitors are turned on, a propulsive force is generated in the direction of the combined vector from the center to the two capacitors. When the three capacitors are turned on, the horizontal propulsion force is canceled and not generated, and only the levitation force is strengthened. The basic number is a multiple of 3 in order to maintain symmetry, that is, to stabilize the levitation and propulsion of the device. If the number of divisions is large, instantaneous propulsion in 360 degree directions is possible.

3. Results

3.1 Using wire

In order to prove that the above mentioned proposed methods actually work, I conducted an experiment in which the propulsion direction was controlled to the left and right. It was constructed using the method shown above, with only using the lacked wire electrode. The altitude was controlled by applying pulse voltage. As a result, I succeeded in propelling EHD devices left and right. I was able to confirm that it moved in the direction of the lacked wire.

(a)

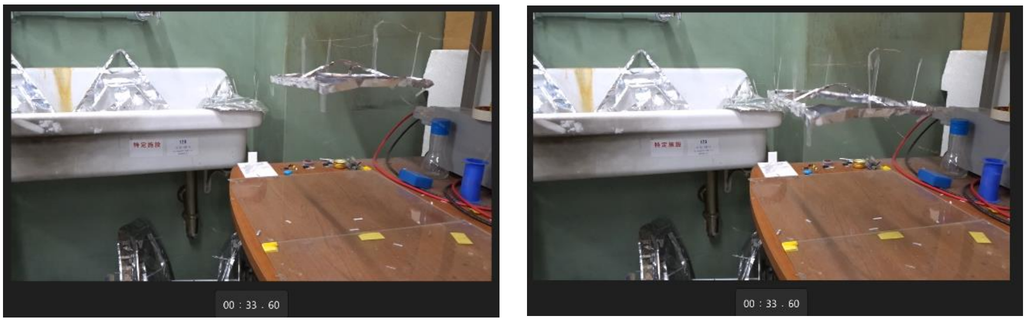


(b)

Fig.5 Experimental result for controlling propulsion direction. (a)Right side propulsion, (b)Left side propulsion.

3.2 Using additional uni-pole capacitors.

Similarly, with setting multiple capacitors at near the bottom electode, I conducted an experiment in which the propulsion direction was controlled to the left. An additional capacitor was used in the method shown above. I succeeded in propelling the EHD device to the left as shown in Fig.5(b). Experiments have confirmed that the EHD device move to the side where the capacitor is charged and is propelled in that direction.



(a) (b)

Fig.5 Experimental result for controlling propulsion direction. (a) Adding high voltage, (b) Moved to the left side.

4. Discussion

Here, I consider the lateral propulsion control of the propulsion device. First, for comparison, anyone consider for drone control. In a drone, the rotational speed of the motor is controlled to a constant level. For the upward direction, there is height information and input values from sensors, etc., and the rotation speed is adjusted so that the height is constant. In order to propel it laterally, in this state, the relative speeds of only two of the four motors are controlled to be high, and the robot moves forward while tilting in a specific direction.

However, upper concept does not apply to EHD devices. This is because if the high voltage is only turned on, the device will only rise rapidly. The reason is that the principle of levitation is different in the first place. There is no input voltage threshold that allows it to just float in a certain space. If you try to adjust the input voltage, it will swing from side to side and become unstable, like leaves falling from a tree, and eventually fall.

When propelling the EHD device horizontally, it is necessary to apply pulse voltage to maintain the height. As shown in Fig. 3, a part of the wire is de-energized, the spatial distribution of the electric field of the EHD device is made non-uniform, and the wire is caused to fly in the direction where the electric field is weaker. By devising the structure and increasing the number of divisions of the upper wire, it will be possible to propel the device in two-dimensional directions in an instant compared to a drone when viewed from above. Also, although the speed is in the lateral direction, there will be less friction because it is not in contact with the ground. Although there is friction with the air, if the force is applied horizontally for a long time, the velocity will increase considerably. This has to be balanced with air resistance.

In Fig. 4, the method is shown in which the capacitors are separately arranged at the bottom of the device to directly generate a levitation force in the traveling direction while leaving the upper portion as it is. However, the capacitor that controls direction may be either a type that stores charge or a cylindrical thrust generator with a hollow interior. You can tilt the EHD device from a position parallel to the ground.

I discuss the advantages and disadvantages of the method of modifying the upper part and the method of placing an additional capacitor in the lower part. The disadvantage of the wire splitting method is that when the switch is disconnected, the overall flying force and thrust force decreases. Furthermore, the structure for holding the wire becomes complicated, and the holding structure becomes unstable. Arranging thin lines makes structure and design troublesome. Also, there are aerodynamic issues during flight. While, an additional unipolar capacitor has the advantage that the levitation force is maintained. In addition, the structure is stable and wiring is easy. The disadvantage is that in the OFF state, it becomes a surplus load of levitation force.

References

[1] T. T. Brown, “Electrokinetic Apparatus,” U.S. Patent N°2949550, 1960.
[2] http://www.jlnlab.com/
[3] http://www.blazelabs.com/
[4] M. Tajmar, “Biefeld–Brown Effect: Misinterpretation of Corona Wind Phenomena”, AIAA Journal 42(2) (2004).
[5] L. Zhao and K. Adamiak, “Numerical analysis of forces in an electrostatic levitation unit,” J. of Electrostatics, **63**, pp.729-734 (2005).
[6] L. Zhao, K. Adamiak, “EHD gas flow in electrostatic levitationunit”, J. of Electrostatics, **64**, pp. 639–645 (2006).
[7] K. Masuyama and S.R.H. Barrett, Proc. of the Royal Society A - Mathematical, Physical and Engineering Sciences **469**, 20120623 (2013)
[8] T. Saiki, "Enhanced EHD and Electrostatic Propulsion Devices Based on Polarization Effect Using Asymmetrical Metal Structure", J. of Electrical and Electronic Engineering, (2015), 3 (4), Jul., pp.76-86.
[9] T. Saiki, “High-voltage Pulse Generation Using Electrostatic Induction in Capacitor”, Int. J. of Electrical Components and Energy Conversion, 5(2), Dec. pp.20-29 (2019).
[10] Taku Saiki,
“Analysis for Levitation of EHD and Electrostatic Propulsion Device in Direction of Gravity using Optical Flow Method”, J. of Electrical Electronics Engineering, (2024) Vol.3(1) pp.1-12.