Property on levitation for EHD and Electrostatic Propulsion Device Using Multi-layered Electrode

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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.

In this time, I had developed an EHD propulsion device with multi-layered electrodes, and confirmed that the multiple layers work efficiently. Commonly, we think that the weight of electrodes increases and the threshold of the input voltage for levitation should increase when the number of the layers increase. However, it has been confirmed in the experiment that the threshold voltage for levitation is kept constant and the levitation force increases even if the number of the electrodes increase. This means that the power efficiency of the device per unit weight is also improved. However, it was also found that this threshold increases when the size of the device is large.

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.

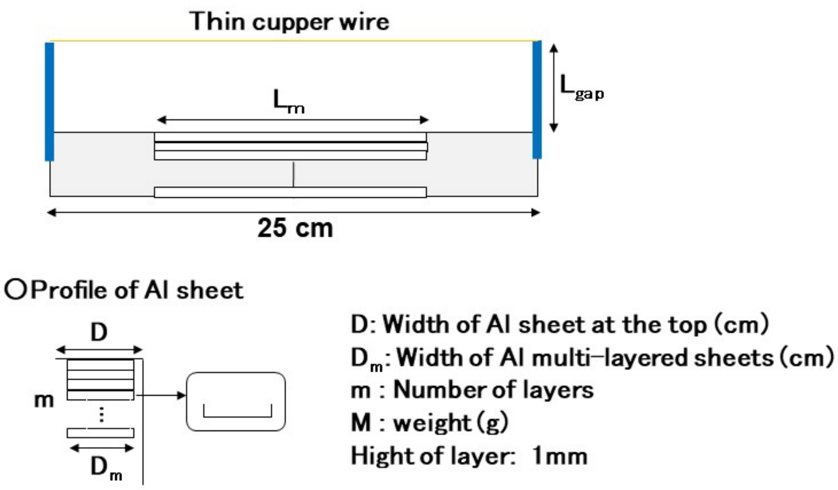
In order to realize drone, the levitation force needs to exceed the weight of the EHD device. Of course, the efficiency of thrust per unit weight (N/kg) and thrust per unit power consumption (N/W) are need to improve. Electrode multiplexing, utilization of polarization structures, and low voltage operation of ion sources, and generation of magnetic field by pulse operation are effective methods to improve them. However, even with these improvements, the levitation force cannot exceed the weight of the EHD device unless the above weight problem is solved.

Multi-layering of wide plate-shaped electrodes is expected to improve the amount of accumulated charge. In this study, I investigated whether the levitation force per unit power consumption can be improved by multi-layering the electrodes and obtained the threshold value of the input voltage for levitation experimentally.

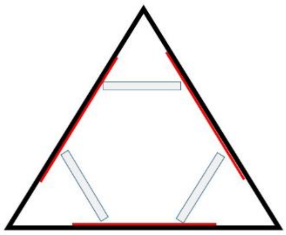
2. Experimental set up

The experimental setup for EHD propulsion is shown Fig.1. A single electrode (1 unit) is shown Fig.1(a). The triangle EHD propulsion device in this experiment is shown Fig.1(b). A triangle EHD device is shown in Fig.1(b). Three multi-layered electrodes are set at the tree red parts one by one. The devices are made of Aluminum foil. The length of the electrode was 25 cm. L_m is set to be 12.5cm. The maximum output voltage of the used DC rectified power supply in this experiment was 30 kV. A Cockcroft-Walton rectifier driving by single output wire of Tesla coil with CW mode operation was used to obtain DC high voltage output. The output frequency of the TC was 1.9 MHz. We can rectify the output signal from TC by connecting only single wire. The L_{gap} was chosen to be 4.5 cm. The used ultra-thin wire (the thickness was 50 µm) was connected to the + electrode, and the long plate electrode was connected to - electrode. The reason for using the ultra-thin wire is to enable low voltage operation. The EHD devices can operate up to be 30 kV. The input voltage is limited by the discharge between the wire and the body.

The threshold of the input voltage for levitating the EHD device was decided to judge if the device start to keep floating in the air.

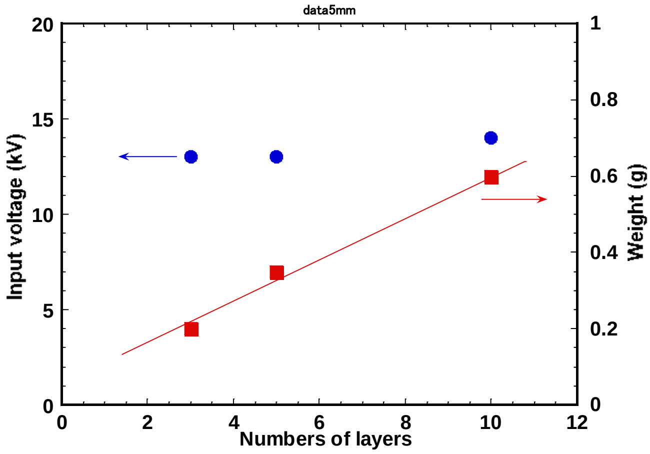


(a)

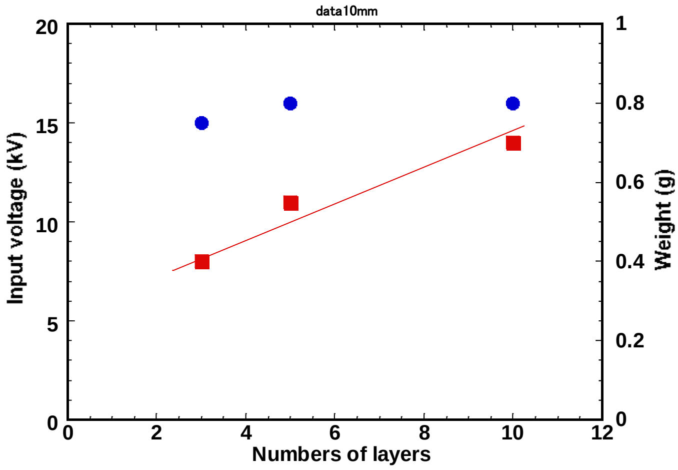


(b)

Fig.1. Experimental setup for levitation of EHD device. (a) Single plate electrode (1 unit), (b) triangle EHD device.



(a)



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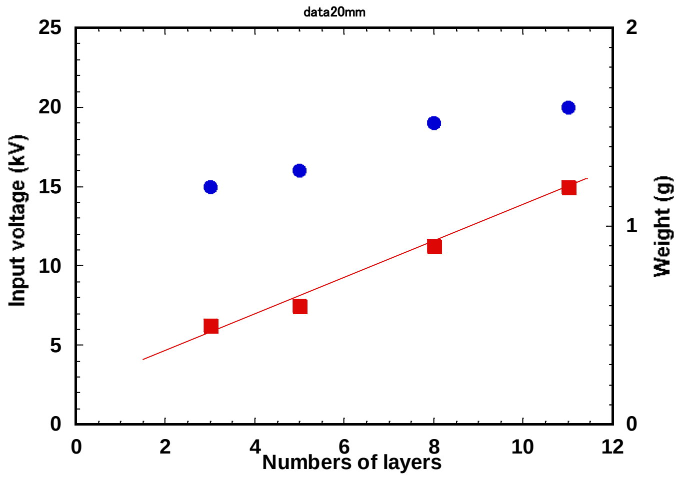

(c)

Fig.2. Threshold of input voltage for levitation. (a) D=0.5cm, (b) D=1.0cm, (c) D=2.0cm.

Threshold of input voltage for levitating 1 unit is shown in Fig.2. It was found that the threshold is saturated and constant regardless of the magnitude of D. The mass of the devices increased. When the value of D was small, the threshold was small. When D is large, the threshold is high.

It has been found that when the D is small, the saturation occurs with respect to low number of layers, and when the D is large, the saturation does not occur with respect to the number of layers.

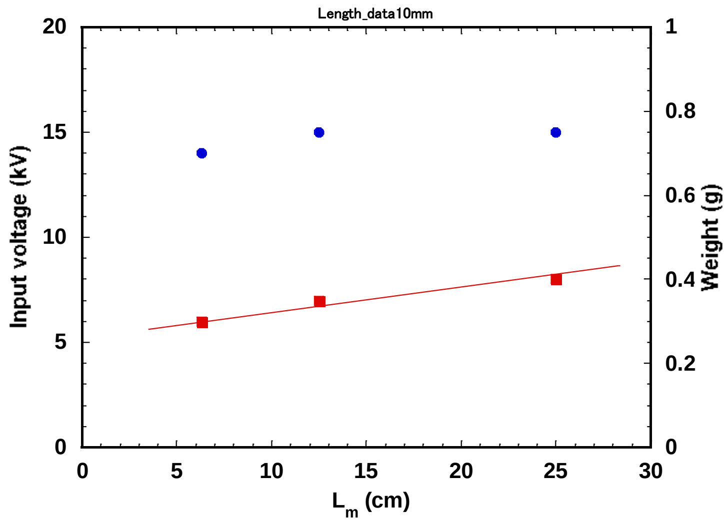

Fig. 3. Threshold of input voltage for levitation as a function of L_m .

Threshold of input voltage for levitation as a function of L_m is shown in Fig. 3. It saturates and becomes constant when L_m becomes to be long to 25cm.

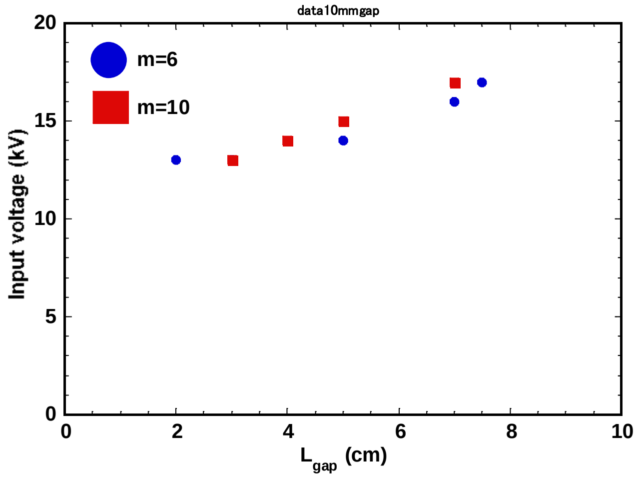

Fig.4. Threshold of input voltage for levitation as a function of L_{gap}.

Threshold of input voltage for levitation as a function of L_{gap} is shown in Fig. 4. When the gap was increased from 2 cm to 8 cm, the device could lift up by overcoming its own weight. The threshold increased with increasing L_{gap}. At L_{gap} of 8 cm, the threshold increased to 22 kV. The threshold when the number of layers is 10 is slightly higher than the case of using the number of layers is 6.

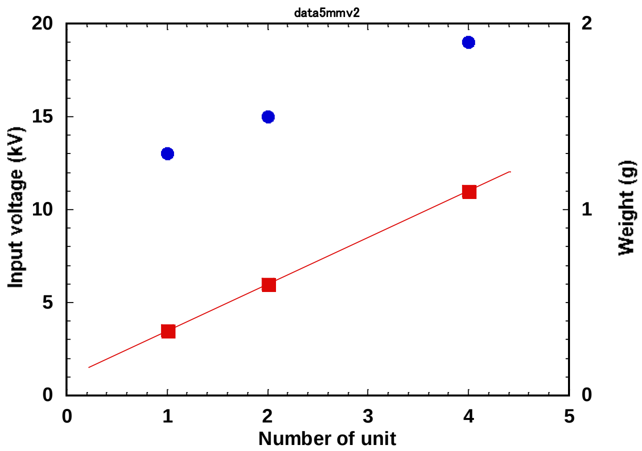

Fig.5. Threshold of input voltage for levitation of multi-layered electrode module.

Threshold of input voltage for levitation of multi-layered electrode module is shown in Fig.5.When one multi-layered electrode (1 unit: D=5mm, m=5) was combined to increase the length in the horizontal direction, the threshold simply increased linearly rather than decreased.

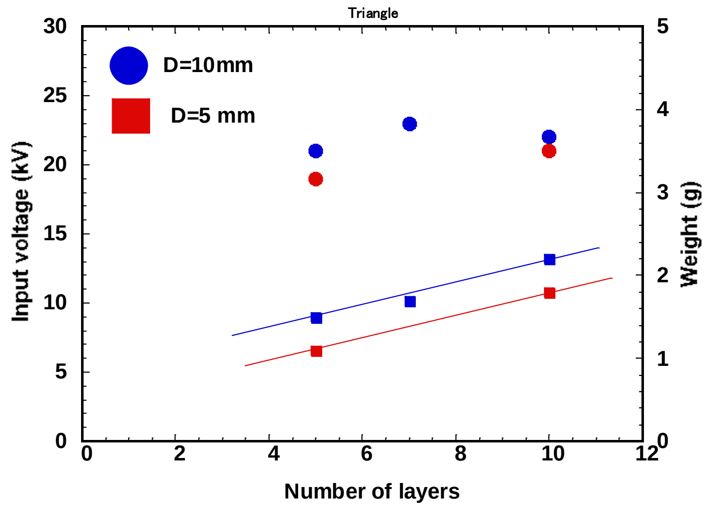

Fig.6. Threshold of input voltage for levitation of triangle EHD devices.

Threshold of input voltage for levitation of triangle EHD devices is shown in Fig. 6. I measured the threshold by next method. Once the triangle EHD device was levitated, and the voltage was lowered to confirm the input voltage at the fall down. When the number of layers was increased, the threshold was saturated when the number of layers was 7 or more. This tendency was the same when the single unit was used. The threshold was slightly higher when D was large.

Discussion

I have developed an EHD propulsion device with electrodes arranged in layers, and confirmed the effectiveness of the multilayered structure. The threshold voltage for levitation was kept constant even if the weight was increased by adding layers. This means that the more layers there are, the higher the levitation force and the more efficient the levitation force per unit weight can be achieved. Commonly, the weight of the metal increases, which should increase the threshold, but this result means that the levitation force increases proportionally to the number of layers. Also, this means that metal having a large air volume can be levitated if a high voltage is adapting to a structured metal containing cavities rather than in a bulk state. Making a structure to a metal to include cavities is equivalent to degrade its density.

The summary of the multi-layering performed this time is as follows. The difference in the electrode width and length, that is, the difference in the aspect ratio changed the property of the threshold. This may be interpreted to be caused by whether the leakage of the electric flux density generated from the charge in the lateral direction is large or small. It is thought that when the width of the wide upper part of the negative electrode is narrow and the number of layers is large, electric flux leakage is small and the electric field is strengthened in the layer direction. Computer simulations of charge and electric field are necessary in the future.

1) The smaller the cross-sectional area of the structural material can obtain the higher the thrust density. It will because that the charge density is high. 2) Using the long electrode plate makes the higher the threshold. 3) It should function lowering the thrust density by using the units of the layered structure. 4) As the number of layers increases, the threshold becomes higher and saturates at a certain number. A large number of layers should improve the levitation force. Although there is no experimental result, multi-layered electrode with several hundred layers instead of 10 layers can be used to the EHD device.

A large amount of charge is required to increase the levitation force in order to increase the size of the device. It is necessary to: 1) Enlarging the cross-section of the microstructure electrode, 2) lengthening the plate electrode, and 3) increasing the number of layers to 10 or more. However, increasing the size causes an increase in the threshold. The threshold should be lowered as much as possible in the design.

In this time, I adopted a structure that divides the layer structure for the configuration of the triangular EHD device, which combines three units. This is for stable floating of the device. It has been confirmed by experiments that the stability is lowered when the multi-layered electrodes are combined and arranged in a circle.

Conclusion

As a result of studying the effectiveness of multi-layering for EHD propulsion devices with multi-layered electrodes, I could confirm it. It was shown that the threshold voltage of levitation is kept constant even with multiple layers. As the number of layers increased, the levitation force increased and the levitation force per unit weight, and the power efficiency was improved. However, it became clear that this threshold increases when the size of the device is large.

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