Electrostatic force that acts on non-sphere shape charged conductors

Katsuo Sakai
Electrostatic generator Research Center
Yokohama Japan
phone: (81) 45-973-4014
e-mail: gy7a-ski@asahi-net.or.jp

***Abstract*— Electrostatic forces that acts on charge (q) on non-sphere shape conductors at electric field (E) were simulated and the following three new knowledge became clear. The magnitude is not equal to qE. If the shape is special, it becomes larger than qE. But, it is smaller than qE normally. The direction is not the same as the direction of electric field when the conductors have asymmetric shapes to the horizontal direction of electric field. If the direction of electric field is reversed, the magnitude is changed when the conductors have asymmetric shapes to the vertical direction of electric field. The confirming of the theory of the new electrostatic generator that use the third new knowledge was not performed because of wrong design of the experiment instrument.**

I. INTRODUCTION

When a point charge "q" is placed in a uniform electric field "E", the electrostatic force "F" that acts on the point charge is calculated with the following equation (1).

$$F = qE \qquad (1)$$

This force is normally called Coulomb force. Coulomb force has following three characteristics.

1) The magnitude is qE.
2) The direction is the same as the direction of electric field.
3) If the direction of electric field is reversed, the magnitude is not changed.

Figure 1 shows those characteristics schematically.

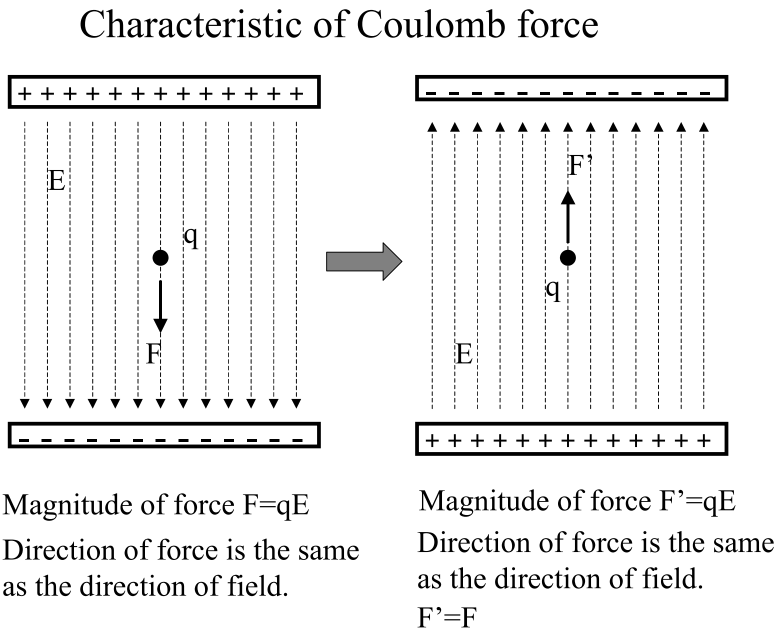


Fig. 1. The three characteristics of Coulomb force that acts on point charge.

The equation (1) can be applied to not only point charge but also sphere shape conductor. But, it can not be applied to other shape conductor [1]. And, I have not read a paper that reports the electrostatic force that acts on the other shape conductors. Therefore, I simulated the electrostatic force that acts on the other shape conductors.

II. SIMULATION OF ELECTROSTATIC FORCE

A. Simulation method and shape of charged conductors

I prepared 19 different shape conductors for this simulation. I made them from one simple conductive plate. Figure 2 shows the plate.

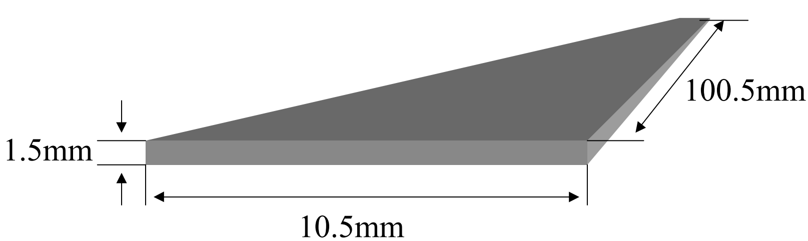


Fig. 2. The element plate that was used to compose all 19 conductors.

The arrangement of this plate was limited to four angles as shown in figure 3.

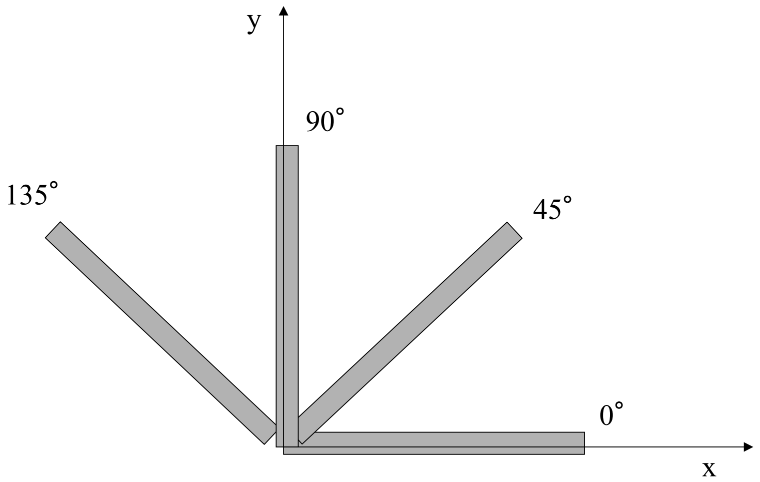


Fig. 3. The four angles that was used to compose all 19 conductors.

The angle was 0, 45, 90, 135 degrees from the X axis.

Figure 4 and 5 show 19 different shape conductors.

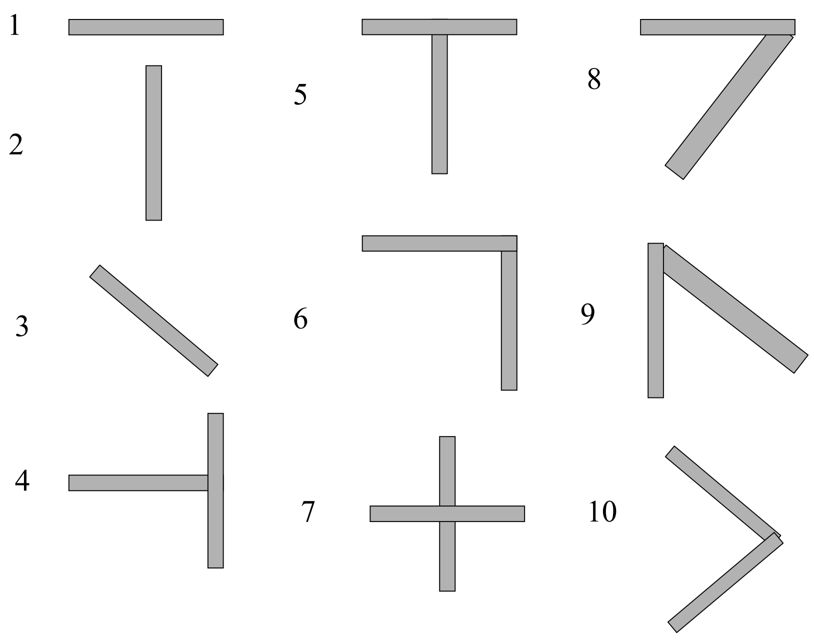


Fig. 4. First ten shapes of the 19 conductors

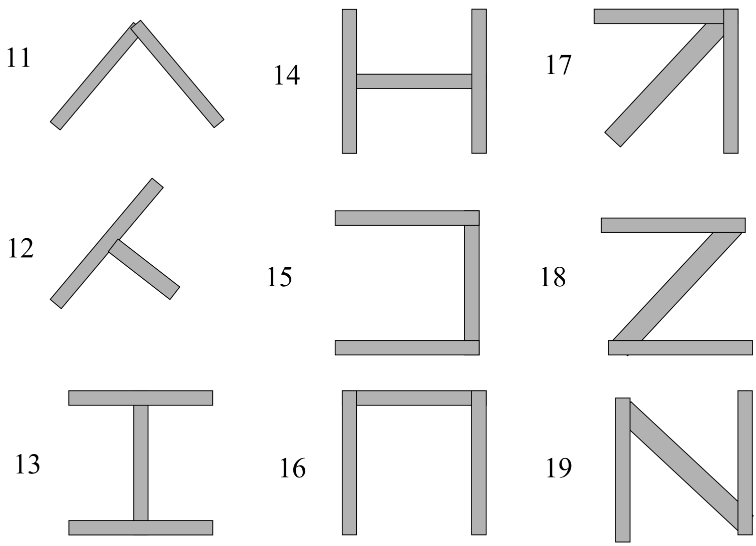
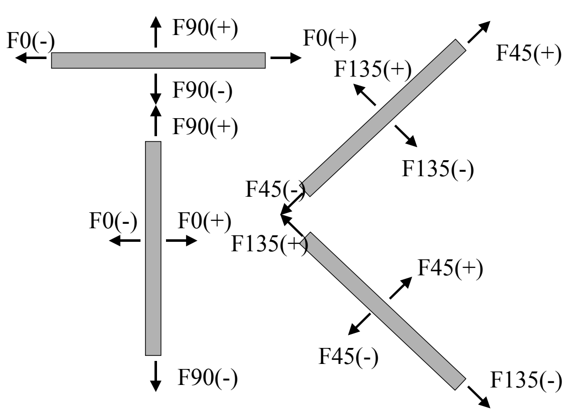


Fig. 5. Last nine shapes of the 19 conductors

Conductors 1, 2 and 3 are made from one plate. Conductors 4, 5, 6, 7, 8, 9, 10, 11 and 12 are made from two planes. Conductors 13, 14, 15, 16, 17, 18 and 19 are made from three planes.

Those 19 different shape charged conductors were placed in uniform electric field one by one. And electrostatic force that acts on those charged conductors were simulated. I did the simulation with two dimensions finite difference method. The details were reported on this conference last year [2]. Therefore, it is omitted this time.

Figure 6 shows layout of two large plate electrodes that made uniform electric field.



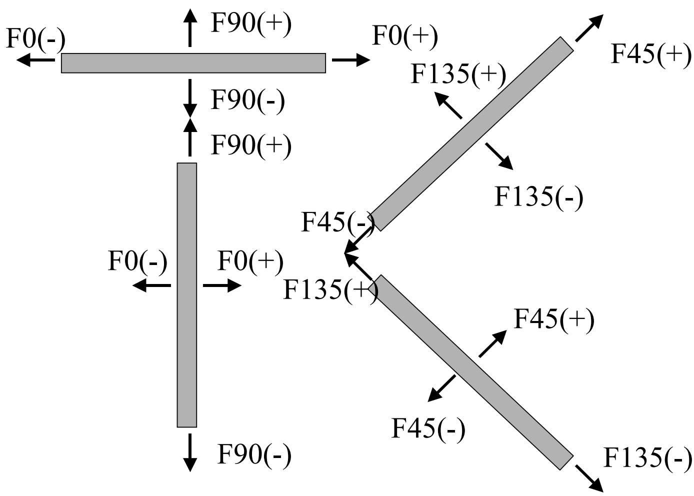
$$F_x = F0(+) - F0(-) + (F45(+) - F45(-) - F135(+) + F135(-))/\sqrt{2}$$

$$F_y = F90(+) - F90(-) + (F45(+) - F45(-) + F135(+) - F135(-))/\sqrt{2}$$

Fig. 6. Layout of two large electrodes and one small charged conductor that was placed at center of the electrodes

Upper electrode was applied to +1021500V and lower electrode was grounded. Distance between the two electrodes was 1021.5mm. As a result, intensity of the electric field took 1.0 MV/m. -0.1 μ C was given to each conductor. If it was point charge or shape of the conductor was sphere, electrostatic force will be simply calculated into 0.1N with formula (1). But, they were not a sphere shape. So, electrostatic forces that act on those 19 different shape charged conductors were simulated one by one.

Since the direction of the electrostatic forces that act on conductive plate is always perpendicular to the surface of the plate, as shown in figure 7, there are eight directions of the forces that act on those 19 charged conductors.



$$Fx=F0(+)-F0(-)+(F45(+)-F45(-)-F135(+)+F135(-))/\sqrt{2}$$

$$Fy=F90(+)-F90(-)+(F45(+)-F45(-)+F135(+)-F135(-))/\sqrt{2}$$

Fig. 7. Eight directions of the forces that act on the 19 charged conductors

Four directions of them are different from x or y axis. The angles are 45 degrees from x and y axis. Therefore, those forces were resolved into force of x direction and y direction with the following equations.

$$F45(+).x = F45(+) * (\frac{1}{\sqrt{2}}) \quad (2)$$

$$F45(+).y = F45(+) * (\frac{1}{\sqrt{2}}) \quad (3)$$

All forces that have the same direction with x axis were gathered into Fx as shown the following equation.

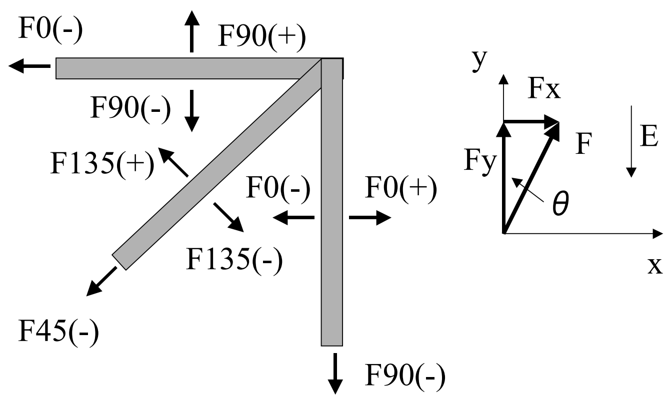
$$Fx = F0(+) + F0(-) + F45(+).x - F45(-).x - F135(+).x + F135(-).x \quad (4)$$

And, all forces that have the same direction with y axis were gathered into Fy as shown the following equation.

$$Fy = F90(+) + F90(-) + F45(+).y - F45(-)y + F135(+).y - F135(-).y$$
(5)

In this processing, I supposed all those forces to act on the center of gravity of the charged conductors for simplifying this calculation. As a result the torque was ignored this time.

Magnitude of the electrostatic force that acts on those 19 charge carriers and direction of the force were calculated with using Fx and Fy. Figure 8 shows one example of the calculation.



$Fx=F0(+)-F0(-)+(-F45(-)-F135(+)+F135(-))/\sqrt{2}$

$Fy=F90(+)-F90(-)+(-F45(-)+F135(+)-F135(-))/\sqrt{2}$

$F=(Fx^2+Fy^2)^{1/2}$

$\tan\theta = Fx/Fy$

Fig. 8. Calculation procedure of magnitude and direction of the electrostatic force that acts on No.17 charged conductor

Magnitude and direction of the electrostatic force that acts on charged conductors were calculated by the following equation (6) and (7) respectively.

$$F = \sqrt{fx^2 + fy^2} \quad (6)$$

$$\tan\theta = \frac{fx}{fy} \quad (7)$$

In figure 6, the upper electrode was applied to +1021500V and the lower electrode was grounded. And they produced strong electric field between them. I call the force acting on negative charge in this electric field as forward force. On the contrary, if the upper electrode is grounded and the lower electrode is applied to +1021500V, the direction of the electric field is reversed. And the direction of the force is too reversed. I call this force the backward force.

The ratio of the backward force as opposed to the forward force was calculated by the following equation (8).

$$\frac{f'}{f} = \frac{f.bw}{f.fw} \qquad (8)$$

B. Simulation results and consideration

Figure 9 shows simulated magnitude of the force that acts on 19 different shape charged conductors.

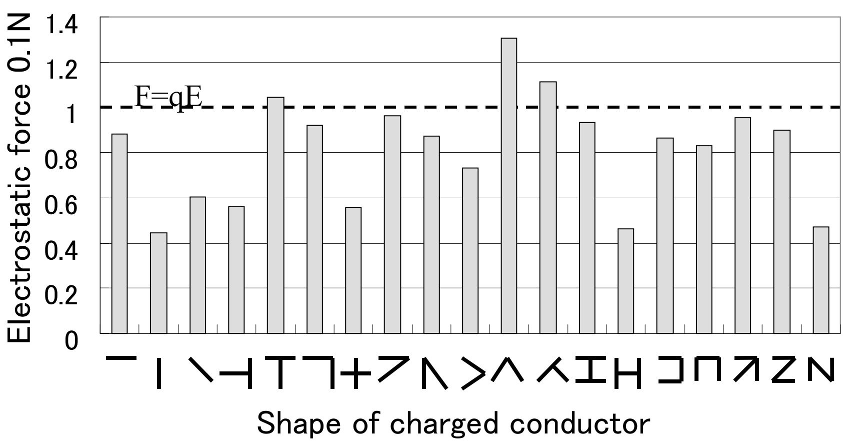


Fig. 9. Simulated magnitude of the force that acts on 19 different shape charged conductors

It is apparent from figure 9 that a few charged conductors have larger electrostatic force than point charge, but many conductors have less force. As mentioned before, magnitude of electrostatic force that acts on point charge 0.1μC in parallel electric field 1.0MV/m is 0.1N.

Magnitude of forces with conductors consisting of mainly vertical plate is small. It is apparent from figure 9 that "I" character, "H" character and "N" character conductors have most small forces. On the contrary, conductors having horizontal plates on the front line have larger forces. The reason can be clear explained with figure 10. Figure 10 shows charge distribution on a solo horizontal plate and a solo vertical plate.

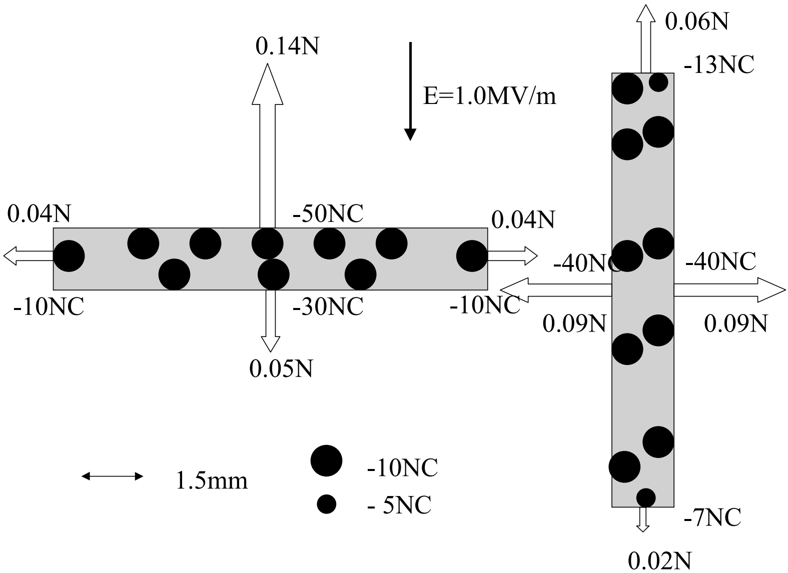


Fig. 10. Charge distribution and electrostatic forces on surfaces of a solo horizontal plate and a solo vertical plate.

It is apparent from figure 10 that 50% charges gather on the large front surface of the solo horizontal plate. But, only 20% charges gather on the both small side surfaces. And the remaining charges gather on the large back surface.
On the contrary, only 13% charges can gather on the small front surface of the solo vertical plate. And 80% charges gather on the both large side surfaces. And only 7% charges gather on the large back surface.

Magnitude of the right side force that acts on charges on the right side surface of the plates is the same as magnitude of the left side force that acts on charges on the left side surface of the plates. Therefore, both forces cancel each other perfectly. As a result, 20% charges of the solo horizontal plate and 80% charges of the solo vertical plate can not contribute to produce effective force. 50% charges of the solo horizontal plate can produce forward force, but only 13% charges of the solo vertical plate can produce forward force. And 30% charges of the solo horizontal plate and 7% charges of the solo vertical plate produce backward force. But intensity of the electric field that acts on the back surface of the two plates is weaker than that of the front surface. Therefore, effective force is mainly produced by front surface charge. Those are the reasons that the solo horizontal plate has larger force than the solo vertical plate.

Figure 11 shows simulated direction of the force that acts on 19 different shape charged conductors.

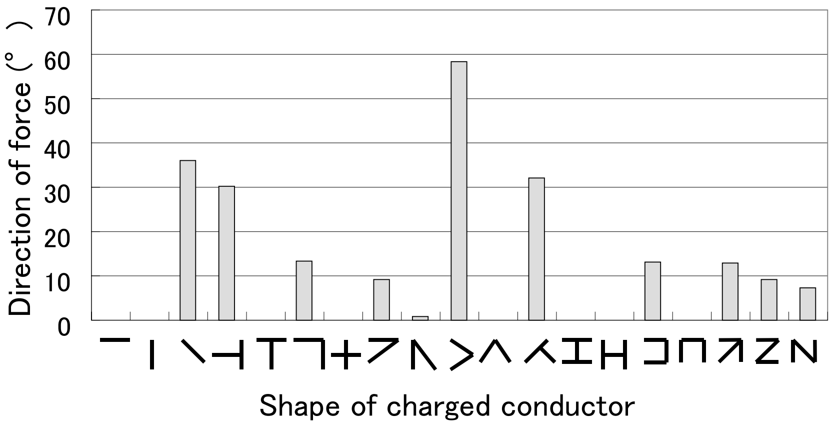


Fig. 11. Simulated direction of the force that acts on 19 different shape charged conductors

It is apparent from figure 11 that the direction of the force that acts on right and left symmetric shape charged conductors is the same as the direction of electric field. And the direction of the force of asymmetric shape charged conductors is different to the direction of electric field. This reason can be explained with charge distribution as mentioned before.

Figure 12 shows a ratio of the backward force as opposed to the forward force.

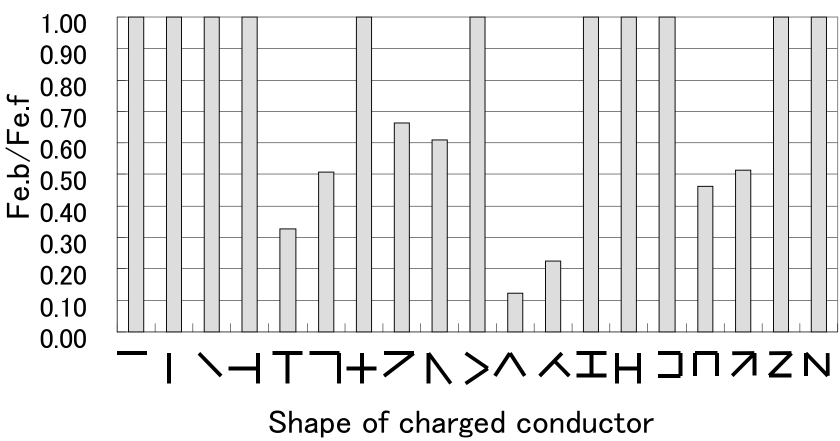


Fig. 12. Ratios of the backward force as opposed to the forward force for the 19 difference shape charged conductors

It is apparent from figure 12 that if the charge carriers have upper and lower symmetric shapes, the backward force is the same as the forward force. But, if the charge carriers have upper and lower asymmetric shape, the backward force is smaller than the forward force. The reason can be explained too by charge distribution as mentioned before.

Coulomb force has following three characteristics as mentioned before

1). The magnitude is qE.

2). The direction is the same as the direction of electric field.

3). If the direction of electric field is reversed, the magnitude is not changed.

But, the electric forces that act on non-sphere shape charged conductors have not the three characteristics.

4). The magnitude is not equal to qE. If the shape is special, it becomes larger than qE. But, it is smaller than qE normally.

5). The direction is not the same as the direction of electric field when the charged conductors have right and left asymmetric shapes.

6). If the direction of electric field is reversed, the magnitude is changed when the charged conductors have upper and lower asymmetric shapes.

We can produce new useful machines by using those three new characteristics. I will introduce a new electrostatic generator that uses the last characteristics this time.

III. A NEW ELECTROSTATIC GENERATOR

The total concept of the new electrostatic generator will be presented by the book published this summer from Nova Science Publisher Ins. [3]. The basic theory only is presented here.

A. Basic theory of the new electrostatic generator

The method of an electrostatic power generator has been defined by lifting charge to higher potential by mechanical power against electric force that acts on this charge. It is impossible that mechanical force carry charge directly. Therefore the charge is put on a suitable body. We call this body as a charge carrier.

The most popular electrostatic generator is Van de Graaff type electrostatic generator [4]. This was invented by Dr. Van de Graaff in 1931 in USA. Today, it is used with huge high voltage power supply. It can produce ten million volts. In this machine, insulating belt is used as a charge carrier. Fig. 13 shows this generator.

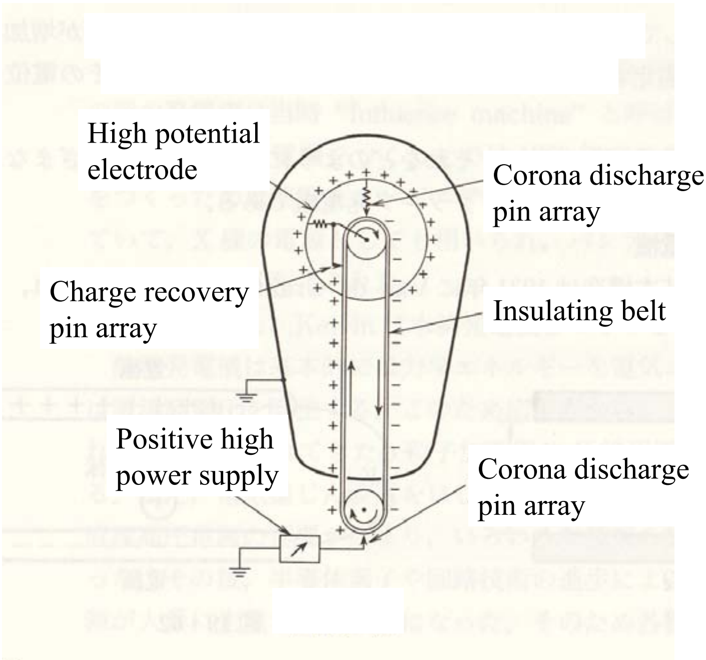


Fig. 13. Schematic layout of the Van de Graaff electrostatic generator [4]

The insulating belt is moved to a direction of arrow by a motor. The bottom corona discharge pin array put positive ion on the insulating belt. The positive ion on the insulating belt is carried into the high voltage electrode sphere by a mechanical power of a motor forcibly. Corona discharge occurs between the charge recovery pin array and the positive ion on the insulating belt. As a result, the positive ion on the insulating belt is neutralized by the negative corona ion. And, positive charge is added to the high voltage electrode sphere.

The principle of this power generator is shown by figure 14 schematically.

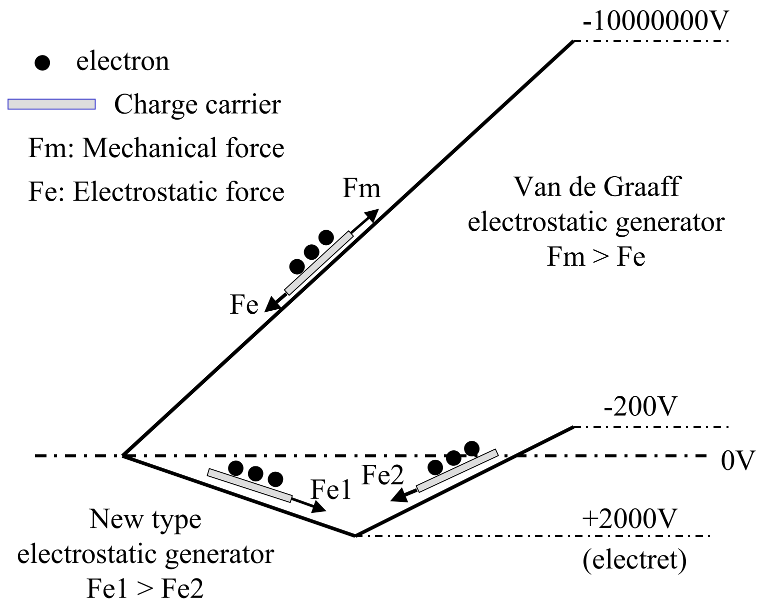


Fig. 14. Schematic explanation of principle of two electrostatic generators

In Figure 14, Bold line represents potential and arrow represents force. Black small circle represents electron and gray plate represents charge carrier. In the Van de Graaff electrostatic generator the charge carrier is straightly transported by strong mechanical force Fm against electrostatic force Fe.

On the contrary, in the new electrostatic generator, the charge carrier that is injected negative charge is first pulled from start place (0V) to the center electret (+2000V) by electrostatic force Fe1. In this process, the charge carrier is given some kinetic energy. After the carrier passes through the center electret, the carrier is pulled backward by electrostatic force Fe2, however it continue to move forward with expending the given kinetic energy. If this charge carrier has asymmetric shape to the vertical direction of the electric field, magnitude of Fe2 becomes smaller than magnitude of Fe1 as mentioned before. As a result, the charge carrier can arrive at lower voltage place (-200V). This is an electrically higher potential place for negative charge. Therefore, this is just electrostatic generating.

B. *Experiment instrument*

Figure 15 shows the front view of the experiment instrument that was used to confirm the theory of the new electrostatic generator.

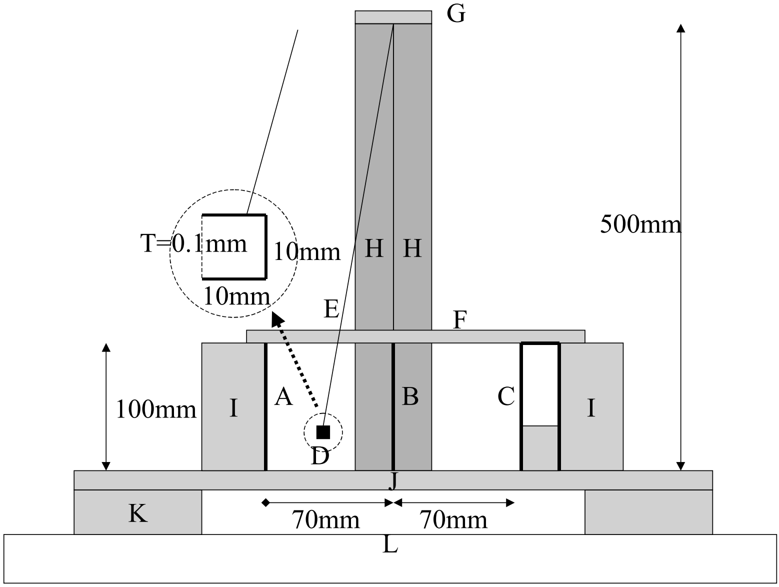


Fig. 15. Front view of the experiment instrument of the new electrostatic generator

In the figure 15, sign A shows a charge injection electrode that was grounded,

Sign B shows an electric field producing electrode that was applied to high voltage, (This electrode is replaced with electret when an actual electrostatic generator is made.)

Sign C shows a charge recovery electrode that was connected to capacitor,

Sign D shows a left open box type charge carrier that was electrically floated,

Sign E shows insulating threads that floated the charge carrier,

Sign F shows insulating guide bar that guided the threads,

Sign G shows insulating plate that held the threads,

Sign H shows insulating high pillars that held the plate and the field producing electrode,

Sign I shows insulating pillars that held the guide bar and the injection and recovery electrodes,

Sign J shows insulating base plate,

Sign K shows insulating spacers,

Sign L shows experiment desk,

Sign M shows a capacitor (See fig.18),

In figure 15, the inside of big circle on the left is an enlarged picture of the charge carrier (D). The three electrodes (A, B, C) were made from copper plate with 0.3mm thickness and the charge carrier (D) was made from copper plate with 0.1mm thickness. The insulating thread (E) was made from raw silk that is used by Japanese kimono. The other insulating parts (F, G, H, I, J, K) consisted of Acryl or Polypropylene resin.

Figure 16 shows the side view of the center of the experiment instrument.

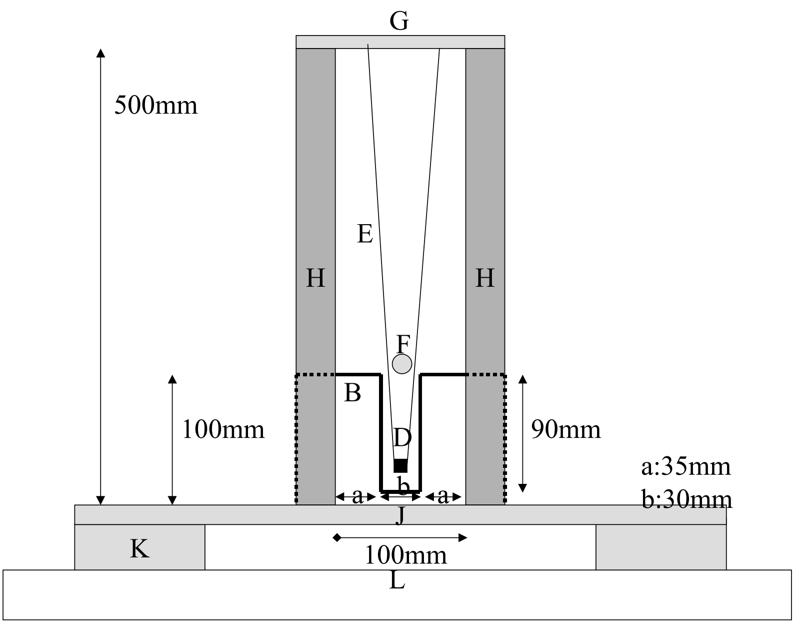


Fig. 16. Side view of the center of the experiment instrument of the new electrostatic generator

The electric field producing electrode (B) was partly cut out as shown in figure 16 at the center. As a result, the charge carrier (D) can pass through the electric field producing electrode (B).

Figure 17 shows the plane view of the experiment instrument.

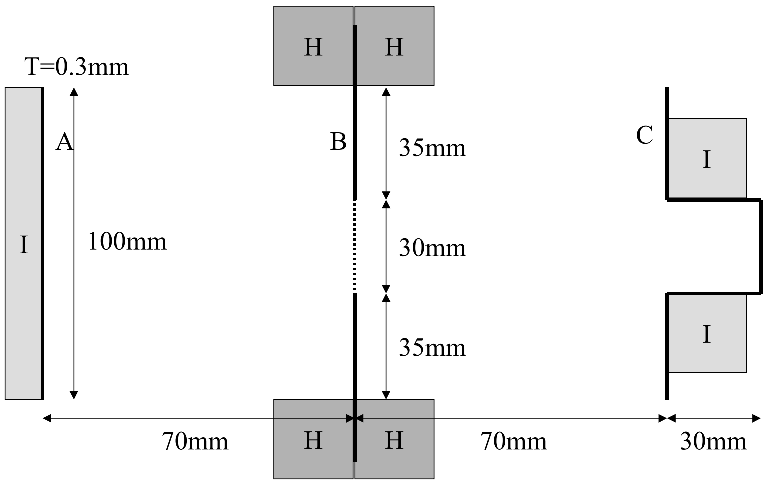


Fig. 17. Plane view of the experiment instrument of the new electrostatic generator

The charge recovery electrode (C) was partly bent as shown in figure 17 at the center. As a result, the charge recovery electrode (C) can perform semi-Faraday gauge. When the charge carrier (D) touch the charge recovery electrode (C), 95% charge on the charge carrier is transferred to the charge recovery electrode (D).

Figure 18 shows the electric circuit of the experiment instrument.

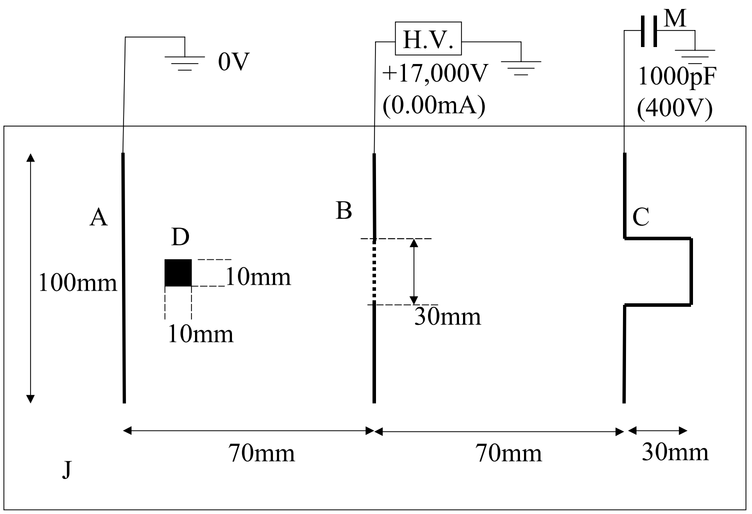


Fig. 18. Electric circuit of the experiment instrument of the new electrostatic generator

The three electrode (A,B,C) and the charge carrier (D) are electrically separated by the air and the insulating base plate (J) as shown in figure 18. The electric field producing electrode (B) is applied +17,000V, and the charge injection electrode (A) and the charge recovery electrode (C) are grounded. As a result, an electric field +0.24MV/m is produced between the electric field producing electrode (B) and the charge injection electrode (A). This electric field acts on negative charges on the charge carrier and generate an electric force that force the charge carrier to the right.

On the contrary, an electric field -0.24MV/m is produced between the electric field producing electrode (B) and the charge recovery electrode (C). This electric field acts on negative charges on the charge carrier and generate an electric force that force the charge carrier to the left.

As mentioned before, the former electrostatic force is larger than the latter electrostatic force. Because, the shape of the charge carrier (D) is left open box.

When the charge carrier (D) is touched to the charge injection electrode (A), some negative charge is injected to the charge carrier (D) from the charge injection electrode (A). This charge is transferred to the charge recovery electrode (C), and it is saved in the capacitor (M). The capacitance of the capacitor (M) is 1000pF, therefore potential of the capacitor (M) is risen when the charge is saved in the capacitor. This potential change can be measured by a surface potential meter.

C. Experiment results and consideration

At first, the electric field producing electrode (B) was applied to +17kV. Then, the charge carrier (D) was touched to the charge injection electrode (A). Some times it hit the back of the charge recovery electrode (C). However, it stalled in case of most on the way. On that case, it turned from side to side repeatedly.

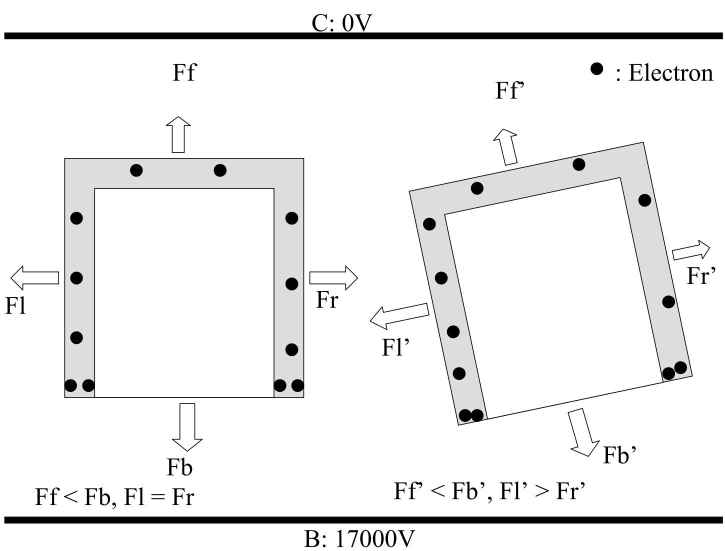


Fig. 19. Charge distribution and electrostatic forces of the charge carrier in normal and declined conditions

This experiment instrument was designed with right and left symmetry about the guide bar F (See fig.16, 17, 18). Therefore, the electrostatic force that acts on the right side of the charge carrier (D) is the same as that of the left side as described in figure 19 left side pictorially. However, after the charge carrier (D) passes through the electric field producing electrode (B), if it inclines left a little, charges move to left and left downward electrostatic force occurs as described in figure19 right side. This force turn it left more, and pulls it backward more. Finally, the threads that are twisted by the electrostatic force turn it right. This is the reason of the charge carrier's turning from side to side.

As a conclusion, this is wrong design. We need an improved design that can cancel the turning.

Anyway, it can hit the back of the charge recovery electrode (C) if the turning does not occur. So I tried to measure the transfer charge by a surface potential meter. But I found the surface potential of the capacitor (M) becomes about 100V when the electric field producing electrode (B) was applied to 17kV. The expected potential change of the transferred charge is only 2V. Therefore, this too is wrong design. We need an improved design that can protect the capacitor from leak current.

IV. Conclusion

An electrostatic force that acts on non-sphere shape charged conductor has been overlooked for a long time. However, it has very useful characteristics. Therefore, it must be studied from now. Especially, the new electrostatic generator that uses the characteristics is very important. It will solve the CO_2 problem and the energy crisis at the same time in near future. The confirming experiment of the theory of the new electrostatic generator was not performed because of wrong design of the experiment instrument. However, possibility of it was recognized in the experiment.

References

[1] David Halliday, Robert Resnick, Jearl Walker, *Fundamentals of Physics.* 6th edition Chapter “Electric Charge“ question 1, Wiley & sons. Inc.
[2] K. Sakai, “The electrostatic force that acts on the charged asymmetric conductor in a high electric field,” Proceedings of 2009 Electrostatics Joint Conference (2009) P2.07
[3] K. Sakai, “Asymmetric electrostatic forces and a new electrostatic generator,” *Nova Science Publishers, Inc.*, to be published.
[4] Handbook of electrostatics (Japan) (1998) p.962