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Dimension Optimization of a High Voltage Asymmetrical Capacitor for the Purpose of Maximizing the Generated Mechanical Force

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ABSTRACT

This paper deals with the influence of changes of physical dimensions on the magnitude of the force generated by a capacitor with asymmetrical electrodes connected to high voltage. The impact of these changes was verified through measurements and further analysed. The resultant data give us a way to optimize the dimensions and increase the generated force. The authors also found that the mechanical force generated by a capacitor using a wire mesh instead of a solid larger electrode, while providing a significant increase of the generated force, will also correspond much better with a previously derived formula.

Keywords: Biefeld-Brown effect, high voltage, electrode dimensions, asymmetrical capacitor, wire mesh electrode, generated mechanical force

INTRODUCTION

In the early parts of the 20th century a phenomenon was discovered by two physicists, dr. P. A. Biefeld and T. T. Brown. This phenomenon bearing the names of these notable figures consists of a mechanical force originating on a set of two asymmetrical electrodes (sometimes called asymmetrical capacitor), after high voltage is applied to them [1]. This force affects both electrodes in the same direction - always from the larger electrode to the smaller one, thus it can not be confused with the simple Coulomb attraction of electrodes with opposite charge.

Although this discovery was made more than 90 years ago and several other researchers and organizations have investigated this phenomenon, there is still no definitive description of it. Many of the recently published papers deal with the electrical properties, which influence the phenomenon. But the mechanical properties, meaning size and shape of the electrodes, remain largely unstudied.

BASIC THEORY

This phenomenon, commonly called Biefeld-Brown effect after its discoverers, is based on the motion of charged particles through a gaseous medium between two asymmetrical electrodes. The smaller of the two electrodes is usually a thin wire connected to high DC voltage (>10 kV). The high electric field strength causes the neutral air around the thin wire electrode to ionize. The charged particles with the opposite charge polarity from the smaller electrode are immediately drawn to it and neutralized. The charged particles of the same polarity are repulsed and drawn to the second, larger electrode, which is grounded (this effect is sometimes called ion drift [2]). Since they are moving through the air and not vacuum, this results in a tremendous amount of collisions with the surrounding neutral molecules [3]. The charged particles are still present in the electric field generated around the electrodes and so they are forced to move in the same direction as before the collision. The momentum from the collision is transferred through the electric field onto the electrode. Since both electrodes are mechanically connected by an insulating frame, the generated force resulting from the sum of transferred momentums affects both electrodes in the same direction. This principle also gives the reason for the direction of the force always being from the larger to the smaller electrode (independent on their polarity).

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A simple linear formula has been derived [4], which provides a basic mathematical description of the generated force *F*:

$$F = (I \,.\, d) / \mu, \qquad (1)$$

where *I* is the electrical current flowing through the capacitor, *d* is the distance between the electrodes and μ represents the ion mobility coefficient.

MEASUREMENT OF THE GENERATED FORCE

Since the generated force is a result of interactions of charged and neutral particles, it is very small in the range of mN. To measure such a small force we used a precise digital balance. The generated force is then acquired as a change in weight. To protect the balance from the effects of the high voltage the measured device is connected to, the capacitor is placed upon a grounded support stand made of Styrofoam, which in turn was set onto the balance (see Figure1). Because the neutral air flow resulting from the numerous collisions happening during the phenomenon could disrupt the measurement, the capacitor is set with its smaller electrode down and larger one up. This way the generated force aims downward and the neutral air flow is free to go upwards unimpeded, with no ill effect on the measurement [5].

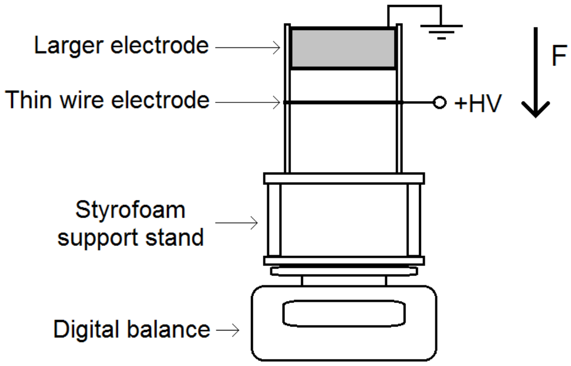
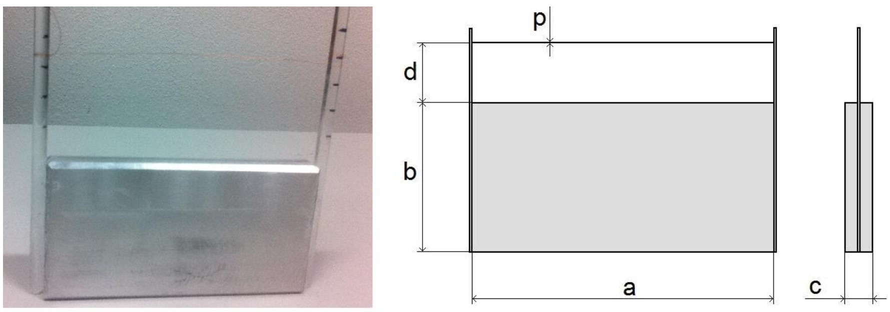


Figure1. *The whole measuring setup: digital balance, Styrofoam support and the measured asymmetrical capacitor.*

DIMENSIONS OF THE LARGER ELECTRODE

We are aware of the fact that the change of dimensions of the small wire electrode or the distance between the electrodes has an influence on the generated force too, but to make this paper more concise we will concern ourselves only with the larger electrode here, leaving the other two variables for further study.

Our main focus in this paper is to describe the influence of the changes of dimensions of the larger electrode. For this purpose several capacitors have been constructed with identical smaller electrodes (diameter *p* = 0,1 mm) and distance between them (*d* = 30 mm), but with larger electrodes of various dimensions. Hence the basic shape of the capacitor larger electrode was chosen in such a way, that it will be possible to change its dimensions one at a time, without changing any of the others (see Figure2). This will provide clearer results.



1) 2)

Figure2. *A picture of* ***1)*** *the real asymmetrical capacitor with basic dimensions (length* a *= 100 mm, height* b *= 50 mm, thickness* c *= 10 mm),* ***2)*** *a schematic of the capacitor with highlighted dimensions.*

A. Influence of the Length of the Larger Electrode a

To measure the influence of a change in length on the generated force, capacitors with the dimension *a* = 100 mm, 200 mm, 300 mm were used. The results seen in Figure3 show that by increasing the dimension *a*, there is a marked increase in current flowing through the capacitor. Since in this setup changing the length of the larger electrode means an equivalent change of length of the smaller electrode. This means that by increasing the length of the capacitor we also increase the volume in which air is ionized and thus more charged particles appear and contribute to the current between the electrodes.

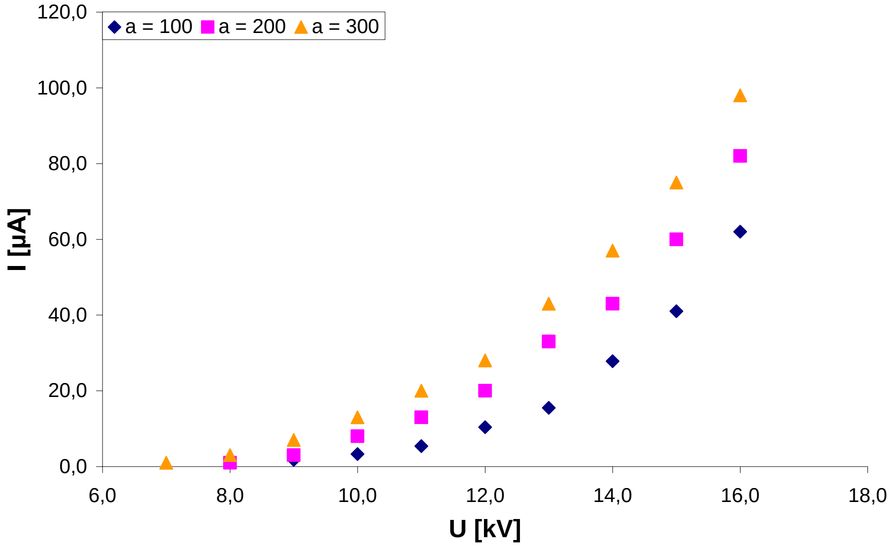


Figure3. *Graph representing relation between the electrical current* I *flowing through the capacitor and applied voltage* U *for capacitors of several values of length* a.

Figure4 reveals, that this can not be the only effect the change of capacitor length has on the generated force.

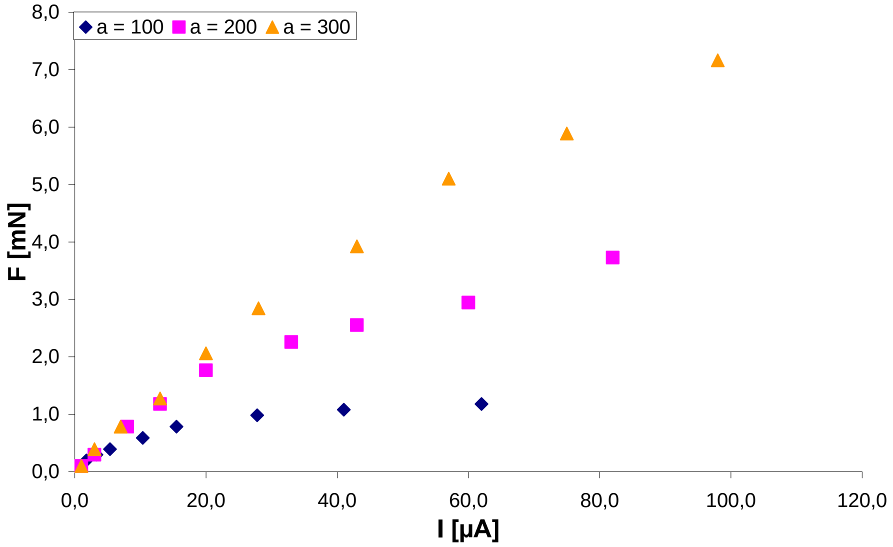


Figure4. *Graph representing relation between generated force* F *and electrical current* I *flowing through the capacitor for capacitors of several values of length* a.

The difference in generated force *F*, while at comparable values of electrical current *I*, can be understood as a change of efficiency. The less current is needed to achieve a certain value of generated force, the more efficient the capacitor. The explanation for this is a bit more complicated. It has been shown [6], that the characteristic the generated force follows is linear, but only to a certain value of applied voltage. While linear, the simple formula (1) can be used for its description. By increasing the length *a* we can achieve more current at lower applied voltage (see Figure3), thus the force remains longer in the linear part of the characteristic for higher values of the dimension *a* (see Figure4).

B. Influence of the Height of the Larger Electrode b

To observe what influence a change of dimension *b* (height of the larger electrode) has on the generated force, capacitors with the dimension *b* = 25 mm, 50 mm, 100 mm were used. As can be seen in Figure5, the difference in generated force is minimal. What difference there is, can be attributed to the change in the length of trajectories, the charged particles have to travel around the changed surface of the larger electrode. This causes a slight relative change to the number of collisions with neutral air particles. During this experiment there was no change in electrical current.

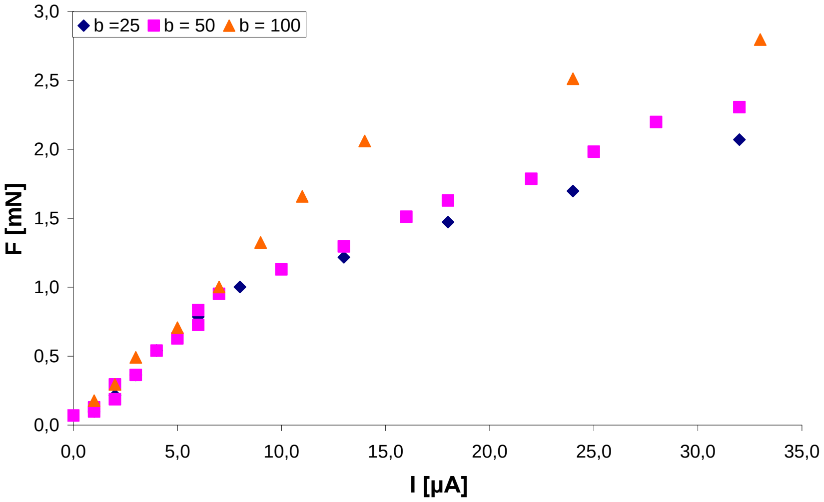


Figure5. *Graph representing relation between generated force* F *and electrical current* I *flowing through the capacitor for capacitors of several values of length* b.

Thus it can be said that changing the height of the larger electrode *b* has a negligible effect on the resulting generated force *F*.

C. Influence of the Thickness of the Larger Electrode c

Last dimension remaining is *c*, the thickness of the larger electrode. For this experiment capacitors with the dimension *c* = 5 mm, 10 mm, 20 mm, 40 mm, 60 mm were used. The results seen on Figure7 show, that for lower values of *c*, the initial direction of the characteristic has much steeper incline.

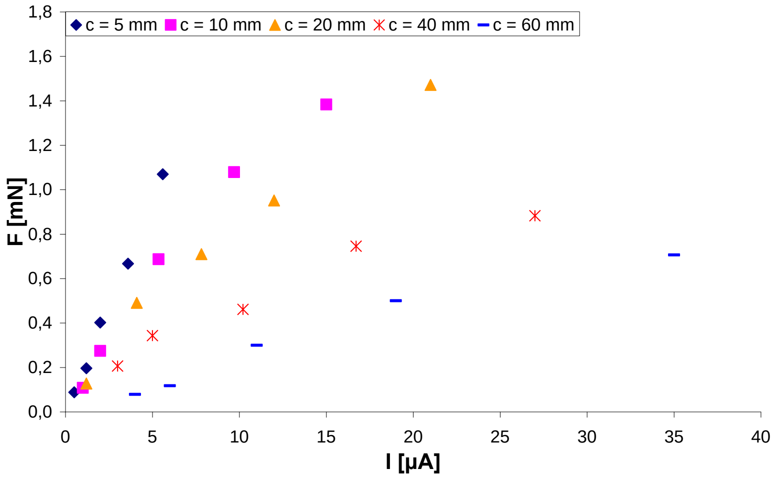


Figure6. *Graph representing relation between generated force* F *and electrical current* I *flowing through the capacitor for capacitors of several values of thickness* c.

However, we can also observe a noticeable increase in current consumption for higher values of *c*. This can be better seen on the current-voltage characteristic in Figure7.

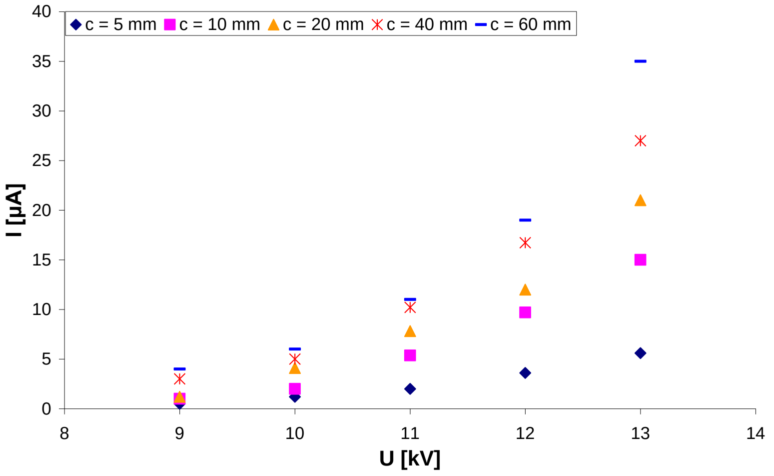


Figure7. *Graph representing relation between the electrical current* I *flowing through the capacitor and applied voltage* U *for capacitors of several values of thickness* c.

Although electrodes with higher *c* values seem to generate lower force, thus being less efficient, they also have higher current flowing between electrodes. However this would suggest, that with higher current there should be higher generated force. At this point it is necessary to realize, what the presence of the previously mentioned neutral air flow means for the force generation. The force is the result of the sum of momentum of the charged particles gained from the collisions with the neutral air particles. But this sum may be lowered by the momentum of the neutral air particles, which, if the circumstances allow, can collide with the larger electrode, thus returning their momentum to the capacitor and negating the contribution of the charged particle, with which they previously collided. The circumstances for this include a sufficiently large upper surface of the larger electrode. This lowers the probability that a neutral particle already traveling in the direction of the larger electrode would miss it, thus carrying its gained momentum away from the capacitor (see Figure8). The more neutral particles transfer their gained momentum back to the capacitor, the lower is the resulting generated force.

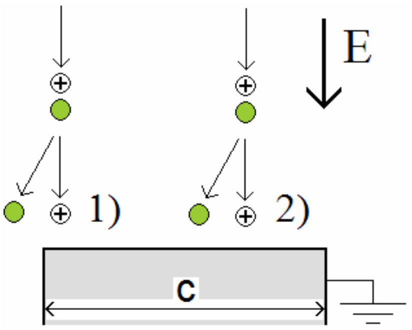


Figure8. *Schematic representation of two possible behaviour variants of neutral and charged particles in the vicinity of the larger grounded electrode - neutral particle after the collision with the charged particle* ***1)*** *misses the electrode, or* ***2)*** *hits the electrode and transfers to it the momentum gained from the previous collision.*

Yet judging by the measured current, if we were to increase the upper surface of the larger electrode, we should be able to generate higher forces, were it not for the neutral air flow colliding with the electrode.

OPTIMAL SHAPE OF THE LARGER ELECTRODE

Easiest way to maximize the generated force, based on the results so far, would be to minimize the thickness of the larger electrode *c*. This would decrease or even nullify the ill influences of the air flow around the electrode by minimizing the drag forces. However this may cause the larger electrode dimension *c* to be so small, that ionization starts to occur around its surface too. This would cause a generation of two opposing forces - one on the smaller electrode, the second one on the former larger electrode - resulting in diminishing the resultant force.

Because of this we may have to consider changing the structure of the electrode instead of its dimensions. By changing the solid character of the larger electrode, we allow the air flow to pass through the electrode. This way we could even use devices with larger values of thickness *c* since those show much higher electric current flowing through them, which should in turn increase the generated force.

For this purpose we used a wire mesh electrode (wire thickness of 1 mm and distances of 10 mm, see Figure9) instead of a solid shape. This is possible, since the electric field around a wire mesh with these parameters can be considered equivalent with an electric field around a solid plane [7] with our distance between the two electrodes (30 mm).

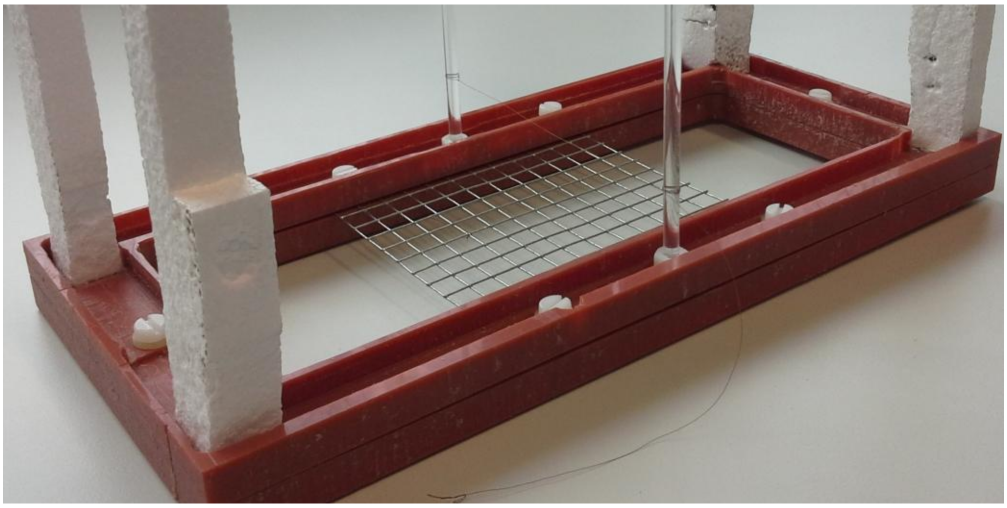


Figure9. *Picture of the new device, where smaller electrode is still a thin wire, but the larger electrode is no longer solid and is formed by a wire mesh.*

This should result in the charged particles still discharging on the larger electrode, but the neutral air flow passing unhindered through.

Once we applied high voltage to this new capacitor with a wire mesh electrode and compared the measured values with those obtained on the basic capacitor with a solid electrode, we received the following graph (see Figure10).

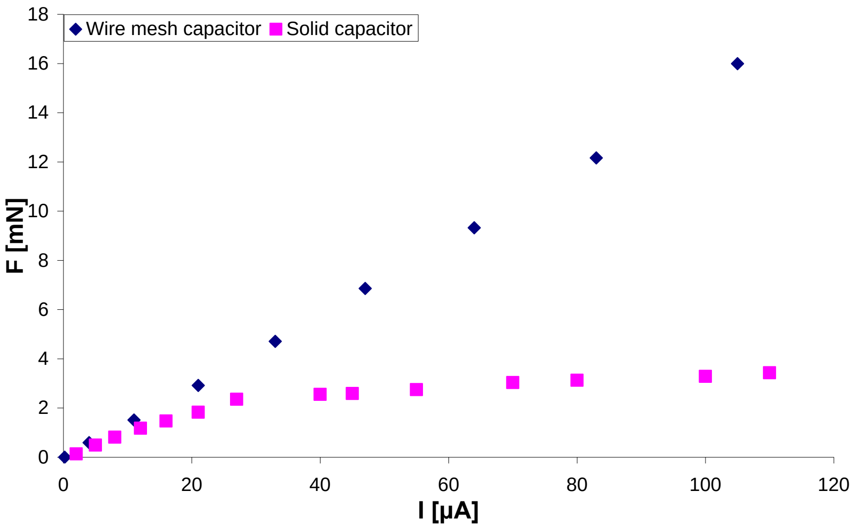


Figure10. *Graph representing relation between generated force* F *and electrical current* I *flowing through the capacitor for a capacitor with a solid larger electrode and a capacitor with wire mesh electrode.*

From Figure10 it can be clearly seen, that not only does the wire mesh capacitor generate a much greater force, but also its characteristics in the graph is almost exactly linear. This would also correspond with the formula (1), where the relation between the current *I* and force *F* is also linear.

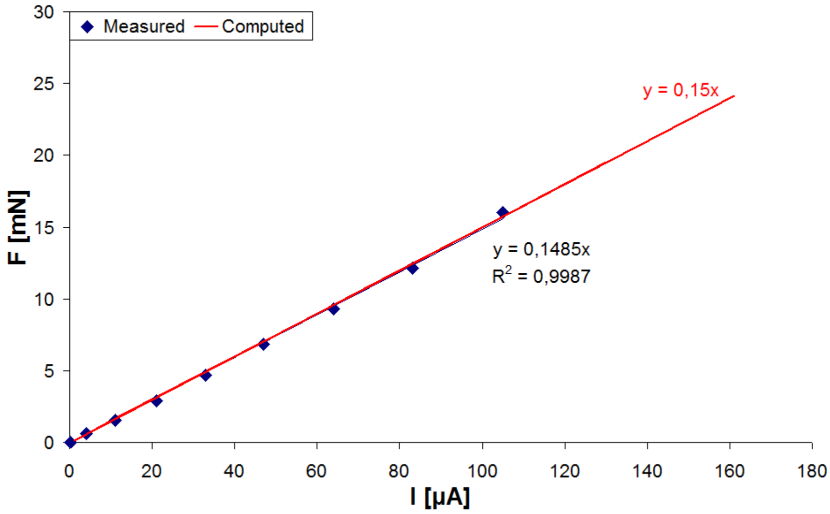


Figure11. *Graph representing relation between generated force* F *and electrical current* I *flowing through the capacitor for a capacitor with a wire mesh electrode compared to values obtained using formula (1).*

This similarity can be seen in Figure11, where we compare the values obtained from measurements and those computed with the formula. For this purpose we were using the following constants: distance between electrodes d = 30 mm, ion mobility coefficient $\mu = 2.10^{-4}\ m^2V^{-1}s^{-1}$.

Using linear regression function on the measured values, we can see the trend it follows is almost identical with that of the computed values. This shows, that using the new capacitor with a wire mesh electrode, we have achieved a real state of conditions, which are almost identical to those used as initial conditions for the derivation of the formula (1).

CONCLUSION

The purpose of this paper was to ascertain possible influence of the physical dimensions of a high voltage capacitor with asymmetrical electrodes on the generated force and to measure it. This has been achieved. From the results we have also been able to find dimensions responsible for the greatest possible changes in the generated force, be it because of the neutral air flow or change in the electric field around the electrodes.

Capitalizing on this, we have presented a possibly ideal construction of the capacitor using the wire mesh electrode. This design generates a far greater force then the basic one and even more important is its correlation with the formula (1) derived to describe the process of the force generation. This means that by using this particular design we have removed all the factors (mainly drag force), that have been responsible for disagreements between the theoretically computed and measured data concerning this phenomenon.

While this design has already been mentioned in an US patent by Alexander de Seversky [8] from 1964, we have now proven its viability and reasons for its performance through systematic measurements.

Another benefit to this new design is that since it allows the neutral air flow through its larger wire mesh electrode, it can be used as an air flow generator with no moving parts. This side of the phenomenon is still being studied at Technical University of Liberec, Czech Republic.

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REFERENCES

[1] F. X. Canning, C. Melcher, *Asymmetrical Capacitors for Propulsions* (National Aeronautics and Space Administration, Fairmont, West Virginia, 2004).

[2] T. B. Bahder, Ch. Fazi, *Force on an Asymmetric Capacitor* (Army Research Laboratory, Adelphi, 2003).

[3] T. B. Jones, *Electromechanics of particles* (Cambridge University Press, Cambridge, 1995) p.218

[4] J. Primas, M. Malik, D. Jasikova, V. Kopecky, in *11th International Symposium on Microwave and Optical Technology 2011: Proceedings of the 2011 ISMOT Conference*, Prague, Czech Republic, 20 June-23 June 2011 (FEL, ČVUT, 2011).

[5] M. Malik, J. Primas, V. Kopecky, M. Svoboda, *Calculation and measurement of a neutral air flow velocity impacting a high voltage capacitor with asymmetrical electrodes*, AIP Advances Vol. 4, No. 1 (2014).

[6] J. Primas, M. Malik, D. Jasikova, V. Kopecky, in *ICAP 2010: International Conference on Applied Physics: Proceedings of the 2010 ICAP Conference*, Amsterdam, Netherlands, 15 September - 17 September 2010 (WASET, Amsterdam, 2010), pp. 335-339.

[7] R. P. Feynman, R. B. Leighton, M. Sands, *The Feynman Lectures on Physics* (Addison-Wesley, Massachusetts, 1964).

[8] de Seversky, A. P. *Ionocraft*. U.S. patent no. 3130945, 1964

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Michal Malík, was born in 1983 in Liberec, Czech Republic. In 2008 he received an engineering degree (Ing.) in Mechatronics at the Technical University of Liberec, where he also received his doctoral degree (Ph.D.) in Applied sciences in engineering in 2014.