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# The Influence of Electrode Heating On the Force Generated On a High Voltage Capacitor with Asymmetrical Electrodes

Jiří Primas, Michal Malík, Darina Jašíková, and Václav Kopecký



***Abstract*—**When a high DC voltage is applied to a capacitor with strongly asymmetrical electrodes, it generates a mechanical force that affects the whole capacitor. This is caused by the motion of ions generated around the smaller of the two electrodes and their subsequent interaction with the surrounding medium. If one of the electrodes is heated, it changes the conditions around the capacitor and influences the process of ionisation, thus changing the value of the generated force. This paper describes these changes and gives reasons behind them. Further the experimental results are given as proof of the ionic mechanism of the phenomenon.

***Keywords*—**Capacitor with asymmetrical electrodes, Generated force, Heated electrode, High voltage.

## I. Introduction

In recent years, there has been a growing interest in the so called Biefeld-Brown effect [1], which was discovered in the 1920s by Paul A. Biefeld and Thomas T. Brown. When a capacitor with strongly asymmetrical electrodes is connected to the DC high voltage, there appears a force, which tends to move with the whole capacitor towards the smaller electrode. It has nothing to do with the Coulomb force, which causes attraction of the electrodes and thus does not move the whole capacitor. The Biefeld-Brownian force moves the whole device and also causes the detectable flow of the surrounding medium (usually air). Recent publications bring the detailed mathematical description of the phenomenon derived both from the basic physical principles as well as (in much more general form) from the Maxwell equations [2]. Both approaches agree on the underlying physics – the cause of the Biefeld-Brownian force is in the oriented motion of ions, which are generated from the air molecules in the very high electric field around the small electrode (which is positive) and travel towards the big electrode (which is grounded). During their travel they collide with the neutral air molecules. The exchange of momentum between the ions and neutral molecules causes both the Biefeld-Brownian force and the flow of the surrounding medium. When the small electrode is heated, there is a hypothesis that a greater amount of ions will be generated and that is why the magnitude of the force is supposed to be greater. The purpose of this article is to bring proof or to falsify this hypothesis and further prove or disprove the ionic mechanism of the Biefeld-Brownian force.

J. Primas is with the Department of Measurements of the Faculty of Mechatronics, Informatics and Interdisciplinary Studies at the Technical University of Liberec, Czech Republic (phone: +420-485-353-510; e-mail: jiri.primas@tul.cz).
M. Malík is with the Department of Measurements of the Faculty of Mechatronics, Informatics and Interdisciplinary Studies at the Technical University of Liberec, Czech Republic (e-mail: michal.malik@tul.cz).
D. Jašíková is with the Department of Measurements of the Faculty of Mechatronics, Informatics and Interdisciplinary Studies at the Technical University of Liberec, Czech Republic (e-mail: darina.jasikova@tul.cz).
V. Kopecký is the dean of the Faculty of Mechatronics, Informatics and Interdisciplinary Studies at the Technical University of Liberec, Czech Republic (e-mail: vaclav.kopecky@tul.cz).

## II. Experimental Apparatus

The main part of the experimental setup is the capacitor with strongly asymmetrical electrodes. The small electrode (positive) is a thin bare steel wire with a diameter of 0,2 mm and length of 100 mm, the big electrode (grounded) is a Styrofoam box completely wrapped in a thin aluminium foil. The dimensions of the big electrode are 100 x 50 x 10 mm. The small electrode is fixed 30 mm above the big electrode on glass supporting rods. A detailed view of the asymmetrical capacitor can be seen in Fig. 1.

Fig. 1 A detail of the asymmetrical capacitor

It is quite difficult to precisely measure a small force on the capacitor, which is connected to the voltage of several tens of kilovolts. The most reliable way, which was previously used by our team, is to measure the force as a gain of weight (in order of tens to hundreds of milligrams) of the whole capacitor. The precise laboratory digital balance KERN is used to measure the gain of weight $\Delta m$ and the force $F$ is very easily calculated using the basic formula:

$$F = \Delta m \cdot g \ ,$$

where $g$ is the standard gravity; $g$ = 9,81 $ms^{-2}$. The whole measuring setup can be seen in the Fig. 2. Detailed description of the measurement technique (grounded stand to protect the digital balance, very thin wires connecting the capacitor to the high voltage, etc) can be found in [3].

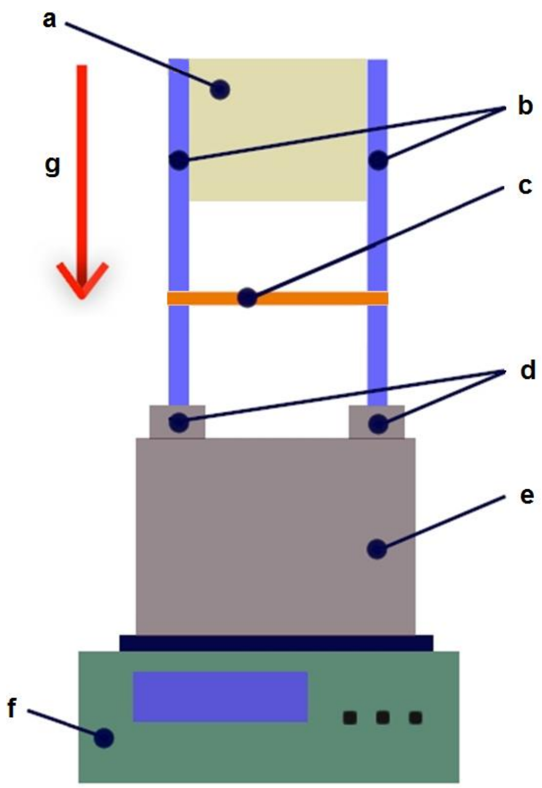


Fig. 2 The whole arrangement used to measure the force on the asymmetrical capacitor
(a – big electrode, b – glass supporting rods, c – small electrode, d – stand fixtures, e – styrofoam grounded stand, f – digital balance KERN, g – direction of the generated force)

Another difficult task was to heat the thin electrode to the temperature of several hundreds degrees of Celsius. In our setup a Joule heating was used. When an electric current passes through a conductor, it generates heat - the Joule heat. We must not forget that the electrode is connected to the high voltage, so the entire heating circuit must be floating. The schematic diagram of the heating circuit can be seen in Fig. 3.

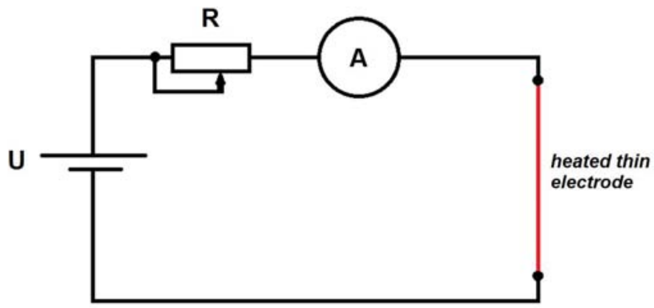


Fig. 3 The schematic diagram of the heating circuit

The main components of the heating circuit are a battery with the voltage $U$ = 12 V and a rheostat with maximum resistivity $R$ = 3 Ω. Of course it is very important to have a battery with enough capacity to assure the constant heating voltage during the measurement (in our case 16,2 Ah) and it is also very important to have rheostat, which can stand the passing current (in our case the $I_{max}$ = 13 A). With this circuit we are able to control the passing current and thus the temperature of the heated electrode. This simple setup works perfectly and we can see the detail of the small electrode being heated in the Fig. 4.

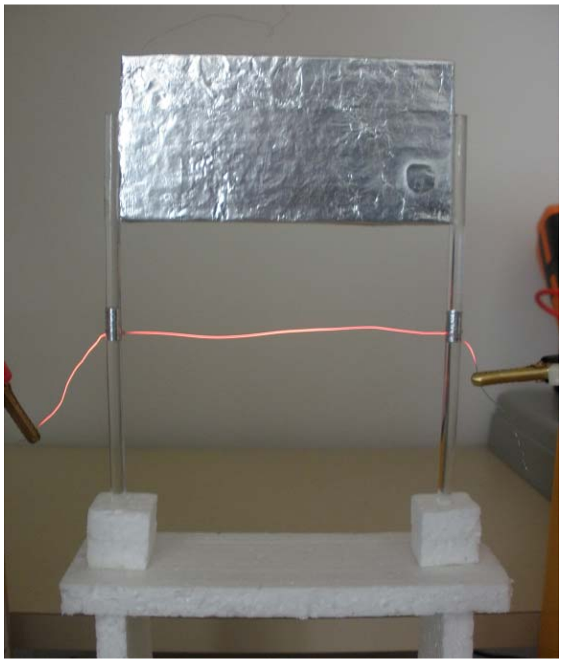

Fig. 4 Detailed view of the small electrode being heated

In this article we want to prove the hypothesis, that when the small electrode is heated, a greater amount of ions is generated and that is why we suppose the magnitude of the force will be greater. To measure the temperature of the thin wire which is connected to the voltage of several tens of kilovolts we would have to use some very special contactless measuring device – e.g. precise thermal imaging camera. It is obvious that the temperature is directly proportional to the passing current - higher current causes higher temperature of the wire. This means we do not need to know the exact temperature of the wire. So we will easily measure the current passing through the heated wire instead of its temperature.

## III. Experimental Results

The big electrode was grounded and the small electrode was connected to high voltage ($U$ = 19 kV). For this purpose we used regulated high voltage power source Glassmann 50 kV/10mA. Using a rheostat the heating current was set to several values and generated force was measured. In Fig. 5 we can see the results of the measurement done on our experimental apparatus.

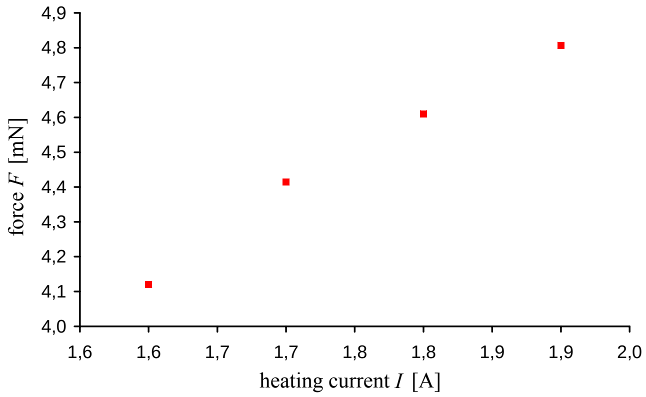


Fig. 5 Influence of the heating current on the magnitude of the force

The force $F$ without any heating (at the room temperature) was 2 mN. From Fig. 5 we can see that with the heating current the magnitude of the force is more than two times greater than without any heating. And it also shows that the greater the heating current (and as we know also higher temperature) the greater the magnitude of the force.

## IV. Conclusion

The purpose of this article was to experimentally prove the ionic mechanism of the Biefeld-Brownian force. The high temperature of the small electrode may have in general two effects. Firstly the high temperature of the wire heats up the surrounding air. It generates a cylinder of heated air, where the molecules have higher root-mean-square velocity and so are much more easily ionised. And secondly the high temperature of the wire may cause thermal emission of the electrons. Their presence might cancel the influence of the first effect due to positive ion neutralisation. But thermal emission may occur only if the heated electrode is negative. In our case the electrode is highly positive, so we can ignore this effect. Thus the experimental results prove beyond all doubt the hypothesis and confirm the ionic principle of the Biefeld-Brownian force.

## Acknowledgment

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