An Investigation into the Application of Biefeld Brown Effect on Flight

Conor Lawrence
Department of Electrical Engineering
Otago Polytechnic
Dunedin, New Zealand
lawrecp1@op.ac.nz

William Phipps
Department of Electrical Engineering
Otago Polytechnic
Dunedin, New Zealand
william.phipps@op.ac.nz

***Abstract*— It has been previously demonstrated that thrust can be produced in asymmetrical capacitor configurations when exposed to high voltage in what is known as the Biefeld-Brown effect. One example of such a device that utilises this effect is called an ionic flyer. The device has no moving parts, no combustion emissions and near silent. The Biefeld-Brown effect causes the flyer to be able to float in the air. The thrust that causes the device to float is created by the application of high voltage dc across a capacitor configuration resulting in an ionic wind, creating a net force from the negative toward the positive terminal. An investigation is undertaken to determine if the Biefeld-Brown effect could be used to create a lifting effect on an aircraft wing and as such aid flight. A model aerofoil wing was tested in a wind tunnel under the application of high voltage dc in order to reproduce the Biefeld-Brown effect. This paper outlines the tests that were conducted in the wind tunnel on a wing aerofoil model, as well as the empirical measurements taken. Results are analysed and arguments presented on the potential benefits of using the Biefeld-Brown effect on fixed wing aircraft.**

Keywords—Biefeld-Brown effect; ionic propulsion; high voltage; aircraft flight.

I. Introduction

The Biefeld-Brown effect was discovered by Paul Alfred Biefeld and Thomas Townsend Brown the 1920's [1]. They claimed that if a capacitor were to be charged up to high dc voltages, it would create a thrust from the negative to positive terminal. For the Biefeld-Brown effect to take place, two electrostatic forces and a neutral fluid are needed. Ions are generated within the neutral fluid due to the presence of an applied electric field between the two electrostatic body forces. The ions collide with neutral fluid molecules unaffected by the electric field. These collisions are what generate an ionic wind (Fig. 1). The resulting force on the electrodes generates a net thrust in the opposing direction to the direction of ion flow, without moving parts or gas emissions [2].

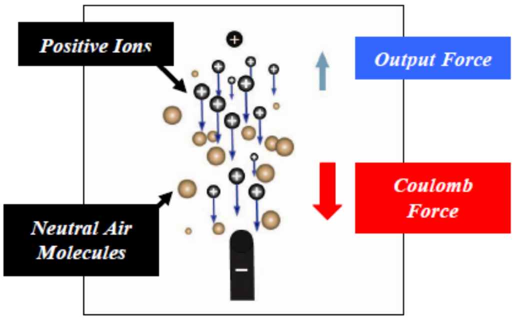

Fig. 1 Microscopic view of Biefeld-Brown effect (Chung & Li, 2007)

The ionic wind is generated by the corona discharge when a high voltage exists between a sharply pointed electrode and a larger radius ground electrode. It is characterized by a high voltage and low current. A typical application of the Biefeld-Brown effect is the ionic lifter which uses ionic momentum exchange to provide thrust [3]. The design is that of an asymmetrical capacitor consisting of an emitter and collector. The emitter consists of a thin wire that is connected to the high voltage positive. The collector is typically made of foil and is rounded at the top. The ionic flyer is considered as a capacitor with two asymmetrical electrodes and air as the dielectric. The ionic flyer floating under the Biefeld-Brown effect can be seen in Fig. 2.

Fig. 2 Ionic flyer under Biefeld-Brown effect

The variation of corona discharge current with applied voltage of the ionic flyer is very similar to that of an electrical precipitator [3] and is shown in Fig. 3.

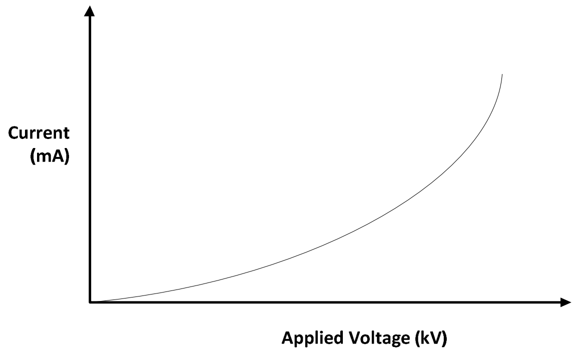

Fig. 3. Corona discharge characteristic

Previous studies have been conducted on ionic thruster performance analytically [4] and experimentally [5] and have shown to have a thrust to power ratio relative to a gas turbine engine. It was however concluded that the use of an ionic wind for propulsion alone does not currently have practical application due to scalability limitations [6].

This paper describes a novel application of using high voltage to generate ionic wind flow as a means to aid aircraft flight by introducing a lift effect. The paper outlines the tests that were undertaken in the wind tunnel on a wing aerofoil, as well as the empirical measurements taken. Results are analysed to determine the potential benefits, with conclusions and future recommendations discussed.

II. Experimental Setup

The ionic wind is the creation of movement of air by means of a corona discharge. An aerofoil wing was constructed out of polystyrene and has a wire across the leading edge of the wing which is positively charged, and the trailing edge of the wing was covered with foil and received the negative charge. This produces the asymmetrical capacitor configuration and produces the Biefield-Brown force when the high voltage dc is applied (Fig. 4).

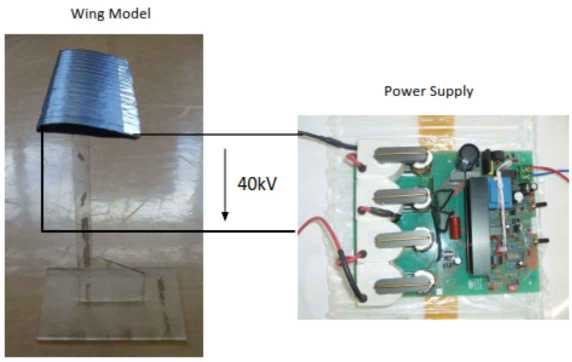

Fig. 4 Experimental setup to generate corona discharge across wing

A. Power Supply

The power supply used has a flyback type converter topology a shown in Fig. 5. The converter works by varying the duty cycle of the Mosfet switch which varies the output voltage. When the switch is on the current ramps up in the primary and energy is built up in the transformer core. When the switch is off the energy is dumped into the secondary allowing the voltage to rise in the secondary. The transformer is a step up which causes high voltage to be generated at the output. The power supply has a maximum output voltage of 60kV. At 40kV the power supply outputs around 24W used to charge the wing.

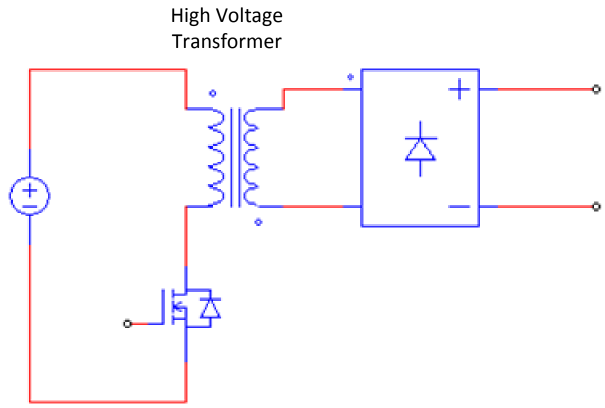

Fig. 5 Basic flyback converter

B. Wind Tunnel

The wind tunnel is an open indraft type construction which draws in air from the laboratory and out through the back (Fig. 6). It is powered by a 2kW fan which produces a maximum wind speed of 30km/h. The tunnel has a length of 4m and the test section is 42cm square.

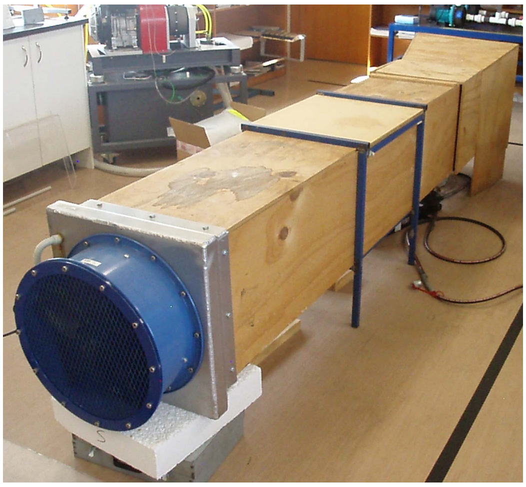

Fig. 6 Wind tunnel

C. Lift and Drag Measurement

The lift measurement was performed by using a scale and measuring the changes in the weight. The wing is mounted on a stand designed by the first author and cut out of perspex using a laser cutter. The stand sits on the scale at the bottom of the wind tunnel as seen in Fig. 7. The scale has a resolution of 0.1g and a maximum weight of 5kg.

Fig. 7 Lift measurement setup

The drag was measured using a design developed which uses a vertical swinging action that applies a force on a vertical scale so that as the drag increases so do the scale readings (see Fig. 8).

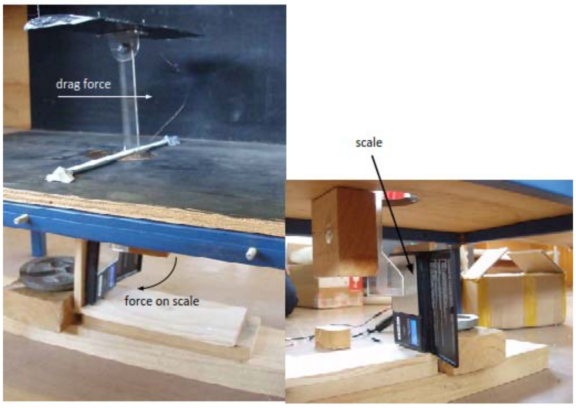

Fig. 8 Setup for drag measurement

III. RESULTS

The wing was placed in the wind tunnel and a voltage of 40kV was applied across the wing. Tests were carried out at various wind speeds and angles of the wing. The results are shown and discussed in this chapter.

A. Lift Measurements

The wind speed was increased incrementally from 2ms to 7ms and at each point lift was measured with no voltage applied to the wing and with voltage applied. The angle of the wing to the horizontal plane called the angle of attack α was increased and the experiment repeated. The lift force was detected by a drop in the weight reading on the scales.

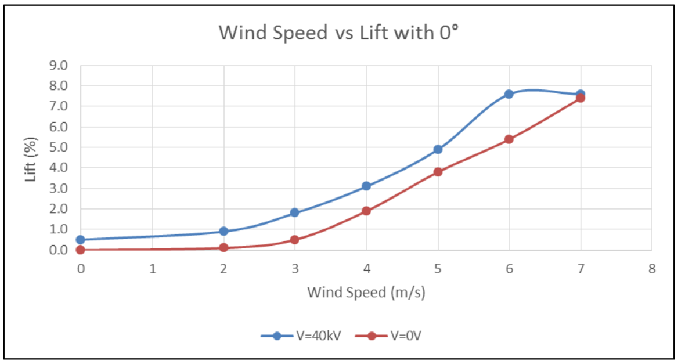

Fig. 9 Percentage increase in lift with $\alpha=0^0$

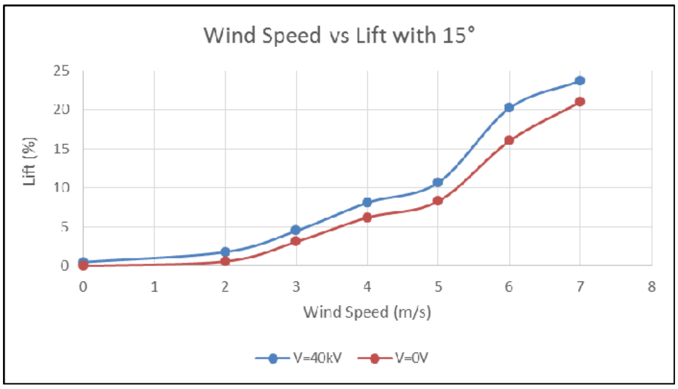

Fig. 10 Percentage increase in lift with $\alpha=15^0$

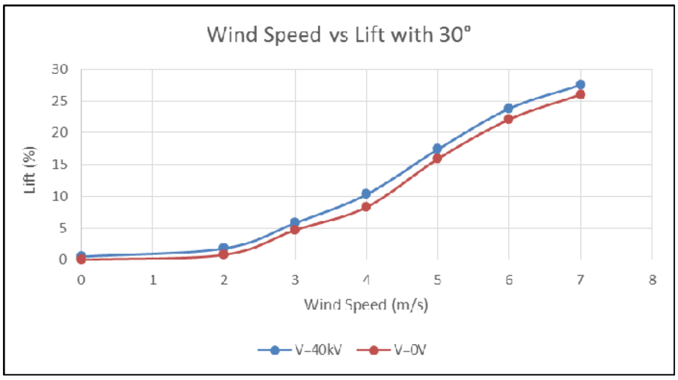

Fig. 11 Percentage increase in lift with $\alpha=30^0$

As can be seen in Figures 9 to 11, with the application of 40kV across the wing, one can see there is in an increase in the lifting force exerted on the wing. The graphs show the percentage increase in lift force versus the wind speed. Having $\alpha=0^0$ it was found that there was a maximum 2.2% increase in lift, with $\alpha=15^0$ a maximum of 4.2% increase was achieved, and at $\alpha=30^0$ an increase of 2% was observed. Hence, there is a clear increase in the lift upon the application of high voltage corona wind.

B. Drag Measurements

The drag was measured by applying a fixed 7m/s wind speed through the tunnel and measuring the horizontal drag force exerted by the wing on a scale at varying angles of attack. The percentage change in drag at each angle when voltage is applied is shown in Fig. 12.

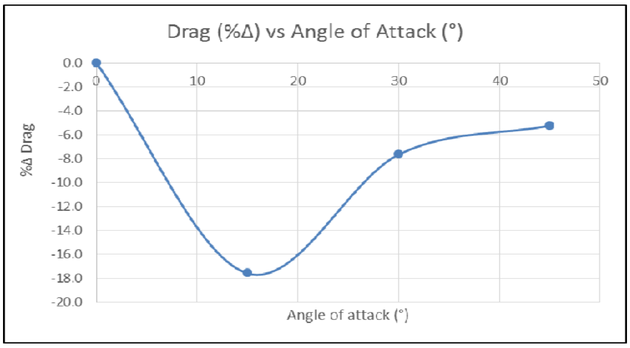

Fig. 12 Drag vs angle of attack

As the angle of the wing is increased so the drag force is reduced reaching a maximum of 17.6% reduction at an angle of 15^0. As the angle is further increased the drag begins to increase and at the angle of 45^0 a 5% drag reduction occurs.

IV. DISCUSSION

The Biefeld-Brown effect has two phenomena associated with it. The first is the creation of an ionic wind which flows from the positive electrode to the negative. The second is the creation of a net force from the negative to the positive. An investigation was conducted to determine if these phenomena could be used to improve the aerodynamic performance of a wing structure.

A wing generates lift due to Bernoulli's principle, which states that if air speeds up the pressure is lowered. Thus, a wing generates lift because the air goes faster over the top creating a low pressure, and thus lift occurs.

It was found that accelerating a stream of charges across the top of the wing from the leading to trailing edge generated an ionic wind. This ionic wind caused the increased lift that was measured. The increase in lift was varied and depended on the angle of the wing. A lift increase between 2-4% was found. A further increase in the lift would be achievable with an increase in applied voltage to just below the point of corona breakdown.

The drag experiment showed that there was a significant decrease in drag as angles increase with the drag reducing by almost 20% at 15^0. As the angle increased further the natural drag starts to increase as expected, however, the results show that this drag is reduced when voltage is applied. This can be explained in terms of the forward thrust that takes place as a consequence of the Biefeld-Brown effect, and is also what causes the ionic flyers to hover, as discussed in the introduction.

V. FUTURE WORK

Future work would be to see how this could be applied to gliders as an aid to artificially generating lift. Also, further tests could be done on multi stage electrodes placed across the wing to investigate performance. Other applications that warrant additional investigation are the energizing of the two aircraft wings independently in order to aid steering, as well as aircraft performance characteristics under supersonic conditions with the application of the Biefield-Brown effect.

Further research that is planned is the testing of the Biefeld_Brown effect on a kitset aircraft being developed by Otago Polytechnic (Fig. 13). This could determine whether this propulsion can result in a better flight performance and reduced fuel consumption.

Fig. 13 A plane being constructed by Otago Polytechnic students

VI. CONCLUSION

A new method to aid propulsion has been proposed that utilizes a capacitor configuration that when exposed to high voltage produces thrust, known as the Biefeld-Brown effect. This asymmetrical capacitor configuration was applied to an aerofoil wing.

When supplied with 40kV at varying angles of attack, the wing's performance was tested in a wind tunnel to measure lift and drag. These results were compared to the wing's performance without power supplied to gain an understanding of how the Biefeld-Brown effect affects air flow on the wing. It was found that when every angle of attack was tested, power supplied to the wing resulted in an improvement in lift. As the angle of the wing is increased, the drag force is reduced too. It can be concluded that the wing's performance was improved as a result of the Biefeld-Brown effect.

ACKNOWLEDGMENT

I would like to thank Otago Polytechnic for giving me the opportunity to attend the IYCE conference as well as to Graham Harris of Ara Institute of Technology for providing the wing models.

REFERENCES

[1] T.T. Brown, "Electrokinetic Apparatus", U.S. Patent No.2949550, 1960.

[2] C Gilmore and S. Barrett, "Electroaerodynamic thruster performance as a function of altitude and flight speed", AIAA Journal, vol. 56, No. 3, pp. 1105-1117, March 2018.

[3] C. Chung and W. J. Li, "Experimental studies and parametric modeling of ionic flyers, IEEE international conference on advanced intelligent mechatronics, pp. 1-6, Sep.2007.

[4] L. Pekker, M. Young, "Model of ideal electrohydrodynamic thruster", journal of propulsion and power, Vol. 27, No. 4, 2011.

[5] E. Moreau, E, Bernard, N. Alicalapa and A. Douyere, "Electrohydrodynamic force produced by a corona discharge between a wire active electrode and several cylinder electrodes: application to electric propulsion", journal of electrostatics, Vol. No.76.

[6] J. Wilson, "An investigation of ionic wind propulsion", ASRC Aerospace Corporation, Cleveland, Ohio, 2009. [Online]. Available: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20100000021.pdf