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Electric Plasma Jet Engine – A Clean Aircraft Propulsion Power Plant

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***Abstract*---Electric plasma jet engines was defined and its necessary components explain. It was found out that simple experiments can be conducted in a laboratory to experience the behavior of plasma jet engine. Furthermore, it was clearly stated that though plasma jet engines can provide sufficient thrust just as a fossil fuel-based jet engine, it is a lot safer, clean and cheap and more reliable to run a jet engine on plasma. Recommendation was also made on further research especially in the area of temperature, where plasma engine jet engine temperature need to be dropped way below 1000℃.**

***Keywords*---Jet engine, Plasma jet engine, Thrust, Clean environment, Microwave power, Jet propulsion.**

I. Introduction

Human beings have depended for long on fossil fuels as primary source of energy, especially in the area of transportation. However, fossil fuels are both depletable unsustainable and produces toxic gases as byproduct, leading to diverse respiratory problems and eco-destruction due to global warming [1]..

Electric Plasma Jet Engine is a propulsion thruster that makes use of air plasma (fourth state of matter) induced by microwave ionization. This engine utilizes basically air and electricity to produce high temperature pressurized plasma for jet propulsion. Using simple experiment to determine how this device works, as carried out by a team of researchers at the Institute of Technological Sciences, Wuhan University, China, measurement of the lifting force and jet pressure at various settings of microwave power and the air flow rate can be ascertained. Such carbon emission free thruster could potentially be used as a jet thruster in the atmosphere [2].

1.1 How Plasma Jet Engine Works

Against fossil fuel, plasma jet engines use electricity to create propulsion; they do so by generating electromagnetic fields. This process compresses and excites certain gases such as air or argon into a plasma (a hot, dense ionized state of matter similar to that inside a fusion reactor).

Plasma jet engines are usually designed to work in vacuum or low-pressure environments where they would need to carry a gas supply alongside. However, Göksel's and his team has found a way to produce plasma jet engines that can operate at a pressure of one atmosphere, that can reach speeds of up to 20 kilometers in a second. "The team used a rapid stream of nanosecond-long electric discharges to fire up the propulsion mixture. A similar technique is used in pulse detonation combustion engines, making them more efficient than standard fuel-powered engines [3].

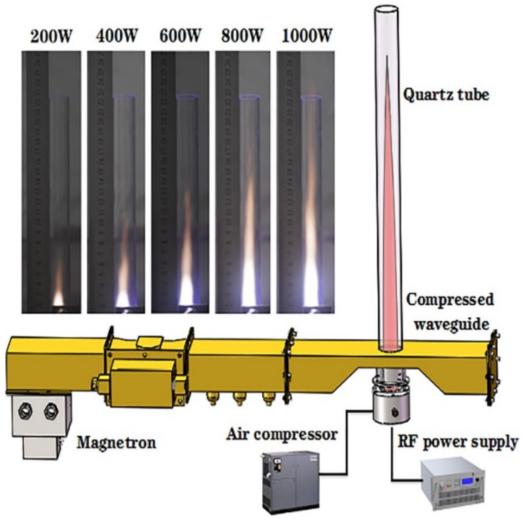

Fig. I: A schematic diagram of a prototype microwave air plasma thruster [5]

Figure I is a device that readily ionizes compressed air by running it over electrodes (positive ion accelerates through electrodes), forcing the mixture through a specifically designed tube. This mixture is recognized as plasma, and it interacts with a waveguide- a pipe that is being used in carrying magnetron generated microwaves. This pipe continually gets narrower as it gets closer to the quartz tube.

The microwave meets the low temperature plasma at the narrowest point, and at their greatest intensity. When this happens, the microwaves cause charged particles in the plasma to oscillate wildly, releasing energy at a stunning 1000℃ of heat, creating thrust for propelling the jet.

II. JET AIRCRAFT PROPULSION

Jet propulsion demonstrates in practice the Isaac Newton's third law of motion, the law of action and reaction. A jet aircraft engine produces thrust by rapidly expelling fast moving stream of hot gas to the rear of the aircraft, while the resulting opposite effect propels the aircraft forward [9]. The propelling force is the most important aspect in the design and operation of aircraft/spacecraft mission. Every major technological breakthrough in propulsion and associated system has redefined the frontiers of aerospace sciences. The urge to improve propulsion systems keeps engineers and scientist busy alike till this day and will continue to do so in the future [4].

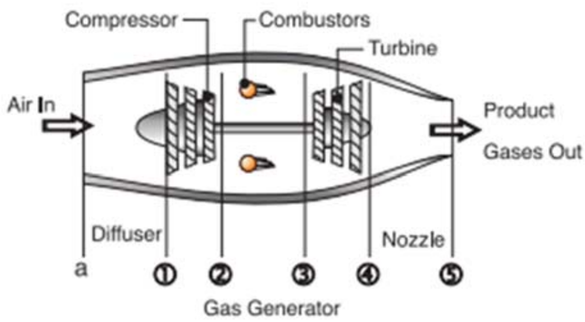

Fig. II: major parts of a typical jet engine

From figure II, air sucked into the engine from the air intake opening is compressed inside the compressor to between three (3) to twelve (12) times its original pressure. As fuel is introduced into the combustion chamber, the air is burned and the temperature of the fluid mixture is raised to about 1,100°F to 1,300° F. The resulting hot air is passed through a turbine, which drives the compressor. With an efficient turbine and compressor, the pressure at the turbine discharge will be about two times atmospheric pressure. This excess pressure is channeled to the exhaust nozzle and expelled to produce a high-velocity stream of gas which results to thrust.

Jet engine thrust is characterized by the mass flow of propellant and an effective exhaust velocity. That is [6].

$$V_{eff} = V_e \left[1 + \frac{1}{\gamma_e M_e^2}\left(1 - \frac{p_\infty}{p_e}\right)\right] \quad (2.0)$$

V_{eff} = Effective velocity

V_e = Exit velocity

p_∞ = Ambient pressure

p_∞ = Exit pressure

III. Effects Of Jet Engines Pollution

Gas turbine or simply jet engines have become the major prime movers in aircraft transport these days. Today, gas turbine engines are widely used in most places related to aviation.

Extensive studies, such as energetic flight performance, economic, environmental, safety, and controls have been performed to evaluate the jet aircraft engines and propulsion systems of aircrafts. For environmental based studies, it was realized that turbine engines emissions contribute only little proportion of the total global emissions. This constitutes 2.6% for CO_2 and about 3% for Nitrogen based pollutants. Furthermore, due to these pollutions, the ozone depletion and CO_2 create negative effects on both the ecosystem and the health of humans.

Another damning effect of expelled jet fume is global warming; this causes climate changes because a change in the amount of CO_2 causes changes in atmospheric temperature. On an average, the quantity of CO_2 is 385 ppm (parts per million), compared to the amount of 280 ppm in the 17th century. From thence till now, atmospheric temperature has risen by approximately one degree. According to the International Civil Aviation Organization (ICAO), the rate of carbon emissions from aviation has increased from 2.5% to 3% in recent years. The production of CO_2 from aviation has increased each year with growth in population. The conclusion in simple linear regression, which is approximately 90%, shows that aviation CO_2 production is equivalent to $137.98kg$ of CO_2 per person as at 2012, and will continuously increase by an annual average factor of $2.19kg$.

IV. Organization Of Work

The remaining part of the paper is organized as follows: section 5.0 explicitly describes work relating to this one, identifying the gaps this research paper attempts to fill. Section 6.0 gives details of the materials and methods applied to clearly prove that the development and use of plasma jet engines will help mitigate jet fume-based pollution. The benefits and contributions of this proposed techniques to knowledge, conclusion as well as suggested work for researchers in the future are stated also.

V. Related Work

Peter Bjarnholt did some work on how all-electric engines will take over fossil fuel powered aircraft engines due to economic and environmental concerns. The research identifies limiting factors in achieving the development of an electric powered passenger jet airplane, and also predicted the range that can be achieved and possible attainable future of such development. A literature study was done to find the necessary performance data for all required components. To analyze the performance of an electric propulsion system, the paper referenced Boeing 787-8 as sample plane.

Using Piano-X, a simulation for the performance of the aircraft under different conditions was done so as to obtain data for fuel consumption and performance. From experiment, in terms of gravimetric power density, electric motors and power electronics were found to have about the same performance as a modern turbofan engine. The results also proved that these batteries have energy density of only about $250wh/kg$. Peradventure, if battery technology improves significantly, airplanes can travel up $1400km$, as compared to the popular $600m$ which is currently attainaible [7]

The paper was written with a certain electric motor in mind. This motor is the **Emrax 268 motor**.

Fig. III: Emrax 268 motor

S/NO	PERFORMANCE METRIC	VALUE	UNIT
1	Continuous Mechanical Power	100	kW
2.	Peak Mechanical Power	200	kW
3.	Weight	20.3	kg
4.	Power to Weight Ratio	5, 10	-
5.	Electrical Efficiency	93 to 98	%

Fig. IV: Emrax 268 Motor Parameters

Unfortunately, the related work does not consider the use of plasma to power jet engines. That is the gap being considered in this work.

VI. Methodology

A propulsion thruster that makes use of air plasma induced by microwave ionization is proposed. A home-made device to measure the lifting force and jet pressure at various settings of microwave power and the air flow rate is built. The experiment aims at demonstrating that, given the same power consumption, a plasma jet propulsion pressure is comparable to that of conventional fossil fuel jet engines.

For an experiment such as this, plasma can be generated in the laboratory using an electric arc, microwave cavity, laser, fire flame, or discharging high-voltage needle. Experimentally, a simple prototype plasma jet thruster can generate up to $10N$ of thrust at $400W$ power using 0.5 l/s airflow. This corresponds to the lifting force of $28N/kW$, yielding a jet pressure of $2.4exp104N/m^2$. At a higher microwave power or greater airflow, propulsion force and jet pressures comparable to those of commercial airplane jet engines can be achieved. A typical plasma jet propulsion experiment is as shown in figure (V) [8].

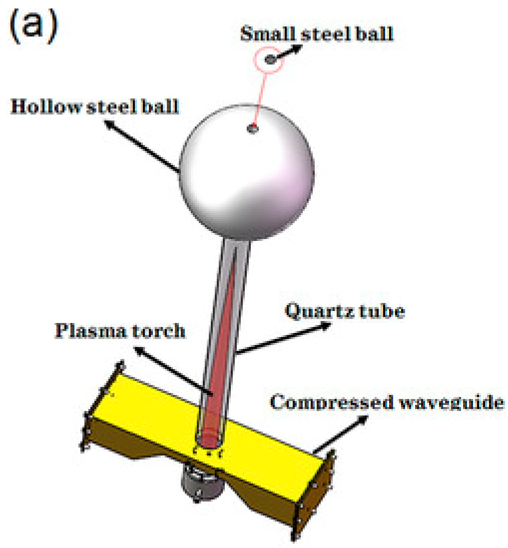

Fig. V: Simple electric plasma jet propulsion setup

Even in the absence of microwave power, the injected compressed air can provide some propulsion to the steel ball. Therefore, when calculating the net propulsion force (F_{net}) generated purely by the plasma jet, it is necessary to subtract the F_0 propulsion contribution that is present in the absence of microwave irradiation. Thus, the net propulsion force is given by:

$$F_{net} = F - F_0 = (M - M_0)g \quad (6.0)$$

Where,

F_{net} = Net propulsion force

F_0 = Propulsion force present in the absence of microwave radiation

M_0 = Critical steel ball weight obtained in the absence of the microwave irradiation

M = Critical steel ball weight obtained in the presence of microwave irradiation

The total pressure generated by the air jet plasma becomes:

$$P = \frac{F}{\pi R^2} \quad (6.1)$$

Where, R = inner diameter of quartz tube.

From the given equations, the net jet pressure becomes:

$$P_{net} = \frac{(F - F_0)}{\pi R^2} \quad (6.2)$$

The threshold weight at which the steel ball begins to vibrate, corresponding to the jet propulsion force of the plasma jet under different microwave power settings and airflow rates was measured. Figures VI indicates the total jet propulsion force, with some injected air with but zero microwave power.

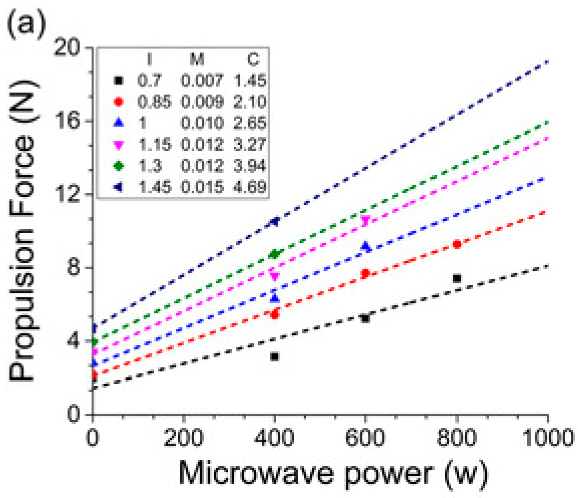

Fig. VI: Jet propulsion force with zero microwave power

Also, figure VII shows net pressure contribution with zero air and zero microwave power.

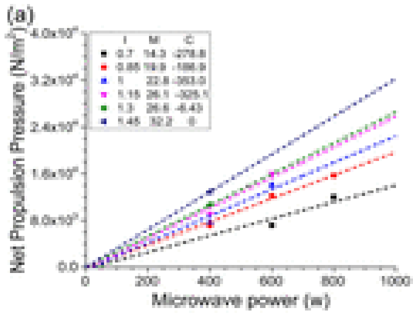

Fig. VII: Jet propulsion force with zero microwave power

VII. BENEFITS AND CONTRIBUTIONS OF PROPOSED TECHNIQUES

This work is beneficial not just in the area of research but also in the area making the universe a more habitable planet to live in.

Some benefits of the proposed techniques are:

i. Maintaining a clean, safe and carbon pollution free environment.

ii. Providing quieter jet aircrafts.

iii. Proposing long lasting and cheap energy source for jet aircrafts.

iv. Suggesting and opening up a new area of research.

VIII. CONCLUSION/FUTURE WORK

From the discussions made and details provided, it has been clearly deduced that electric plasma jet aircrafts are futuristic possibilities. Variables can be inputted to make necessary calculations.

As recommendation for future work, further experiments should be carried out particularly in the area of cooling electric plasma jet engines way below the current experimental $1000°C$ mark.

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