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Electron Air Hypersonic Propulsion

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Abstract

Aviation, in general, and aerospace in particular needs new propulsion systems which allow the craft to reach high speeds by cheaper and more efficient methods. Author offers a new propulsion system using electrons for acceleration of the craft and having a high efficiency. As this system does not heat the air, it does not have the heating limitations of conventional air ramjet hypersonic engines. Offered engine can produce a thrust from a zero flight speed up to the desired space apparatus speed. It can work in any planet atmosphere (gas, liquid) and at very high altitude. The system can use apparatus surface for thrust and braking. For energy the system uses high voltage electricity which is not a problem if you have an appropriate electrostatic generator connected with any suitable engine.

Key words: Electron propulsion, EABP, hypersonic propulsion, space propulsion.

Introduction

Currently, turbo-rocket engines are widely used in aviation. Although they are good for subsonic speed, they are worse for small ($M < 2 \div 3$) supersonic speed and has tremendous difficulties achieving hypersonic speed ($4 < M < 6$). The current designs of ramjet hypersonic engines using high temperature compressed air are limited because current materials cannot withstand any greater temperature. Another significant limitation is that aircraft must use complex expensive hydrogen fuel [1]-[17].

A **jet engine** is a reaction engine that discharges a fast moving jet which generates thrust by *jet propulsion* in accordance with Newton's laws of motion. This broad definition of jet engines includes turbojets, turbofans, rockets, ramjets, and pulse jets. In general, most jet engines are internal combustion engines.

In common parlance, the term *jet engine* loosely refers to an internal combustion air breathing jet engine (a *duct engine*). These typically consist of an engine with a rotary (rotating) air compressor powered by a turbine ("Brayton cycle"), with the leftover power providing thrust via a propelling nozzle. These types of jet engines are primarily used by jet aircraft for long-distance travel. Early jet aircraft used turbojet engines which were relatively inefficient for subsonic flight. Modern subsonic jet aircraft usually use high-bypass turbofan engines which offer high speed with fuel efficiency comparable (over long distances) to piston and propeller aeroengines [18].

Electrostatic generators operate by using manual (or other) power to transform mechanical work into electric energy. Electrostatic generators develop electrostatic charges of opposite signs rendered to two conductors, using only electric forces, and work by using moving plates, drums, or belts to carry electric charge to a high potential electrode. The charge is generated by one of two methods: either the triboelectric effect (friction) or electrostatic induction.

Innovations

One simple version of the offered electronic ramjet propulsion engine (EABP) is shown in fig.1. Engine contains the tube. The ejectors of electrons 2 are installed in the entrance of the tube. The collector of electrons (grille) 3 is installed in the end of tube. The electric circle having the battery (electrostatic generator) 4 and regulator of voltage 7 connects the ejector and grille.

The engine works the following way. The ejectors eject the electrons into tube. The strong electric field between injectors and grill moves them to grill. Electrons push (accelerate) the air to tube exit. When the electrons reach the grill, they enter the grill and close the electric circuit. The accelerated air (air jet) with high speed flows out from engine and creates the thrust. In correct design engine this thrust may be enough for moving the craft.

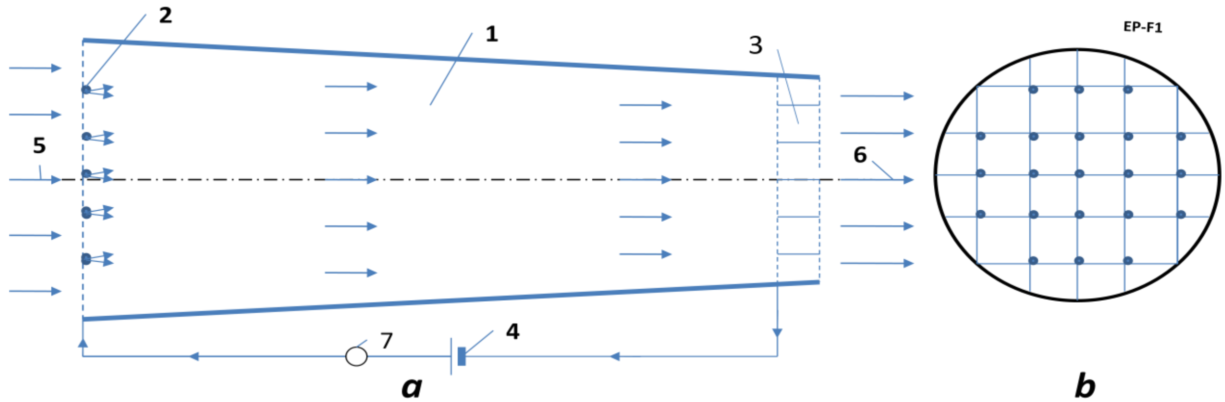

Fig.1. Electron ramjet engine (EABP). ***a*** – side view, ***b*** – forward view. *Notations:* 1 – engine; 2 – injector of electrons; 3 – collector of electrons; 4 – electric issue; 5 – enter air; 6 – exit air jet; 7 – regulator of an electric voltage (electron regulator).

The proposed idea of a propulsion engine has many versions. One of them is shown in fig. 2a. That is a conventional fuselage or wing (in fig. 2a it is shown the gross section of the wing). The electron injectors are installed in beginning of the fuselage (wing) surface. The collectors are installed in the end of the fuselage/wing. The electrons accelerate the air around the flying apparatus and the electric forces produce the thrust.

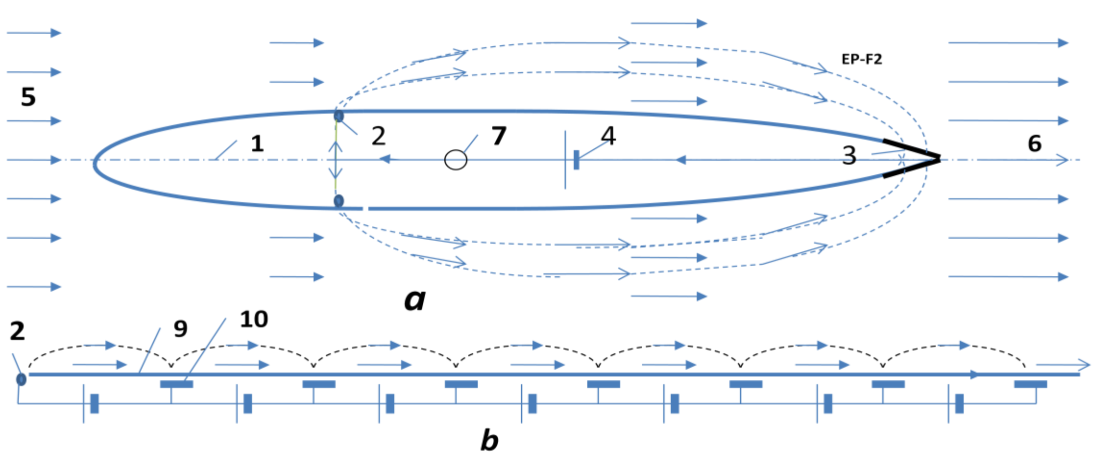

Fig.2. Outer Electron ramjet engine (EABP). ***a*** – side view of the fuselage or a gross-section of wing, ***b*** – surface electron engine. *Notations:* 1 – fuselage or wing; 2 – injector of electrons; 3 – collector of electrons; 4 – electric issue; 5 – enter air; 6 – exit air jet; 7 – electric (electron) regulator; 9 –surface (isolator) of fly apparatus; 10 – electric plate.

One possible electric schema of the proposed engine, shown in fig. 3, has an additional closed loop electric circles which allows extracting the electrons from main electric circle and collecting electrons from air flow to back into main circle, to heat the electron ejectors (cathodes) if it is necessary.

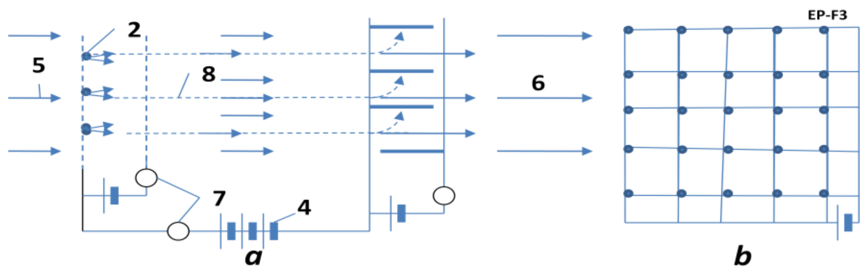

Fig.3. The electrical circuit of one version EABP engine. Notations are same with figs. 1 – 2. ***a*** is side view, ***b*** is forward view.

Principal differences the offered EABP engines from known propulsion systems/engines.

From air-breathing engine:

1. Air-breathing propulsion engine as any heat engine compresses and HEATS the air.
   The electronic propulsion engine does not compress and does not heat the entered air.
2. Air-breathing propulsion engine expends liquid fuel.
   The electronic propulsion engine expends electric energy.

From rockets:

1. Rocket expends fuel.
   The electronic propulsion engine expends electric energy.

From the electric rocket engine.

1. The electric rocket engines and the electronic propulsion work in different mediums. The electronic propulsion uses the outer medium (atmosphere, gas, liquid, etc.) while most electric rockets may work only in vacuum.
2. The electric rocket engines can use only positive ions.
   The electronic propulsion system use only electrons.
3. The electric rocket engines expends the apparatus mass (for example, plasma).
   The electronic propulsion system does NOT expends the apparatus mass.

Advantages and disadvantages of the proposed electron propulsion system in comparison with the conventional air propulsion systems.

The suggested new propulsion principle has the following advantages and disadvantages in comparison with conventional air-breathing engine propulsion systems used at present time.

Advantages:

1. All current air-breathing propulsion engines as any heat engine compresses and HEATS the air. As the result the heat efficiency is about 30% or low.
   The electronic propulsion engine (EABP) does not compress and does not heat the entered air. His electric efficiency is about 100% which makes it 3 more times efficient.
2. All current the air-breathing engines has small efficiency in hypersonic speed ($3 < M < 5$), because the high compressed air has big temperature and current material cannot keep them. Conventional hypersonic engine is very complex, needs hydrogen fuel. There is no production of the hypersonic engine at present time although its research and design is doing about 20 years. For $M > 6$ the heat hypersonic engine cannot work.
   The electron engine not heat an air and can work at any speed. That means one may be used as a cheap space launcher and engine of the super speed aircraft.
3. The electronic engine is very simple and cheap.
4. The outer air ship surface may be used as engine. The aircraft may not have nacelles (moto-gondols). That means high aerodynamic efficiency of flight apparatus.
5. The outer surface electronic engine (fig.2b) may be used for creating the laminar boundary layer.

That means low (minimal) air friction and very high aerodynamic efficiency of flight apparatus.

6. The outer surface electronic engine (fig.2b) may be used for creating the high lift force. That means a low landing speed, decreasing the take-off and landing distances, VTOL aircraft.
7. The electron engines can work at very high atmosphere.
8. The EABP can works in any atmosphere and in other planets; space apparatus can use any matter of planets, asteroids and apparatus garbage in the EABP engine.

Possible Disadvantages:

1. Main disadvantage of electron propulsion engine: the aircraft needs strong high voltage electric power. This problem may be solved by connecting the conventional engine with static electric generator. The static electric generator is lightweight and cheap. Electrostatic generator must be researched and developed in order for it to produce high voltage direct electricity. One, although not suitable for use by population and industry, but the electrostatic generators are needed for electron propulsion engine needed in very high voltage (up 2 millions volts).

Theory of Electron Propulsion (EABP). Computation and Estimation.

1. Thrust of EABP. The thrust of the jet electron engine is (we use the Law of Impulse):

$$T = m\,(V_f - V) = m\Delta V, \quad m = \rho S V, \quad T = \rho S V \Delta V, \quad T_s = \rho V \Delta V, \quad (1)$$

where T is thrust, N; m is air mass passed through engine in one second, kg/s; V_f is an exit speed of air (medium), m/s; V is an entry speed of air (medium), (flight speed of the apparatus), m/s; ΔV is increasing of air (medium) speed into engine, m/s; ρ is air (medium) density, kg/m^3; S is ender area of engine, m^2; T_s is specific thrust of engine, N/m^2.

The energy A_t [J] getting by flight apparatus from thrust is

$$A_t = TVt\,, \quad (2)$$

where t is time, sec.

From other hand, the energy A_e [J] getting from of electric current is

$$A_e = UIt\,, \quad (3)$$

where U is voltage between entrance and exit of engine, V; I is electric current, A.

The heat efficiency of the EABP is close to 1, because no heating of air into engine (the increasing the speed of all air mass is in one direction by electric field).

That way

$$A_t \approx A_e\,. \quad (4)$$

From (1) – (4) and $I_s = I/S$ we get ($V \neq 0$)

$$T_s = \frac{U}{V} I_s\,, \quad \Delta V = \frac{U I_s}{\rho V^2}\,, \quad (5)$$

where I_s is density of electric currency about apparatus, A/m^2, ΔV is increasing air (medium) speed into engine, m/s.

Example 1. Let us take the $U = 10^6$ V, $I_s = 10$ A/m^2, flight speed $V = 200$ m/s, $\rho = 1$ kg/m^3. Then $T_s = 5\times10^4$ N/m^2 = 5 tons/m^2, $\Delta V = 250$ m/s.

Example 2. Let us take the $U = 4\times10^6$ V, $I_s = 100$ A/m^2, flight speed $V = 8000$ m/s, $\rho = 1$ kg/m^3. Then $T_s = 5\times10^4$ N/m^2 = 5 tons/m^2, $\Delta V = 6.25$ m/s.

The same way we can get the request power and getting thrust when the flight speed equals zero:

$$P_s = 0.5m\,\Delta V^2, \quad m = \rho\Delta V\,, \quad T_s = P_s/\Delta V\,, \quad P_s = 0.5\rho\Delta V^3\,, \quad T_s = 0.5\,\rho\Delta V^2\,, \quad (6)$$

where P_s is electric power for 1 m^2, W/m^2; ΔV is increasing air speed into engine, m/s;

m is air exemption mass passed throw engine in one second, kg/s;

Example 3. Let us take the $U = 10^6$ V, $I_s = 10$ A/m^2, exit speed $\Delta V = 100$ m/s, $\rho = 1$ kg/m^3. Then the start thrust is $T_s = 10^5$ N/m^2 = 10 tons/m^2 if the start power is $P_s = 10^7$ W/m^2.

2. Efficiency of Electron EABP engine.

Efficiency η of any jet (air flight) propulsion is production of two values: propulsion efficiency η_p and engine (cycle) efficiency η_e :

$$\eta = \eta_p \eta_e , \quad \text{where} \quad \eta_p = V/(V + 0.5\,\Delta V) . \qquad (7)$$

The flight efficiency for heat and electronic propulsion are same. They depend only on ΔV . But thermodynamic (cycle) efficiency of the heat engine is low about 25 ÷ 35%**.** The heat engine looses a great deal of energy from the hot exit jet. For high speed over $M > 3$ the conventional air rocket (jet) engine looses efficiency very quickly. The aviation designers try to use the hydrogen fuel, but after M > 5 the hydrogen fuel is also useless. The offered electronic jet engine accelerates air by electricity. It has efficiency close to 100% as the only loss of energy is the extraction of the electrons from cathode and ionizations of air molecules. This energy is about tens electron-volts (eV). The energy spent for acceleration of the air molecules by electrons/ions is hundreds of thousands of eV. That means the total efficiency of EABP is 3 times more than conventional air jet propulsion.

The second very important point: efficiency of EABP does not depend upon speed of apparatus.

The other advantages: we can make a very large entrance area of engine, we can use the fuselage and wings, stabilizer and keel of plane as engine.

3. Electron speed. The electron speed about the gas (air) jet may be computed by equation:

$$j_s = qn_-b_-E + qD_-(dn_-/dx) , \qquad (8)$$

where j_s is density of electric currency about jet, A/m^2; $q = 1.6\times10^{-19}$ C is charge of single electron, C; n_- is density of injected electrons (negative charges) in 1 m^3; b_- is charge mobility of negative charges, m^2/sV; E is electric intensity, V/m; D_- is diffusion coefficient of charges; dn_-/dx is gradient of charges. For our estimation we put $dn_-/dx = 0$. In this case

$$j_s = qn_-b_-E , \quad Q = qn , \quad v = bE , \quad j_s = Qv , \qquad (9)$$

where Q is density of the negative charge in 1 m^3; v is speed of the negative charges about jet, m/s.

The negative charge mobility for normal pressure and temperature $T = 20^o$C is:

In dry air $b_- = 1.9\times10^{-4}$ m^2/sV, in humid air $b_- = 2.1\times10^{-4}$ m^2/sV. (10)

In diapason of pressure from 13 to 6×10^6 Pa the mobility follows the Law bp = const, where p is air pressure. When air density decreases, the charge mobility increases. The mobility stregnth depends upon the purity of gas.

For normal air density the electric intensity must be less than 3 MV ($E < 3$ MV). Otherwise the electric breakdown may be:

If $v > 0$, the electrons accelerate the air into engine ($E > 0$ and engine spend energy). If $v < 0$, the electrons beak the air into engine ($E < 0$ and engine can produce energy). If $v = 0$ (electron speed about apparatus equals V), the electric resistance of jet into engine is zero.

Example 4. If $E = 10^6$ than $v = 200$ m/s.

4. Electron injectors.

There are some methods for getting the electron emissions: hot cathode emission, cold field electron emission (edge cold emission, edge cathode), photo emission, radiation emission, radioisotope emission and so on. We consider only the hot emission and shortly the cold field electron emission (edge cathodes).

The **hot cathode** emission computed by equation:

$$j_s = BT^2 exp(-A/kT) \,, \qquad (11)$$

where B is coefficient, A/cm^{2}K^2; T is catode temperature, K; k = 1.38×10^{-23} [J/K] is Bolzmann constant; A is thermoelectron exit work, eV. Both values A, B depend from material of cathode and its cover. The "*A"* changes from 1.6 to 5 eV, the "*B*" changes from 0.5 to120 A/cm^{2}K^2. Boron thermo-cathode produces electric currency up 200 A/cm^2. For temperature 1400 ÷1500K the cathode can produce currency up 1000 A/cm^2. The life of cathode can reach some years [19]-[20].

The edge cold emission. The cold field electron emission uses the edge cathodes. It is known that the electric intensity E_e in the edge is

$$E_e = U/a \,. \qquad (12)$$

Here a is radious of the edge. If voltage between the edge and nears net (anode) is U = 1000 V, the radius of edge a = 10^{-5} m, electric intensity at edge is the E_a = 10^8 V/m. That is enough for the electron emission. The density of electric current may reach up 10^4 A/cm^2 . For getting the required currency we make the need number of edges.

Summary and Discussion

The author proposed the principally new propulsion system (engine) using the outer medium (air) and electric energy. It is not comparable to conventional heat propulsion because the heat jet engine gets the thrust by compressing the air, burning the fuel into air, heating, accelerating the hot air and expiring the hot gas in atmosphere.

The offered EABP engine is accelerating the air (medium) by a principally new method – by electric field which does not need atmospheric oxygen and thus can work in any atmosphere of other planets. This engine does not require compressing and heating of medium and, as such, does not have limitations of high temperature, high flight speed and rare atmosphere.

This engine is also dissimilar to known space electric engines. The space electric engine takes an extracted mass from itself, ionizes it, and accelerates springing forward in a vacuum. It has very small thrust, works poorly into any atmosphere and works worse if the atmosphere has a high density. The EABP does not take the extracted mass, can work only in atmosphere and works better if the atmosphere has a high density.

The main disadvantage of the offered engine is the requirement of high voltage electricity. For getting the electricity may be used the conventional internal turbo engine connected with electro-statics generator. Electro-statics power generator is light-weight and produces high voltage electricity.

The researches having relation to this topic are presented in [1]-[17].

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