International Journal of Research and Innovation in Engineering Technology
Volume: 01 Issue: 10
ISSN: 2394 – 4854
Pages:11 – 16

IJRIET

APPRAISAL OF ANTIMATTER PROPULSION

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Abstract

Antimatter propulsion is the Holy Grail of space flight. When matter and antimatter react, the energy produced is several billion times larger than the thermomechanical energy resulting from burning a kilogram of a hydrocarbon fuel. In our paper we have explained about the usage of antimatter as fuel for the futuristic propulsion. Because the future of space exploration will require massive amounts of energy.

Keywords: Production of Antimatters, Preservation, WARP Propuslion System.

1. INTRODUCTION

Antimatter a material composed of antiparticles, which have the same mass as particles of ordinary matter but have opposite charge and other particle properties such as lepton and baryon number. Encounters between particles and antiparticles lead to the annihilation of both, giving rise to varying proportions of high-energy photons, neutrinos, and lower-mass particle–antiparticle pairs. Setting aside the mass of any product neutrinos, which represent released energy which generally continues to be unavailable, the end result of annihilation is a release of energy available to do work, proportional to the total matter and antimatter mass, in accord with the mass-energy equivalence equation, $E=mc^2$.

2. HISTORY

The history of antimatter begins in 1928 with a young physicist named Paul Dirac. From 1930, the search for the possible constituents of antimatter, antiparticles, began, and it has been the main influence behind a major scientific and technical evolution over the last 70 years. Dirac's equation could have two solutions, one for an electron with positive energy, and one for an electron with negative energy.

But in classical physics the energy of a particle must always be a positive number. Dirac interpreted this to mean that for every particle that exists there is a corresponding antiparticle, exactly matching the particle but with opposite charge. For the electron, for instance, there should be an "antielectron" identical in every way but with a positive electric charge.

He decided the tracks were actually antielectrons, each produced alongside an electron from the impact of cosmic rays in the cloud chamber. He called the antielectron a "positron", for its positive charge. In 1954, European physicists decided to create in

Geneva, Switzerland, a central, European laboratory, that they called CERN (CamseilEuropean pour la Recherché Nucleaire).

The first electron-positron collider was the "Anello d'Accumulazione" (AdA), built by Bruno Touschek in Frascati (Rome) in 1960. The biggest of all is CERN's Large Electron Positron (LEP) collider, which began operation in the summer of 1989 with a collision energy of 91.2 GeV.

The proton - antiproton collider, complementary to the studies and discoveries made by electron-positron colliders, unfortunately presented a much greater challenge. Since an antiproton (or proton) is almost 2000 times heavier than an antielectron (or electron), it takes a lot more energy to create them. It was also more difficult to collect antiprotons and store them long enough to make an antiproton beam circulate in a collider.

However, in the early 1980s, Simon van der Meer at CERN invented "stochastic cooling" - a technique that now made it possible to accumulate, concentrate and control antiproton beams. In 1982 the Low Energy Antiproton Ring (LEAR) appeared: it could decelerate the antiprotons coming from the PS to different intermediate energies, down to a few MeV.

In 1995 a team of German and Italian physicists (experiment PS210) succeeded for the first time in building up nine atoms of "anti-hydrogen": while in normal hydrogen an electron arbitrates around a proton, in such antiatoms a positron was made to orbit around an antiproton. The result was confirmed, by the end of 1996, by a team at Fermi-lab.

3. PRODUCTION OF ANTIMATTER

Antiparticles bind with each other to form antimatter just as ordinary particles bind to form normal matter. For example, a positron and an antiproton can form an anti-hydrogen atom. Physical principles indicate that complex antimatter atomic nuclei are possible, as well as anti-atoms corresponding to the known chemical elements. To date, however, anti-atoms more complex than the anti-helium have neither been artificially produced nor observed in nature. Antimatter in the form of anti-atoms is one of the most difficult materials to produce. Antimatter in the form of individual anti-particles, however, is commonly produced by particle accelerators and in some types of radioactive decay.

3.1 Natural Prodcution

Positrons are produced naturally in β+ decays of naturally occurring radioactive isotopes (for example, potassium-40) and in the interactions of gamma quanta (emitted by radioactive nuclei) with matter. Antineutrinos are another kind of antiparticle created by natural radioactivity (β− decay). Many different kinds of antiparticles are also produced by cosmic rays. Recent research by the American Astronomical Society has discovered antimatter (positrons) originating above thunderstorm clouds; positrons are produced in gamma-ray flashes created by electrons accelerated by strong electric fields in the clouds. Antiprotons have also been found to exist in the Van Allen Belts around the Earth by the PAMELA module.

Antiparticles are also produced in any environment with a sufficiently high temperature (mean particle energy greater than the pair production threshold). During the period of baryogenesis, when the universe was extremely hot and dense, matter and antimatter were continually produced and annihilated. The presence of remaining matter, and absence of detectable remaining antimatter, also called baryon asymmetry, is attributed to CP-violation: a violation of the CP-symmetry relating matter to antimatter. The exact mechanism of this violation during baryogenesis remains a mystery. Positrons can be produced by radioactive β+ decay, but this mechanism can occur both naturally and artificially.

Preliminary results from the presently operating Alpha Magnetic Spectrometer (AMS-02) on board the International Space Station show that positrons in the cosmic rays arrive with no directionality, and with energies that range from 10 GeV to 250 GeV, with the fraction of positrons to electrons increasing at higher energies. These results with interpretation have been suggested to be due to positron production in annihilation events of massive dark matter particles. Antiprotons arrive at Earth with a characteristic energy maximum of 2 GeV, indicating their production in a fundamentally different process from cosmic ray protons, which on average have only one-sixth of the energy.

3.2 Artificial Prodcution – Positrons

A laser drove electrons through a millimeter-radius gold target nuclei, which caused the incoming electrons to emit energy quanta that decayed into both matter and antimatter. Positrons were detected at a higher rate and in greater density than ever previously detected in a laboratory. Previous experiments made smaller quantities of positrons using lasers and paper-thin targets; however, new simulations showed that short, ultra-intense lasers and millimeter-thick gold is a far more effective source.

3.3 Antiprotons, Antineutrons, and Anti-Nuclei

An antiproton consists of two up antiquarks and one down antiquark (uud). The properties of the antiproton that have been measured all match the corresponding properties of the proton, with the exception of the antiproton having opposite electric charge and magnetic moment from the proton. The antineutron was discovered in proton–proton collisions at the Bevatron. In addition to antibaryons, anti-nuclei consisting of multiple bound antiprotons and antineutrons have been created. These are typically produced at energies far too high to form antimatter atoms.

3.4 Anti-Hydrogen Atoms

CERN announced that it had successfully brought into existence, nine anti-hydrogen atoms by implementing the SLAC/Fermi lab concept during the PS210 experiment. The experiment was performed using the Low Energy Antiproton Ring (LEAR), and was led by Walter Oelert and Mario Macri. Fermi lab soon confirmed the CERN findings by producing approximately 100 anti-hydrogen atoms at their facilities. The anti-hydrogen atoms created during PS210 and subsequent experiments (at both CERN and Fermilab) were extremely energetic ("hot") and were not well suited to study. To resolve this hurdle, and to gain a better understanding of anti-hydrogen, two collaborations were formed in the late 1990s, namely, ATHENA and ATRAP. In 2005, ATHENA disbanded and some of the former members (along with others) formed the ALPHA Collaboration, which is also based at CERN. The primary goal of these collaborations is the creation of less energetic ("cold") anti-hydrogen, better suited to study.

CERN activated the Antiproton Decelerator, a device capable of decelerating antiprotons from 3.5 GeV to 5.3 MeV — still too "hot" to produce study-effective anti-hydrogen, but a huge leap forward. In late 2002 the ATHENA project announced that they had created the world's first "cold" anti-hydrogen. The ATRAP project released similar results very shortly thereafter. The antiprotons used in these experiments were cooled by decelerating them with the Antiproton Decelerator, passing them through a thin sheet of foil, and finally capturing them in a Penning-Malmberg trap. The overall cooling process is workable, but highly inefficient; approximately 25 million antiprotons leave the Antiproton Decelerator and roughly 25,000 make it to the Penning-Malmberg trap, which is about 1⁄1000 or 0.1% of the original amount.

ALPHA announced that they had trapped 309 anti-hydrogen atoms, some for as long as 1,000 seconds (about 17 minutes). This was longer than neutral antimatter had ever been trapped before. ALPHA has used these trapped atoms to initiate research into the spectral properties of the anti-hydrogen. The biggest limiting factor in the large-scale production of antimatter is the availability of antiprotons. Recent data released by CERN states that, when fully operational, their facilities are capable of producing ten million antiprotons per minute. Assuming a 100% conversion of antiprotons to anti-hydrogen, it would take 100 billion years to produce 1 gram or 1 mole of anti-hydrogen (approximately 6.02×1023 atoms of anti-hydrogen).

3.4 Anti-Helium Atoms

Antihelium-3 nuclei (3He) were first observed in the 1970s in proton-nucleus collision experiments and later created in nucleus-nucleus collision

ISSN: 2394 – 4854
Pages:11 – 16

experiments. Nucleus-nucleus collisions produce anti-nuclei through the coalescence of antiprotons and antineutrons created in these reactions. In 2011, the STAR detector reported the observation of Antihelium-4 nuclei (4He).

4. PRESERVATION

Antimatter cannot be stored in a container made of ordinary matter because antimatter reacts with any matter, it touches, annihilating itself and an equal amount of the container. Antimatter in the form of charged particles can be contained by a combination of electric and magnetic fields, in a device called a Penning trap. This device cannot, however, contain antimatter that consists of uncharged particles, for which atomic traps are used. In particular, such a trap may use the dipole moment (electric or magnetic) of the trapped particles. At high vacuum, the matter or antimatter particles can be trapped and cooled with slightly off-resonant laser radiation using a magneto-optical trap or magnetic trap. Small particles can also be suspended with optical tweezers, using a highly focused laser beam.

5. PENNING TRAP

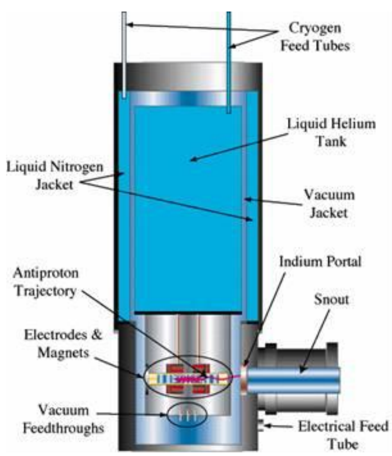

Figure: 1 Penning Trap

A Penning trap is a device for the storage of charged particles using a homogeneous static magnetic field and a spatially inhomogeneous static electric field. This kind of trap is particularly well suited for precision measurements of properties of ions and stable subatomic particles which have a non-zero electric charge. Recently this trap has been used in the physical realization of quantum computation and quantum information processing as well. The Penning trap has also been used in the realization of what is known as a geonium atom. Currently Penning traps are used in many laboratories worldwide. For example, they are used at CERN to store antiprotons.

6. WARP PROPULSION SYSTEM

A star-ship's Warp Propulsion System (WPS) consists of three major assemblies:

First, the matter/anti-matter reaction assembly (M/ARA) generates power from a controlled annihilation of matter and antimatter.

Second, the power transfer conduits carry the energy plasma from the reaction chamber to the warp engine nacelles; at this point, power to run the bulk of the ship's non-propulsive systems are accessed by the electro plasma system (EPS) taps.

Finally the plasma is directed to the warp engine nacelles, where it is used to create the subspace mechanics necessary for faster-than-light travel.

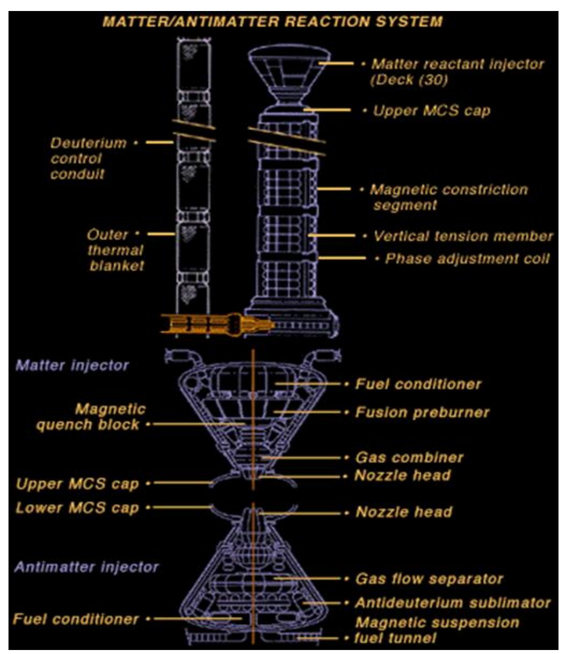

Figure: 2 Antimatter Reaction System

While a star ship carries "traditional" fusion reactor fuel as well, the bulk of ship's systems depends upon the WPS for their operation. One simple design is based on the NERVA nuclear rocket, with the nuclear reactor replaced with a tungsten heat exchanger core. The reaction products (both gammas and pions) would be stopped in the tungsten and the energy used to heat hydrogen gas passing though the heat exchanger. This engine would use 13 µg/s of antiproton fuel to produce a specific impulse of 1100 at a thrust level of4.4x105 N (100,000 lb) for a power level of 2.7 GW. Such an engine could take 100 tonnes of payload to Mars and back in six months (only three months each way) with a mass ratio of 4. By comparison, a LOX/hydrogen system would require a mass ratio of18 and would take 12 months to get there and 9 months to get back. AIM is Antimatter-Initiated Micro-fusion.Electric and magnetic fields continuously compress antiproton plasma while droplets containing D-T are injected into the plasma.The antiprotons annihilate with a fissile seed, which together heat the plasma.The resulting product is expelled out a magnetic nozzle to produce thrust.The Figure shows a profile model of an AIMS tar spacecraft, which uses the AIM system for propulsion. In the AIMStar engine, reaction traps, and antiproton storage are located behind the payload attached to a booster. When the burnout occurs the booster separates and only the payload continues on the mission.

7. COST

Scientists claim that antimatter is the costliest material to make. In 2006, Gerald Smith estimated $250 million could produce 10 milligrams of positrons (equivalent to $25 billion per gram); in 1999, NASA gave a figure of $62.5 trillion per gram of anti-hydrogen. This is because production is difficult (only very few antiprotons are produced in reactions in particle accelerators), and because there is higher demand for other uses of particle accelerators. According to CERN, it has cost a few hundred million Swiss Francs to produce about 1 billionth of a gram (the amount used so far for particle/antiparticle collisions).Several studies funded by the NASA Institute for Advanced Concepts are exploring whether it might be possible to use magnetic scoops to collect the antimatter that occurs naturally in the Van Allen belt of the Earth, and ultimately, the belts of gas giants, like Jupiter, hopefully at a lower cost per gram.

8. ADVANTAGES

Such an engine would be safer for the astronauts and for the environment, for several reasons: it would reduce the travel time to Mars, increasing safety for the crew by reducing their exposure to cosmic rays; the reactor would not be radioactive after its fuel is used; and there should be no risk to the public even if the reactor exploded during its launch because "gamma rays would be gone in an instant."

Antimatter propulsion would be if you wanted to send a probe to another star and have it get there within a human lifetime. For this type of mission, you can't use solar power or beamed energy, and you need a relativistic “Delta”, which means that the energy density of chemical or fusion or fission reactions is not high enough.

9. RESULT

Numerous conceptual studies have examined antimatter as a fuel for extra solar spacecraft. A full design effort is somewhat pointless at this stage, as at present we don't know how to manufacture, store, or manipulate large quantities of antimatter - the current cost of that gram of antimatter is roughly estimated at about a trillion US dollars.

10. CONCLUSION

The future of space exploration will require massive amounts of energy. The destruction that follows when antimatter and matter collide, may prove to be just the source of energy that is needed.

It would be possible to make trips to Jupiter and even beyond the heliopause, the point at which the sun's radiation ends. We could reach all of the planets within our solar system in a matter of days rather months and years.

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