Variable Specific Impulse Magneto Plasma Propelled SPACETUG/OTV

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***Abstract*: A desire to the space among all over the globe demands a new propulsion technologies in rockets and spacecrafts , and transferring payloads to International Space Stations (ISS) makes the space travel as a daily constituition .This research paper deals about designing a spacetug /Orbital Transfer Vehicle (OTV) to transmit a huge payload from one orbit to another orbit with different energy characteristics .It would be propelled by variable specific impulse magneto plasma VASIM This alternative way of propulsion system would drastically reduce the fuel consumption and space transit time ,the system provided very & variable thrust and exhaust velocities . The latest theoretical and experimental results,mission applications, system engineering,as well as the fist space experiment being planned for this technology are discussed in detail.**

Keywords: Spacetug, plasma, radiofrequency

I. INTRODUCTION

Research on the VASIMR engine began in the late 1970's, as a spin-off form investigations on magnetic divertors for fusion technology. A simplified schematic of the engine is shown in Figure1. Three linked magnetic stages perform specific interrelated functions. The first stage handles the main injection of propellant gas and its ionization; the second, also called the ''RF booster'' acts as an amplifier to further energize the plasma; the third stage is a magnetic nozzle, which converts the energy of the fluid into directed flow.

VASIMR is a radio frequency (RF,) driven device where the ionization of the propellant is done by a helicon type discharge .The plasma ions are further accelerated in the second stage by ion cyclotron resonance heating (ICRH), a well-known technique, used extensively in magnetic confinement fusion research.

Due to magnetic field limitations on existing superconducting technology. The system presently favours the light propellants; however, the helicon, as a stand-alone plasma generator can efficiently

II. SYSTEM PERFORMANCE

The performance of this concept can be examined by considering that of the various subsystem and their interrelationships. Electric power P is partitioned into two legs by the power partition fractions f. The RF generators convert this electrical power into RF at efficiency $\mathbf{h}_{RF}$. The transmission lines and antennas also have associated efficiencies $\mathbf{h}_A$ which for the sake of simplicity we can assume are equal. The power transfer efficiencies of the ionization and booster stages, h_i and h_b respectively, are not equal however, and much of the physics investigations of the current experiments are focused on understanding these quantities. Finally the plasma output at the RF booster is further scaled by the magnetic nozzle efficiency $\mathbf{h}_N$.

A representative set of expected component efficiency values for various propellants has been used to develop a realistic performance chart for a hypothetical 1MW engine[3]. These come from a review of recent experiments in similar geometries, reasonable extrapolations of system performance and theoretical estimates[4,5].

III. ENGNE SIZE AND WEIGHT

Preliminary estimates of engine size and weight for a 1MW VASIMR have been conducted. These assume present state-of-the-art technology for high power RF equipment, high-temperature superconducting magnets and cryocooler technology. A simplified schematic of a 1MW engine including its power processing equipment and magnet power processing equipment and magnet power supplies.

IV. EXPERIMENT STATUS

The physic of the VASIMR engine are begin investigated primarily in the VX-10 device at the NASA Johnson Space Center (JSC.) However, supporting investigations are also being carried out at the Oak Ridge and Los Alamos National Laboratories, The University of Texas at Austin and the NASA Marshall Space Center in Huntsville Alabama. A trimetric view of the JSC device and associated diagnostic is shown. The axial magnetic field profile is also the graph. Present operations use a cups field at the upstream end of the helicon antenna, but future configurations will move away from this feature

The helicon first stage is critically important in as much as it performance sets the tone for that of the second stage or RF booster

The present helicon sources has now been well characterized theoretically and experimentally with hydrogen , helium, deuterium and other propellants.Stable plasma discharge are now routinely produced with densities in the 10^{18} to 10^{19} m^{-3} range.

The present configuration features a 9cm. Inner diameter helicon tube threaded through a water-cooled, double saddle ''Boswell'' type antenna.

Unlike more conventional helicon discharge used in plasma processing and other applications, the VASIMR source operates in a following mode, which required careful control of the pressure fields within the discharge tube. Discharge with nitrogen, argon and xenon have also been studied but data with these propellants is still rather spares.

Plasma production and electron temperature as functions of the neutral gas injection rate for helium. Discharge brightness at various color change, and elevated electrons temperature confirm neutral gas depletion.

V. RF BOOSTER EXPERIMENTS

With a well-characterized helicon stage, present activities now focus o the physics of the RF booster, or ion cyclotron stage .An important consideration involves the rapid absorption of ion cyclotron waves by the high speed plasma flow. This process differs from the familiar ion cyclotron resonance utilized in tokamak fusion plasma as the particles in VASIMR pas under the antenna only once. Sufficient ion cyclotron wave (ICW) absorption has nevertheless been predicted by recent theoretical studies

Recent experiments have confirmed these theoretical predictions with a number of independent measurements. What follows are brief highlights of some of these results.

The plasma act as a resistive load on the RF circuit. Measurement of the plasma loading on the ICRF antenna is therefore a good measure of power absorption. This quantity has been measure & compared with theoretical predictions. Shows these results plotted as functions of the RF frequency normalized to the cyclotron resonance frequency at the axial midpoint of the antenna.

Several conclusions can be drawn from Figure first, loading values of the order of 200 mOhms are considered acceptable for achieving a preliminary demonstration of the ICRH process (our goal in 2003.) these are mainly a result of the high plasma density produced by the helicon source and the ICRH antenna design. Second as a significant check, it was verified that loading with Argon is virtually zero as expected, as cyclotron resonance does not exist for heavy gases in our configurations.

Third, in comparing theory and experiments, two models are considered: a reduced order one, which neglects electron collisions and a collisional one, which does otherwise. It is seen that the collisional model fits experiments data best. Fourth a 5% shift in the measured vi-a-vis predicated resonance, may be due to a number of things, including a possible Doppler effect caused by these features of the data are undergoing further evaluation and verification.

Two other measurements provide further evidence of significant RF absorption in the booster stage. First, the data from two distinct retarding potential energy analyzers (RPAS) show a shift in the energy distribution of the collected ions when.1.5KW of ICRH is applied.

The collimated RPA measures axially moving ions at three different axial locations (35,55 and 90 cm) downstream from the booster antenna Ion Kinetic energy increases downstream.

The second evidence for ion acceleration by the booster stage comes from a 70GHz microwave interferometer placed several centimetres downstream of the antenna Integrated line density measurements are done with the ICRH on and off. The density trace recovers as the RF is turned off. Total flux measurements carried out during these experiments confirm that the ion flux does not decrease with the application of ICRH (some measurements have actually it increase, but these are under investigation.) we conclude that the local density decrease is mainly due to plasma acceleration.

A sudden drop in the line-integrated density is observed during ICRH applications, indicating plasma acceleration. Applying ICRH power earlier in the shot produce a slightly larger effect probably due to better vacuum conditions.

VI. OTHER ONGOING ACTIVITES

Present efforts continue to expand the experimental database on the RF booster, in particular, the demonstration of similar wave absorption behaviour with deuterium. In addition, improvements in the diagnostics suite are being studies; specifically the gradual integration of non-invasive and spectroscopic measurements to validate the probe data.

Another important focus area continues to be the validation of the trust measurements with the use of the MSFC developed force sensor[9]. This activity is being coordinated with sensor measurements on known thrusters, mounted on calibrated thrust stands at MSFC, the University of Michigan and others. These measurements aim to produce a versatile and transportable thrust Sensor which can be used on a number of thrusters and locations

The physics experiments accomplished thus far point to an improving of the rocket performance at higher power levels .For example recent helicon experiments by our collaborates at the Oak Ridge National Laboratory have uncovered a high-density mode of helicon operation at higher power and magnetic fields then those used thus far[13].

A higher helicon density will, in turn in higher helicon loading at the booster stage and hence increased coupling of the ion cyclotron waves. According, our experiments in 2004 are strongly geared to high power operation.

However, while experiments proceed, a major physic objective continues to be the demonstration of plasma/field detachment after expansion in the magnetic nozzle .To this end, resource are also begin allocated to numerically model the expansion physics and describe the mechanisms at play in the detachment process. A leading theory propose detachment at the so called super alfvenic transition, when the flow velocity surpasses the Alfven speed. As the plasma flows past the nozzle throat, its increase rapidly, as the magnetic pressure drops faster with B then does the plasma density.Result gfor a 50KW VASIMR simulation show transition to greater then1 taking place a couple of meters downstream of the nozzle throat, Our collaborates at Los Alamos National Laboratory and the Hannes Alfven Laboratory in Sweden are pursuing important experimental initiatives along these lines.

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