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MDT-2A Teflon Pulsed Plasma Thruster

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Abstract

A PULSED plasma microthruster system (MDT-2A) was designed, built, and laboratory tested for space test. The impulse bit amplitude of the thruster is 13 μlb-s. Five watts of bus power are required. An ignition subsystem of low voltage is used. The thruster has passed a series of performance and environmental tests. The microthruster system is ready for space test.

Contents

Pulsed plasma thrusters using solid Teflon as propellant have been researched and used in many countries because of their advantages, such as simplicity, reliability, ease of control, fast action, and ability to produce small, precise, reproducible impulse bits. The MDT-2A Teflon pulsed plasma thruster, shown in Fig. 1, is a flight test model. It consists of three subsystems: 1) a thruster subsystem, 2) a power conditioner and telemetry signal converter subsystem, and 3) an ignition subsystem. All of the subsystems are enclosed in a metallic package.

The thruster subsystem has two nozzles in a side-by-side arrangement and works alternately. The two nozzles have a common main energy storage capacitor and ignition capacitor. In addition, each nozzle has its own propellant, feed system, and discharge channel formed by a pair of electrodes and a pair of insulation sides. The electrode material is stainless steel and insulation sides are made of 95-98% aluminum oxide. The operation process of the thruster subsystem is similar to the LES-6 thruster.[1]

The power conditioner accepts a low dc voltage (24-28 V) and converts it to a 2 kV and 150 V dc needed by the thruster. At the same time the power conditioner also provides a controlling pulse for the ignition subsystem so that the two nozzles of the thruster work alternately. By using a constant-rate-of-energy transfer technique, using the proportional exciting mode of the power switch transistor and decreasing the "hold time" at peak voltage on the main energy storage capacitor, a total power conditioner efficiency of not less than 80% has been attained.

Two telemetry signals control the MDT-2A thruster. One is for the main discharge current and the other for the charge voltage of the main energy storage capacitor. Based on these two signals, the operation situation of the thruster in space can be determined. The block diagram of the power conditioner and telemetry signal converter is shown in Fig. 2.

A feature of the MDT-2A thruster is that it uses a low voltage discharge initiating circuit and coaxial solid state igniter plug with an interior electrode of large diameter. This circuit is shown in Fig. 3. The silicon controlled rectifier (SCR) is an important component in the circuit. It controls the ignition capacitor C_I discharge into transformer T. At the beginning of the experiment, the capacitance of the ignition capacitor was 0.5-1 μF and its charge voltage was selected at 500 V. It was similar to other circuits which work at 450-650 V.[1-3] But experiments indicated the SCR failed to control the discharge under vacuum conditions because the seal of the SCR was not good. This permitted air that was trapped inside

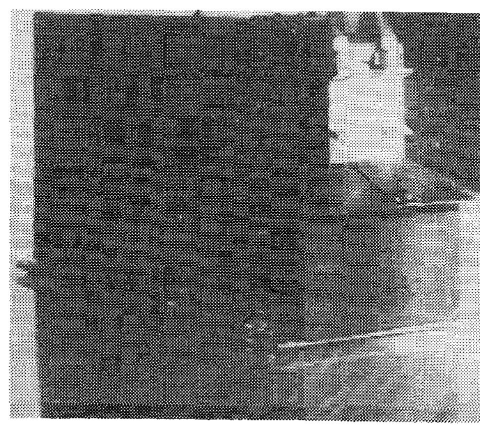

Fig. 1 MDT-2A thruster.

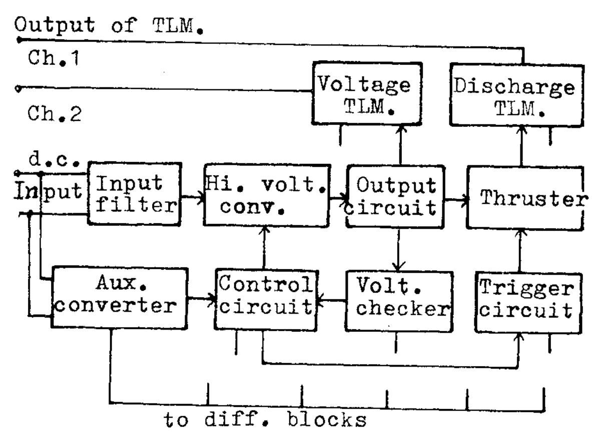

Fig. 2 Block diagram of the power conditioner and telemetry signal converter.

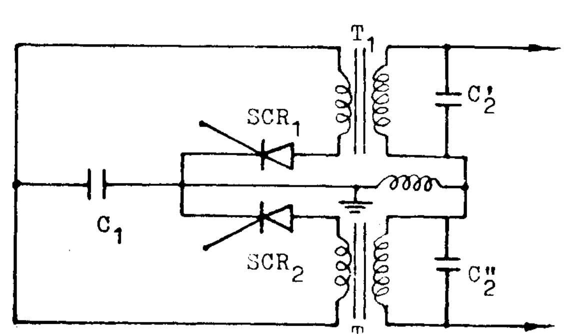

Fig. 3 Ignition circuit of MDT-2A.

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Table 1 General performances

Capacitance of main capacitor, μF	2±5%
Charge voltage to main capacitor, kV	2±1%
Charge voltage to ignition capacitor, V	150
Propellant profile, cm^2	1.0×2.5
Pulse frequency, Hz	1
Energy per discharge, J	4
Mass ablated per discharge, kg	2.2×10^{-8}
Average impulse bit, mg-s	6.5
Average specific impulse, s	280
Efficiency of power converter, %	80
Thruster efficiency, %	2
Total energy consumption, W	5
Total weight (include power conditioner), kg	2.75
Dimension, cm^3	31.6×12.6×16.5

the SCR during manufacture to slowly leak out. When the pressure within the SCR was reduced to a critical value, Paschen breakdown occurred within the SCR. In order to solve this problem it was necessary to select the SCR very carefully. Unfortunately, the number of SCRs satisfying the demands of sealing are very few.

As it is well known, however, the lowest value of Paschen breakdown voltage is not less than 200 V, independent of pressure, electrode separation, and gas composition. Thus, if the charge voltage of the ignition capacitor is less than 200 V, even if the SCR is situated in a vacuum, it should not be affected. In fact, the charge voltage for the MDT-2A thruster is only 150 V. Many experiments for various types of SCRs have proved that such a low voltage is appropriate. An ordinary commercial SCR can be used without any trouble.[4] The final voltage applied to the igniter plug via the transformer is several thousand volts, which is quite enough to energize the igniter plug.

The MDT-2A thruster uses a coaxial solid state plug with an interior electrode of large diameter. This kind of plug causes the arc formed by the discharge of the main energy storage capacitor to move over a larger area. It means that the arc column has a wider contact with the ablated profile of the propellant rod and thus causes the horizontal curvature of the ablated profile to decrease.[5] In addition, the life of the plug is increased. There are some records of 10^7 discharges for such plugs.

The general performance of the MDT-2A thruster is summarized in Table 1. This thruster has already passed the environmental tests, including vibration, shock, and thermal-vacuum tests. It is ready for space test.

Conclusions

In the past few years the MDT-2A solid Teflon pulsed plasma thruster was built and tested. Subsequently it also passed a series of environmental tests. The low voltage (150-V) ignition system can greatly lower the performance demands of the SCR. Now the MDT-2A thruster is ready for space test.

References

[1] Guman, W.J. and Nathanson, D.M., "Pulsed Plasma Microthruster Propulsion System for Synchronous Orbit Satellite," *Journal of Spacecraft and Rockets*, Vol. 7, April 1970, pp. 409-415.

[2] Hirata, Nakayama, Tanatsugu, and Nagatomo, "Experiment of Pulsed Plasma Thruster for Flight Test," 18th Symposium of Space Science and Technology, Tokyo, Japan, 1974 (in Japanese), C-2-8, pp. 257-260.

[3] Vondra, R.J., "The MIT Lincoln Laboratory Pulsed Plasma Thruster," AIAA Paper 76-998, Nov. 1976.

[4] Shiming, An, "The Investigation of Low Voltage 150 V Ignition Circuit," Interior Rept. 39, EPL, IEE, CAS, 1979 (in Chinese).

[5] Shiming, An, "The Effect of Spark Plug on the Ablated Profile," Interior Rept. 33, EPL, IEE, CAS, 1977 (in Chinese).