

## Continuous Operation of Micro Plasma Thruster “Microwave Engine”

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**Abstract.** A low-power, microwave-discharge type electrostatic thruster named “microwave engine” has been developed for applications to 50 kg-class satellites at Advanced Technology Institute Ltd. (ATI) in Hokkaido, Japan. A prototype of the engine was manufactured, and its performance and random vibration tests have been reported in previous papers. An endurance test followed, and showed no failure in the engine after 400 hours of operation.

### Introduction

In recent years, there has been a growing interest in launching a constellation of small satellites into low earth orbit for their networking operations, instead of launching traditional large geostationary satellites. For this new change, there is a need for low power electric propulsion system which will be used in small satellites for attitude control and station keeping. A low-power, microwave-discharge type electrostatic thruster named “microwave engine” (Fig. 1) has been developed for applications to 50 kg-class satellites at Advanced Technology Institute Ltd. (ATI) in Hokkaido, Japan. In the microwave engine, low power operation is made possible by employing microwave to generate plasma. The microwave engine performance and qualification tests have

been reported in previous papers.<sup>1,2,3</sup> A prototype engine generated a thrust of 0.36 mN with a specific impulse of 1250 seconds at a total power of 26.6 W. The random vibration test of the microwave engine showed no visible failure, and its tolerance on the mechanical environment was confirmed. The thermal analysis concluded that white paint should be applied to all surfaces of the microwave



**Fig. 1 Microwave Engine Head**

engine assembly while using the engine mounting bracket as a radiator surface. This design gives a maximum on-orbit temperature of the engine head (including both magnets) of 86 °C, which is well below the maximum temperature limit of 110 °C.

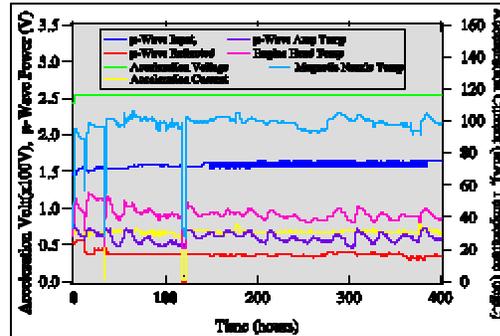
**Continuous Operation Test**

Continuous operation of the microwave engine was conducted as a test of its endurance. The test system consists of thruster system, vacuum chamber and pumps, recorder and PC. The experiment is automated using the PC. All data are stored in the PC's hard disk. The setup for the endurance test is shown in Fig. 2.



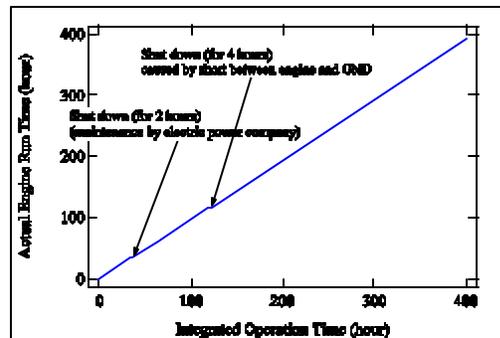
**Fig. 2 Setup for Endurance Test of Microwave Engine System**

400 hours have passed so far, and the operation characteristics over that period are shown in Fig. 3. A brief shut down on the 34th hour was necessary for maintenance by the electric power company. There was another shut down on the 118th hour. Investigations revealed that the engine was shorted to the vacuum flange which was grounded and that the fuse on the acceleration voltage supply had been blown. The short between the engine and ground was



**Fig. 3 Endurance Test of Microwave Engine (400 hours so far and continuing)**

caused by the failure of the insulating sheet between the engine and the engine stand which is directly attached to the vacuum flange. The sheet was replaced, and the discontinuity between the engine and ground was verified before the endurance test was resumed. This failure was not related to the microwave transmission path or internal components of the engine. Therefore, operation and endurance of the microwave engine is considered to be in good condition. Figure 4 shows actual run time of the engine during the first 400 hours of the test. Small accumulation of sputtered materials was observed in the corner where the upstream end wall and side wall of the discharge chamber met. Analysis with a scanning electron microscope revealed that the sputtered



**Fig. 4 Actual run time of Microwave Engine during the endurance test**

materials consisted of mostly iron. And the rest were made up of the components Sm-Co magnets. The iron was the material for the discharge chamber. However, the small buildup of sputtered materials seemed to have little effect on the performance of the engine. The endurance test will continue.

2001.

### **Conclusion**

A prototype of the microwave engine was built, and its continuous operation test was conducted. The test has run 400 hours so far, and there has been no failure in the engine. Small accumulation of sputtered materials could be seen in the corner where the upstream end wall and side wall of the discharge chamber met. But, the engine performance was not affected by the presence of the sputtered materials.

### **References**

1 Satori, S., Okamoto, H., Sugiki, T.M., and Aoki, Y., "NEW ELECTROSTATIC THRUSTER FOR SMALL SATELLITE APPLICATION", July 2000, AIAA-2000-3

2 Satori, S., Okamoto, H., Aoki, Y., Nagata, A. and Sugiki, T.M., "Design Status of Engineering Model of Microwave Discharge Electrostatic Thruster", 3rd International Conference on Spacecraft Propulsion, Cannes-France, Oct. 2000

3 Satori, S., Okamoto, H., Sugiki, T.M., Aoki, Y., Nagata, A., Itoh, Y., and Kizaki, T., "Development of Microwave Engine," 27th International Electric Propulsion Conference, Pasadena, CA, USA, Oct.

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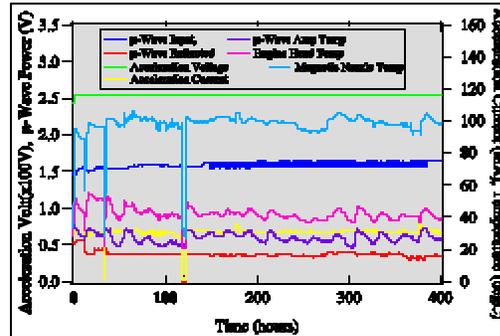
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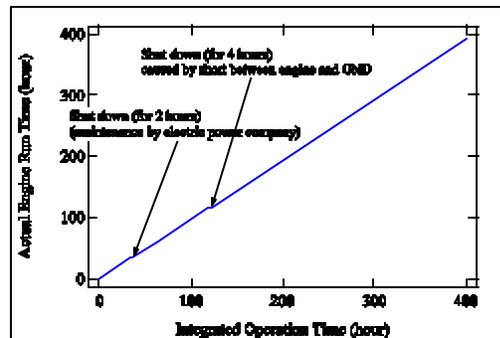
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