Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 185 (2017) 61 – 68

Procedia Engineering

www.elsevier.com/locate/procedia

6th Russian-German Conference on Electric Propulsion and Their Application

Simulation of the motion of charged particles in an ablative pulsed plasma thruster at the initial stage of the discharge.

Antipov A.A.[a*], Bogatyy A.B.[a]

[a] Research Institute of Applied Mechanics and Electrodynamics of the Moscow Aviation Institute, Moscow, Russian Federation,antipant@mail.ru

Abstract

A basic scheme of an ablation pulsed plasma thruster with rail geometry and a side feed of the propellant bar is considered. For such geometry, a theoretical description of the initial stage of the vacuum discharge, which would serve to explain the experimental results, does not exist. It was demonstrated experimentally that the configuration of the discharge channel depends essentially on the initial stage of discharge. A model of the motion of charged particles in the inhomogeneous electric and magnetic fields was developed. Due to the low plasma density at the initial stage of discharge, the model of the charged particles motion in electric and magnetic fields is described well by differential equations.

Peer-review under responsibility of the scientific committee of the 6th Russian-German Conference on Electric Propulsion and Their Application

Keywords: *Ablative pulsed plasma thruster, Charged particles, Electric field, Electrons, Magnetic field, Mathematical Model*

1. Introduction

Ablative pulsed plasma thruster (APPT) with a side feed of propellant is one of the most promising types of thrusters as a propulsion system for small spacecraft (50-150 kg), as shown in [1, 2, 3, 4]. The principle of APPT operation consists of the ionization of the propellant and its subsequent acceleration in crossed electric and magnetic fields. The APPT discharge channel is formed by the surfaces of the electrodes and the propellant bars (Teflon), which, as they wear, are fed into the discharge channel through their sidesurfaces towards each other.

To initiate a discharge in one of the electrodes, an igniter is used between the propellant bars; this forms a primary plasma blob which causes the breakdown of the interelectrode gap under the conditions of high voltage applied to the electrodes. The current flow between the electrodes results in the formation of a plasma blob in the APPT channel due to the propellant ablation from the surface of the Teflon bars in contact with the plasma and exposed to radiation. Acceleration of the plasma blob in the APPT occurs under the action of electromagnetic and gas dynamic forces. The electromagnetic forces (F) are generated during the interaction of the APPT discharge current (J) with a transverse self-magnetic field (B) Fig. 1.

* Corresponding author. Tel.: +7-967-205-62-95.
E-mail address: antipant@mail.ru

Peer-review under responsibility of the scientific committee of the 6th Russian-German Conference on Electric Propulsion and Their Application
doi:10.1016/j.proeng.2017.03.292

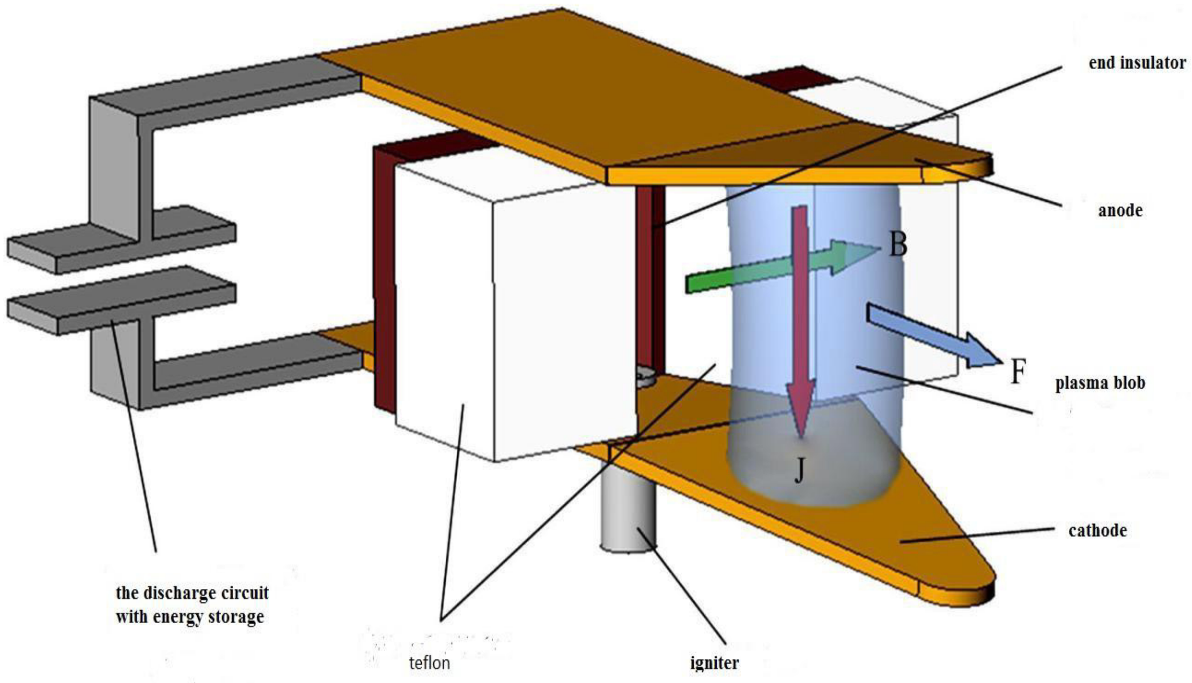

Fig. 1. Schematic diagram of the APPT with rail geometry

The distinctive feature of electric discharge in APPT, in contrast to the vacuum interelectrode breakdown, is the presence of the consumable dielectric material in the discharge area, which, when ablated, participates in the discharge process.

Conventionally, the discharge in APPT can be divided into three stages: dark, spark and arc. In about 10^{-7} s after the igniter operation the visible spark discharge appears (dark stage); during the subsequent $\sim 1.5 \cdot 10^{-6}$ s the current spots form on the propellant bar surface (spark stage), after which the arc is formed Fig. 2.

When viewed from the end, it is obvious that the discharge develops at an angle that depends not only on the geometric parameters of the channel, but also on the electrical parameters of the circuit. Therefore, different APPT differ in their tilt angle.

The choice of angle at the initial stage of the discharge predetermines the angle of the development of the main discharge. Fig. 3 shows that the angle selected is not correct leading to carburization of the bars.

The Angle does not change during all of the stages of discharge.

The material of the bars located in the zone unoccupied by the plasma begins to carburize and is not involved in the ablation process. After prolonged operation this will lead to failure of the thruster. Experimental study of the dark (initial) stage of the discharge is extermely complicated in view of the high speed of its progress. It was decided to explore dark stage of the discharge using a mathematical model, with the aim of discovering which factors affect the tilt angle.