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Experimental Measurement of Equatorial Ring Current Generated by Magnetoplasma Sail in Three-Dimensional Spatial Coordinate

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Abstract : Magnetoplasma Sail (MPS) is a future spacecraft propulsion that generates high levels of thrust by inducing an artificial magnetosphere to capture and deflect solar wind charged particles in order to transfer momentum to the spacecraft. By injecting plasma in the spacecraft's magnetic field region, the ring current azimuthally drifts on the equatorial plane about the dipole magnetic field generated by the current flowing through the solenoid attached on board the spacecraft. This ring current results in magnetosphere inflation which improves the thrust performance of MPS spacecraft. In this present study, the ring current was experimentally measured using three Rogowski Current Probes positioned in a circular array about the laboratory model of MPS spacecraft. This investigation aims to determine the detailed structure of ring current through physical experimentation performed under two different magnetic field strengths engendered by varying the applied voltage on the solenoid with 300 V and 600 V. The expected outcome was that the three current probes would detect the same current since all three probes were positioned at equal radial distance of 63 mm from the center of the solenoid. Although experimental results were numerically implausible due to probable procedural error, the trends of the results revealed three pieces of perceptive evidence of the ring current behavior. The first aspect is that the drift direction of the ring current depended on the strength of the applied magnetic field. The second aspect is that the diamagnetic current developed at a radial distance not occupied by the three current probes under the presence of solar wind. The third aspect is that the ring current distribution varied along the circumferential path about the spacecraft's magnetic field. Although this study yielded experimental evidence that differed from the original hypothesis, the three key findings of this study have informed two critical MPS design solutions that will potentially improve thrust performance. The first design solution is the positioning of the plasma injection point. Based on the implication of the first of the three aspects of ring current behavior, the plasma injection point must be located at a distance instead of at close proximity from the MPS Solenoid for the ring current to drift in the direction that will result in magnetosphere inflation. The second design solution, predicated by the third aspect of ring current behavior, is the symmetrical configuration of plasma injection points. In this study, an asymmetrical configuration of plasma injection points using one plasma source resulted in a non-uniform distribution of ring current along the azimuthal path. This distorts the geometry of the inflated magnetosphere which minimizes the deflection area for the solar wind. Therefore, to realize a ring current that best provides the maximum possible inflated magnetosphere, multiple plasma sources must be spaced evenly apart for the plasma to be injected evenly along its azimuthal path.

Keywords : Magnetoplasma Sail, magnetosphere inflation, ring current, spacecraft propulsion
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