Pulsed Inductive Thruster Using Martian Atmosphere as Propellant

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Pulsed Inductive Thruster (PIT)

Inductive Pulsed Plasma Thrusters Demonstrated

- High, relatively constant $\eta_t$ over an $I_{sp}$ range
- Operate on arbitrary power level while maintaining constant performance
- Increase pulse rate to process significant levels of power in a single thruster unit
- Electrodeless, operates on range of propellants: Ammonia, Hydrazine, Hydrocarbons, Water

Other Inductive PPT Variants

- Field-Reversed Configuration
- Conical Theta-Pinch

Ammonia, 16 kV, PIT MkVa

Energy = 4.6 kJ/pulse
Impulse = 0.1 N-s
$I_{sp}$ = 5,000 s
$\eta$ = 50% (or better)
$\rightarrow$ Thrust = 3 N ($f_{rep}$ = 30 Hz)
$P_{Jet}$ = 75 kW

Performance of PIT on Various Propellants

PIT MK V – 4.5 µF, PIT MK Va – 9 µF

Demonstration of significant advancement in operation capability from MK V to MK Va
- Due to better dynamic impedance matching
- Further advances possible

Expect all other atomic / molecular propellants to follow suit in terms of performance trends and improvements

Performance of PIT

MK V performance
- NH₃, N₂H₄ – ηₜ ~ 20-30%
- Ar, He, CO₂ – ηₜ ~ 15-20%
- Dynamic Impedance not optimum

MK Va performance
- NH₃ – ηₜ ~ 40-50%
- N₂H₄ – ηₜ ~ 35-40%
- Dynamic Impedance spans optimum

Takeaways
- PIT will operate on many propellant options
  - Provides consistent performance and flexibility for a mission
  - Variations in efficiency across various propellants, but performance likely better for all options with improved dynamic impedance match
  - Higher efficiency possible with inductive energy recapture
    - Electrical / Power System challenge: Independent of propellant choice

The Martian Atmosphere as Propellant

Concept

- If an EP system can operate on CO$_2$ (as PIT can), Mars atmosphere is a simple ISRU option
- Only need to carry propellant for one way trip (mass and systems advantages)
- Can produce propellant at Mars by compressing atmosphere and filling a COPV tank
- Variation in $\eta_t$ with propellant (but still fairly close)
  - Analysis of system and mission concept required to quantify effects
  - Testing will be conducted at NASA-MSFC using a PIT thruster on simulated Martian atmosphere.
- Spacecraft could also leave Mars and go to a different destination (other than returning to Earth)
- Potentially permits *in situ* refueling at any other destination where the atmosphere is accessible

<table>
<thead>
<tr>
<th>Chemical Species</th>
<th>Mole fraction</th>
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<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>95.32%</td>
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<tr>
<td>Nitrogen</td>
<td>2.7%</td>
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<tr>
<td>Argon</td>
<td>1.6%</td>
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<tr>
<td>Oxygen</td>
<td>0.13%</td>
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<tr>
<td>Carbon Monoxide</td>
<td>0.07%</td>
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