Final Summary of GRSP Activities

Development of Predictive Models of Advanced Propulsion Concepts for Low Cost Space Transportation

NGT8-52887
August 1, 2000 through October 31, 2002

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Advisor's Note

Mr. Morrell left the PhD program at Georgia Tech in September of 2001 to pursue a permanent job with GE Power Systems. This final report summarizes the GSRP research work Mr. Morrell was able to complete as a summer intern at NASA - MSFC during the summer of 2001 and represents the sum of work completed under NGT8-52887 from inception through project termination.

Dr. John R. Olds
School of Aerospace Engineering
GSRP Summer Internship Experience at NASA MSFC

Randy Michael Morrell
NGT8-52887
Summer 2001
NASA TD40 Organization

Propellantless

Monopropellant

Pulse Detonation Rockets

Advanced Plasma

Nuclear
Combustion Physics Lab

- Unique facility for investigating high pressure rocket combustion
- Pressures of up to 6000 psi (~400 atm)
- O₂ – H₂ and O₂ – hydrocarbon flames
- Small scale, e.g. flow rates of 50 g/sec for 10 sec
- Optically accessible combustion chamber
- Bldg 4549 / TD40 Lab A
Advanced Hydrocarbon Fuels

- High Energy Density Matter (HEDM) hydrocarbons currently being researched by the military, principally the AFRL
- NASA interested in possible applications to future launch vehicles
- Plan to add AFRL chemist to the group to develop and synthesize these fuels ‘in-house’
GSRP Summer Tasks

- Assist in the installation of the high pressure combustion facility
- Research issues related to high pressure combustion
- Literature review of HEDM hydrocarbon characteristics for future work
High Pressure Facility Installation

- Funding approved for the facility
- High pressure piping, pumps, and storage purchased
- Optical diagnostic equipment purchased
- Combustor funding applied for
- Waiting for lab space to be vacated
High Pressure Combustion Issues

- Supercritical behavior
  - local vs. global
- Mixing / shear layer interaction
- Diagnostic techniques in high density flows
- Scaling from lab scale to full scale

## HEDM Hydrocarbons

The energy content of a molecule is increased by adding unsaturation:

<table>
<thead>
<tr>
<th>Compound</th>
<th>ΔH&lt;sub&gt;f&lt;/sub&gt; (kcal/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>-(CH₂)&lt;sub&gt;n&lt;/sub&gt;-</td>
<td>-4.9</td>
</tr>
<tr>
<td>H₂C=CH₂</td>
<td>+6.3</td>
</tr>
<tr>
<td>HC≡CH</td>
<td>+27.0</td>
</tr>
</tbody>
</table>

The energy content of a molecule is increased by incorporating strain:

<table>
<thead>
<tr>
<th>Compound</th>
<th>ΔH&lt;sub&gt;f&lt;/sub&gt; (kcal/mol)</th>
</tr>
</thead>
<tbody>
<tr>
<td>cyclopentane</td>
<td>-18.4</td>
</tr>
<tr>
<td>cyclobutane</td>
<td>+6.8</td>
</tr>
<tr>
<td>cyclopropane</td>
<td>+12.7</td>
</tr>
</tbody>
</table>

Selected candidate fuels:

- Spiropentane
- Bicyclopropylidene
- HC≡C-CH₂-CH₂-C≡CH (1,5-hexadiyne)

Isp sec (RP-1 = 299) 311 313 312

* from PRC briefing to Rocketdyne
GSRP Summer Intern Summary

- High pressure lab now expected to begin installation this fall and operation this winter/spring.
- Limited work done to date on high-pressure, supercritical combustion. Most of work on supercritical combustion being done in Europe.
- Key contacts made with HEDM hydrocarbon researchers.