Monopropellant-Powered Actuation

Motivation

• Conventional robotic power supply and actuation do not provide the energy and power densities required for self-powered human-scale robots.
• Batteries are too heavy for the amount of energy stored, and DC motors are too heavy for the amount of power delivered.
• Self-powered human-scale robots require order-of-magnitude greater energy and power density.

General Objective

• Develop power supply and actuation system as controllable as battery/DC-motor combination but with order-of-magnitude greater energy and power density.
• Approach is to utilize liquid monopropellants as gas generators for hot gas actuators.
• Requires compact mechanisms for converting gas generation (via catalytic decomposition) into controlled mechanical work.

Centralized

• Equivalent to air compressor (boxed in red) and standard pneumatic servo actuator (boxed in blue)

Pros:  
• Simple
• Leverages knowledge of standard pneumatic servocontrol
• Minimal hardware for multi-DOF systems

Cons:  
• Control power losses
• Hot-gas delivery lines

Direct Injection

• Eliminates reservoir in favor of a direct-injection configuration

Pros:  
• Cool liquid power delivery lines
• Minimal hot surface area (and thus heat loss)
• Essentially no control losses, regardless of load or speed

Cons:  
• Somewhat more hardware, especially on high-DOF systems
• Complex control required

Prototype

• Honda P3 humanoid robot

Energetic Properties of Hydrogen Peroxide

<table>
<thead>
<tr>
<th>Concentration (%)</th>
<th>LHV (MJ/kg)</th>
<th>ADT (°C)</th>
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<tbody>
<tr>
<td>70</td>
<td>0.4</td>
<td>233 (452 °F)</td>
</tr>
<tr>
<td>80</td>
<td>0.8</td>
<td>487 (908 °F)</td>
</tr>
<tr>
<td>90</td>
<td>1.2</td>
<td>740 (1364 °F)</td>
</tr>
<tr>
<td>99.9</td>
<td>1.6</td>
<td>996 (1824 °F)</td>
</tr>
</tbody>
</table>

Energetic Figure of Merit for Various Power/Actuation Approaches

<table>
<thead>
<tr>
<th>System</th>
<th>Actuation Potential (kJ-kW/kg²)</th>
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<tbody>
<tr>
<td>Definition</td>
<td>( A_p = e \eta p_s )</td>
</tr>
<tr>
<td>Honda P3 Robot</td>
<td>4.8</td>
</tr>
<tr>
<td>Centralized with 70% H₂O₂</td>
<td>11.2-22.4</td>
</tr>
<tr>
<td>DI with 70% H₂O₂</td>
<td>49.8</td>
</tr>
<tr>
<td>DI with 80% H₂O₂</td>
<td>99.6 (projected)</td>
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