Solid Motor Casing & Design

Solid Design Team:
Tony, Jason, Andrew, Tarique, Esteban, Jack
Quick Recap

Motor and Propellant Selection

- Non-Toxic
- Non-Detonable
- HTPB/AP/AL Composite

Aerotech L2200G-P Mojave Green
Design Process

- Payload
- Drogue Chute
- Payload/Avionics
- Main Chute
- Motor and Casing
Motor Case Design Considerations

What we know:
- Peak Thrust $\approx 3100$N
- Burn Duration $\approx 2.4$ s
- Dimensions

What we need to know:
- Chamber Pressure
- Chamber Temperature
Nozzle Design Considerations

What we know:
- Peak Thrust ≈ 3100N
- Burn Duration ≈ 2.4s
- Dimensions

What we need to know:
- Chamber Pressure
- Gas Exit Velocity
- Gas Exit Temperature
Igniter Considerations

What we know:
● Motor Overall Performance

What we need to know:
● Nothing
Solid Rocket Motor

- Case
- Solid Propellant
- Igniter
- Nozzle
# Motor Case Loadings/Stresses

<table>
<thead>
<tr>
<th>Origin of Load</th>
<th>Type of Load/Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intern</td>
<td>Tension, compression, bending, shear,</td>
</tr>
<tr>
<td></td>
<td>torsion</td>
</tr>
<tr>
<td>Axial</td>
<td>Bending, shear</td>
</tr>
<tr>
<td>Motor</td>
<td>Axial, bending, shear, torsion</td>
</tr>
<tr>
<td>Thrust</td>
<td>Axial, bending, shear</td>
</tr>
<tr>
<td>Thrust</td>
<td>Axial, bending, shear</td>
</tr>
<tr>
<td>Aerodynamic control surfaces or wings mounted to case</td>
<td>Tension, compression, bending, shear, torsion</td>
</tr>
<tr>
<td>Staging</td>
<td>Bending, shear</td>
</tr>
<tr>
<td>Flight maneuvering</td>
<td>Axial, bending, shear, torsion</td>
</tr>
<tr>
<td>Vehicle mass and wind forces on launch pad</td>
<td>Axial, bending, shear</td>
</tr>
<tr>
<td>Dynamic loads from vehicle oscillations</td>
<td>Axial, bending, shear</td>
</tr>
<tr>
<td>Start pressure surge</td>
<td>Biaxial</td>
</tr>
<tr>
<td>Ground handling, including lifting</td>
<td>Tension, compression, bending, shear, torsion</td>
</tr>
<tr>
<td>Ground transport</td>
<td>Tension, compression, shear, vibration</td>
</tr>
<tr>
<td>Earthquakes (large motors)</td>
<td>Axial, bending, shear</td>
</tr>
</tbody>
</table>
Motor Case Materials

- Composite
  - E-glass
  - Aramide (Kevlar 49)
  - Carbon fiber

- Metal
  - Titanium alloy
  - Alloy steel
  - Aluminum alloy 2024

- Combination
Composites

Table 2.1 E357 T-6 Casted Aluminum

<table>
<thead>
<tr>
<th>AMS 4288</th>
<th>$F_{tu}$ (ksi)</th>
<th>$F_{ty}$ (ksi)</th>
<th>$F_{cy}$ (ksi)</th>
<th>$F_{th}$ (ksi)</th>
<th>E (ksi)</th>
<th>$\nu$</th>
<th>$\rho$ (lb/in$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T=72°F</td>
<td>45</td>
<td>36</td>
<td>36</td>
<td>28</td>
<td>10.4E3</td>
<td>0.33</td>
<td>0.097</td>
</tr>
<tr>
<td>T=300°F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2.2 H

$\begin{bmatrix} \varepsilon_1 \\ \varepsilon_2 \\ \gamma_{12} \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} & 0 \\ S_{21} & S_{22} & 0 \\ 0 & 0 & S_{66} \end{bmatrix} \begin{bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{bmatrix}$

<table>
<thead>
<tr>
<th></th>
<th>G12 (psi)</th>
<th>v12</th>
</tr>
</thead>
<tbody>
<tr>
<td>room temperature</td>
<td>348,000</td>
<td>232,000</td>
</tr>
<tr>
<td>300°F</td>
<td>313,200</td>
<td>208,800</td>
</tr>
<tr>
<td>1.5 Safety Factor</td>
<td>208,800</td>
<td>139,200</td>
</tr>
</tbody>
</table>

$v$
Filament Winding

- Orientation of Filament
  - Compromise

FIGURE 14-5. Filament winding terminology (each sketch is drawn to a different scale).
<table>
<thead>
<tr>
<th>Material</th>
<th>Tensile Strength, N/mm² (10³ psi)</th>
<th>Modulus of Elasticity, N/mm² (10⁶ psi)</th>
<th>Density, g/cm³ (lbm/in.³)</th>
<th>Strength to Density Ratio (1000)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Filaments</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-glass</td>
<td>1930–3100 (280–450)</td>
<td>72,000 (10.4)</td>
<td>2.4</td>
<td>140</td>
</tr>
<tr>
<td>Aramid</td>
<td>1240 (180)</td>
<td>124,000 (18.0)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>900</td>
<td>102,000 (14.8)</td>
<td>1.55</td>
<td>400</td>
</tr>
<tr>
<td>Epoxy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Metals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Titanium alloy</td>
<td>1240 (180)</td>
<td>110,000 (16)</td>
<td>4.60</td>
<td>270</td>
</tr>
<tr>
<td>Alloy steel</td>
<td>1400–2000 (heat treated)</td>
<td>207,000 (30)</td>
<td>7.84</td>
<td>205</td>
</tr>
<tr>
<td>(heat treated)</td>
<td>(200–290)</td>
<td>(30)</td>
<td>(0.289)</td>
<td></td>
</tr>
<tr>
<td>Aluminum alloy</td>
<td>455 (66)</td>
<td>72,000 (10.4)</td>
<td>2.79</td>
<td>165</td>
</tr>
<tr>
<td>2024 (heat treated)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Metals

- Titanium alloy
  - Heavy
  - Good strength to weight ratio
- Alloy steel
  - Heavier
  - Strongest
- Aluminum
  - Provides good strength to weight ratio
  - Lightest
<table>
<thead>
<tr>
<th>Material</th>
<th>Tensile Strength, N/mm² (10⁶ psi)</th>
<th>Modulus of Elasticity, N/mm² (10⁶ psi)</th>
<th>Density, g/cm³ (lbm/in³)</th>
<th>Strength to Density Ratio (1000)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Filaments</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E-glass</td>
<td>1930–3100</td>
<td>72,000</td>
<td>2.6</td>
<td>640</td>
</tr>
<tr>
<td>Aramid</td>
<td>1450–2000</td>
<td>124,000</td>
<td>(8.4)</td>
<td></td>
</tr>
<tr>
<td>Carbon</td>
<td>0.18</td>
<td>90,000</td>
<td>(5.5)</td>
<td></td>
</tr>
<tr>
<td>Graphite</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Epoxy</td>
<td></td>
<td></td>
<td></td>
<td>70</td>
</tr>
<tr>
<td><strong>Metals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Titanium alloy</td>
<td>(240) (180)</td>
<td>(110,000) (16)</td>
<td>4.6</td>
<td>(0.166)</td>
</tr>
<tr>
<td>Alloy steel</td>
<td>1450–2000 (heat treated) (200–290)</td>
<td>257,000 (30)</td>
<td>7.94</td>
<td>(0.289)</td>
</tr>
<tr>
<td>Aluminum alloy</td>
<td>(66)</td>
<td>(72,000) (10.4)</td>
<td>2.79</td>
<td>(0.101)</td>
</tr>
<tr>
<td>(heat treated)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
There are five types of nozzles:

- Fixed (a)
- Movable (b)
- Submerged (c)
- Extendible (d)
- Blast-Tube-Mounted (e)
Nozzles: Design and Construction

- Ablatively Cooled
- Steel or aluminum Shells
- Composite ablative liners
Nozzle Design Decision

WE’RE NOT BUILDING ONE!!

Why?!?
Nozzle Selection

- Aerotech L2200G-P Mojave Green and RMS 75/5120 kit comes with a nozzle
Solid Rocket Motor Expert

Robert Watson

Robert at BuyRocketMotors.com
817-494-3834

rwatson@buyrocketmotors.com
www.BuyRocketMotors.com
Igniters

Pyrogens
Pyrotechnic

FIGURE 14-13. Simple diagrams of mounting options for igniters. Grain configurations are not shown.
Igniters

Most frequent is Electroexplosive device (Pyrotechnic)

- Bridgewire

3.0.1 Design Requirements

The igniter design shall be based on the following priority of requirements:

(1) Specified Performance
(2) Specified Reliability
(3) Lowest Possible Cost
Field Trip?

Oregon State University

University in Corvallis, Oregon

Directions Write a review

Oregon State University is a coeducational, public research university in Corvallis, Oregon, United States. The university offers more than 200 undergraduate, graduate, and doctoral degree programs and has the largest total enrollment in Oregon. Wikipedia
Summary

- **Motor Case: 2024 Aluminum Alloy**
  - Lightweight
  - Capable of enduring thermal and pressure loads
  - Machined or Off-The-Shelf (TBD)

- **Nozzle: Built into Motor**
  - Saves time and money
  - Redundant to build additional nozzle

- **Igniter: Bridgewire explosive**
  - Reliable
  - Good “performance”
  - Cheap
Whats Next?

- Propellant Combustion
  - Burn rate
  - Flame Pattern
  - Ignition Characteristics

- Propellant Stability
  - Acoustic Resonance
  - Ignition Wire Configurations
  - Internal Gas Flow Cavity Considerations
References

(2) *Solid Rocket Motor Igniters*. NASA
Questions?