Product Readiness Review

Zerodur® Incorporated Mirror Mount

Team #2 (ZIMM)
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May 10, 2010

MAE 490-01
Dr. Christina Carmen
Dr. Tim Blackwell
Overview

- Purpose of PRR
- Mission Statement
- Product Design Specifications
- Detailed Drawings
- Technical Analysis
- Verification Tests
- Final Cost Information
- Manufacturing/Assembly/Installation
- Problems and Solutions
- Lessons Learned
- Summary
The purpose of the Product Readiness Review (PRR) is to present the following:

- Review the results of the system verification process
- Provide final cost information
- Demonstrate the product to verify it meets the Product Design Specifications (PDS)
The Zerodur® Mirror Mount is a mounting system that attaches a Zerodur® mirror, a high efficiency mirror, in place. The apparatus provides translational ability in two axes, as well as, tilting ability in two axes.

- These features should provide for easier maneuverability of the mirror for a better location of lazing, while increasing the efficiency of the laser from 43% to 47% or greater.
Performance:
- Translational ability in two axes: ±1 mm
- Rotational ability in two axes: ± 1°

Aluminum material (6061-T6): Must remain below the melting point of 582-652°C during lazing

Safety: Follows the class 4 LASER ANSI (Z136) standard

Size: Apparatus must fit within the laser apparatus, 3.251 inches (height) X 3.503 inches (width).

Weight: Must be able to be handled by one person.

Strength: Mount must be able to survive a four foot fall, without the mirror attached.
Design Drawings

- General assembly view without the aluminum box

- Bottom Plate
- Tilting Plate
- Zerodur Mirror
- Dowel Pin
Design Drawings

Bronze Inserts

Tilting Plate

Bottom Plate

Tilt Screws

Translation Screws
Design Drawings

Top View (Dimensions in inches)
Design Drawings

Front View (Dimensions in inches)
Design Drawings

Right Side View (Dimensions in inches)
Thermal Calculations

Technical Analysis 1-Thermal

\[
\begin{align*}
\text{Power} & := 180\text{W} \\
\text{TotalSpotArea} & := 12 \cdot \pi \cdot (2.5\text{mm})^2 = 0.365 \cdot \text{in}^2 \\
\text{TotalHeatFlux} & := \frac{\text{Power}}{\text{TotalSpotArea}} = 0.467 \cdot \frac{\text{BTU}}{\text{in}^2 \cdot \text{s}} \\
\text{PercentHeatNotReflected} & := 0.1\% \\
\text{ActualHeatFlux} & := \text{TotalHeatFlux} \cdot \text{PercentHeatNotReflected} = 4.671 \times 10^{-4} \cdot \frac{\text{BTU}}{\text{in}^2 \cdot \text{s}}
\end{align*}
\]
Technical Analysis 1-Thermal (0.001 s)

Initial temperature is 70 degrees Fahrenheit
Final temperature is 70.1 degrees Fahrenheit
Technical Analysis 2 & 3 – Force Calculations

\[ \rho := 0.0975 \frac{\text{lb}}{\text{in}^3} \]

Volume := 8.292 in\(^3\)
mass := \(\rho \cdot \text{Volume} = 0.025\) slug

**Energy Equations**

\[ \frac{1}{2}\text{mass} \cdot V_0^2 + \text{mass} \cdot g \cdot h_0 = \frac{1}{2}\text{mass} \cdot V_1^2 + \text{mass} \cdot g \cdot h_1 \]

\(V_0 := 0 \frac{\text{ft}}{s}\)
\(h_0 := 4\text{ft}\)
\(h_1 := 0\text{ft}\)
g = 32.174 \frac{\text{ft}}{s^2}

\(V_1 := \sqrt{\frac{2 \cdot \text{mass} \cdot g \cdot h_0}{\text{mass}}} = 4.89 \frac{\text{m}}{s}\)

**Impulse-Momentum Equations**

Force = \text{mass} \cdot a = \text{mass} \cdot \frac{\Delta V}{t} = \text{mass} \cdot \frac{V_2 - V_1}{t}

\(V_2 := 0 \frac{\text{ft}}{s}\)
\(t_1 := \frac{1}{1000} \text{s}\)
\(t_2 := \frac{1}{100} \text{s}\)

Force\(_1 := \text{mass} \cdot \frac{V_2 - V_1}{t_1} = -403.14\text{-lbf}\)

Force\(_2 := \text{mass} \cdot \frac{V_2 - V_1}{t_2} = -40.314\text{-lbf}\)
Deflection of 0.0419in under 40.314lbf from stopping time of 1/100 seconds
Technical Analysis 2 – Stress

Stress of 52.8psi – 56,700psi under 40,314lbf from stopping time of 1/100 seconds
Deflection of 0.419in under 403.14lbf from stopping time of 1/1000 seconds
Stress of 528psi – 567,000psi under 403.14lbf from stopping time of 1/1000 seconds
There will be no “towers” on the final product
Reduces possible stress concentrations
Verification Tests

- Translational verification results:
  - $\pm 2.159$ mm in both axes

- Rotational verification results:
  - $\pm 3^\circ$ on the long side
  - $\pm 3.5^\circ$ on the short side
Verification Tests
## Final Cost Information

<table>
<thead>
<tr>
<th>Component</th>
<th>Material</th>
<th>Material Source</th>
<th>Quantity</th>
<th>Retail Cost</th>
<th>Team Cost</th>
<th>Cost Per Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plates</td>
<td></td>
<td>UAHuntsville Machine Shop</td>
<td>4</td>
<td>$321.00</td>
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<tr>
<td>Mounting Plate</td>
<td>Aluminum 6061-T6</td>
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<td>N/A</td>
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<td>Tilting Plate</td>
<td>Aluminum 6061-T6</td>
<td></td>
<td>2</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>Rings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mirror Holding Ring</td>
<td>Aluminum 6061-T6</td>
<td><a href="http://www.mcmaster.com">www.mcmaster.com</a></td>
<td>3</td>
<td>$26.94</td>
<td>$26.94</td>
<td>$8.98</td>
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<tr>
<td>Rings</td>
<td>Mirror Holding Ring</td>
<td><a href="http://www.mcmaster.com">www.mcmaster.com</a></td>
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<td>N/A</td>
<td>N/A</td>
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<tr>
<td>Threaded Insert</td>
<td>Oil-Impregnated Bronze</td>
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<td>$36.35</td>
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<td>$36.35</td>
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<tr>
<td>Tension Spring</td>
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<tr>
<td>3/8 Inch Length Set</td>
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<tr>
<td>Dowel Pins</td>
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<td>Epoxy for Mirror</td>
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<td>Shipping</td>
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**Total Costs**  
- **Retail**: $1,094.34  
- **Team**: $74.10  
- **Cost Per Unit**: $898.29
Manuifacturing Processes

• Location: UAH Department of Mechanical & Aerospace Engineering Design & Prototype Facility and United Plating (anodizing)
• Cost: Paid for by tuition and fees (essentially free to us)
• Duration: Longer than desired...A month and a half at the moment. Probably two to two and a half months total time for the finished product
Manufacturing Processes

- CNC Mill: Used for Bottom Plate, Tilting Plate, & Mirror Holding Ring
- CNC Lathe: Used for Mirror Holding Ring & Threaded Ring
- Manual Lathe: Used for the oil-impregnated bronze inserts
- Difficulties: UAH Moonbuggy and MAE 100 Projects
Problem: Epoxy sample not in for 2 months
  Solution: Found another company to give a free sample

Problem: Getting time to work on the machines in the MAE machine shop
  Solution: Keep trying and coming in at whatever hours possible
Lessons Learned

• Time management
  • Unknown issues can become a problem
  • Have to plan for issues, even if they seem improbable
  • Always be one step ahead

• Team dynamics
  • Everyone’s different
  • Must work together
  • Must work out dispute
  • Must be willing to compromise
Summary

- Presented detailed design documentation
- Updated the technical analyses for the detail design
- Presented the verification test results
Acknowledgements

- Dr. Tim Blackwell – Thanks for your continued support throughout this project
- Dr. Kader Frendi and MAE Department – Thanks for funding this project
- Mr. Steve Collins – Thanks for helping monitor the manufacturing process and answering our questions
- Eric Becnel, Roger Wilson, and Charles Boyles - Thank you for the advice, tips, and some manufacturing
- Dr. Christina Carmen – Thanks for aiding us throughout the design process
- Mr. Brad Hembree – Thank you for NASTRAN/PATRAN tutorials