16.810: Team M4

Optimizing Roller Assembly

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IAP 2007
Motivation

• Roller assembly moves climber up ribbon
• Rollers, plates, and sidebars all have extra mass
• Purpose
  – Less power needed to climb
  – Increased score
Requirements

- Minimize climber weight
- Minimize climber cost
- Minimize time to attach climber to ribbon
  - Must be < 4 min
- Maintain von Mises Factor of Safety > 2
• Climber must survive a 2 m drop test
• Climber must lift own weight
• Average speed > 2 m/s
• Material unaffected by 5.8 GHz microwaves
• Climber unaffected by water
• Climber must resist 11.5 mph winds
Initial Sketch

Rollers:
- Roller tube
- Roller cap (4 per roller)

Side Plate:
- Holes for bolting other pieces to plates (x5)
- Weight reduction rib
- Thru hole holes
- Weight reduction

Side Bar:
- Countersunk holes to bolt into side plate (x5)
- Weight reduction rib structure

Team M5: Initial Concept Orthographic
- Carly O'Brien
- Ryan McInerney
Design Choice

- Initial design was given
- Holes placed in strategic locations
- Refined with FEA software
CAD Model: Side Plate
CAD Model: Side Bar
CAD Model: Drive Roller
CAD Model: Guide Roller
FEA Analysis: Side Plate Left

Forces

FOS

Displacement

min: 20

max: 5.8e-5m
FEA Analysis: Side Plate Right

Forces

FOS

Displacement

\[
\begin{align*}
\text{min: } & 17 \\
\text{max: } & 6.1 \times 10^{-5} \\
\end{align*}
\]
FEA Analysis: Side Bar

Forces

Displacement

FOS

min: 2.2

max: 9.8e-4m
FEA Analysis: Side Bar Belay

Forces

FOS

Displacement

min: 2.3

max: 1.5e-3m
FEA Analysis: Drive Roller

Forces

FOS

Displacement

min: 2.1

max: 4.9e-4m
FEA Analysis: Guide Roller

Forces

FOS

Displacement

min: 2.1

max: 5.7e-4m
Machined Part: Belay Side Bar
Machined Part: Side Plate
## Final Specifications

### Requirements

Minimize Weight

### Results

<table>
<thead>
<tr>
<th>Component</th>
<th>Requirement</th>
<th>Actual 1</th>
<th>Actual 2</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Side Bar Cross (x10)</td>
<td></td>
<td>0.124 lbs</td>
<td>0.051 lbs</td>
<td>.073 lbs</td>
</tr>
<tr>
<td>Side Bar Belay (x2)</td>
<td></td>
<td>0.121 lbs</td>
<td>0.055 lbs</td>
<td>.066 lbs</td>
</tr>
<tr>
<td>Side Plate Left (x2)</td>
<td></td>
<td>0.89 lbs</td>
<td>0.70 lbs</td>
<td>.19 lbs</td>
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<tr>
<td>Side Plate Right (x2)</td>
<td></td>
<td>0.96 lbs</td>
<td>0.65 lbs</td>
<td>.31 lbs</td>
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<tr>
<td>Drive Roller (x4)</td>
<td></td>
<td>1.32 lbs</td>
<td>0.63 lbs</td>
<td>.69 lbs</td>
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<tr>
<td>Guide Roller (x2)</td>
<td></td>
<td>0.91 lbs</td>
<td>0.47 lbs</td>
<td>.44 lbs</td>
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<tr>
<td>Total</td>
<td></td>
<td>33.7 lbs</td>
<td></td>
<td>5.5 lbs</td>
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</table>

Total Difference: 5.5 lbs
# Final Specifications

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Result</th>
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</thead>
<tbody>
<tr>
<td>Keep Cost Low</td>
<td>Cost to team: $100</td>
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<tr>
<td>Clamp Time</td>
<td>Kept clamp simple</td>
</tr>
<tr>
<td>FOS &gt; 2</td>
<td>FOS: Belay Side Bar-2.3</td>
</tr>
<tr>
<td></td>
<td>Side Bar-2.2</td>
</tr>
<tr>
<td></td>
<td>Roller-2.1</td>
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<tr>
<td></td>
<td>Side plate (left)-20</td>
</tr>
<tr>
<td></td>
<td>Side plate (right)-17</td>
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</table>
Focus

Minimize weight in order to aid in speeding up the climber

Cost was less important, but didn’t use strange materials

Wanted something simple and effective
Manufacturing

- Side Bars and Belay Side Bars
  - Water jetted out of $\frac{1}{2}''$ polycarb
  - Milled holes for screws
- Side plates
  - Water jetted
  - Milled holes for axles and screws
- Rollers
  - Cut on bandsaw
  - Lathed
  - Drill pressed holes for screws
Assembly

- **Side Bars and Belay Side Bars**
  - Screwed into the slots on the side plates
  - Belay hook will be added to the central two holes
  - Side bars will be mounted to the motor

- **Side plates**
  - Attached to the motor, side bars, rollers, and clamps by screws or simply pressed together

- **Roller**
  - Attached by screws and an axle to the side plates
## Cost Estimate

<table>
<thead>
<tr>
<th>Section</th>
<th>Rate</th>
<th>Qty</th>
<th>Total Cost</th>
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</thead>
<tbody>
<tr>
<td>I. Design and Engineering</td>
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<tr>
<td>Labor Rate for Each Designer</td>
<td>$75/hour</td>
<td>5</td>
<td>375</td>
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<tr>
<td>Labor Rate for Each Cad/Cam Machine</td>
<td>$40/hour</td>
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<td>II. Materials Cost</td>
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<tr>
<td>Polycarbonate Sheet</td>
<td>$19.47/sqft</td>
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<td>58.41</td>
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<tr>
<td>Polycarbonate Rod</td>
<td>$62.50/ft</td>
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<td>125</td>
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<td>III. Waterjet Manufacturing</td>
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<td>Labor Rate</td>
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<tr>
<td>Machine Use Rate</td>
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<td>100</td>
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<tr>
<td>IV. Other Machining</td>
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<tr>
<td>Labor Rate</td>
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<td>140</td>
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<tr>
<td>V. Assembly Rate</td>
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<tr>
<td>Assembly Work Labor Rate</td>
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<td>110</td>
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<td>Miscellaneous Test Rate</td>
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<table>
<thead>
<tr>
<th>Hours</th>
<th>Cost</th>
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<tbody>
<tr>
<td>Total</td>
<td>21</td>
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</table>
Future Work

• Not everything could be completed during IAP
  – Work will continue after the class ends
    • The side plates will be finished
    • Rollers will be hollowed out
    • Side bars will be created

• After all this occurs, the new pieces will be put together and tested as a new recursion of the climber
Final Conclusions

• The weight drop is significant
• Will alter the performance of the climber for the better
• Cut large pieces out of the materials while maintaining a good FOS
• Further iterations of this process will be necessary to achieve the ideal parts
  – Continued shaving off of material may occur
  – Many of the pieces achieved a radical new design
    • Sign of the evolution of a project
Lessons Learned

• Do not trust random other students regarding the operation of machinery
• If it can go wrong, it will—over and over again.
• The iterative process is effective and can be repeated infinitely
  – There’s always something better out there
• -Double checking position of hole before optimizing
Lessons Learned

• Peel the plastic off before water jetting
• When doing large water jet parts, pause water jet periodically to make sure the piece hasn't shifted
• Standard truss ribs are very inefficient for side bars, ribs connecting forces make much more sense