Automated Spa Centering Table

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Introduction
During spa production at Bullfrog Spas, shells and bases of spas are concentrically centered to each other when they are mated. Our team designed a system to automate the current process, with the goal of improving accuracy and reducing the time taken to center a spa.

After centering, braces are used to keep the spa centered throughout the production process. Our team designed a new prototype brace to reduce the shell movement allowed by the current brace.

Centering System

Centering System Design
We designed the automated centering system with t-slotted framing (Figure 1) to bolt-on to the existing table, keeping production flow and operators in mind. A closed-loop control system was designed to account for material variation. We included t-slot sliding carriages to position the actuators and sensors and allow the actuators to move with the motion of the shell. Laser distance sensors were used to locate the shell and base. We designed base clamps to locate two sides of the base and secure the base to the table.

Finite Element Analysis for Deflection
Because sensors and actuators are mounted on the same beam, we wanted to select a beam with minimal deflection. Deflection of these horizontal beams would result in erroneous readings and inaccurate centering results. We ultimately decided to use 3-inch t-slot framing because its modeled deflection was less than 0.01 inch (Figure 2).

Centering System Outcomes
We used a Click PLC to implement the PID controller, which was tuned using the Ziegler–Nichols method. The laser distance sensors repeatedly located the shell and base within 1 mm using an average filter. The t-slot and slides withstood the forces from the actuators, but the slides that the actuators mount to unexpectedly bound as the shell moved.

Prototype Brace
Brace Design
The bracing system was designed to be installed quickly with no tools. We aimed to design braces that remain in tension throughout the production process. We used turnbuckles in the design so the braces would remain in tension throughout production. The brace was also designed to not damage spa surfaces.

Bracing System Prototype
Prototype brace to keep the spa centered (Figure 1) to 25 s prototype brace to 0.368 in 0.125 in 0.063 in

Brace Outcomes
The bracing prototype produced (Figure 5) can be installed in five steps by hand. Gripping portions were machined from aluminum stock with rubber pads to interface with the spa’s shell and base.

Conclusions
The centering system accuracy needs to be improved before it can be used in production. The new brace design performed well but the cost needs to be reduced for the new design to be justifiable.

Suggestions for Improvement
The base and base clamps were more flexible than expected. As a result the base moved as the shell was actuated. A more rigid base clamp design, or additional sensors, would allow the system to better locate the base which would improve the centering accuracy. A better slide system should also be investigated for the actuator mounts. The current slides work but bind up too easily and don’t allow the actuators to move.

Acknowledgements
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Table 1. Centering system metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Current Capability</th>
<th>Project Goal</th>
<th>Project Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accuracy</td>
<td>0.125 in</td>
<td>0.063 in</td>
<td>0.368 in</td>
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<tr>
<td>Time to Center</td>
<td>50 s</td>
<td>25 s</td>
<td>13 s</td>
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<tr>
<td>Cost</td>
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Table 2. Brace metrics

<table>
<thead>
<tr>
<th>Metric</th>
<th>Current Brace</th>
<th>Project Goal</th>
<th>Project Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shell Movement</td>
<td>0.125 in</td>
<td>0.063 in</td>
<td>- in</td>
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<tr>
<td>Weight</td>
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<td>6 lb</td>
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<td>Steps to Install</td>
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<td>5</td>
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<tr>
<td>Cost</td>
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<td>$15 per brace</td>
<td>$80 per brace</td>
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