The Microbe Mixers

Group 243D

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Meet the Team

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Presentation Agenda

- Hedgehog Concept
- Key Product Specifications
- Subassembly Highlights & Features
- Engineering Analysis
- Product Testing
- Cost Summary
Hedgehog Concept

We aimed to improve our final product by utilizing our members' specializations in CAD, coding, and circuitry.
Key Product Specifications

- **Core XY Movement**
- **Usable Size:** 11.90" x 7.60" x 7.50"
- **Lightweight Design:** 11.75 pounds
- **Max Orbital Diameter:** 53.7 mm
- **Accurate OD/FI Sensors:** Within 3% of calibration
- **Heat Rated Parts:** Aluminum and PETG

<table>
<thead>
<tr>
<th>Customer Need</th>
<th>Metric</th>
<th>Microbe Mixer's Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dimensions: 14” (356 mm) x 9.75” (248 mm) x 7.5” (191 mm)</td>
<td>11.90” x 7.60” x 7.50”</td>
</tr>
<tr>
<td>7</td>
<td>Assembled weight and packaging &lt; 49 pounds</td>
<td>11.75 pounds</td>
</tr>
<tr>
<td>23</td>
<td>IP rating &gt; IP-X5</td>
<td>IP – X5 Silicon Coating</td>
</tr>
<tr>
<td>25/26/27</td>
<td>Adjustable and variably linear, orbital and double orbital patterns at 25 mm diameter and 1200 rpm speed</td>
<td>Max Diameter: 53.7 mm Nema-17 Stepper Motors Used</td>
</tr>
<tr>
<td>28</td>
<td>Number of conical 15 mL tubes held ≥ 6 Number of conical 50 mL tubes held ≥ 6</td>
<td># of 15 mL Clear Tubes = 6 # of 50 mL Clear Tubes = 6</td>
</tr>
<tr>
<td>33</td>
<td>Number of shut-off buttons ≥ 1</td>
<td># of shut off buttons = 1</td>
</tr>
<tr>
<td>34</td>
<td>Number of pause buttons ≥1</td>
<td># of pause buttons = 1</td>
</tr>
<tr>
<td>36</td>
<td>Max rated speed for 2 weeks at 70 C</td>
<td>Aluminum and PETG Parts</td>
</tr>
<tr>
<td>38</td>
<td>355nm wavelength light source Light source ≥ 6V</td>
<td>365nm UV LEDs</td>
</tr>
<tr>
<td>48</td>
<td>OD sensor reading is within 15% of fluid range calibration</td>
<td>Sensor Reading ≤ 3%</td>
</tr>
</tbody>
</table>
Full System Design

- Core XY movement
- Base Plate Subassembly
- Shaker Plate Subassembly
- UI Subassembly
Base Plate Subassembly
Base Plate: Design Highlights

Old Design

- Unthreaded bumper made out of SPR Rubber
- Wall enclosures fastened into thin base plate

New Design

- High-Temperature Load-Rated Threaded Bumper
- L-Brackets added and fasteners now located in manufacturable places
**Base Plate: Design Highlights**

### Old Design
- Holes designed for rail, limit switch, motor and idler mounting, with added holes for tensioning methods and a wire passage
- Two slits for tensioning and a cantilevered structure with complex geometry

### New Design
- Oval-like cut replaced with a circle and holes for tensioning removed for ease of manufacturing
- Redundant tensioning method eliminated and simplified machining implemented
Shaker Plate Subassembly
Shaker Plate: Design Highlights

Old Design

- The designed holes allow for eight 50 mL tubes and three 15mL tubes

- A one-piece design with curves along the sides. A manufacturers nightmare!

New Design

- The designed holes allow for six 50 mL tubes and six 15mL tubes

- Separated into three pieces, which added four holes. Curves replaced with straight edges.
## Shaker Plate: Design Highlights

<table>
<thead>
<tr>
<th>Old Design</th>
<th>New Design</th>
</tr>
</thead>
<tbody>
<tr>
<td>- A chamfer was applied to the cutout located at the top. The fastening location and a protrusion are located on the side of the piece.</td>
<td>- The chamfer and protrusion were eliminated to make a simpler design. The fastening location was moved to the top for ease of assemblance.</td>
</tr>
<tr>
<td>- Holes were designed for top rail, lower idler and limit switch mounting</td>
<td>- Lower idler mount fastening hole was eliminated, while limit switch holes were raised for touching</td>
</tr>
</tbody>
</table>

![Old Design Image](image1.png)  ![New Design Image](image2.png)
User Interface Subassembly
User Interface: Design Highlights

- Redesigned for user safety
- Potentiometers tune the speed and path diameter
- Air vents relocated to the top
- Back panel designed to keep the electronics better protected
- LCD display shows easy to follow instructions and updates
User Interface: Electronics
Featured here is:
- 15ml test tube
- 30 ml test tube
- Arduino Uno
- 4 LDRs
- 2 365nm UV diodes

All housed within a 3D printed unit that will use a USB cord to connect this unit to the main UI.

Housing features a cover to protect electronics from any spillage, as well as keeps all components in one neat package.
Evolution of Design: OD/FI

Old Design

New Design
OD/FI Analysis

**OD Calibration Curve**

\[ y = -6 \times 10^{-5}x + 0.0281 \]

**FI Calibration Curve**

\[ y = 0.1051x - 25.536 \]

- LDR reading vs. Milk %
- PPM vs. LDR reading
Material Ashby Plot Analysis

\[ C_{\text{butyl rubber}} = \frac{\sqrt{\sigma_f}}{\rho} = \frac{\sqrt{2 \text{ MPa}}}{900 \text{ kg/m}^3} = 1.57 \times 10^{-3} \frac{m^3}{\text{MPa} \text{ kg}} \]

\[ C_{\text{aluminum}} = \frac{\sqrt{\sigma_f}}{\rho} = \frac{\sqrt{100 \text{ MPa}}}{275 \text{ kg/m}^3} = 36.3 \times 10^{-3} \frac{m^3}{\text{MPa} \text{ kg}} \]
Shaker Top Plate Bending Analysis

\[
\frac{1}{12} bh^3 = \frac{1}{12} (149.2 \text{ mm})(6.35 \text{ mm})^3 = 3.184 \times 10^3 \text{ mm}^4
\]

\[
\delta = -\frac{PL^3}{3EI} = -\frac{(11.1 \text{ N})(103.25 \text{ mm})^3}{3(68.9 \times 10^3 \text{ MPa})(3.184 \times 10^3 \text{ mm}^4)} = 0.01856 \text{ mm}
\]
Drop Test Analysis

\[ v_f = \sqrt{2gh} = 3.836 \frac{m}{s} \]

\[ m = \rho_{PETG} V_{enclosure} = 0.698 \text{ kg} \]

\[ c = \sqrt{\frac{E}{\rho}} = 1283.744 \frac{m}{s} \]

\[ F = \frac{\Delta p}{\Delta t} = \frac{mv_f - mv_i}{\Delta t} = \frac{2mv}{2L/c} = mv \frac{c}{L} = m \frac{c}{L} \sqrt{2gh} = 17805.88 \text{ N} \]

\[ \sigma = \frac{F}{A} = 712 \text{ kPa} \]

\[ n_{FOS} = \frac{\sigma_t}{\sigma} = \frac{45.8 \text{ MPa}}{0.712 \text{ MPa}} = 63.62 \]
Vibration Analysis

\[ z_r(t) = esin(\omega t) \]

\[ \ddot{z}_r(t) = -\omega^2 esin(\omega t) \]

\[ m\ddot{z} + c\dot{z} + kz = m_p e\omega^2 sin(\omega t) \]

\[ r = \frac{\omega}{\omega_n} = 0.5 \]

\[ Z = \frac{m_p e}{m} \times \frac{r^2}{\sqrt{(1 - r^2)^2 + (2\zeta r)^2}} = 1.55 \]

\[ \theta = \tan^{-1}\left(\frac{2\zeta r}{1 - r^2}\right) = 1.8 \]

\[ z(t) = Z\sin(\omega t - \theta) = 1.392 \text{ mm} \]
Orbital Diameter Calculation

Center of Rail Block in Relation to Top Edge of Base Plate

\[ L_{\text{max}} = 150.66 \text{ mm} \]
\[ L_{\text{min}} = 96.96 \text{ mm} \]

\[ d_{\text{max}} = L_{\text{max}} - L_{\text{min}} = 53.7 \text{ mm} \]
Speed Calculation

\[ F_f = W_{sys} \ast \mu = 150.7 \text{ oz} \ast (0.3) = 45.21 \text{ oz} \]

\[ T = F_f \ast r_p = (45.21 \text{ oz})(0.54 \text{ in}) = 24.20 \text{ in} - \text{ oz} \]

\[ 780 \frac {\text{rev}}{\text{min}} \ast \frac {2\pi}{1 \text{rev}} \ast \frac {1 \text{min}}{60 \text{s}} = 81.68 \frac {\text{rad}}{\text{s}} \]

\[ V_{belt} = C_p \ast \omega_{motor} = \left(81.68 \frac {\text{rad}}{\text{s}}\right) \ast (0.085 \text{ m}) = 6.98 \text{ m/s} \]

\[ \omega_{orbit} = \frac {V_{belt}}{C_{orbit}} = \frac {6.98 \frac {\text{m}}{\text{s}}}{0.0785 \text{ m}} \ast \frac {1 \text{ rev}}{2\pi \text{ rad}} \ast \frac {60 \text{s}}{1 \text{ min}} = 849.09 \text{ rpm} \]
Product Testing: IP-X5

As a preliminary test, the utilized IP-X5 Silicon spray was applied to the moisture indicators.

The strips were stored inside the table’s housing and a constant water stream for the IP-X5 test was placed upon the design.

Only one indicator experienced failure and it was due to improper fastening. The tape holding the strip peeled the adhesive and altered the performance.
Product Testing: OD/FI

- 5 vials of florescent quinine were prepared and tested. Obtaining the concentration of quinine in the solution within a 15% range for all five was considered passing. (Florescent Intensity)
- 5 vials of a milk solution were prepared and tested. Obtaining the concentration of milk in the solution within a 15% range for all five was considered passing. (Optical Density)
- Successfully identified both milk concentrations and quinine concentrations within a range of 0 to 9% offset.
Future Testing

- For acoustic testing, the table must run at the full 350 rpm for 5 minutes while not exceeding a 50dBA sound level. Both linear and orbital patterns will be tested.
- For temperature testing, the table will be heated to a temperature of 70°C and must run at 350 rpm for 4 minutes. The same conditions must be met at a temperature of 4°C.
- The table must be fully functional after being dropped from a height of 75 cm onto concrete.
Cost of Materials

### Prototype

<table>
<thead>
<tr>
<th>Part Type</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTS</td>
<td>$ 843.45</td>
</tr>
<tr>
<td>Raw Material</td>
<td>$ 84.48</td>
</tr>
<tr>
<td>Custom</td>
<td>$ 20.99</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>$ 948.92</strong></td>
</tr>
</tbody>
</table>

- **OTS Parts**
  - Fasteners, pulleys, rails, electronics
  - McMaster-Carr, Amazon, Digi-Key

- **Raw Material**
  - 6061-Aluminum
  - Base Plate, Shaker Plate

- **Custom Parts**
  - 3D-prints (PETG)
  - Wall Enclosures, Tube Rack

### Mass Production

<table>
<thead>
<tr>
<th>Part Type</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTS Parts</td>
<td>$ 676.01</td>
</tr>
<tr>
<td>Raw Material</td>
<td>$ 82.73</td>
</tr>
<tr>
<td>Custom</td>
<td>$ 15.33</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>$ 775.81</strong></td>
</tr>
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</table>
## Cost of Assembly

<table>
<thead>
<tr>
<th>Subassembly</th>
<th>Assembly Time (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>615</td>
</tr>
<tr>
<td>Shaker Plate</td>
<td>490</td>
</tr>
<tr>
<td>User Interface</td>
<td>768</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>1873 sec = 0.52 hours</strong></td>
</tr>
</tbody>
</table>

The average salary for an assembler in Florida: $16.27/hour

Total Assembly Cost: $8.46
# Cost of Manufacturing

<table>
<thead>
<tr>
<th>Subassembly</th>
<th>Assembly Time (Hrs.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base</td>
<td>3.5</td>
</tr>
<tr>
<td>Shaker Plate</td>
<td>2.5</td>
</tr>
<tr>
<td>User Interface</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>6 hours</strong></td>
</tr>
</tbody>
</table>

The average salary for a machinist in Florida: $22.52/hour

Total Assembly Cost: $135.12
Total Cost

**Prototype**

- OTS Parts: $20.99
- Custom Parts: $84.48
- Raw Material: $9.03
- Manufacturing Labor: $135.12
- Assembly Labor: $843.45

**Total**

$1093.07

**Mass Production**

- OTS Parts: $135.12
- Custom Parts: $9.03
- Raw Material: $676.01
- Manufacturing Labor: $82.73
- Assembly Labor: $15.33

**Total**

$918.22
Design Summary

- Expansions in the design make for a multifaceted project.
- Room for improvement in most aspects of the project.
- Low cost and high versatility show enough promise that the concept should be completed.
Thank You.
Questions?