Automated Ply Handling Robot

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Project Problem Statement:
Albany Engineered Composites saw room for efficiency improvements by having robotic arm assistance within their “ply-pack” assembly process.

Abstract:
The pre-impregnated fiber reinforced composite material lay-up and manufacturing process is extremely labor-intensive with room for robotic assistance. By automating this complex process, Albany Engineered Composites can achieve greater efficiency in manufacturing. The goal of the Automated Ply Handling project is to design, test and finalize a 1’ x 1’ 16-point vacuum cup array end effector. This end-effector design will work in conjunction with a provided UR10 robotic arm, to assemble ply packs from a cutting table (see Figure 4). To ensure product quality and operational implementation, we will explore potential issues of material contamination, prepreg damage, foreign object debris, robot error handling and consistent function. In completion of this project’s scope, we intend the Technology Readiness Level to be level Five.

Engineering Analysis:
The analysis for this project involved many different engineering disciplines to design and problem-solve the following:
- Consistent and Powerful Vacuum Application
- Individual Control of Contact Points
- Positioning of End-effector and Integration with UR Bot

The control and routing of the vacuum power were very important engineering aspects of this project. The pneumatic system’s consistency, capacity, and lack of restriction was the largest area of improvement for the end effector. During the first iteration, we ran into a vacuum generation issue, resulting in calculations for a required air capacitance volume (see Equation 1). By making an equivalent electrical circuit and using a state equation solver in MATLAB, we were able to analyze how the flow coefficients and tube lengths affected the vacuum generation (see Figures 2&3).

Equation 1)

\[ V_{tank} = \frac{T(Q_{req} - Q_{avail})(P_{atm})}{(P_t - P_{min})} \]

\[ C_v = \frac{Q + \sqrt{V}}{\sqrt{\Delta P}} \]

\[ Q = \frac{V_{tube}}{t} \ln\left(\frac{P_1}{P_2}\right) \]

\[ \Delta P = \text{Change in Pressure (psig)} \]
\[ \Delta P = \text{Change in Pressure (psig)} \]
\[ V = \text{Chamber Volume (cubic ft)} \]
\[ t = \text{Time to Apply Vacuum (sec)} \]

Performance Results:
The performance of this project’s results were driven by the customer specifications and design requirements. The performance metrics were driven around consistency and operational capability, as shown in Table 1.

Table 1: Specification metrics on resultant project performance.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Resultant Value</th>
<th>Ideal Value</th>
<th>Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum Application</td>
<td>&lt;1 Second</td>
<td>&lt;1 Second</td>
<td>Validated</td>
</tr>
<tr>
<td>Lifting Capacity</td>
<td>~2 square foot ply</td>
<td>~4 square foot ply</td>
<td>(More Testing)</td>
</tr>
<tr>
<td>Plies Per Minute</td>
<td>12*</td>
<td>15</td>
<td>Competitive</td>
</tr>
</tbody>
</table>

*After 1 second of vacuum application, the capacitance tank took 5 seconds to fully reaccumulate vacuum (24 inHg)

Conclusion and Next Steps:
The next steps for the project will be combining the robot’s movement with the kit cutting gantry which will be necessary for more efficient ply handling. A system will be needed to communicate between the UR co-bot and the .dxf files used to cut the plies on the table.