Automated Ply Handling Robot

Department of Mechanical Engineering, The University of Utah

Albany Engineered Composites

Presented by: Caleb Bost, Victor Leao-David, Chase Lee, & Darrick Minshall

Supported by: Prof. Stephen Mascaro

AEC support: Aaron Cann, Cedric Jacob, & Griffin Rowland

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 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).

$$(1)\quad V_{tank} = \frac{T(Q_{req} - Q_{avail})(P_{atm})}{(P_i - P_{min})}$$

$$(2)\quad C_v = \frac{Q * \sqrt{G}}{\sqrt{\Delta P}}$$

$$(3)\quad Q = \frac{V_{tube}}{t} \ln\left(\frac{P_1}{P_2}\right)$$

C_v = Valve flow Coefficient
Q = Flow Rate (cubic feet per min)
ΔP = Change in Pressure (psi)
V = Chamber Volume (cubic ft)
t= Time to Apply Vacuum (sec)

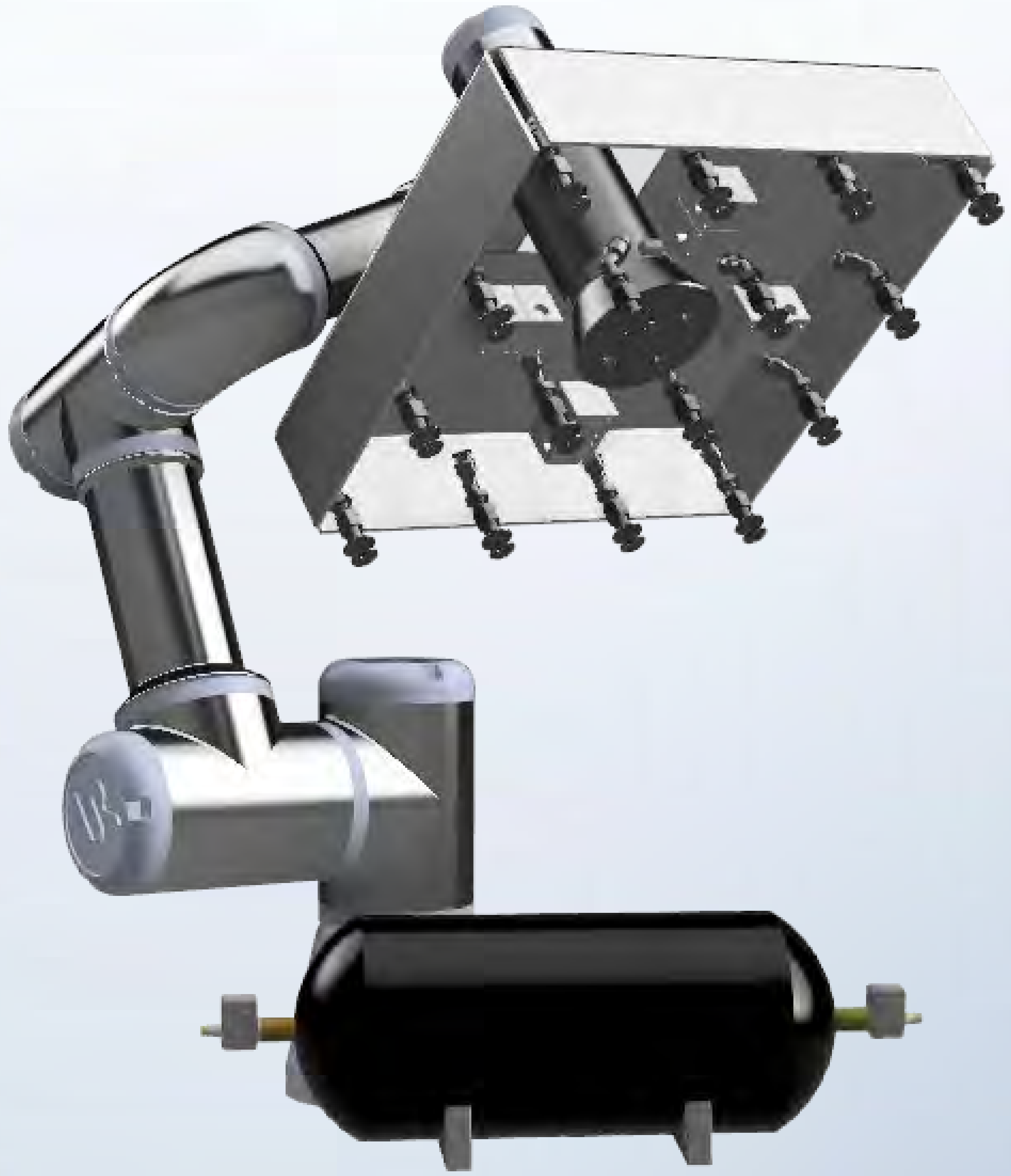

Figure 1: CAD rendering of the UR Co-Bot with our end effector attached along with the vacuum supply tank

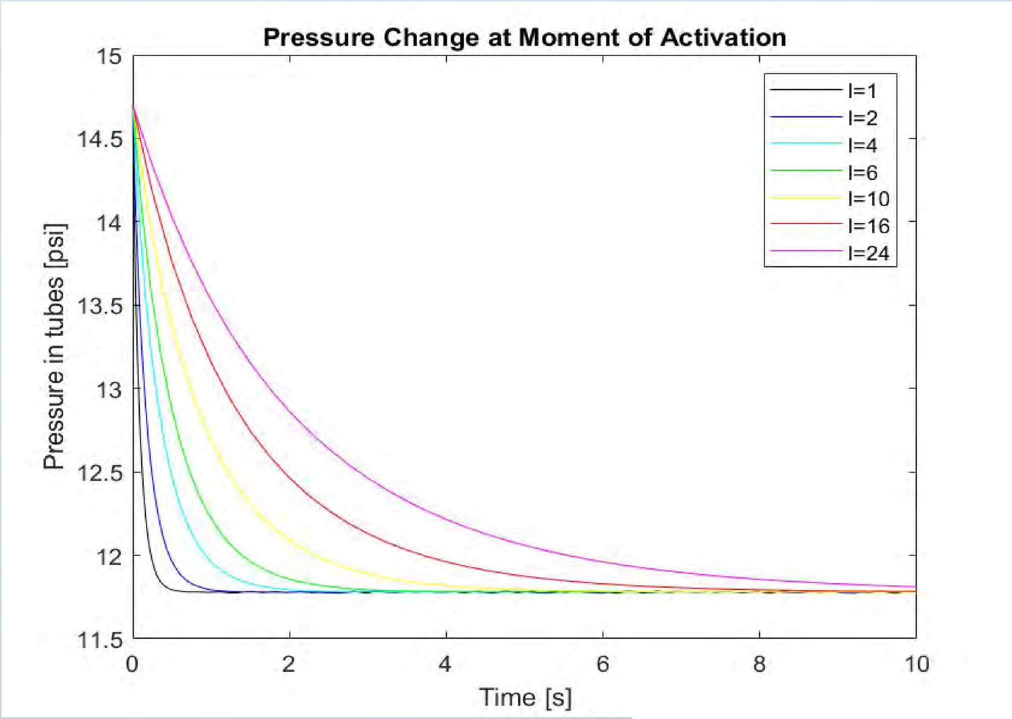

Figure 2: Shows pressure generation vs time considering only tube resistances with varying lengths. Results suggest that to achieve our desired time that tube lengths should not exceed 1 inch, which is not feasible.

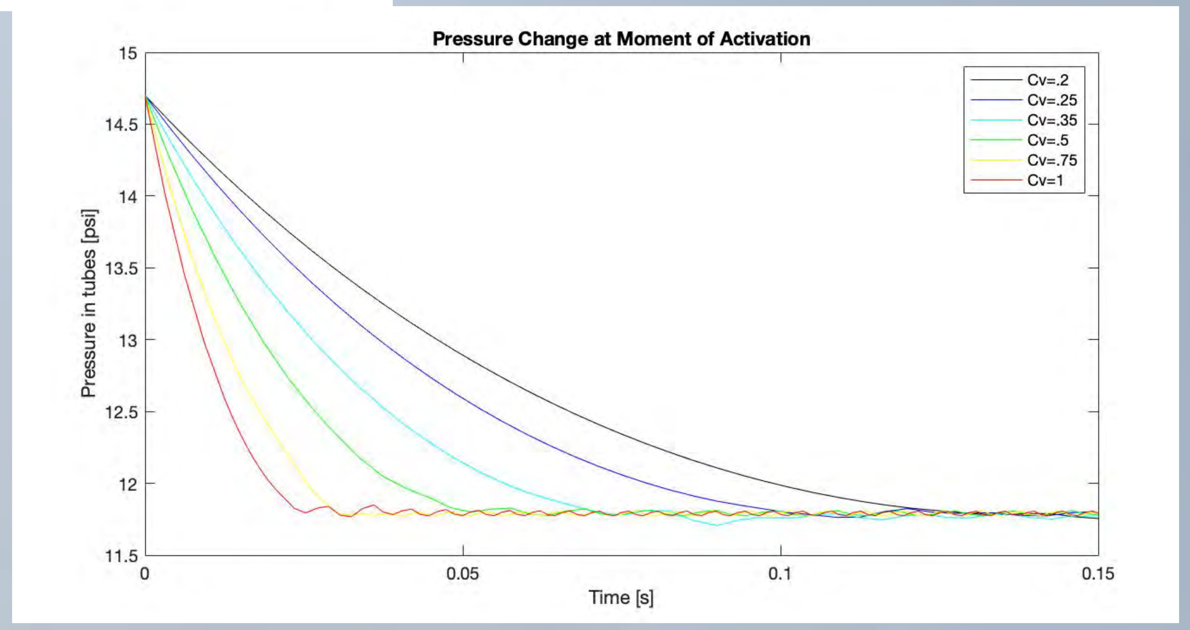

Figure 3: Shows pressure generation vs time accounting for fluid resistance of tubing with varying lengths. The greater reaction times suggest tubing to be the most important factor in reaching target grip speeds.

Product Testing:

Several testing methods and iterations were required to determine performance due to the complicated nature of carbon fiber plies. The carbon plies were covered with polyethene backing film as per standard process, allowing for a non-porous contact point of movement. Testing with multiple different shapes, sizes and material's, the project's performance was able to be tested as if the technology was implemented on the shop floor.

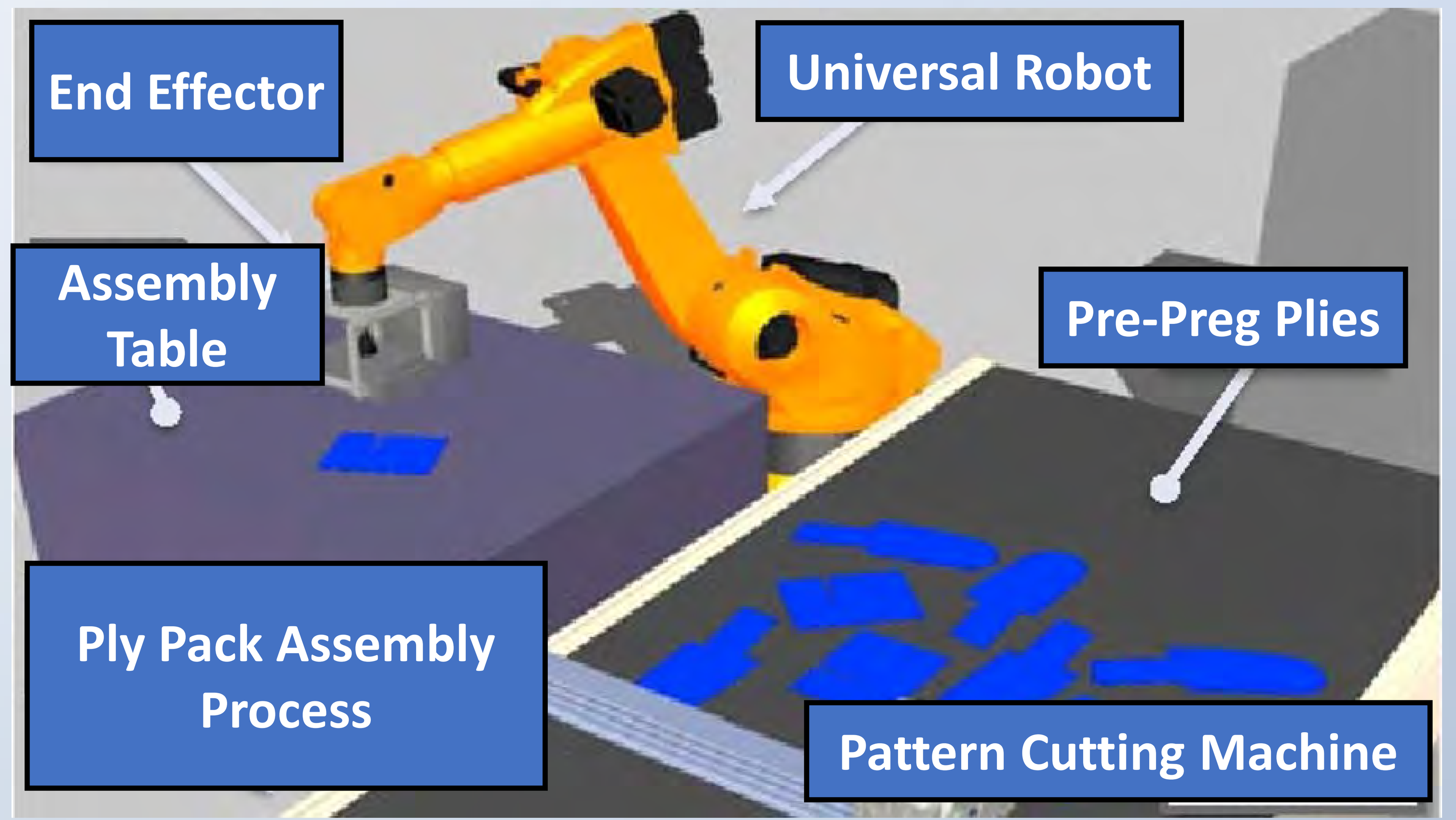

Figure 4: A CAD model showing the problem statement process. The movement between the pattern cutting machine, and the assembly table can be solved with the robotic ply handling robot.

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.

Specification	Resultant Value	Ideal	Analysis
Vacuum Application	<1 Second	<1 Second	Validated
Lifting Capacity	~2 square foot ply	~4 square foot ply	(More Testing)
Plies Per Minute	12*	15	Competitive

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

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 need to communicate between the UR co-bot and the .dxf files used to cut the plies on the table.