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Introduction

Permeability is critical to understand when manufacturing composites using *Liquid Composite Molding* (LCM). Injected resin will flow differently in each direction, which can have a significant effect on part quality and mold fill times.

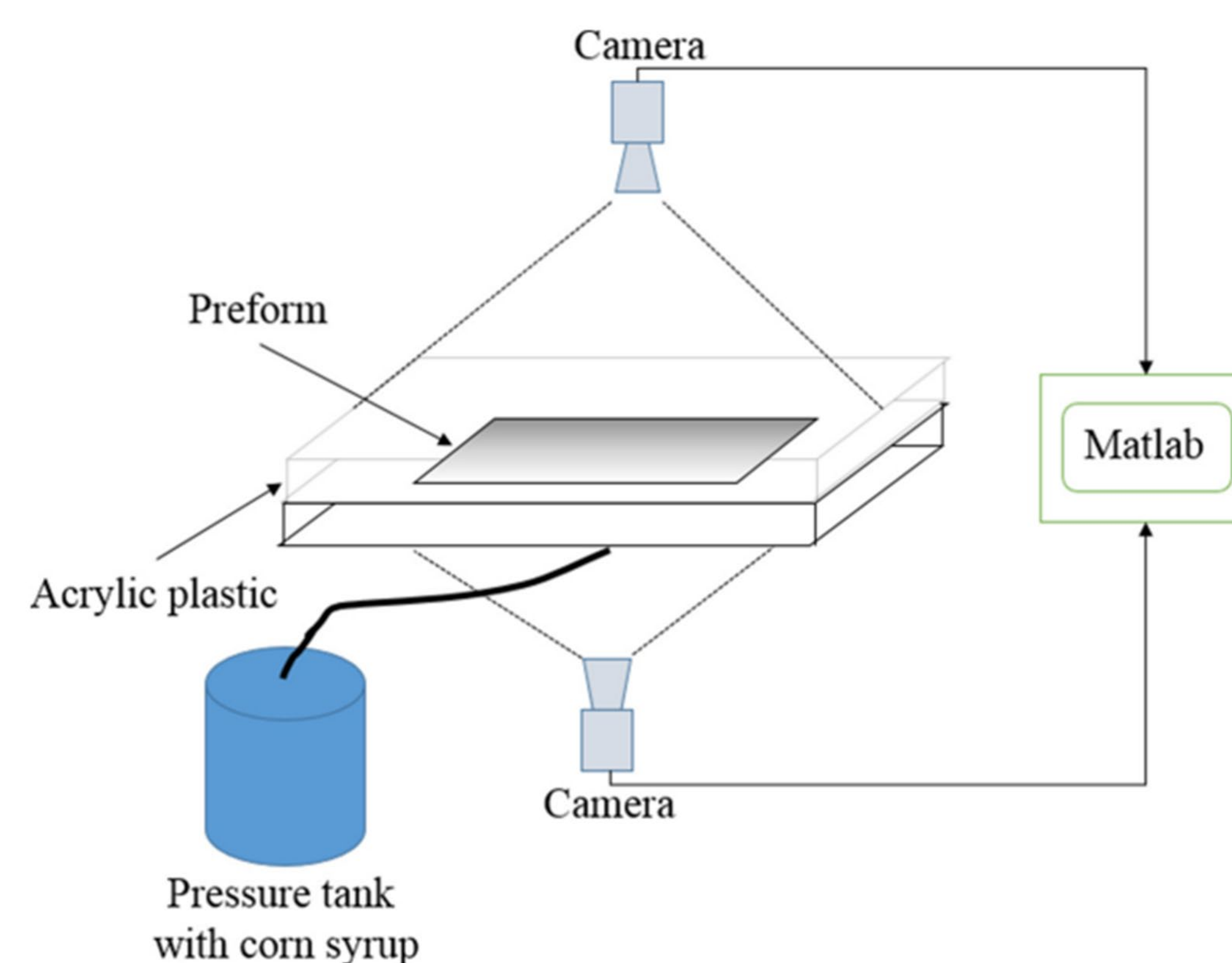
It is possible to measure the 3 in-plane permeability terms in a variety of ways, but a camera-based method allows for approximation of all 6 terms of the permeability tensor from *only a single experiment*.

$$K = \begin{bmatrix} K_{xx} & K_{yx} & K_{zx} \\ K_{xy} & K_{yy} & K_{zy} \\ K_{xz} & K_{yz} & K_{zz} \end{bmatrix}$$

Automating this system is the focus of this research, with the goal being to provide a turnkey solution for quick and simple permeability calculations.

Measurement Methodology

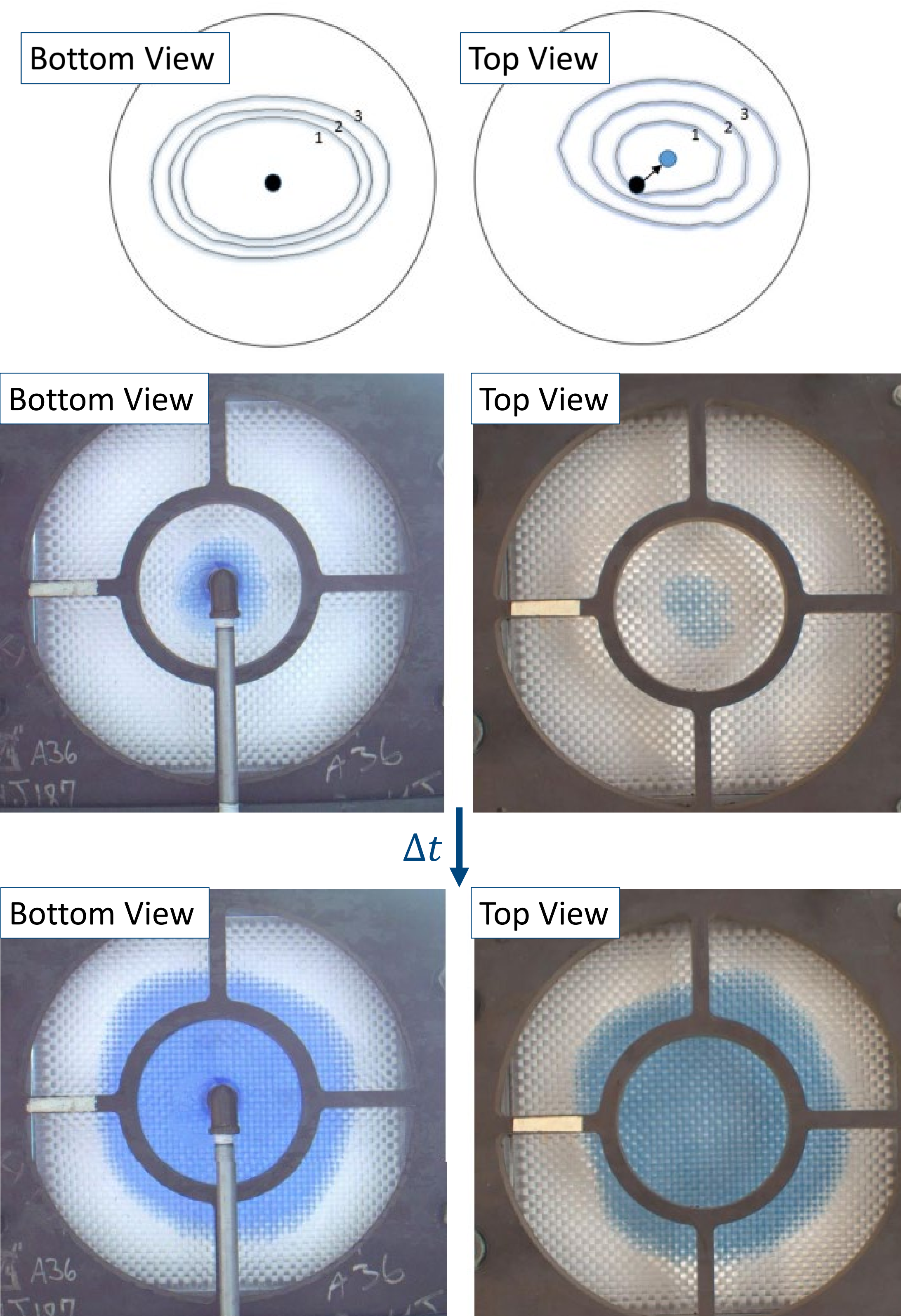
Cameras positioned above and below a clear acrylic mold take images of the flow front at regular time intervals. A Matlab optimization algorithm iterates through permeability values using LIMS until it converges to the experimental value.



System Overview

To visualize the flow, two reinforced acrylic blocks are secured together using metal spacer plates which maintain a constant volume inside the mold. The number of fabric plies and the spacer plate thickness can be adjusted to achieve the desired fiber volume fraction.

As the resin is injected from below, the cameras capture images of the flow. Dye is added to the resin matrix to increase contrast. By capturing images from the top and the bottom of the mold, Matlab can approximate the "slant" permeability of the fabric, or the difference in permeability through the thickness of the fabric.



System Improvements

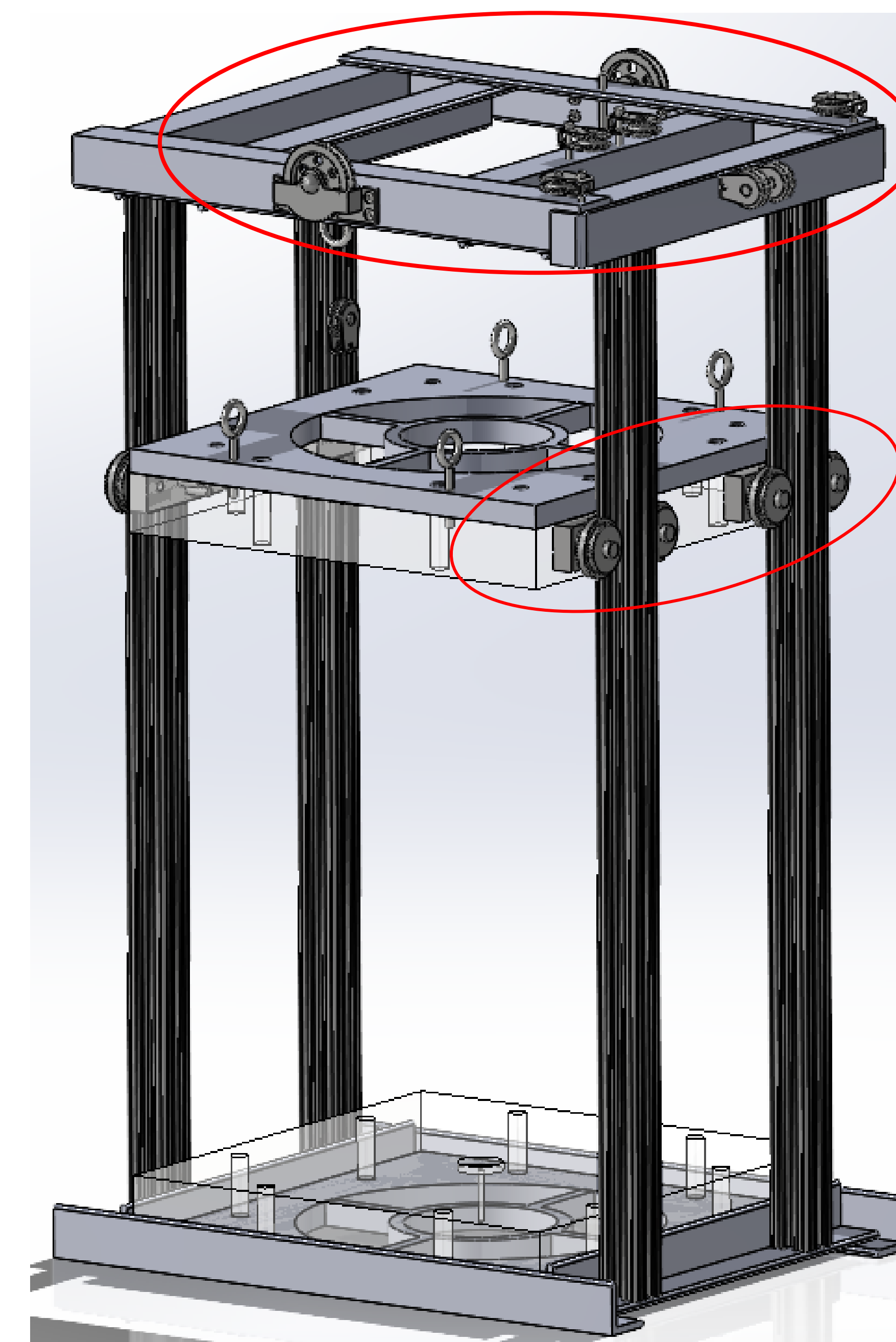
Changes made to the system are intended to **improve measurement accuracy**, and to make the system **easier to operate** by one person.

Operating Efficiency

- Linear Rollers
 - *Improves Acrylic Block Alignment*
 - *Easier to lift and lower the top block*
- Pulley System
 - *One person can operate full system*

Improve Data Collection

- Adjustable Camera Mount
 - *More consistent image collection*
- Blackout Curtains
- High-Contrast Resin Dye



Path to Automation

Future research will involve the gradual integration of each individual part into a single system. For the final system, operators will **prescribe** the following test parameters:

- Fabric or Fiber Type
- Resin Matrix Type
- Desired Fiber Volume Fraction

And the system will **automatically** adjust these settings, which are currently only adjustable manually:

- Acrylic Block Spacing (Mold Volume)
- Injection Pressure
- Injection Temperature
- Dye Concentration
- Image Capture Settings

The goal is to reduce the current 1.5hr experiment setup time to below 20mins, reduce the number of operators from 2 to 1, and to return the calculated permeability values to the operator within minutes of concluding the test.

Acknowledgements

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