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CENTER FOR COMPOSITE MATERIALS
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2005 RESEARCH REVIEWS

Effects of Distribution Media and Vacuum Bag Properties on Permeability Changes during Vacuum Infusion Processing

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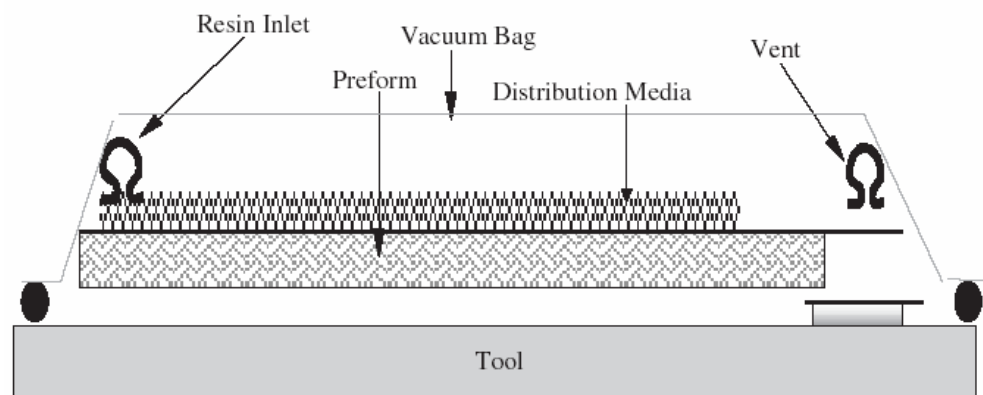
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Background

1. Typical the DM permeability has been calculated without considering the influence of the flexible bagging material, which may have a critical effect on the DM overall permeability.
2. Due to the vacuum pressure, the porosity of the VARTM system is decreased.
3. The vacuum bag occupies the gaps of distribution media, thus leading to a volume change.





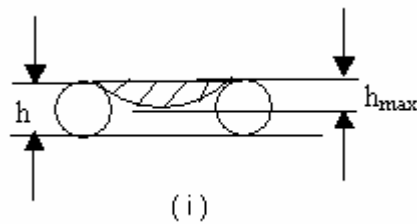
Objectives

- 1. Analytical model to estimate the effects of distribution media and vacuum bag on permeability in VARTM.**
- 2. Generate optimal design curves for DM and plastic bag manufacturers. The relevant parameters: thickness of plastic bag t , modulus of elasticity E , pressure P , dimensions of DM, including length, width and height.**
- 3. The results can also be used to calculate the permeability reduction factors for flow simulations to accurately predict the resin fill for different distribution media-flexible bag systems.**



Modeling

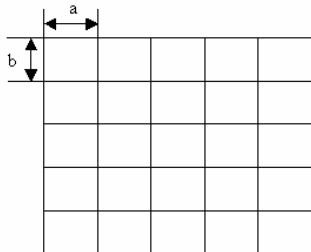
Basic Idea: Model each element of vacuum plastic bag over the distribution media as a rectangular membrane with large deflection under atmospheric pressure.



$$V_0 = \frac{1}{2}(\sigma_x \varepsilon_x + \sigma_y \varepsilon_y + \sigma_z \varepsilon_z + \tau_{xy} \gamma_{xy} + \tau_{yz} \gamma_{yz} + \tau_{zx} \gamma_{zx}) \longrightarrow P = \frac{C_1 \alpha h}{a^2} + \frac{C_2 E t h^3}{a^4}$$

$$C_1 = \frac{\pi^4 (1 + n^4)}{64}$$

$$C_2 = \frac{\pi^6}{32(1 - \nu^2)} \left\{ \frac{9 + 2n^2 + 9n^4}{256} - \left[\frac{(4 + n + n^2 + 4n^3 - 3n\nu(1+n))^2}{2(81\pi^2(1+n^2) + 128n + \nu[128n - 9\pi^2(1+n^2)])} \right] \right\}$$



$$h_{\max} = \left(\frac{[(108Pa + 12\sqrt{3}\sqrt{4C_1^3 \sigma^3 t^2 + 27P^2 a^2 C_2 E}) C_2^2 E^2 t^2]^{\frac{1}{3}}}{6C_2 E t} - \frac{2C_1 \alpha}{[(108Pa + 12\sqrt{3}\sqrt{4C_1^3 \sigma^3 t^2 + 27P^2 a^2 C_2 E}) C_2^2 E^2 t^2]^{\frac{1}{3}}} \right) a$$



Modeling

Once we have the deformed shapes of the membrane, we calculate the volume decrease due the vacuum bag deformation. Then we apply Carman-Kozeny equation to obtain the permeability K .

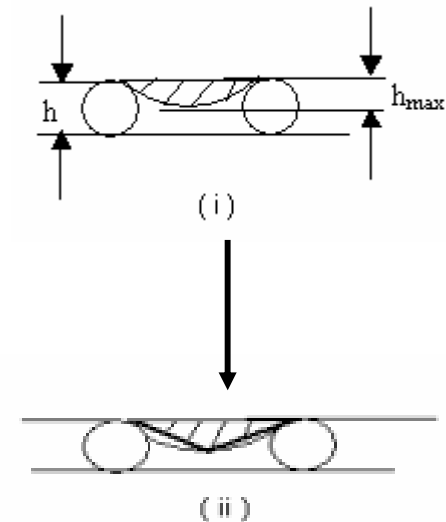
$$\Delta V = \frac{abh_{\max}}{3}$$

$$K_{\max} = k \frac{\phi_{\max}^3}{(1 - \phi_{\max})^2}$$

$$\phi = \frac{abh - \Delta V}{abh + 2 \times \frac{1}{4} \pi r^2 (a + b)}$$

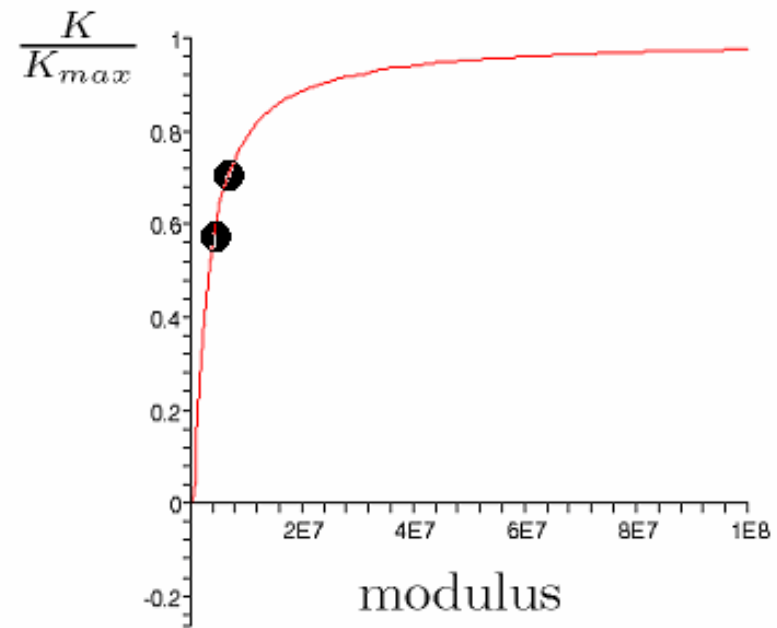
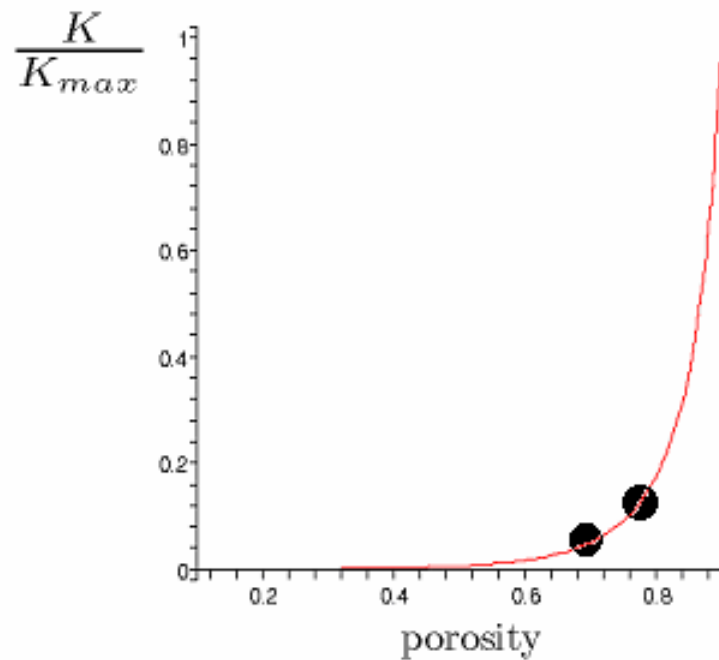
$$K = k \frac{\phi^3}{(1 - \phi)^2}$$

$$\frac{K}{K_{\max}} = f(h, E, t, a, b, P)$$





Design Curves – Preliminary Result

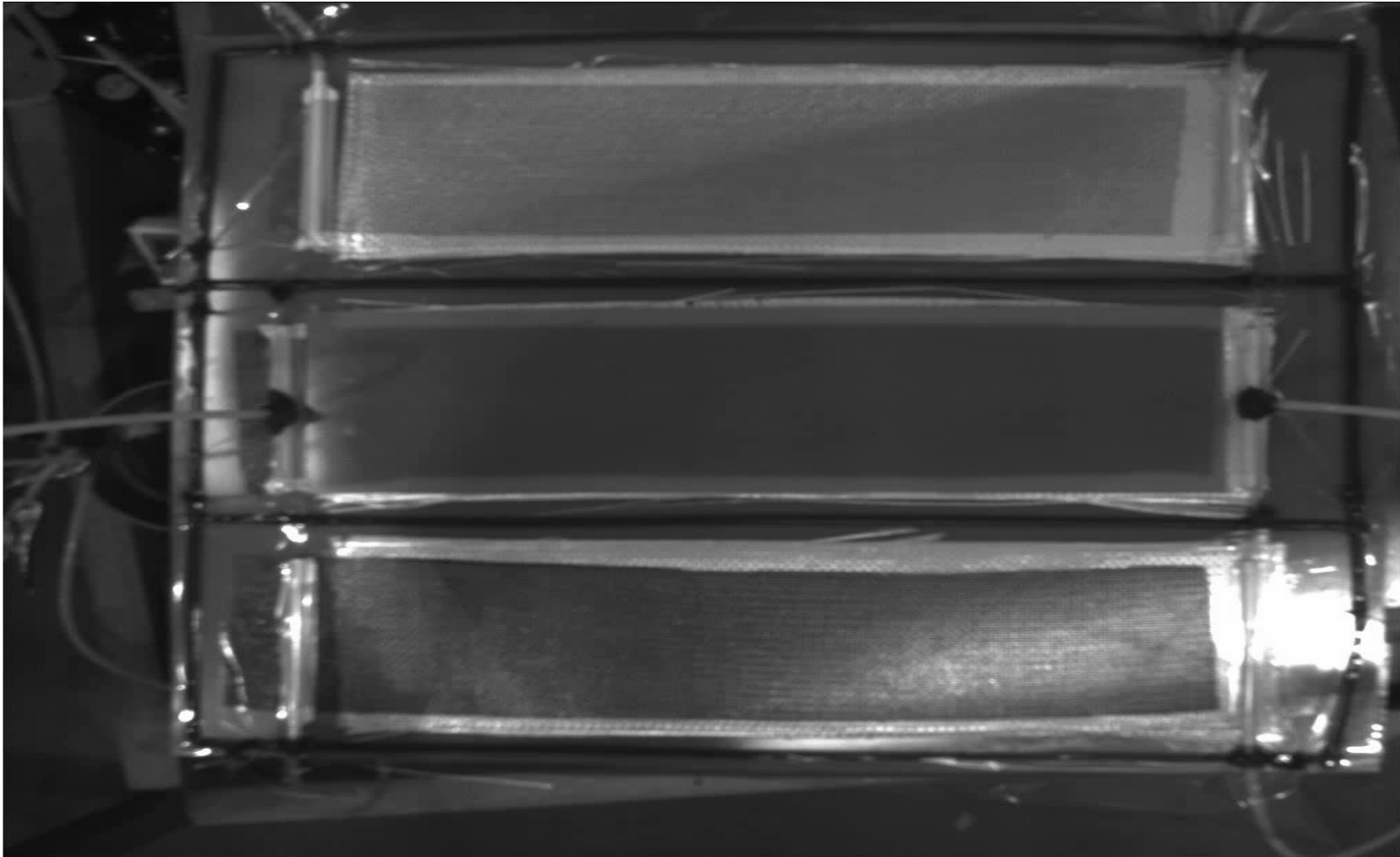




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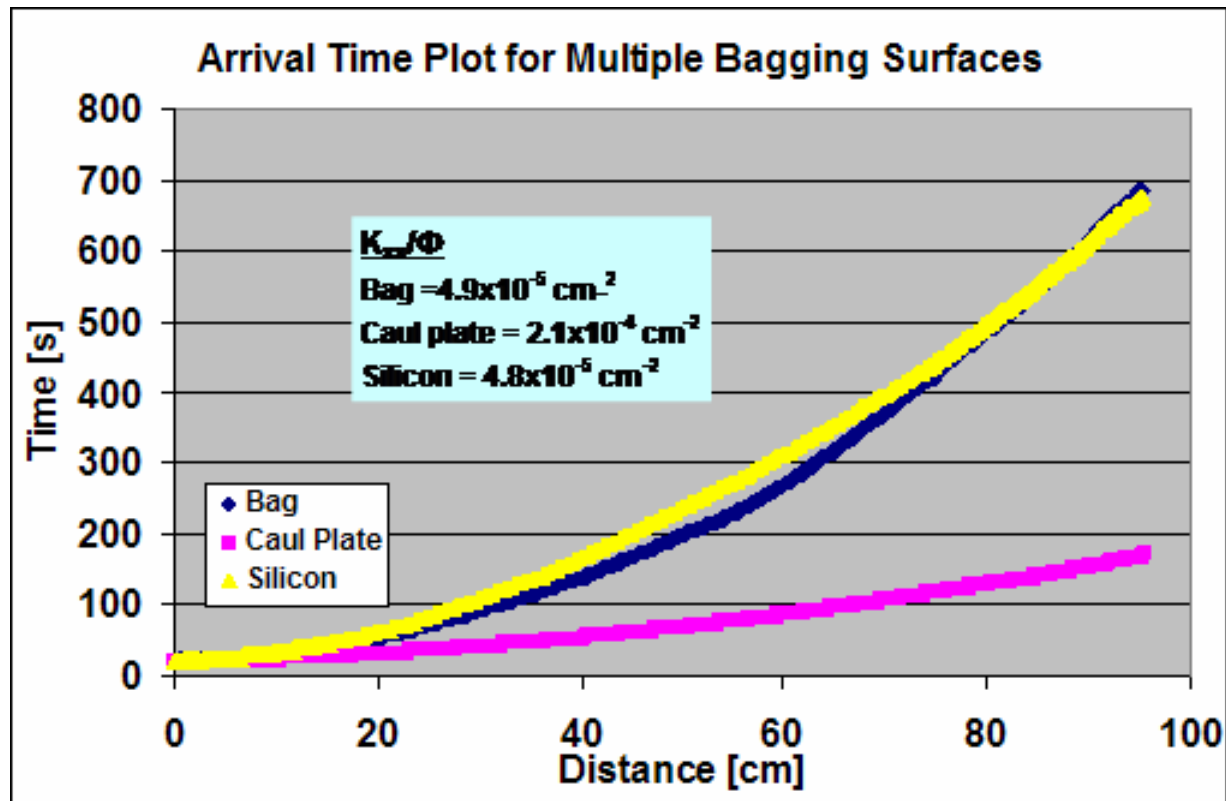


Experimental Setup





Arrival Time Plot for Multiple Bagging Surfaces





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Future Work

- 1. Model validation through experiments.**
- 2. ASTM D0882 to measure the mechanical properties of vacuum bag, coral plate, etc in order to verify the model.**