Miniature Environmental Testing Chamber:

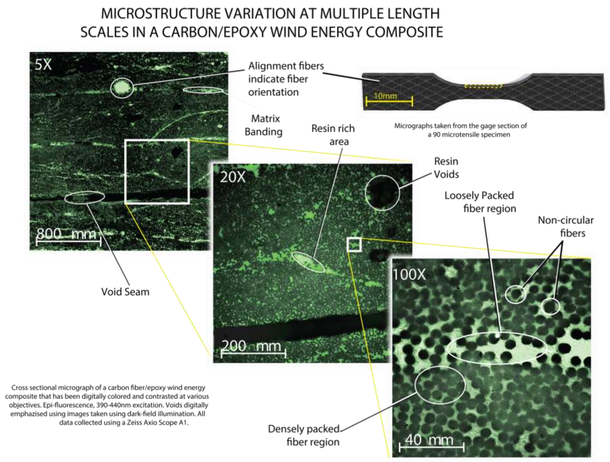
Investigation of Microstructure Failure in Composite Materials

David Veinbergs , Samuel Gates, Gabriel Maestas, Nicholas Turner

Senior Design
Mechanical Engineering
Energy Systems Engineering

Background

- **Research:** Failure of composites at micro-structure level.



- **Goal:** Design a chamber that allows for observation of material micro-structure failure at a *specified temperature and humidity*.
- **Why?**
  - Observe failure mechanisms *in situ*
  - Current devices are expensive and have limited capability.

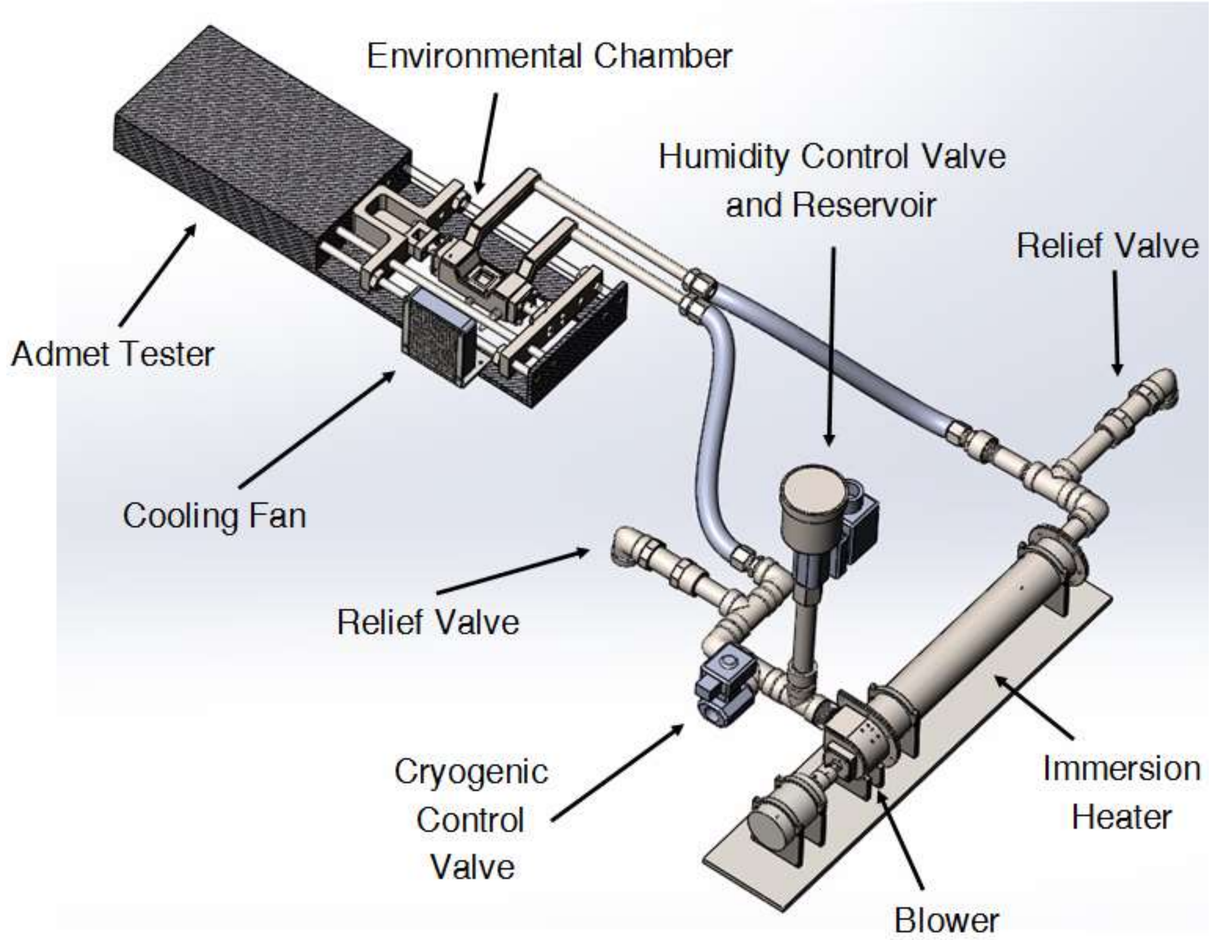
Design Specifications

Specification	Restriction
Maximum Cost	$ 2,250
Maximum Weight	5 lbs
Window Transparency	350-750 nm
Objective Height from Specimen	0.08 in
Chamber Dimensions	3.75x3.375x1.5 in
Temperature Range	-150 ^{o}C to 250^{o}C
Humidity Range	5 to 95% RH
Duration of Operation	4 Weeks
Resistant to Corrosion	

Abstract

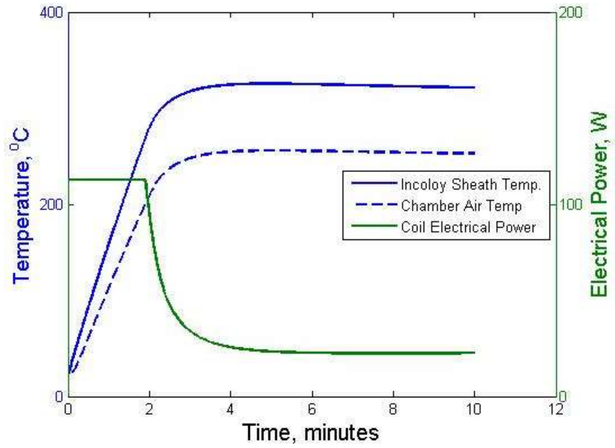
Assistant Mechanical Engineering Professor at the University of Wyoming, Dr. Ray Fertig III, has commissioned Enviro Engineering, Inc. to build a miniature chamber to be used for controlling environmental variables during micro compressive testing. The chamber will operate within a temperature range of -150^{o}C to 250^{o}C. 316L stainless steel is the primary chamber material along with PTFE seals and Pyrogel insulation. The chamber materials and components are resistant to corrosion. Cooling and heating will be achieved through liquid nitrogen and an immersion heater. The fluid is circulated throughout the system using a blower. The chamber will maintain environmental humidity conditions through a custom humidifier. A check valve maintains ambient pressure within the system. A second check valve prevents the system from operating in vacuum. The heating, cooling, and humidification processes will be controlled via LabView and an external multifunctional DAQ. Temperature and humidity sensors will be placed inside the chamber. The cost of the design exceeds the $2,250.00 budget by 10%.

Final Design



Mathematical Modeling

Thermal Performance

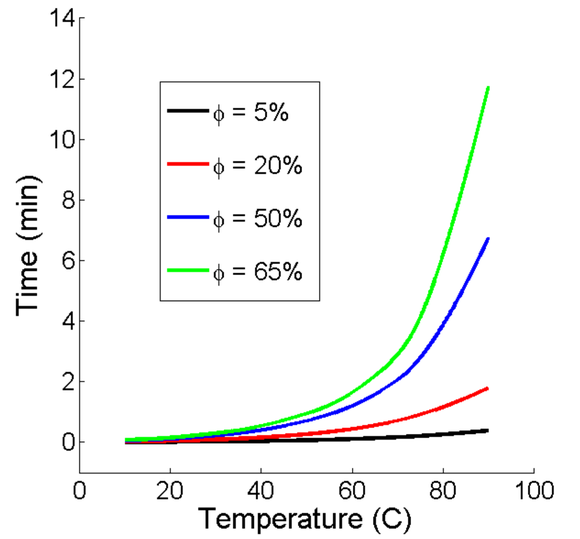


$$\dot{Q}_{convection} = \dot{Q}_{stored} + \dot{Q}_{loss}$$

$$\bar{h}A_s\left(T_s(i) - T_a(i)\right) = (\rho V c)_a \frac{T_a(i+1) - T_a(i)}{\Delta t} + (1 - \eta_{ins})(T_a(i) - T_\infty)$$

$$output(t) = K_p * e(t) + K_i \sum_{n=1}^{t/\Delta t} e(n\Delta t)\Delta t + K_d \frac{e(t) - e(t - \Delta t)}{\Delta t}$$

Humidification Time



$$t = \frac{m_w}{g_w} \qquad m_w = x * m_a \qquad g_w = \Theta\, A\, (x_s - x)$$