Creep Testing of Polypropylene and PP-GF30 LFT

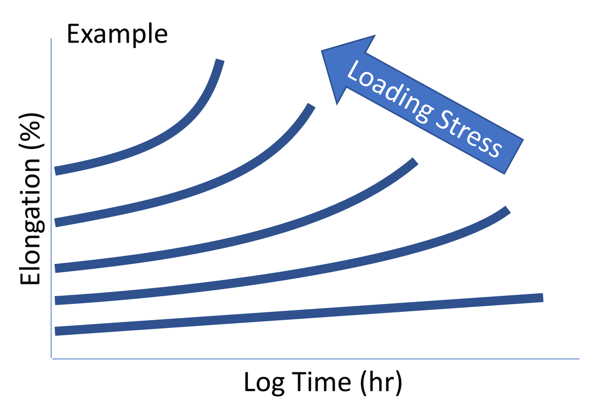
Max Kauphusman, Regan Harvey, Eric Kerr-Anderson

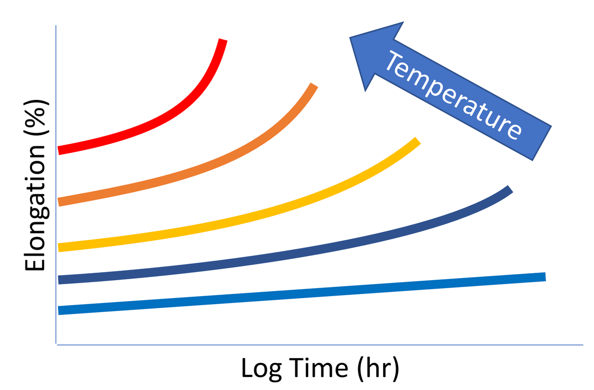
MILLER BROTHERS SCHOOL OF ENGINEERING
COMPOSITE MATERIALS ENGINEERING
WINONA STATE UNIVERSITY

Creep Testing is an expensive and time-consuming process. For thermoplastic materials, it is critical to understand creep and develop fast methodologies to discern creep performance. Long Fiber Thermoplastics (LFT) take advantage of using ceramic glass fibers that are highly resistant to creep to increase a thermoplastic material's creep performance. As creep data can take 3 months, anything that can be done to decrease the characterization time would be highly desired. The first part of this research is analysis using traditional methods, which will be compared in the second phase of research with time temperature superposition methodologies for both polypropylene and a polypropylene reinforced by glass fiber at a 30% loading by weight.

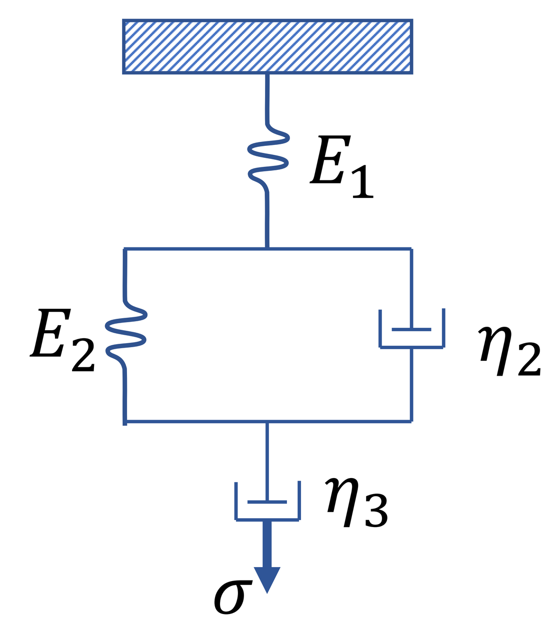
Background

All materials creep over time. This means that when subjected to a load, a part will slowly deform continuously and progressively until failure. Creep increases as the applied loading increases and as the material temperature increases. Thermoplastics dramatically increase creep as the temperature approaches the melt temperature.

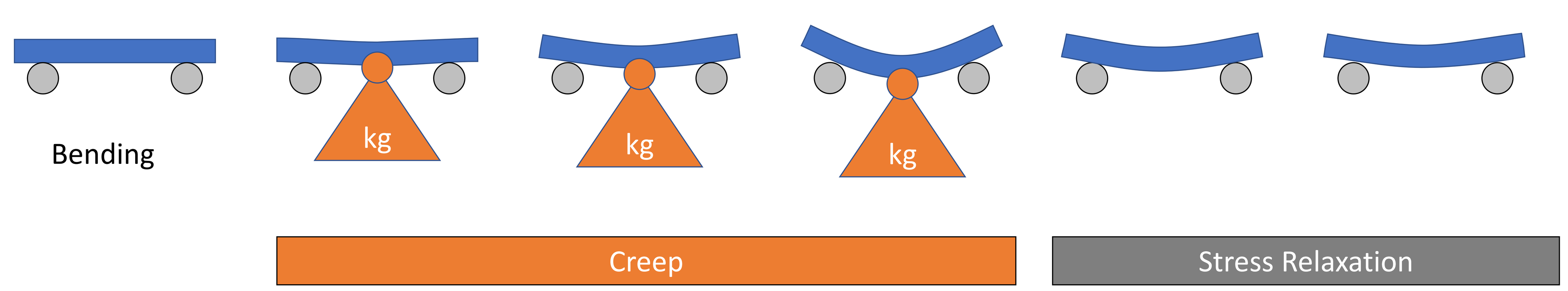




Thermoplastic materials exhibit a combination of immediate deformation resulting from loading, recoverable creep resulting from thermoplastic polymer chain reorientation, and unrecoverable creep generated from polymer chain damage. The combination of loading, temperature, and deformation mechanisms makes modelling creep data challenging. A four-part Maxwell model as shown at right and below is typically used to describe creep behavior.



$$\varepsilon_{Total} = \frac{\sigma}{E_1} + \frac{\sigma}{E_2}\left(1 - e^{-(t/\tau_2)}\right) + \frac{\sigma}{\eta_3}t$$



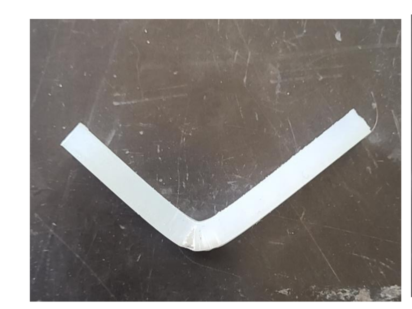
Experimental Setup

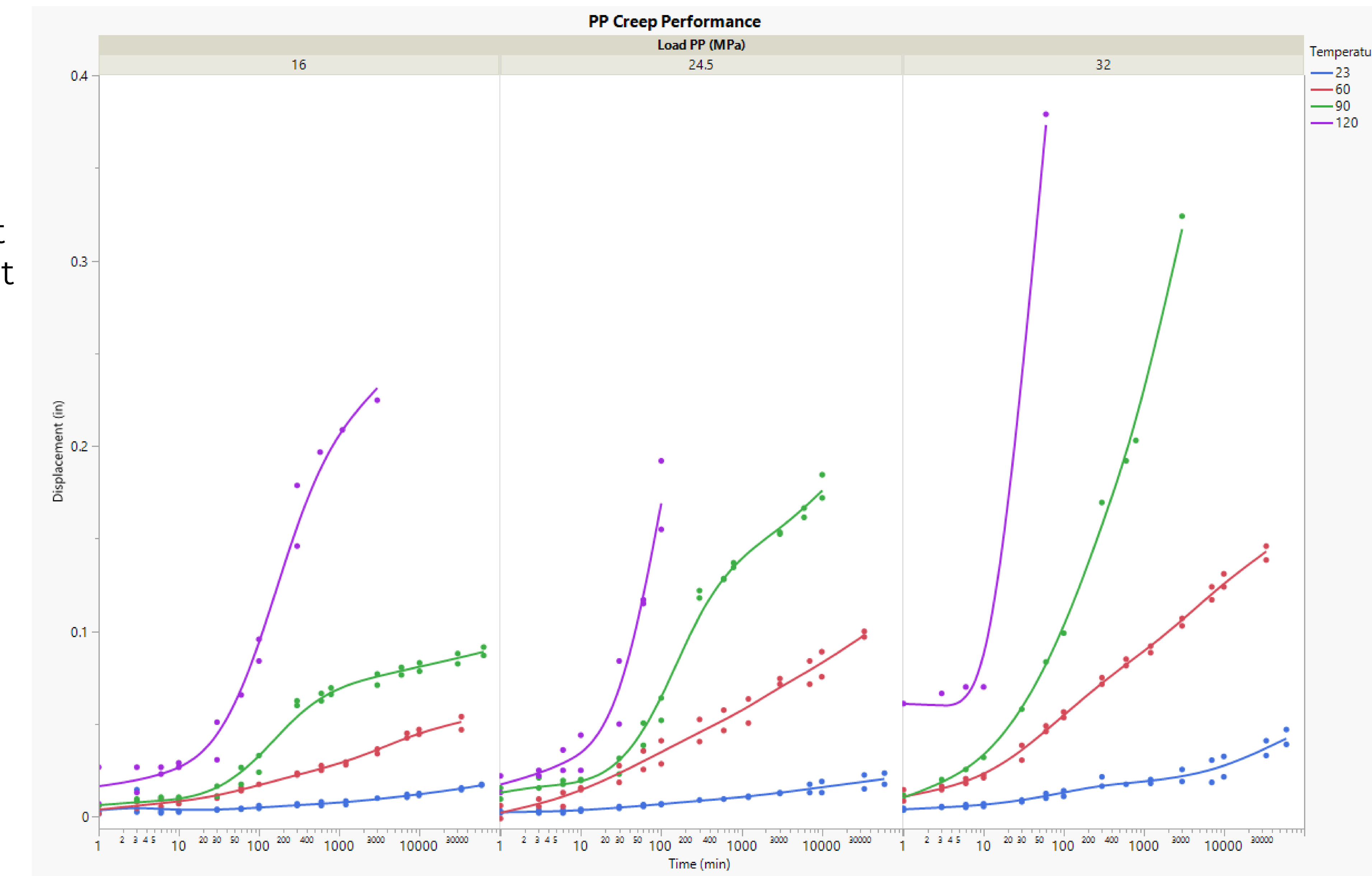
Three-point flexural creep testing was conducted as shown below.

Each specimen was loaded independently with a significant amount of hanging steel plates, and each specimen displacement at center was measured over time. An enclosure was used for creep testing at controlled temperatures. Measurements were planned to be acquired in minute increments of 1, 3, 6, 10, 30, 60, 100, 300, 600, 1000, 3000, 6000 or until failure. Additional room temperature measurements were collected.

Results

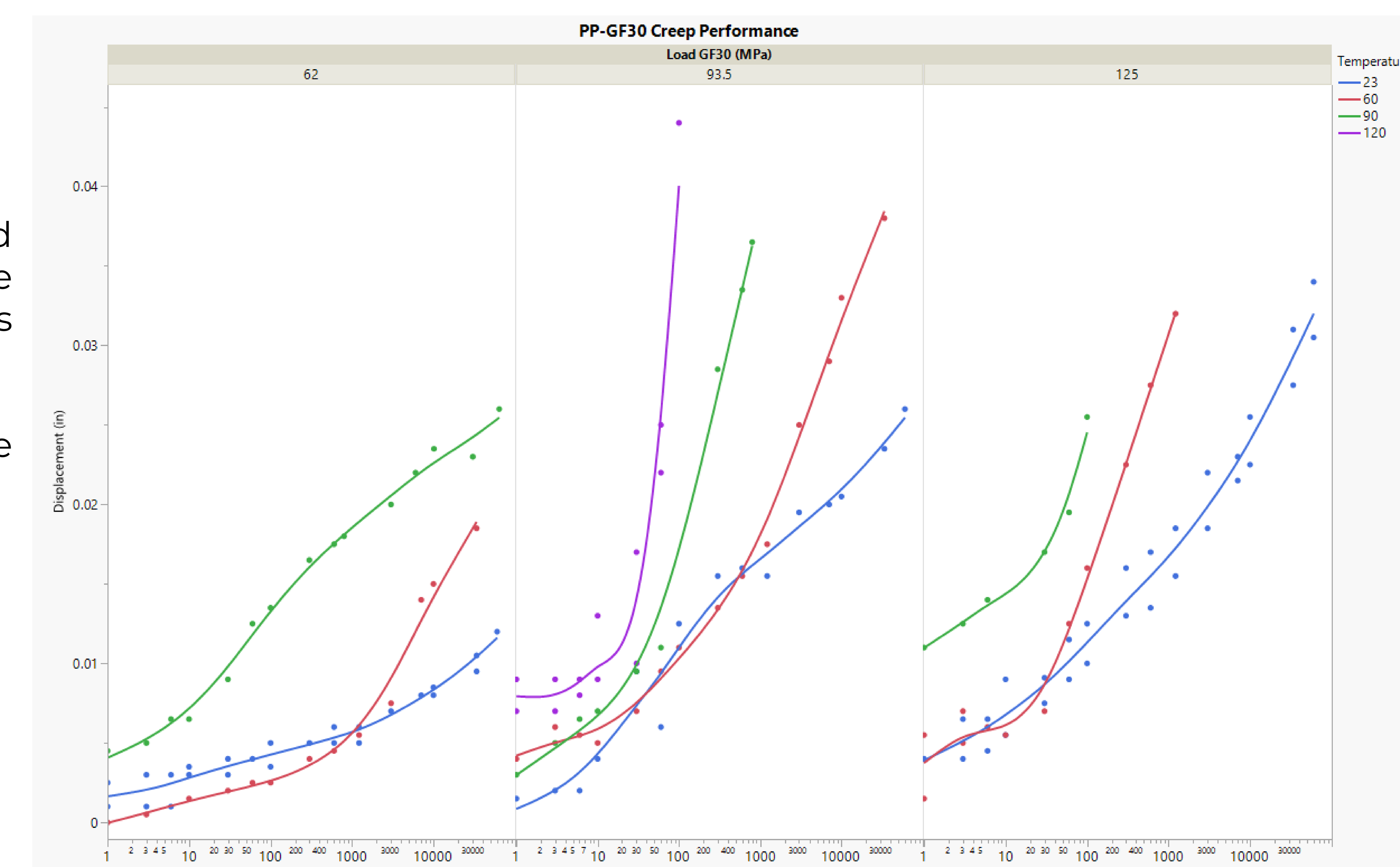
The results of the 3-month long study for the polypropylene flexural creep testing is shown at the right. Results were consistent with theory for polypropylene. Failure developed on the tensile (bottom) side of the flexural specimens as shown below.





The LFT was much more resistant to creep deformation than polypropylene. The results clearly demonstrated an increase in creep as a function of both applied stress and temperature.
Performance generally followed the loading and temperature expectations, but there was more noise than PP

Below is an example of the failure observed for the LFT.



Future Work

The next steps in this research include fitting the above data to standard creep models and conduct time temperature superpositioning using a Dynamic Mechanical Analyzer (DMA).

Winona State University Foundation