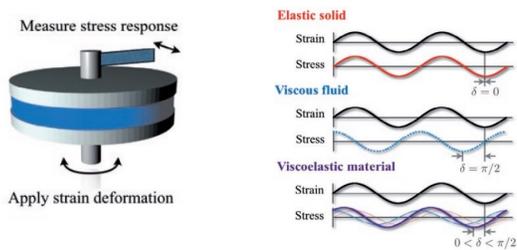


# Effect of Polymer Content on Polymerization Time of Synthetic Hydrogels DOE

## Introduction

Hydrogels are viscoelastic polymer networks that exhibit elastic and fluid Newtonian properties. Purely elastic solids impose a strain that is in phase with a sinusoidal deformation acting upon them, while pure liquids display an out-of-phase stress-strain relationship. Based on this principle, quantities describing physical behaviors of viscoelastic materials can be derived using oscillatory rheometry. As materials are subjected to sinusoidal stress, the stress/strain relationship is used to find these quantities.



The **storage ( $G'$ ) modulus** and **loss ( $G''$ ) modulus**, indicate the relative contribution of the elastic and fluid portion of the substance to its torque. As it cross-links,  $G'$  steeply increases, plateauing at a maximum elasticity value ( $G'_{max}$ ) once formed. Elastic resistance provides real-time assessment of polymer formation in hydrogels.

## Materials and Methods

### Hydrogel Preparation:

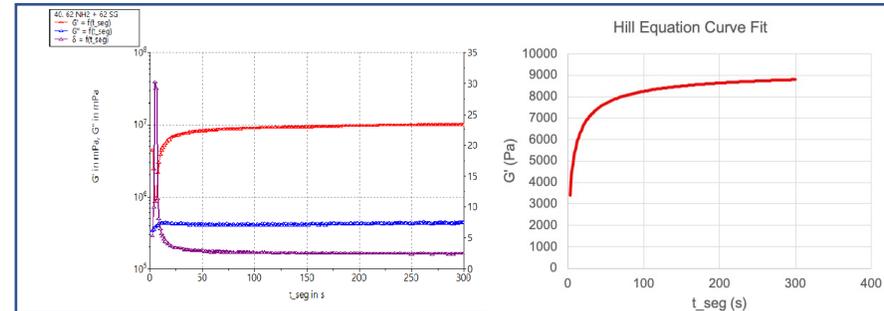
High and low concentrations of monomers A and B were tested in various combinations to assess the limits of their concentrations on reaction rate. pH of A was regulated throughout the study, and B was dissolved immediately before testing.

### Oscillatory Rheometry:

The oscillatory sweep was performed for each hydrogel using the RheoWin MARS IQ rheometer. After launching the oscillatory sweep, the solutions were dispensed with a dual syringe mixing device into an 8mm radius. Each test ran for five minutes to generate a plot of  $G'$  vs. time (seconds).

## Analysis Models

Each rheological test measures the **storage modulus ( $G'$ )**, the most relevant response variable in understanding the polymerization rate of hydrogels. The elastic curve of each oscillatory test was fit using the Hill Equation to derive quantities related to their polymerization time: maximum  $G'$  (max), time at half-maximum  $G'$  (k), and slope at k.



Using surface response regression, the relationship between parameters  $G'_{max}$ , slope at k and the concentrations of constituents A and B was investigated.

## Results

### Slope at k vs. Solution A, B

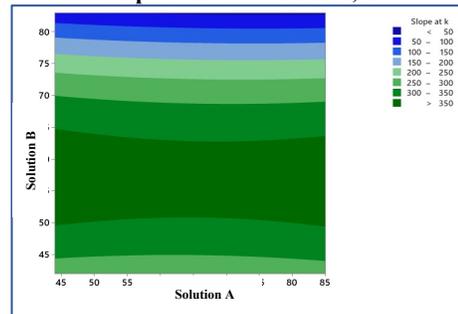


Figure 1: Contour Plot of slope at k vs. Concentration of Solutions A, B (A not significant,  $p > 0.05$ )

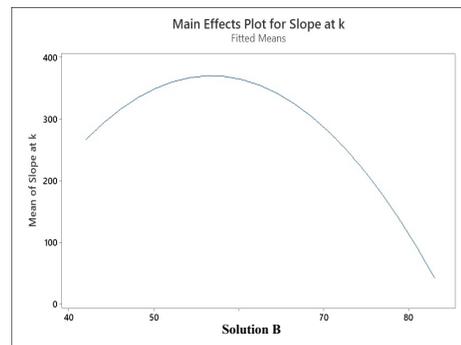


Figure 2: Main Effects Plot of slope at k vs. Concentration of Solution B

### Maximum $G'$ vs. PC, r

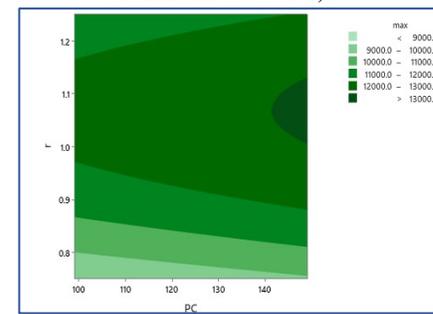


Figure 3: Contour Plot of max  $G'$  vs. Polymer Content,  $r$  – where  $r$  is the ratio of Solution A to Solution B

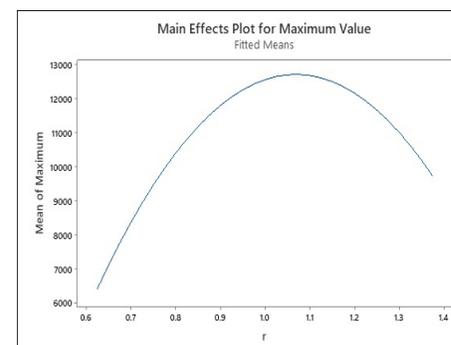


Figure 2: Main Effects Plot of Max  $G'$  vs. Polymer Content and  $r$  (PC  $p > 0.05$ )

## Conclusion

The most rapidly polymerizing hydrogels had nearly equal concentrations of constituents. The concentration of solution B is the only statistically significant contributing variable to the slope at k. At low and high concentrations of B, the slope at k is low. Similarly,  $r$  is the only significant factor in predicting maximum value. Low and high values of  $r$  correspond to low maximum values, consistent with the trend observed with slope at k. It can be inferred that the effect of Solution B on pH is the driving force behind polymerization. High concentrations of Solution B relative to Solution A may reduce buffering capacity and result in slower polymerization rates.

## Further Directions

This preliminary method is extremely variable which may be due to an axial force error in the RheoWin software. It is, however, straightforward to execute with the device and captures, in detail, the material's physical properties as it polymerizes. If the variability can be reduced, the information provided by the rheometer could be extremely useful in polymerization time analysis and understanding the effect of each constituent on the reaction rate.

## References

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