



# Investigation and Optimization of the Recyclability of Thermoplastics for Circular Economy

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## Introduction

### Circular Economy

- Composite are widespread and have many uses
- The use of composite materials generates lots of waste
- Thermoplastics do not form chemical bonds making them attractive to recycle
- Waste is mitigated by using a circular economy method (Figure 1)

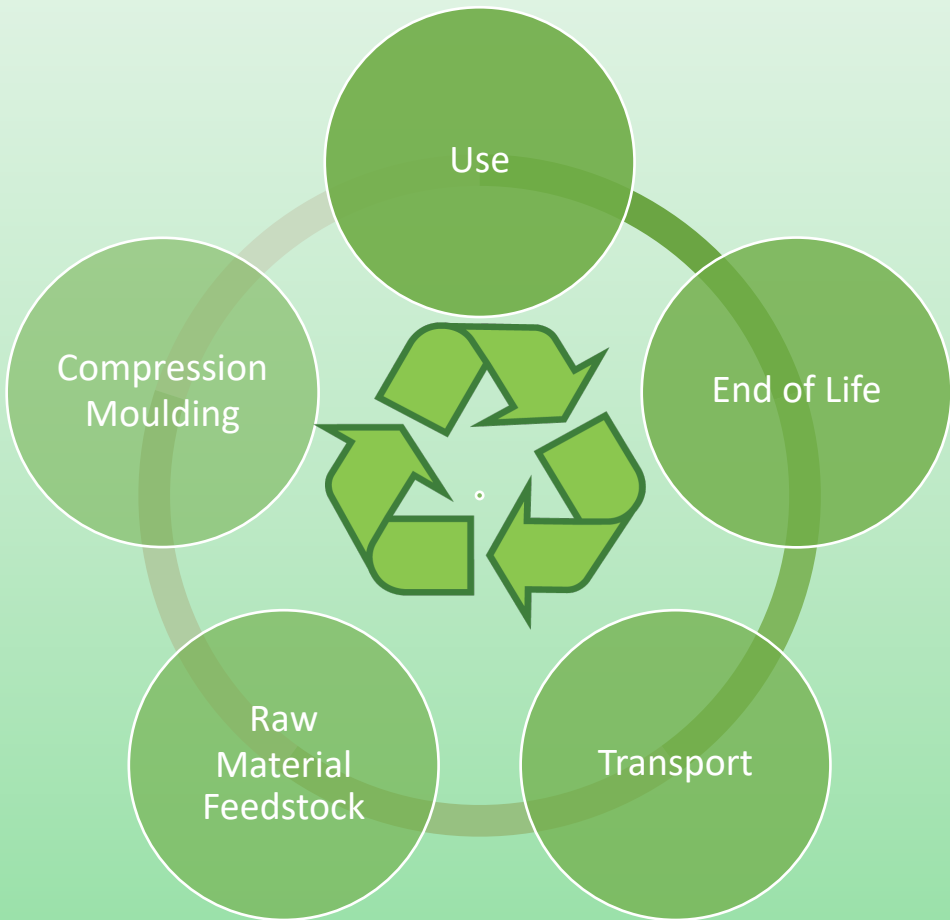


Figure 1 – Overall Recycling Process of a Thermoplastic

### Project Overview

- Thermomechanical, structural and rheological analysis of pristine and recycled samples
- Investigation into a valid recycling methodology and composition
- The Box-Behnken experimental design method utilized to create a quadratic model for behavior optimization

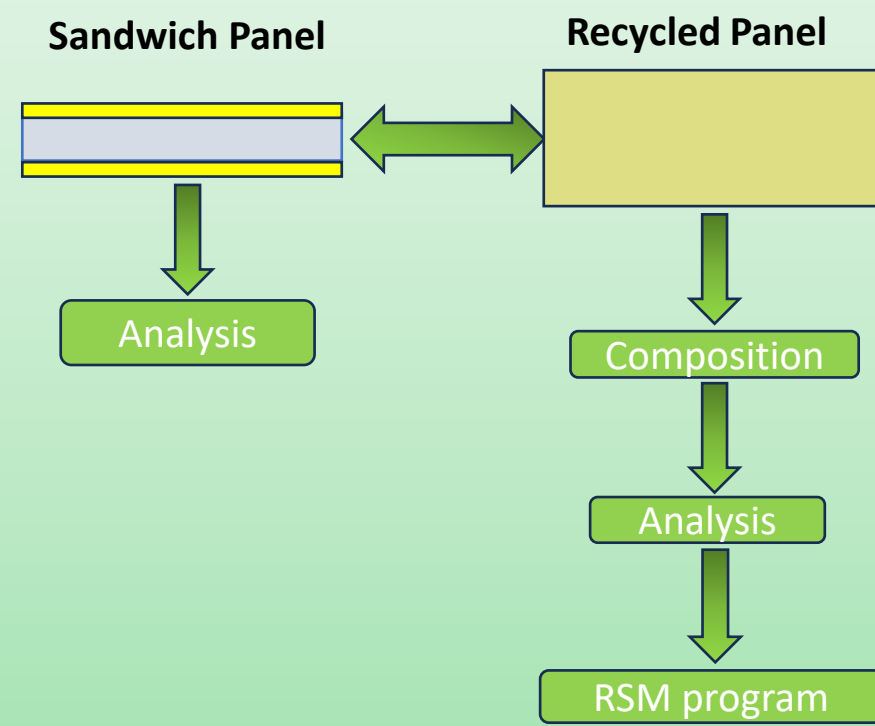


Figure 2 – Project Roadmap

## Materials and Methods

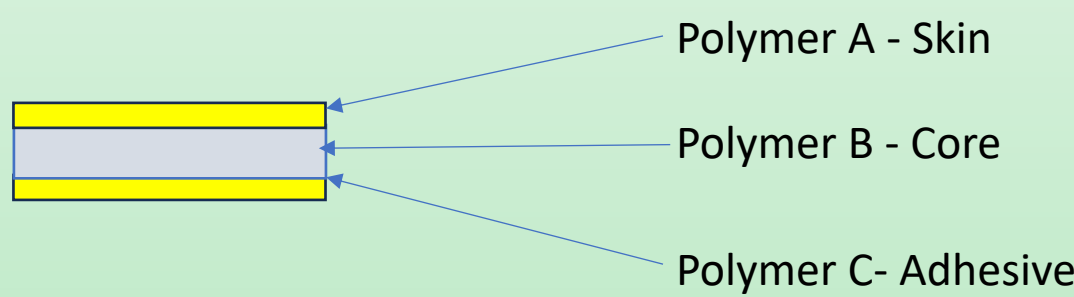


Figure 3 – Sandwich Board Material

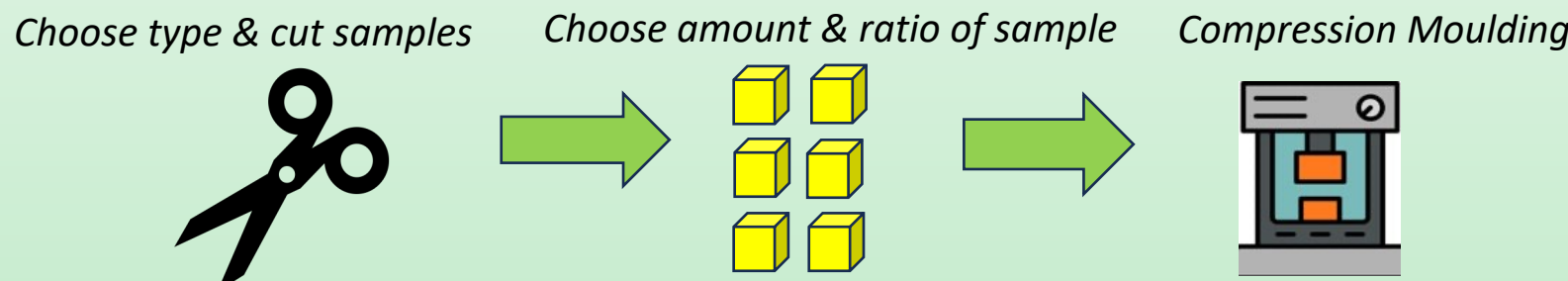


Figure 4 – Recycling Method

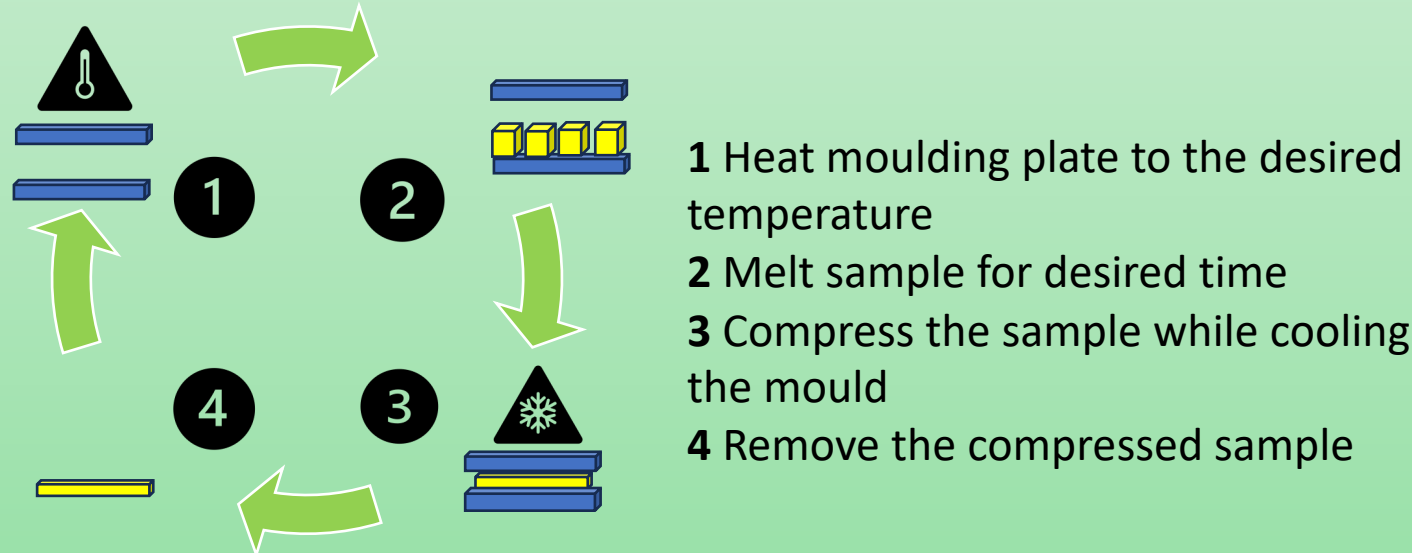


Figure 5 – Compression Moulding Method

### Analysis Methods

- Rheological
- Structural
- Thermal
- Mechanical

Type	Size	Amount	Ratio	Temp	Pressure	Time
Polymer A & Sandwich	Shredded fine	30 grams	50:50	High: 285 °C Low: 265 °C	High: 17 bar Low: 3 bar	High: 23 Min Low: 17 Min

Figure 6 – BBD Experimental Conditions



RSM Program Code



Design of Experiment

## Results and Discussion

### Structural Results

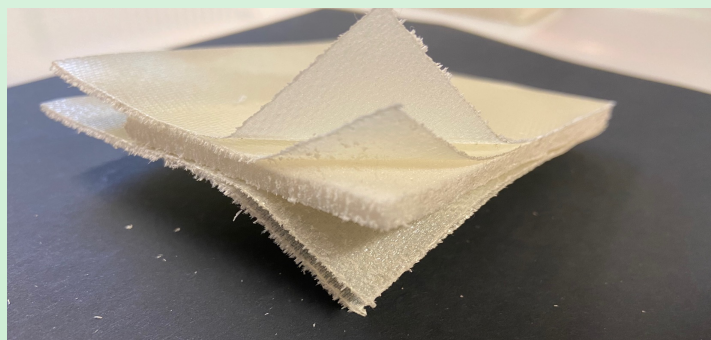


Figure 7 – Sandwich Panel

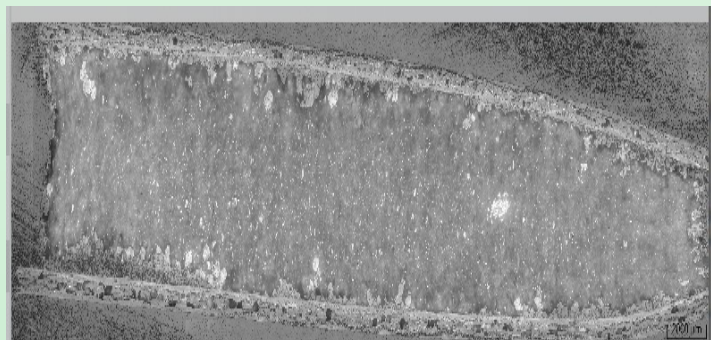


Figure 8 – Optical Microscopy of Sandwich Panel

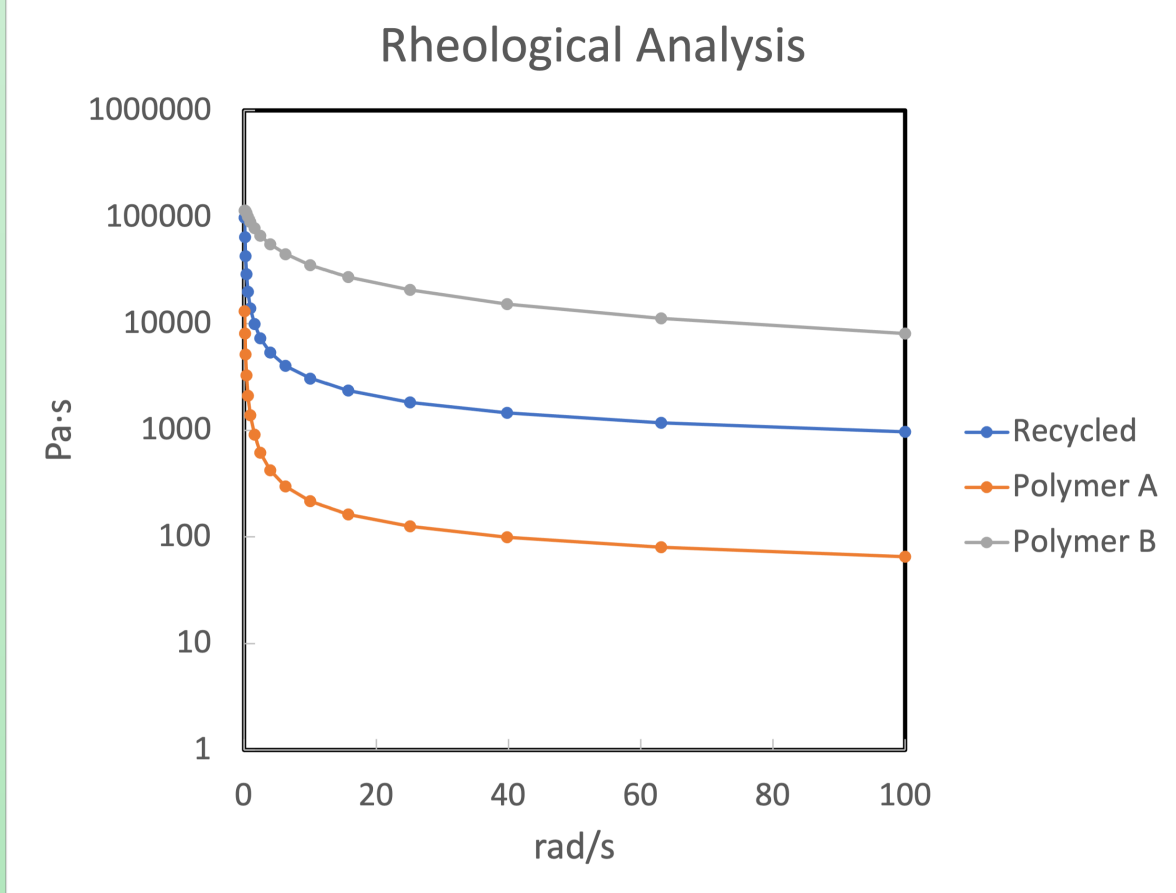


Figure 9 – Rheological Results

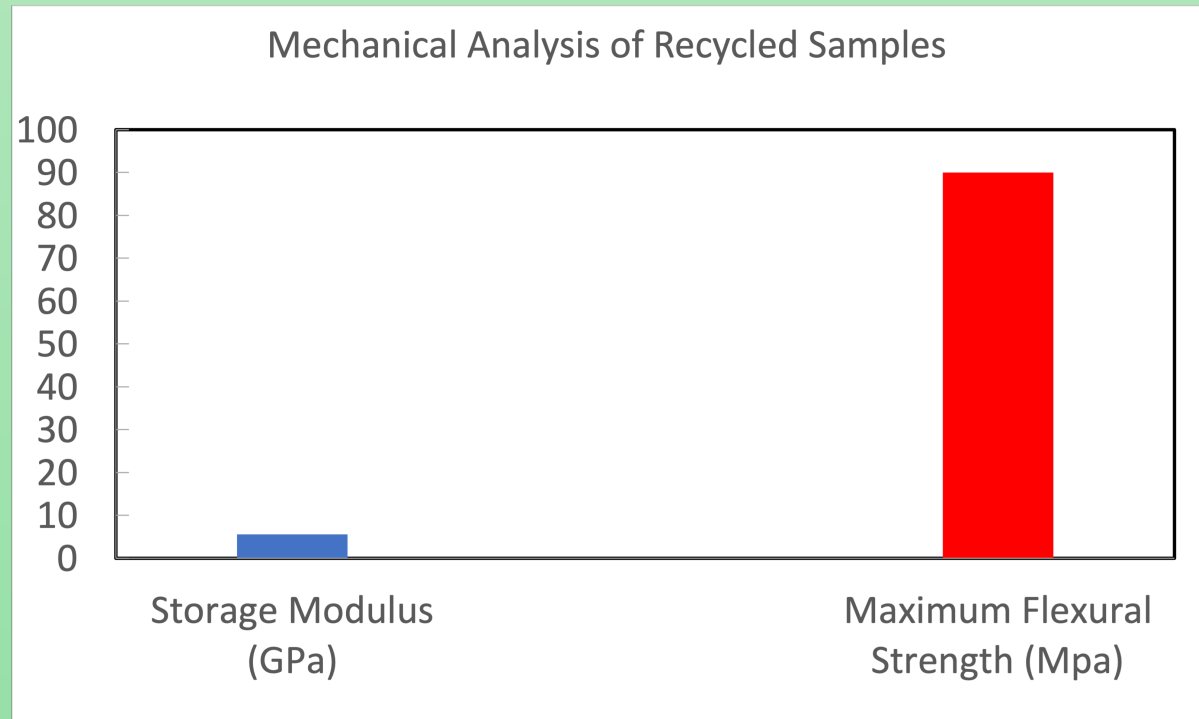


Figure 10 – Mechanical Results

### Thermal Results

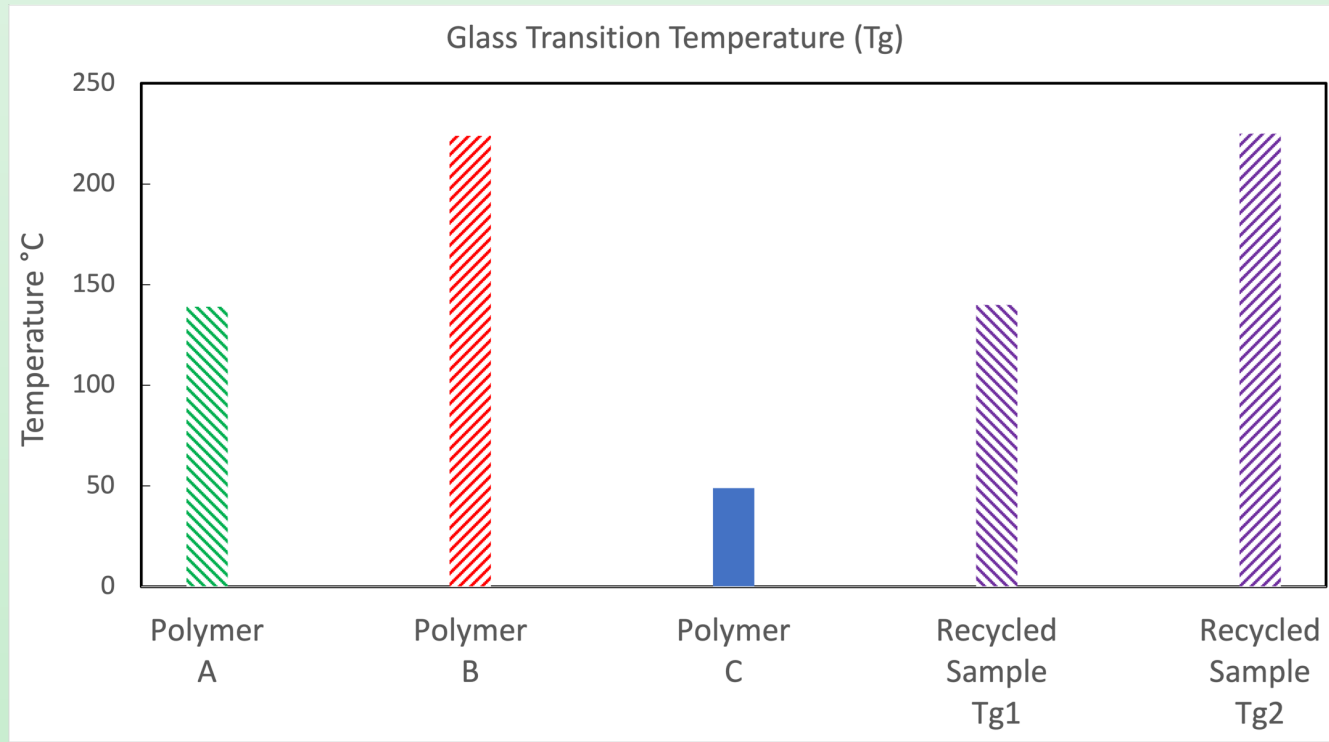


Figure 11 – Tg Comparison

- The recycled sample maintains the same thermal properties as its components
- Degradation of the sandwich panel and the recycled sample occurs at about 410°C

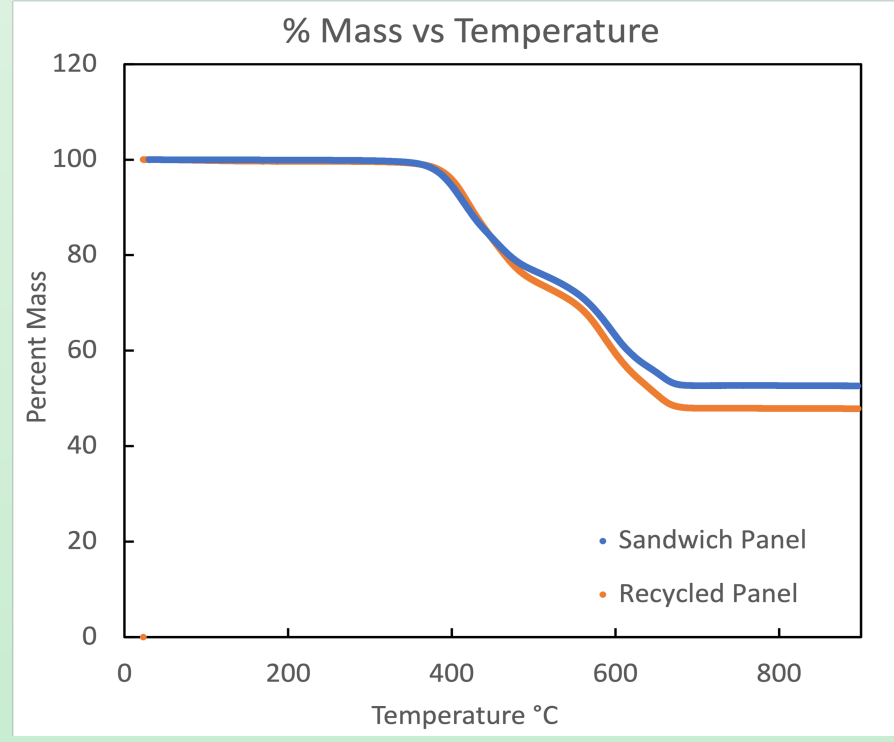


Figure 12 – Degradation Comparison

### Optimization Results

- $x = \text{Temperature}$   $y = \text{Pressure}$   $z = \text{Time}$
- Model: Flexural Strength =  $29 - 4.98x - 16.7y + 7.77z + 5.06*x*y - 3.5*x*z + 6.54*y*z + 8.24x^2 + 5.01y^2 + 13.3z^2$
  - $R^2$ : 0.951
  - Adjusted  $R^2$ : 0.864
  - p-value: 0.00856 --> Statistically Significant

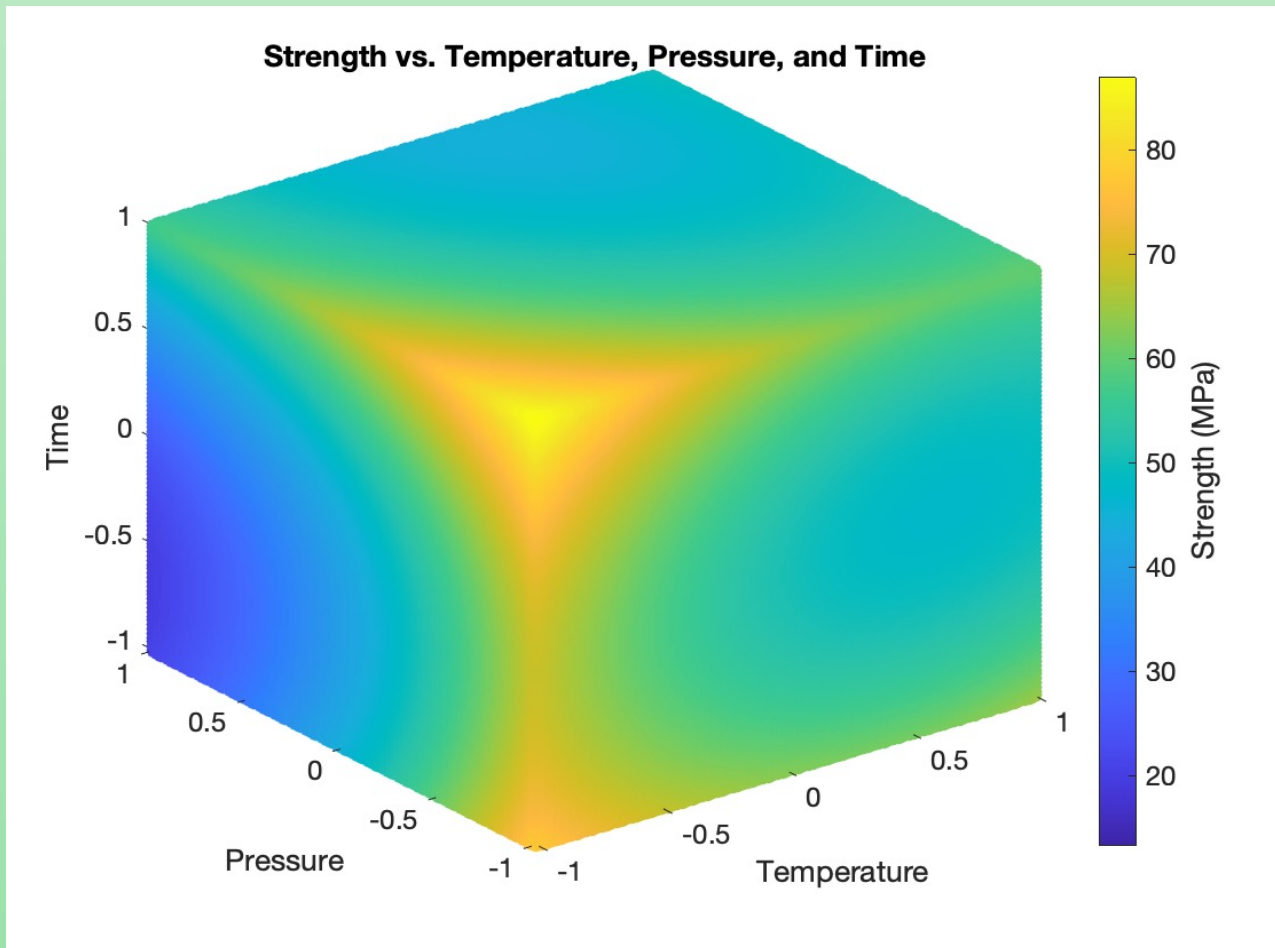


Figure 13 – 3D Scatter Plot Predicting Flexural Strength

- A maximum strength of 87Mpa is predicted to occur at a temperature of 265°C, a pressure of 17 bar and 23 minutes of compression
- As seen in figure 13 pressure and time both significantly affect the strength

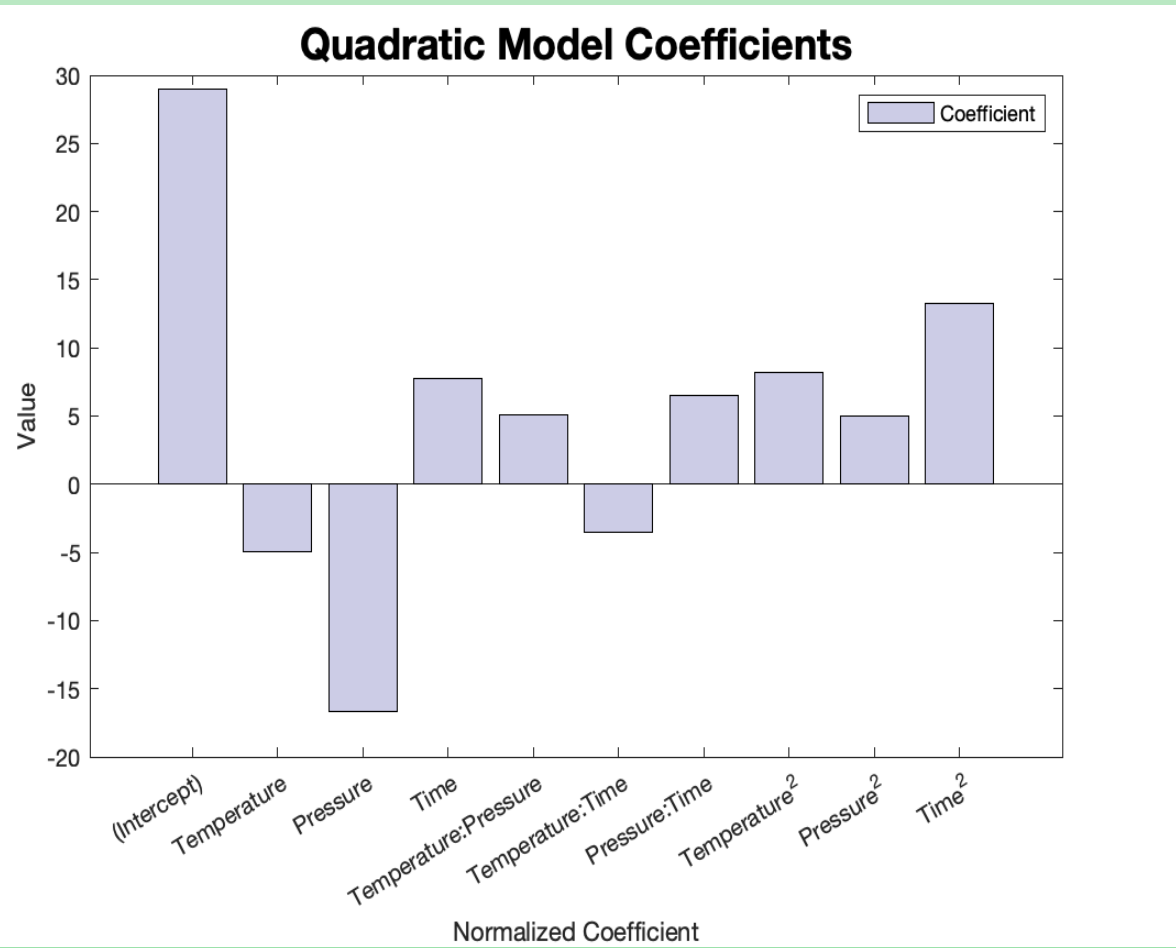


Figure 14 – Model Coefficients Visualized

## Conclusion and Future Work

- Two different ways of composing recycled samples were investigated, one with segregated polymers and another with the entire sandwich
- The sample that exhibited the best properties was created with segregated materials, with a 90:10 ratio of polymer A to B
- None of the samples exhibited significant change in their thermal properties when compared to pristine material
- An accurate mathematical model to determine mechanical properties based on compression moulding conditions was developed
- Future work includes creating a model that optimizes a variable based on composition as well as processing conditions

## Acknowledgements

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