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Western Engineering

Processing Complex Polymer Waste

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Motivation & Background

Opportunity 1:

Polymer recycling is currently limited to simple polymers. Solutions are required for the world to meet future sustainability goals to recover additives, fibers, resins, etc. from complex polymer waste.

Opportunity 2:

Solutions needs to be developed to reduce energy consumption and greenhouse gas emissions.

Canada will have carbon pricing of $95/MT CO_2e in 2025 and $170/MT CO_2e in 2030.

Facts about Plastics Recycling

1. Plastic Waste must be treated locally
2. Clean technologies need to be developed to process plastic waste in Canada
3. There were over 8.3 Billion Metric Tonnes (MT) of plastic produced from 1950 to 2015 (Ritchie & Roser, 2018) & (Geyer et al., 2017)
4. In Canada 3 million MT of plastic waste is discarded every year and only 9% of plastic is recycled (Government of Canada, 2022)
5. Plastic is potentially one of the highest-grade chemical feedstocks

Objectives

1. Identify the most promising complex plastics feedstocks for processing
2. Develop technologies to processes complex plastic wastes into valuable products
3. Research applications for valuable products
4. Evaluate economic and environmental impacts of proposed technologies

Acknowledgement of Sponsors & Support

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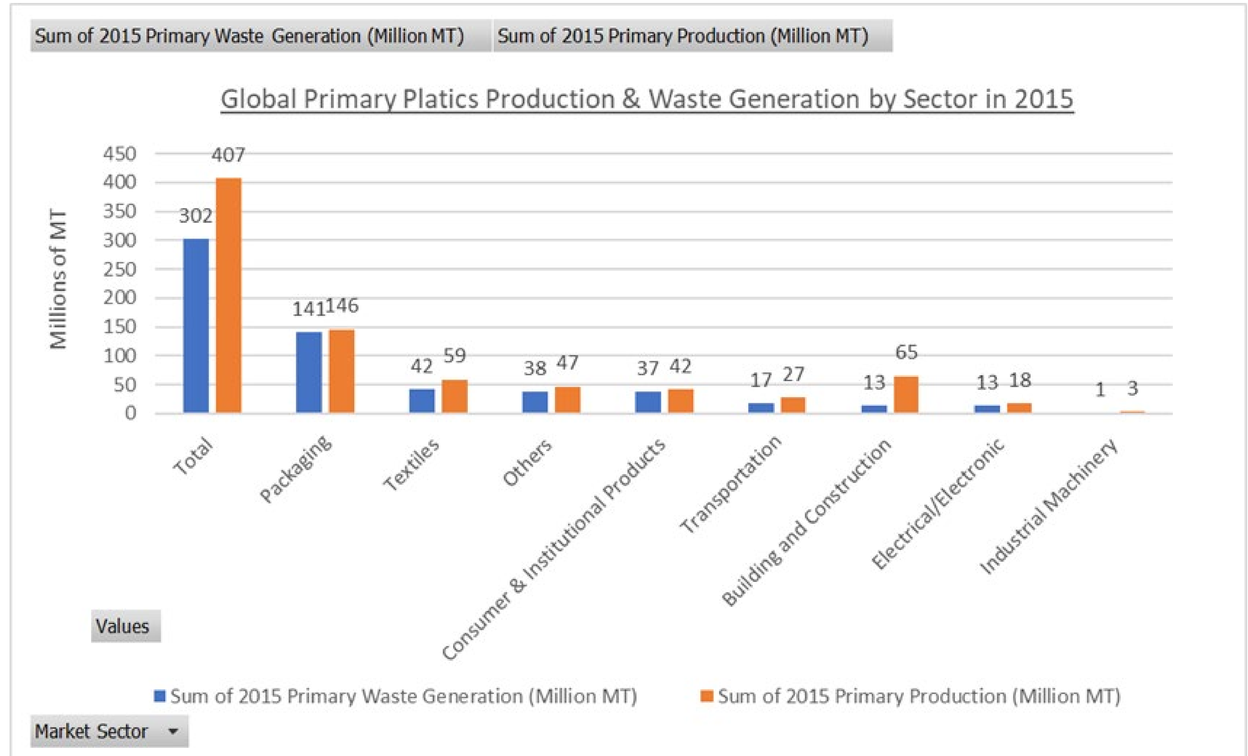
EVERYTHING RECYCLING NSERC CRSNG Mitacs

Global Primary Plastics Production & Waste Generation in 2015 (Geyer et al., 2017)



Most plastic produced, is offset by an equal amount of waste generation, except in Building Construction.

Research Methodology

Based on the wide variety of plastic waste available for recycling, 4 plastic feedstocks were selected for review and comparison using a ranking and scoring criteria.

Plastic Feedstock for Ranking

1. Mixed Plastic Waste

2. Auto Shredder Residues (ASR)

3. Glass Fiber Reinforced Reinforced Polymers (GFRP)

4. Carbon Fiber Reinforced Polymers (CFRP)

Criteria Results

Study Selection Criteria for further study	Available Feedstock	Technology Aspect	Environmental Impact	Value Added	Economic Opportunity	Total Score Out of 50
Mixed Plastic Waste	5	5	8	3	3	**24**
Auto Shredder Residues (ASR)	5	6	4	7	6	**28**
Glass Fiber Reinforced Polymers (GFRP)	8	6	7	5	5	**31**
Carbon Fiber Reinforced Polymers (CFRP)	8	8	9	8	9	**42**

Scale: 1-3 Below Average 4- 6: Average 7-8: Good 9 – 10: Excellent

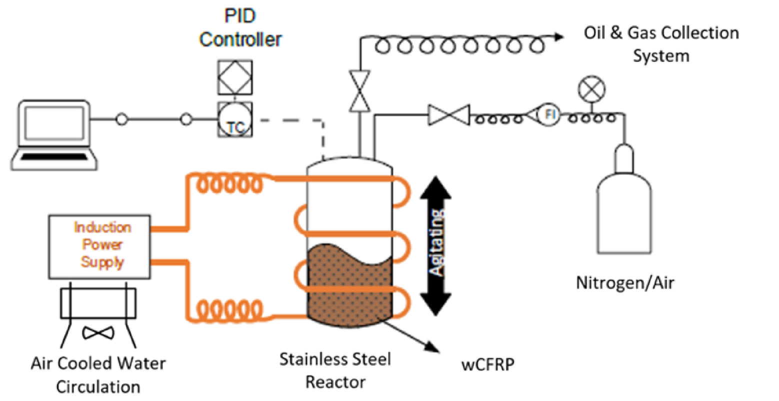
Based on these results, we identified that CFRP was the waste stream of the proposed research.

Equipment

To achieve our objectives, we are utilizing a combination of pyrolysis, melt mix compounding, visual imaging and analytical equipment.

1. Pyrolysis to remove the resin matrix and free rCF using the Jiggle Bed Reactor (JBR) – ICFAR
2. Characterize Pyrolysis Oil & Gas – GC Shimadzu
3. Characterize rCF into polymer composites
   - SEM – Fiber imaging
   - Melt Mixer – Haake
   - Injection Molding - Haake
4. Characterize the Composite
   - Instron – Tensile Testing mechanical strength
5. Economic Modeling & Life Cycle Analysis

Process Flow Diagram for JBR

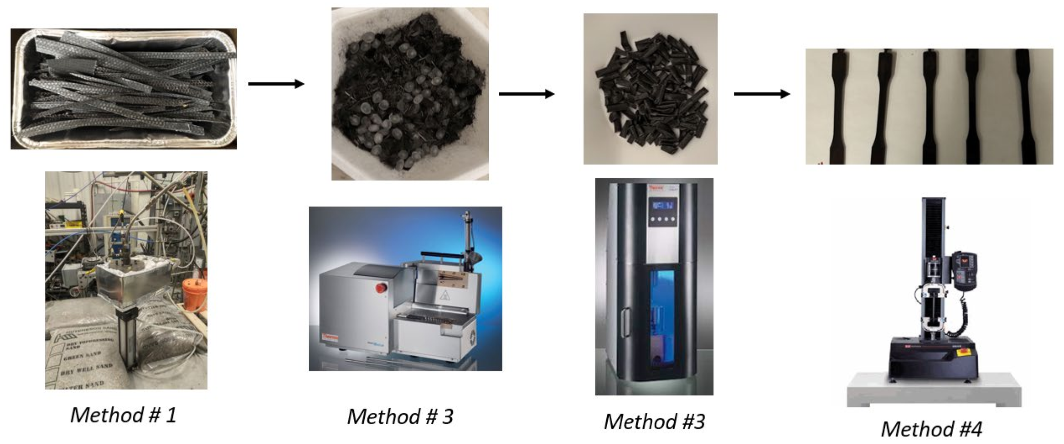


Source: modified from (Chegini, 2021)

The JBR is a good reactor for my application because:

- Excellent agitation
- Excellent bed temperature control, thermocouple in CFRP bed
- Options for introducing gases for any application
- Operates from slow to fast pyrolysis, with heating rates that can be varied

Characterization of rCF –Melt Mixing & Injection Molding into Tensile Bars



Characterization of rCF –Melt Mixing & Injection Molding into Tensile Bars

Selected Conditions for Melt Mixing:

- Barrel Temp (°C): 200
- Residence Time (s): 300
- Screw Speed (RPM): 30
- Barrel Filling Time (s): 200 - 700

Key Results

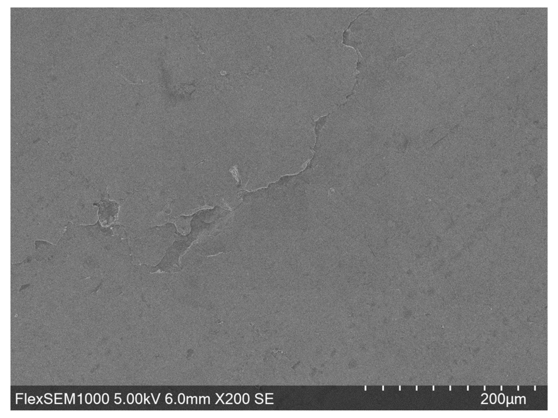
The ideal speed for Tensile testing using rCF + PP specimens is 0.5 mm/min based on ASTM D3039

Average Tensile Stress at Yield (Zero Slope) increases with increasing % rCF used.

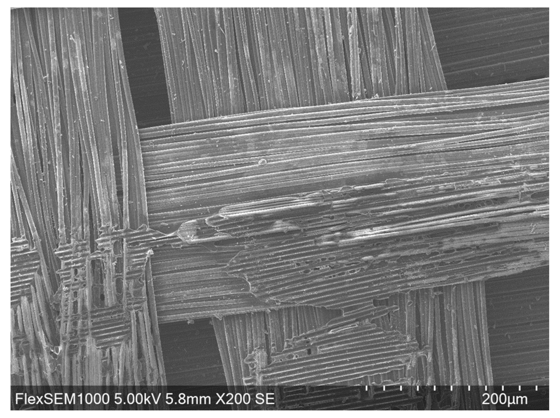
The base polymer blended with the rCF during melt mixing impacts mechanical properties.

SEM Images – 200x Magnification

CFRP Waste

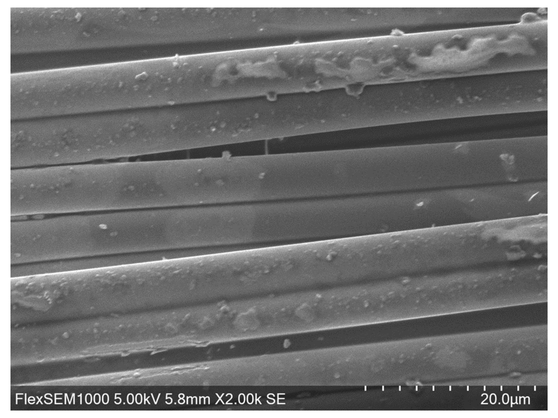


rCF JBR Run #36

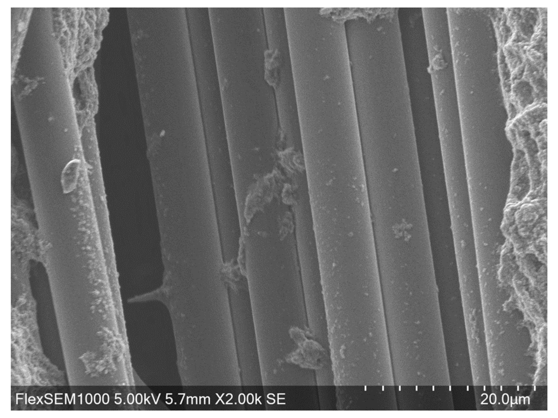


SEM Images – 2,000x Magnification

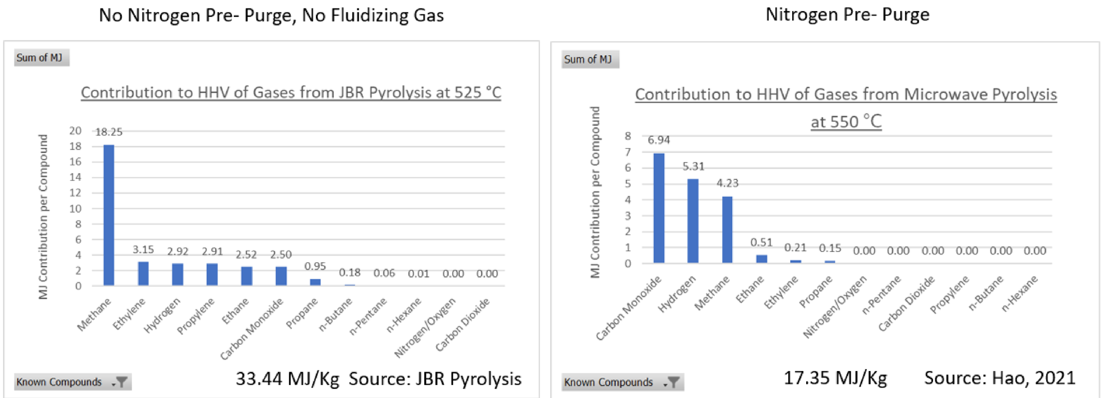
rCF JBR Run #37



rCF JBR Run #36



CFRP Pyrolysis Gas Analysis – GC Results



Key Conclusions

1. Polymer compounding using PP and rCF is an effective way to introduce rCF into light weighting applications for the transportation sector.
2. Mechanical strength testing, is one parameter that can be used to benchmark blended polymer compounds. Exploring others such as impact strength, electrical conductivity, etc. would improve the knowledge and application of rCF.
3. Preparing a predictive model for processing rCF using pyrolysis and melt blending, would aid in the application and adoption of the technology in industry. More experiments are needed to produce primary data for analysis and modeling using Machine Learning and Artificial Intelligence.