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A New Life for Pittsburg State University Surplus Plastics Through Recycling

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ABSTRACT

Recycling polymeric materials has become an area of concern worldwide but may not be as economical as consumers believe. We examined the feasibility of recycling discarded soap dispensers after changes were made in PSU bathrooms campus-wide. First, soap dispensers were deconstructed, cleaned, and granulated to reduce the size of the plastic parts to processable dimensions. To achieve optimal granulation of material from the soap dispensers and aid in the processing of post-consumer regrind (PCR) for other projects, we installed a larger capacity size reduction machine. We then successfully determined the base polymer in each different part through infrared spectroscopy and thermal analysis by differential scanning calorimetry and thermogravimetric analysis. We determined that we had three different plastics in one soap dispenser: polypropylene, polyacetal, and polystyrene. After polymer identification, we injection-molded test bars to produce samples for mechanical property determination. We also performed feasibility calculations to determine if we reduced overhead by using recycled materials. In addition to material cost, we also examined the effect of man-hours and quantity of dispensers to fully determine PCR feasibility. Our calculations determined that small-scale recycling was not optimally feasible even with low-cost starting materials. However, a total of 121 soap dispensers (23.11 ft^3 of waste products) were kept out of landfills, and new plastic parts were successfully made through recycling. We believe that large-scale application of PCR in new parts and improved product design with end-of-life concerns focused on sustainability can improve the feasibility of PCR for consumer product.

INTRODUCTION

Plastic waste has been a controversial topic throughout the past several years. However, to the advantages plastic materials provide to the manufacturing and transportation industries, plastic materials are here to stay. Many consumers believe that most plastics should be recycled to keep the world cleaner. The feasibility of recycling is an area that could stand as a major roadblock. Soap dispensers throughout campus at Pittsburg State University were replaced. Rather than throwing them away, senior students have been tasked with recycling the soap dispensers in a productive, feasible manner. In a preliminary examination, each dispenser was found to contain various types of plastic. Students were tasked with identifying the plastics and finding an efficient method to recycle them.

The overarching problem when recycling plastic waste is the feasibility behind recycling. This is a major issue that our team faces, as well. Many factors play into the feasibility of recycling plastics, such as: amount of recyclable material, cost of recycling, and cost of repurposing. These factors all play major roles in the feasibility of recycling. Additionally, the design of a product may inhibit that product's ability to be recycled. Plastic assemblies that utilize common materials and snap together lend themselves nicely to recycling. Assemblies that utilize chemical adhesion or plastic welding are difficult to recycle and quickly become unmanageable. This study sets out to answer: Is it feasible to manufacture reliable products from a small batch of waste products?

First, this study will discuss materials that were identified after disassembly of the soap dispensers. Then, investigate the material and physical properties of those materials. The major issue of feasibility is then discussed to determine whether it makes sense to continue with the recycling process. Whether or not deemed feasible at the start, the disassembly and recycling process will continue to create a total study of feasibility. This process includes disassembling materials, reducing their size, molding test bars for mechanical testing and production using the recycled materials.

OBJECTIVES

Overall Goal:

- To sort, disassemble, clean, granulate, and manufacture test bars from recycled materials donated by Pittsburg State University
- To identify material properties and feasibility of recycling resulting materials

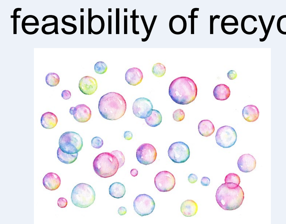

Figure 1: Soap dispenser.

Specific Project Objectives

- Recycle soap dispensers to prevent overflow of landfill
- Granulate each part separately.
- Install new size reduction granulator for Pittsburg State University
- Determine the material used for each piece
- Manufacture reliable parts from recycled materials
- Determine feasibility of recycling materials donated by Pittsburg State University

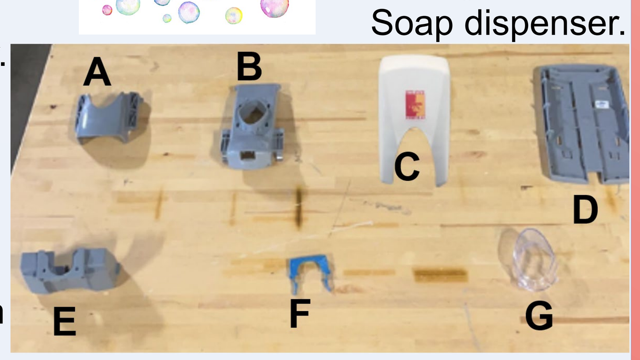

Figure 2: Soap dispenser parts: A) push pump, B) window fitting, C) white cover, D) spine, E) clip holder, F) blue clip, and G) window.

MATERIALS AND METHODS

Material preparation:

- Soap dispenser disassembly was completed by hand.
- Cleaning was performed to remove any adhesive residue.

Adhesive removal procedure:

1. Remove as much adhesive without any chemicals.
2. Soak in cleaner for at least one hour.
3. Simple Green Degreaser
4. Stoner Citrus Clean
5. Remove remaining adhesive with scraper and rags
6. Use a rag and degreaser to remove all adhesive left.

Granulating, or size-reduction:

1. Insert material into granulator reasonably.
2. Run granulator for 2 minutes after all materials are inserted.
3. Break down, clean granulator and hopper system.

Plastic identification:

Analyses Included the following to identify the type of plastic in each part:

FT-IR spectroscopy:

- Perkin Elmer Spectrum 2 spectrometer with ATR capability
- Functional group identification by wavenumber identification

Differential Scanning Calorimetry (DSC):

- TA Instruments DSC 250
- Heat to 250 °C with a temperature ramp of 10 °C/min (first heat)
- Cool to -80 °C with a temperature ramp of 10 °C/min (cool down)
- Heat to 250 °C with a temperature ramp of 10 °C/min (second heat)
- Melting temperature and percent crystallinity were reported

Analysis performed after injection molding:

Melt flow rheology:

- Ceast MF20 melt flow analyzer
- ASTM D 1238 Testing Standards

Mechanical characterization:

- Tensile testing:
  - Instron 34TM-30
  - ASTM D 638
  - Reported values:
    - Tensile modulus
    - Ultimate elongation
- Flexural testing
  - Instron 64TM-R
  - ASTM 790
  - Reported: Flexural modulus
- Impact testing:
  - Instron Ceast 9050
  - ASTM D 256 (Izod)
  - ASTM D 6110 (Charpy)

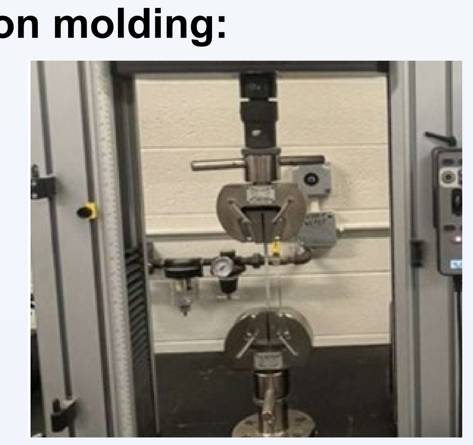

Figure 3: Tensile testing configuration.

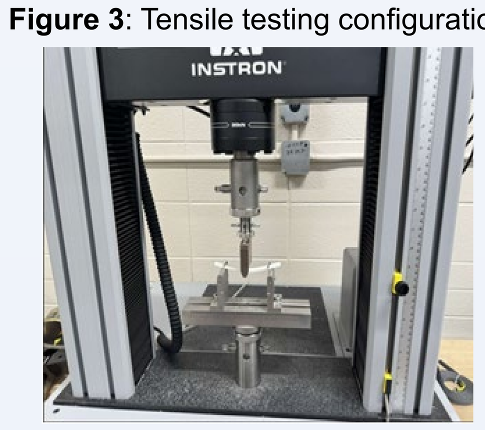

Figure 4: Flexural testing configuration.

Once materials were identified, the following parameters were used for injection molding of test bars and clothes hangers.

Table 1: Injection molding parameters for test bars

Sample	Melt Temp (°F)	Shot Size (in)	Peak Pressure (psi)	Cool Time (s)	Cycle Time (s)
Push Pump & Window Fitting (gray PP)	400	2.895	7,000 – 9,000	11	20
White Cover (white PP)	400	2.895	7,000 – 9,000	11	20
Spine & Clip Holder (gray PA)	400	2.895	7,000 – 9,000	11	20

All polypropylene and polyacetal parts were made into test bars.

Table 2: Injection molding parameters for clothes hangers

Sample	Melt Temp (°F)	Shot Size (in)	Peak Pressure (psi)	Cool Time (s)	Cycle Time (s)
Push Pump & Window Fitting (gray PP)	370 – 400	4.65	8,000 – 10,000	30	44 – 46
White Cover (white PP)	370 – 400	4.65	7,000 – 9,000	30	44 – 46

Only polypropylene was used to make clothes hangers.

Figure 5: Test bars after injection molding.

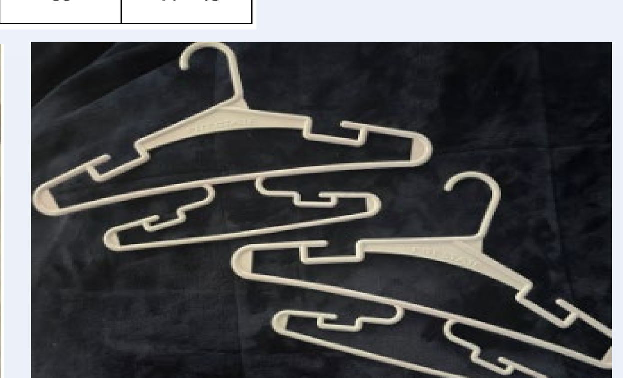

Figure 6: Hangers after injection molding.

RESULTS

DSC and FT-IR were used to determine the polymers that were used for each soap dispenser part.

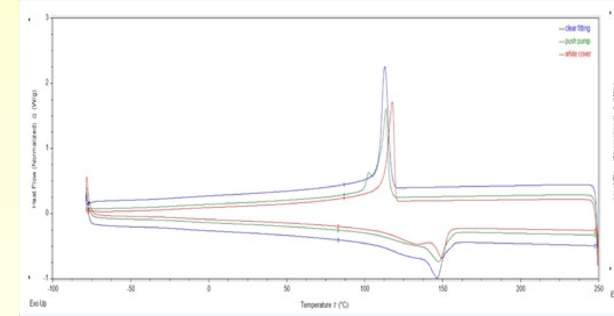

Figure 7: DSC thermogram of parts made from polypropylene.

Table 3: Thermal transitions in polypropylene DSC

Sample	T_{c1} (°C)	T_{c2} (°C)	T_{m1} (°C)	T_{m2} (°C)
Pump	114	104		148
Window fitting	113			147
White cover	118		134	150

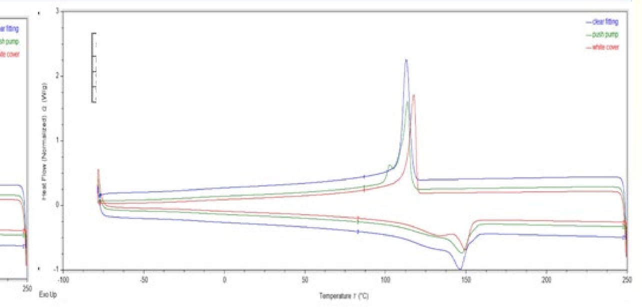

Figure 8: DSC thermogram of parts made from polyacetal.

Table 4: Thermal transitions in polyacetal DSC

Sample	T_{c1} (°C)	T_{c2} (°C)	T_{m1} (°C)
Blue clip	86	146	168
Clip fitting	86	147	166
Spine	86	144	169

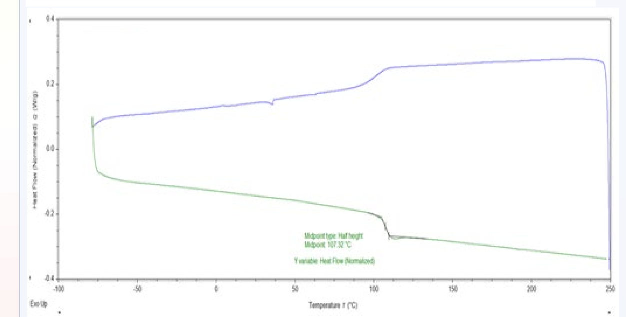

Figure 9: DSC thermogram of parts made from polystyrene.

Table 5: Thermal transitions in polystyrene DSC

Sample	T_g (°C)	T_{c1} (°C)	T_{c2} (°C)	T_{m1} (°C)
Window	107			

No T_c or T_m were observed for the window because PS is an amorphous polymer.

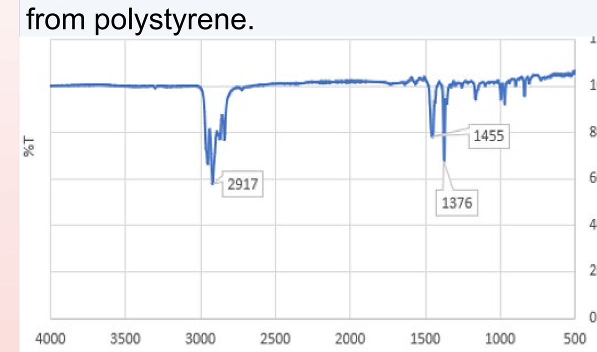

Figure 10: FT-IR spectra of parts made from polypropylene.

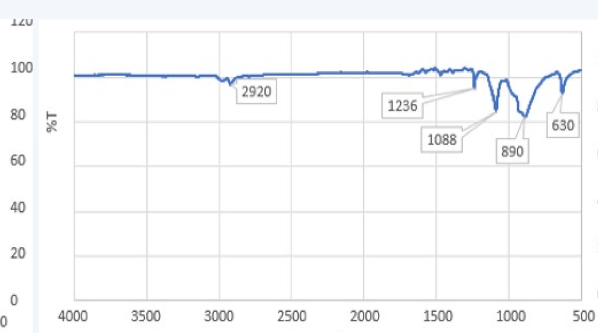

Figure 11: FT-IR spectra of parts made from polyacetal.

Figure 12: FT-IR spectra of parts made from polystyrene.

**** Blue clip (polyacetal) and Window (polystyrene) parts were not used to make test bars or clothes hangers due to lack of sufficient quantities to meet minimum material requirements.**

Table 6: Peak assignments with functional group analysis for soap dispenser parts

Sample	Wavenumber (cm^{-1})	Functional Group	Polymer type
Push Pump (gray) Window Fitting (gray) White Cover (white)	2917	C-H Stretching	Polypropylene
	1456	Asymmetrical C-H bending	
	1376	Symmetrical C-H bending	
Blue Clip** Spine (gray) Clip Holder(gray)	2917	C-H Stretching	Polyacetal
	1237	Asymmetrical C-O-C stretching	
	1087	Symmetrical C-O-C stretching	
	888	C-C Stretch (adjacent to C-O-C)	
	631	C-H bend	
Window**	3028	Aromatic C-H stretching	Polystyrene
	2923	Aliphatic C-H Stretching	
	1494	Aromatic C=C stretching	
	1452	Aromatic C=C stretching	
	759	C-H out-of-plane bending	
	699	C-H out-of-plane bending	

Izod and Charpy impact testing was performed on injection-molded parts to characterize impact properties:

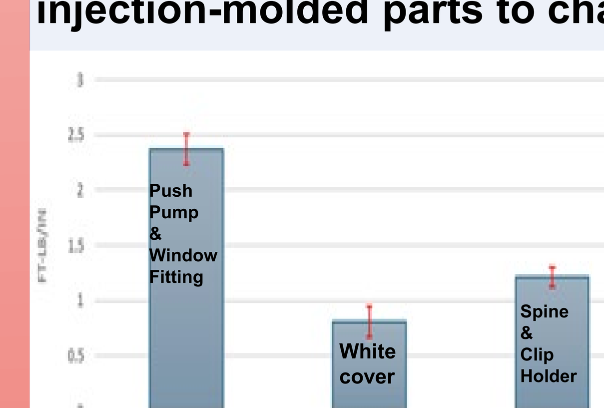

Figure 13: Izod impact strength.

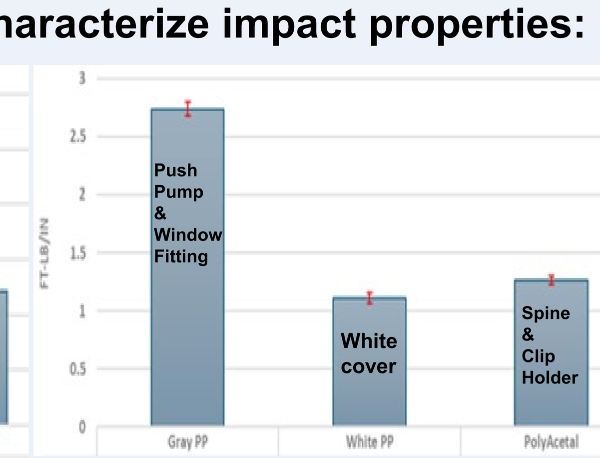

Figure 14: Charpy impact strength.

Flexural and tensile testing was performed on injection-molded parts to characterize mechanical properties.

Figure 15: Tensile modulus of injection-molded parts.

Table 7: Tensile modulus of injection-molded parts

Sample	Material	Tensile Modulus (MPa)
Push Pump (gray) Window Fitting (gray)	Polypropylene	579
White Cover (white)	Polypropylene	519
Spine (gray) Clip Holder(gray)	Polyacetal	1991

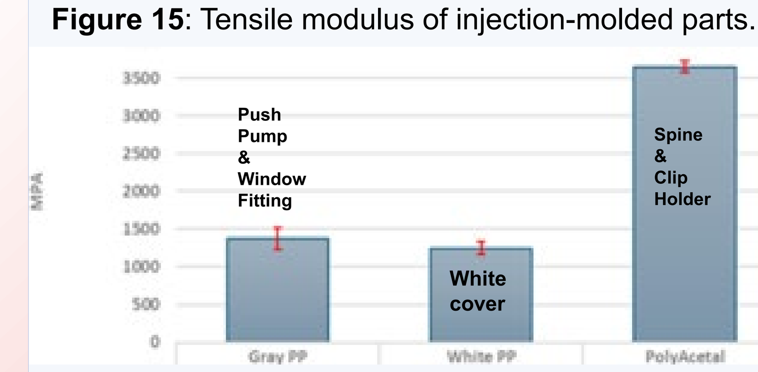

Figure 16: Flexural modulus of injection-molded parts.

Table 8: Flexural modulus of injection-molded parts

Sample	Material	Flexural Modulus (MPa)
Push Pump (gray) Window Fitting (gray)	Polypropylene	1377
White Cover (white)	Polypropylene	1249
Spine (gray) Clip Holder(gray)	Polyacetal	3653

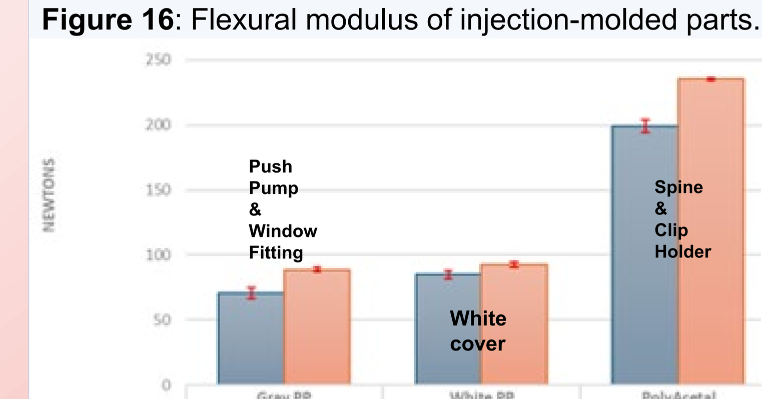

Figure 17: Yield strength (■) and ultimate (■) strength of injection-molded parts.

Table 9: Yield strength and ultimate strength of injection-molded parts

Sample	Yield Strength (N)	Ultimate Strength (N)	Ultimate Elongation (%)
Push Pump & Window Fitting (gray PP)	71	89	12.5
White Cover (white PP)	85	93	18.6
Spine & Clip Holder (gray PA)	199	235	9.8

CONCLUSIONS

Challenges:

- Adhesive removal from the back plate of the soap dispenser
- 16 total man hours spent removing adhesive

Achievements:

- Successfully deconstructed, cleaned and granulated the soap dispensers
- Identified the material used for each dispenser part.
- Characterized each material for its tensile, flexural and impact properties
- Successfully molded parts from PCR
- Tensile bars
- Clothes hangers
- Saved 121 pounds of material from going into a landfill

FUTURE WORK

- Determining feasibility of small-scale recycling using man-hours and material cost
- Continued recycling of Pittsburg State University's soap dispensers
- Optimization of the adhesive removal process.
- Recycling other Pittsburg State University plastic waste
- Research and establishment of a comingled recycled polymer separation process

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