# Green Ellipsis- Splicing of PET Plastic


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## Green Ellipsis


## INTRODUCTION

Green Ellipsis' goal is to reduce waste and create more sustainable engineering practices. They currently have a process that upcycles 2-liter soda bottles made from PET plastic to create filament that can be used by 3D printers. The process works but is currently labor intensive and the filament created is worth less than it costs to create.

To turn the soda bottles into usable filament, they first must be cleaned, then the labels are removed. A special machine called a pultruder then spiral cuts the bottle into a single long ribbon which is pulled through a hot nozzle forming the filament. Each bottle produces 10 meters of filament (about 20 grams). Once the filament is pulled through, it may be used to 3D print any number of things.

Pultruder creating Filament

## OBJECTIVES

One of the biggest limitations to the current process is only being able to produce discrete 10-meter lengths of filament. For use in 3D printing, it is often desired to have much longer continuous filament for use in larger projects. For some types of filament, splicing methods exist to connect one end of filament to another. Unfortunately, this recycled PET does not join well with those methods.

The goal of this project was to pioneer a method of joining this recycled PET filament to improve the value of the product Green Ellipsis produces. Multiple methods needed to be designed and tested for strength and reliability. The hope is to be able to connect many bottles worth of filament together and produce up to 1kg continuous spools.

Requirements

- Process should create minimal waste.
- Filament should be continuous up to 1kg spools.
- Filament should not clog 3D printer or print with imperfections.
- Any changes to the process should be low cost to build so the average consumer can afford to repeat it.
- Project has budget of $1000 to find solution.

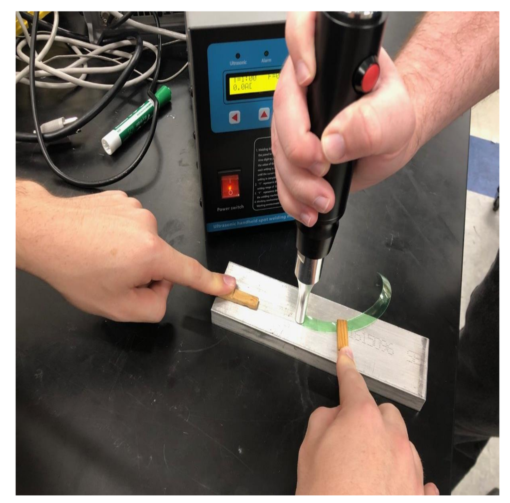
Constraints

- Process must be safe and usable by an average person.
- Filament must be of desirable properties to use on any standard 3D printer: 1.75mm diameter +/- 0.1mm.
- Filament must withstand the stress of spooling and 3D printing. Withstand 45° bend with radius of 5mm.
- Filament must not break or become jammed during the pultrusion process at least 90% of the time.
- Power requirements must be available from a standard 120V outlet.

## Joining Method Designs

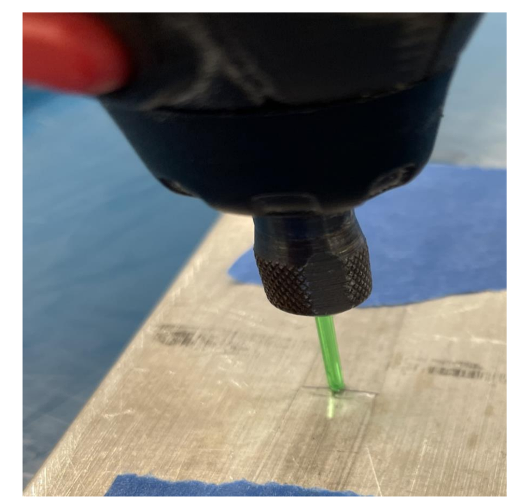
Seven methods of creating filament joints were designed and tested. These methods fall into two categories. Ribbon-based methods are performed before the bottles are turned into filament. The filament-based methods are performed on two pieces of filament that are already formed.

### Ribbon Based Methods



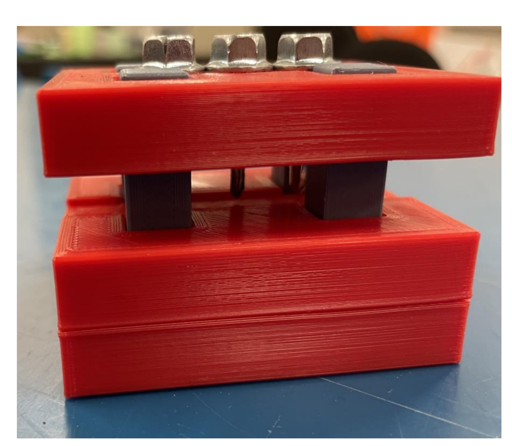
Ultrasonic Welding

Two pieces of bottle ribbon were fused together using an ultrasonic welding device. The joined ribbon was then fed through the pultrusion machine to create continuous filament.



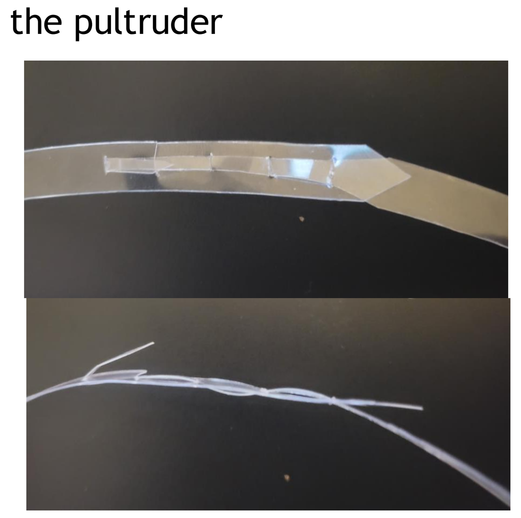
Friction Welding

Two pieces of bottle ribbon were overlayed to create a small gap. A piece of pre-made filament was loaded into a rotary tool and spun at a high rpm to weld the pieces together to be fed through the pultruder



Perforation

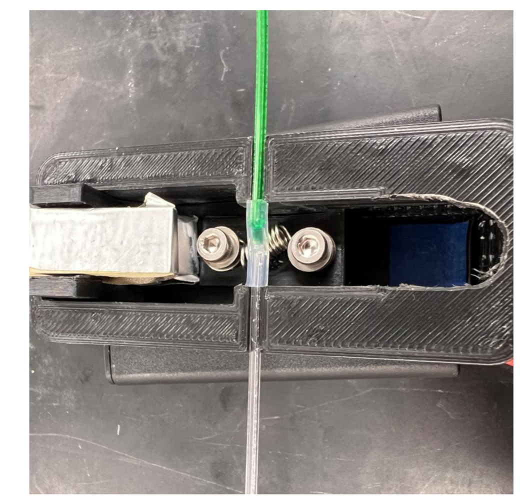
Two pieces of bottle ribbon were joined by being perforated together. Hot metal pins were pressed through the overlapping ribbon joining them together before being sent through pultrusion.



Ribbon Weaving

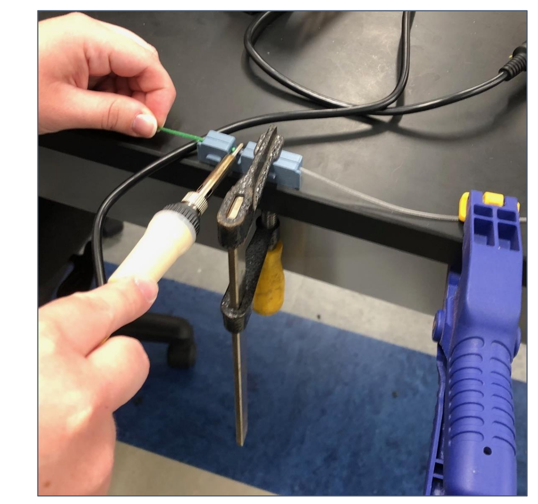
A thin length of bottle ribbon was woven into slits cut into the next length of ribbon. The woven joint fed through the pultrusion machine to create a continuous filament.

### Filament Based Methods



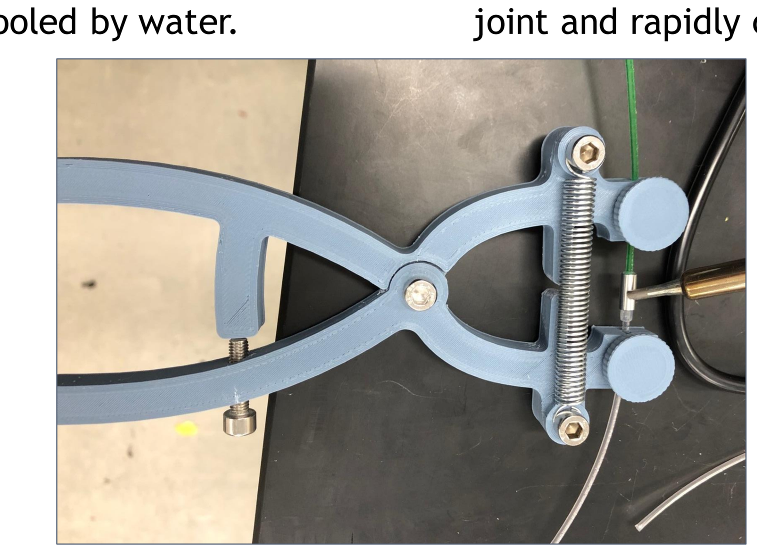
Nichrome

Two pieces of filament were loaded into a jig that held the ends directly above a coil of nichrome wire. The coil was heated by attaching it to a voltage source. The ends were formed together then rapidly cooled by water.



Simple Soldering

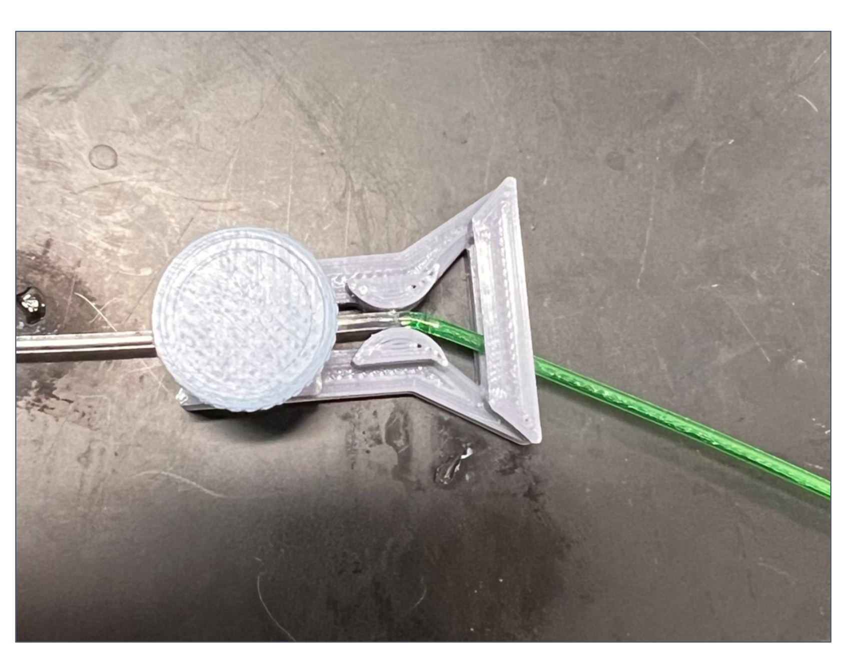
Two pieces of filament were held end to end with a small gap between them. A hot soldering iron was pressed against each end then quickly removed as the filament tips were pressed together to form a joint and rapidly cooled.



Silicone Sleeve

Two filament ends were loaded end to end in a tight-fitting silicone tube. The ends were pressed together by the device seen above while the joint was heated by a soldering iron. Once the joint had formed, it was rapidly cooled by water.

## TESTING PROCEDURE

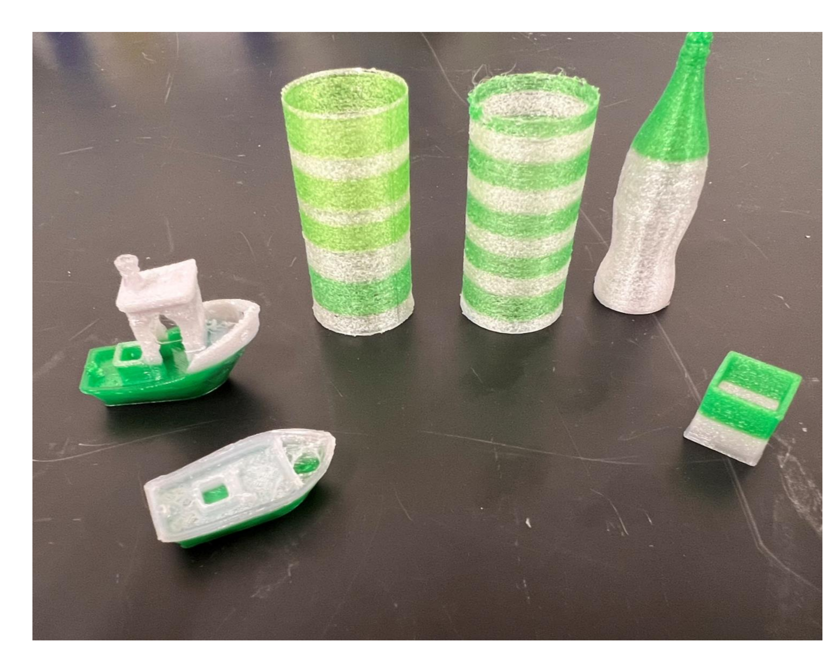


Bend Testing

To test resiliency of each method in bending, the filament joint was fixed in the testing apparatus shown above and bent to 45°on a 5mm radius. Test was repeated 4 times per joint and examined. Fracture or significant reduction in diameter of the joint was considered a failure.

Tensile Testing

To test for tensile strength of each method, the filament joint was attached on one end to a workbench and on the other end to a 3kg weight creating 30N of tension along the filament and joint. Breaking or necking of the joint was considered a failure for this test.

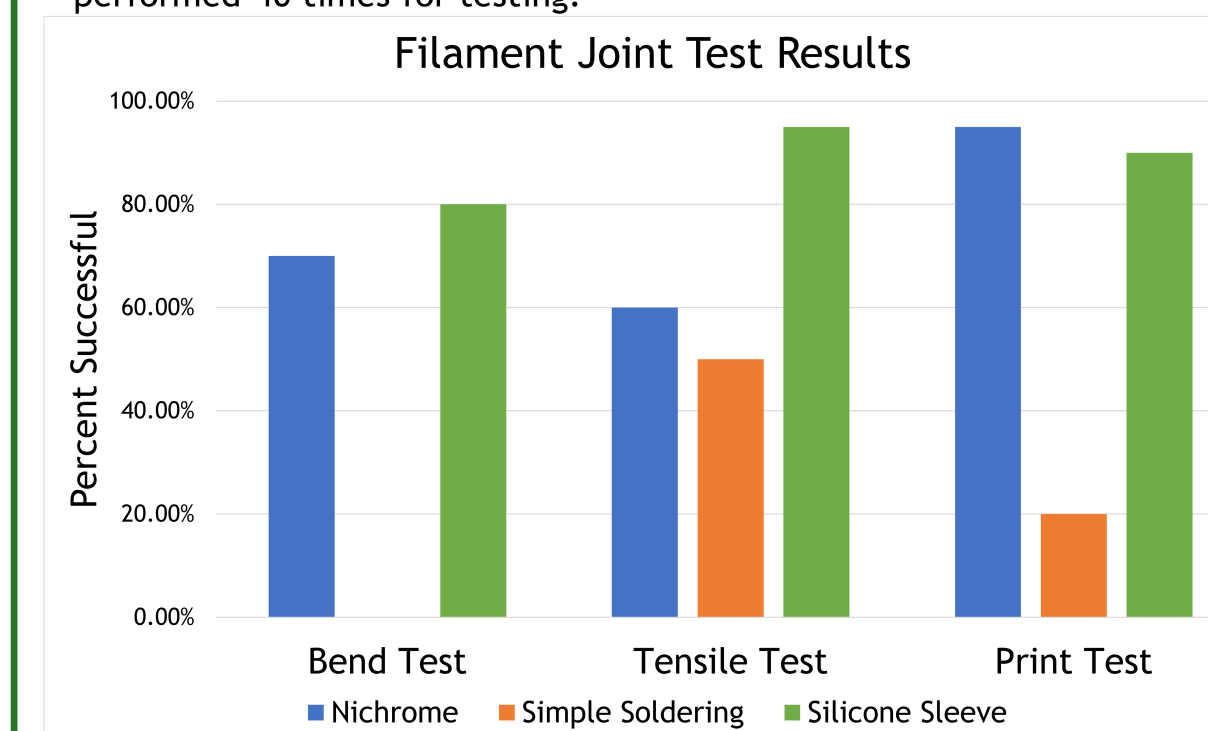


Print Testing

To ensure that the filament joint behaves properly while running through the 3D printer, a test cylinder was printed containing multiple joints and can be seen above. The cylinder was printed at a single wall count in vase mode to make inspecting for flaws easier. Jamming, clogging, or print flaws were considered a failure in this test.

## CONCLUSIONS AND FURTHERING OF DESIGN

None of the explored ribbon-based methods of joining were able to reliably produce a continuous filament joint. Each method either clogged the pultrusion machine or did not properly join. After many iterations of each, it was decided to only move forward with the three filament-based methods of joining: Nichrome, Simple Soldering, and Silicone Sleeve. The results of the testing procedure on joints produced by these three methods can be seen below. Each joint was performed 40 times for testing.

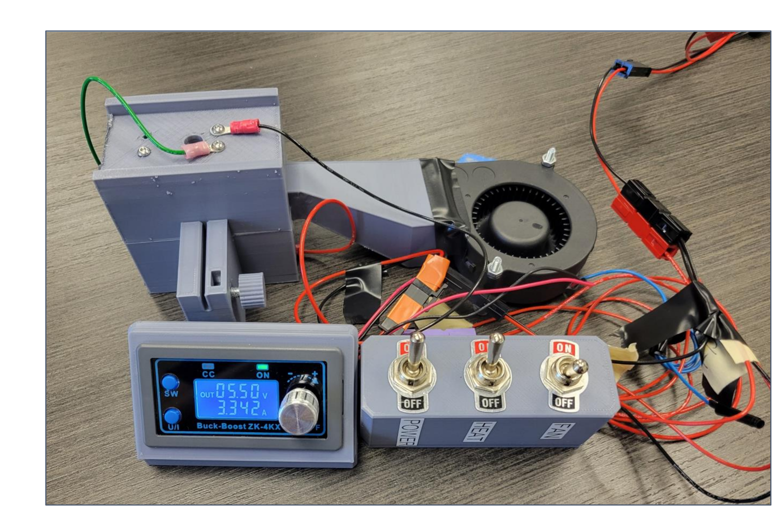



Both the Nichrome and Silicone Sleeve methods of joining show promise at achieving a reliable joint. Example joints for each method can be seen below.

Example of joint made using nichrome method

Example of joint made using silicone sleeve method

It is our recommendation that these methods be optimized further and refined to produce the highest quality joint possible. A prototype combining elements from both methods to improve the joint quality and efficiency has been produced and can be seen below. A design such as this could provide the higher joint quality of the silicone sleeve method with the convenience of the nichrome method.

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## REFERENCES