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Welding 3D Printed Structures for Composite Sacrificial Tooling

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2 years of First Year Research

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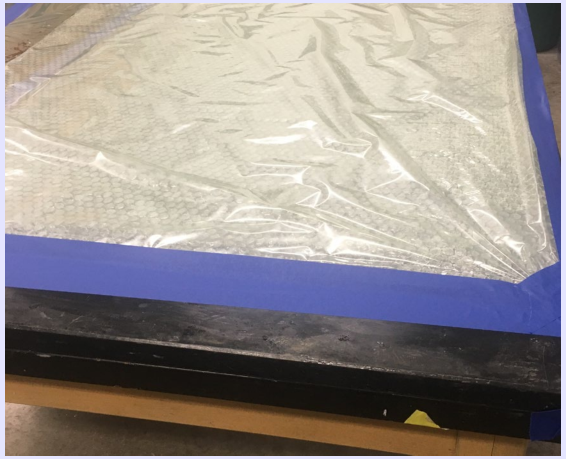
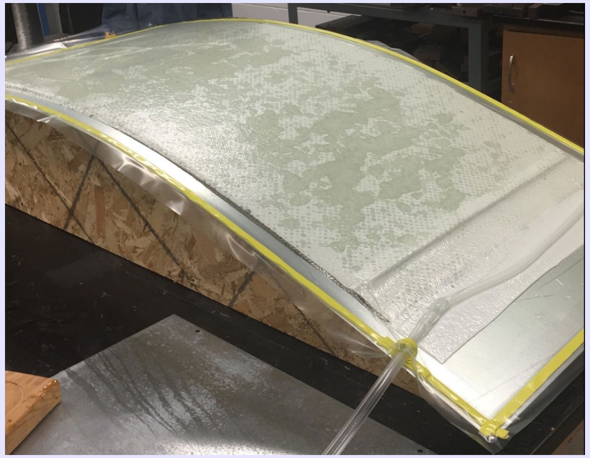
Composite Tooling

- Composites can be light, stiff, and strong.
- Composite Tooling can be simple or complex depending on the part geometry and processing method.
- As complexity increases, the cost and lead time also increases.

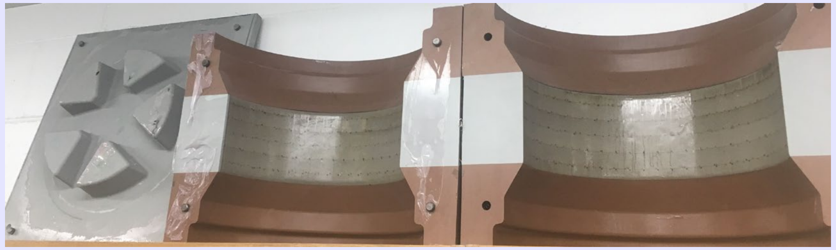
Simple ⟷ Complex



Flat Parts on a Flat Table



Curved parts on a thin sheet of metal clamped to a wooden Form



Complex Geometry Parts with machined, multi-cavity tooling

3D Printing

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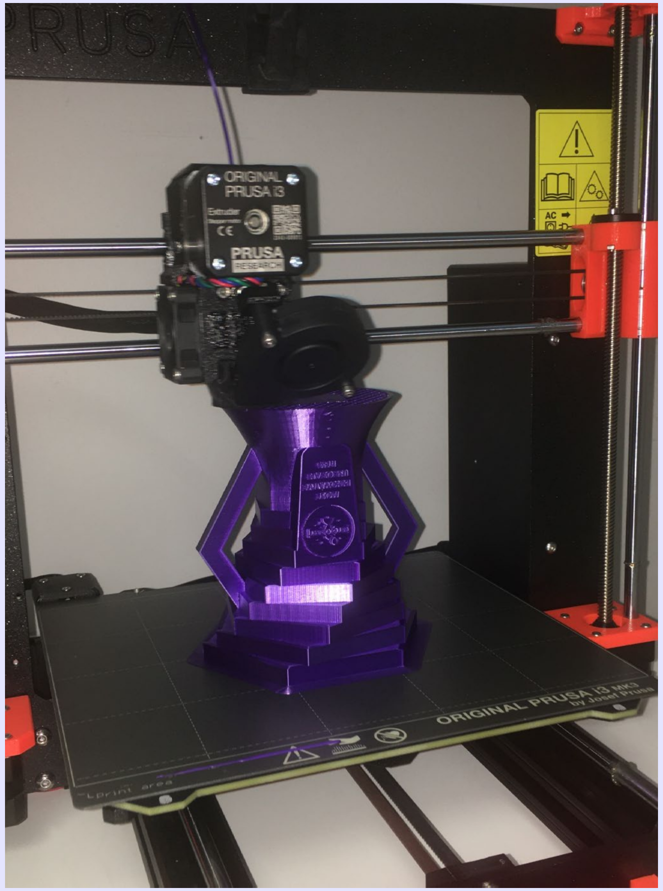
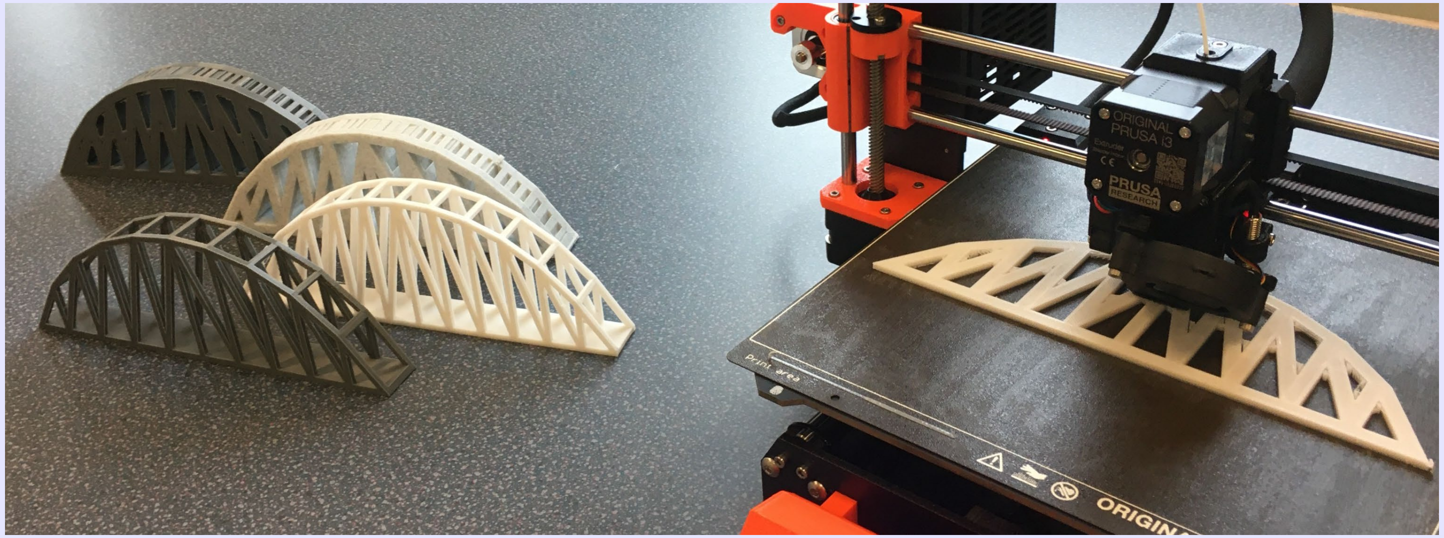


- It is very easy to generate 3D printed parts that have complex geometries that would be difficult and time consuming to produce with conventional machining.
- The print time can be 20+ hours for a large part, but the touch time may be less than 30 minutes.
- Multiple printers can be used as a manufacturing print farm.



Size and Structural issues with 3D Printing

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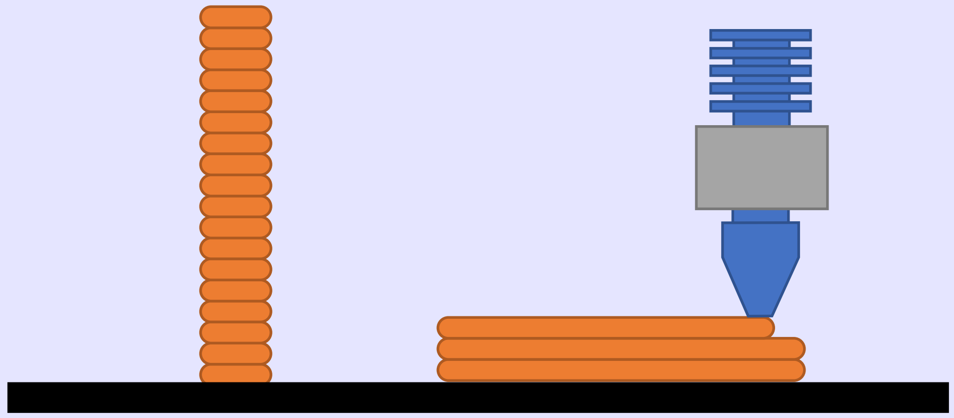
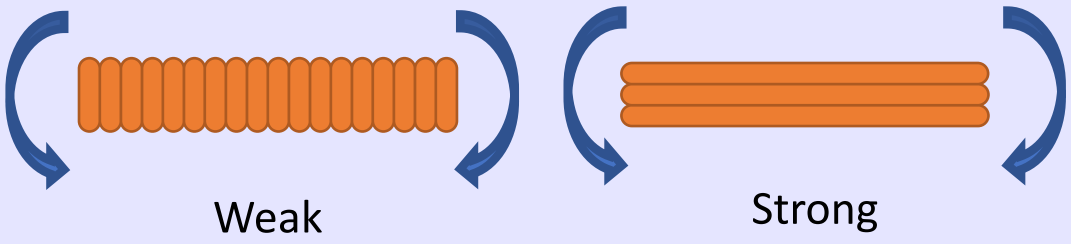
- Small Printers
  - Cheap
  - Technologically mature
  - High Detail
  - Not big enough to print large items for composite tooling use
  - Variety of materials
- Large Printers
  - Expensive
  - Depending on type/brand may be still a prototype
  - Either low resolution or very long print times
  - Some printers can print boats, cars, and small homes
  - Variety of materials
  - Even heating, surface levelness, part shifting, and plate debonding becomes more difficult as parts get larger





Welding 3D Printed Parts

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- Thermoplastic materials processing is relatively simple

Heat → Press → Cool

- Several processing methods were initially screened in 2022
  - 3D Printing Pens
  - Friction Stirring
  - Melt surfaces and clamp
  - Heating copper wire clamped between two parts

3D Printing Pens

Friction Welding

Heat and Press

Tensile Testing 3D Printed Welds - Setup

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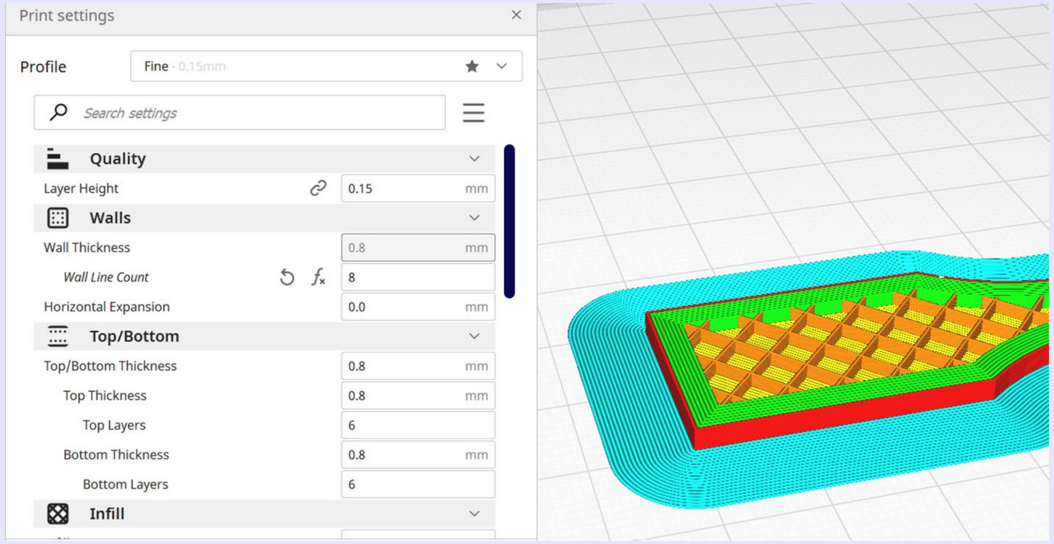
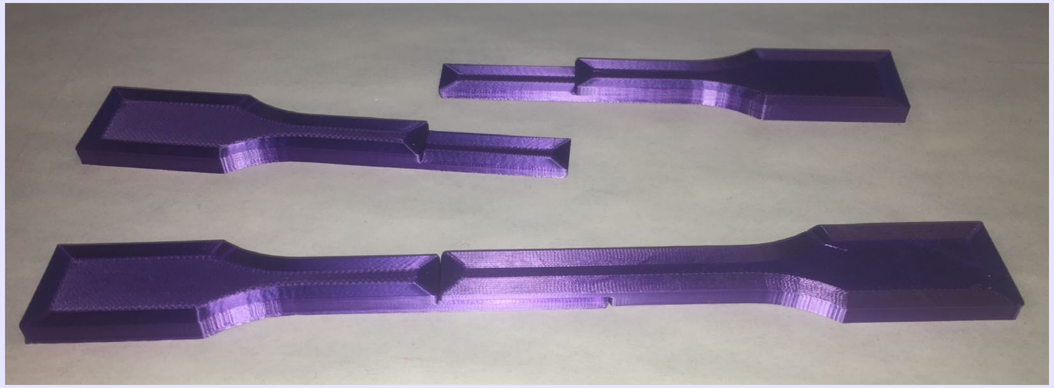
- Single lap shear specimens were 3D printed to create ISO 527 – 1A tensile specimens

- Settings included:
  - layer height of 0.15mm
  - wall count of 8
  - top/bottom set to 6 layers
  - 20% Infill

- A small chamfer was added to the weld lines





Tensile Testing 3D Printed Welds - Results

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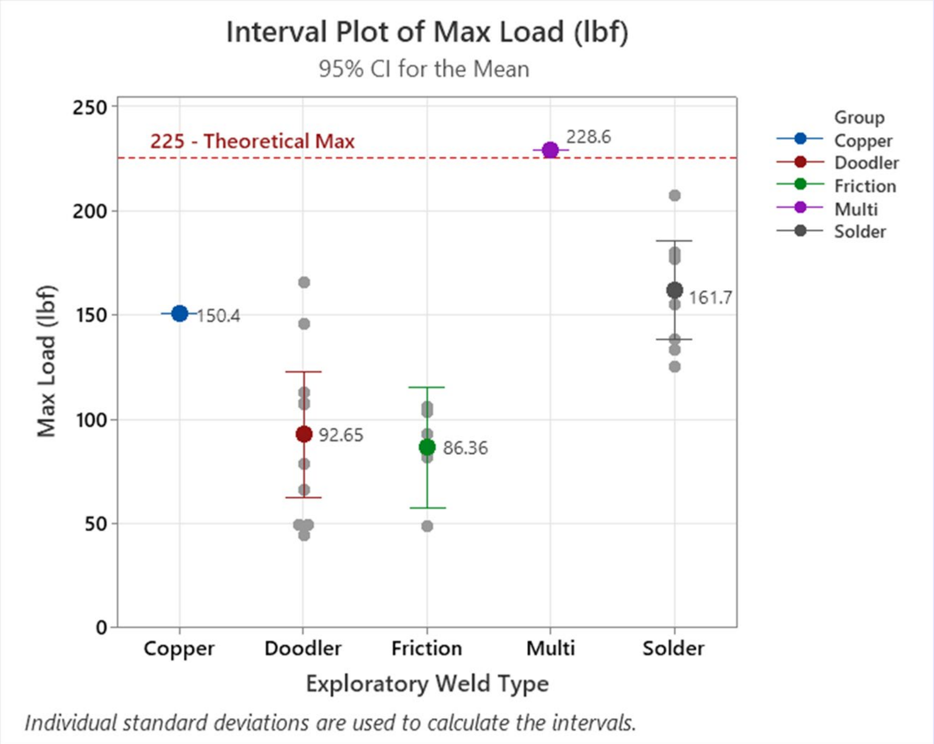
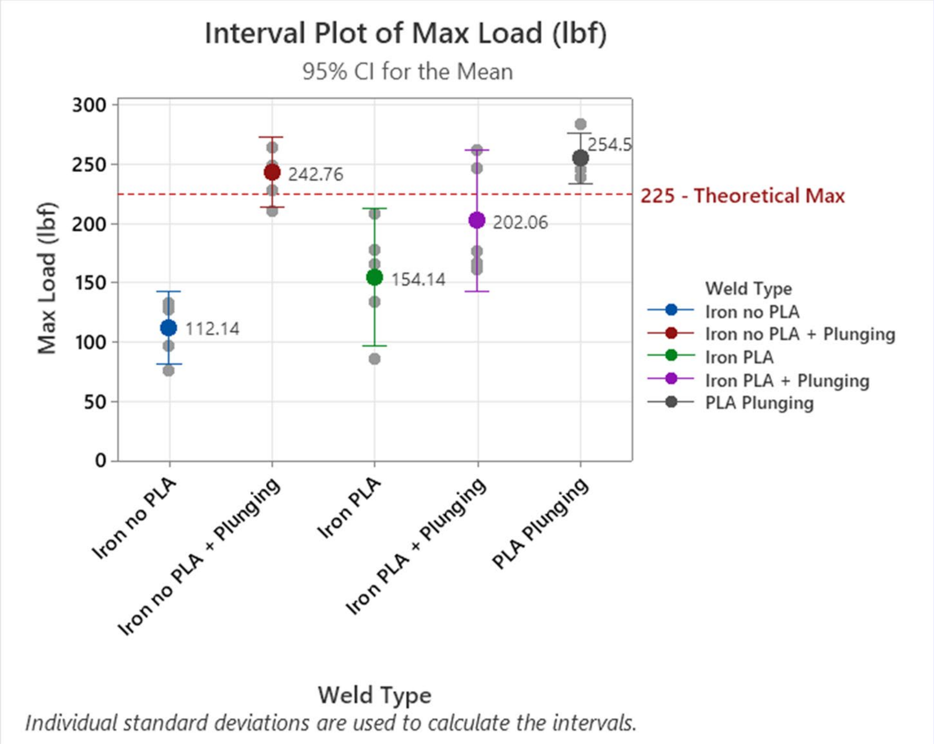
- The exploratory round of welding resulted in a grouping that broke outside of the weld using both a 3D Extruding Pen and a flat smoothing soldering iron.
- The second round with less than 2 hours of practice resulted in several strong welds using both pen extrusion and soldering iron.





Flexural Testing 3D Printed Welds - Setup

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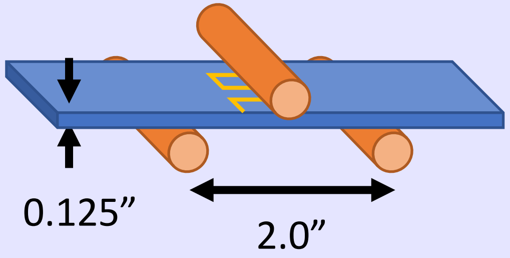
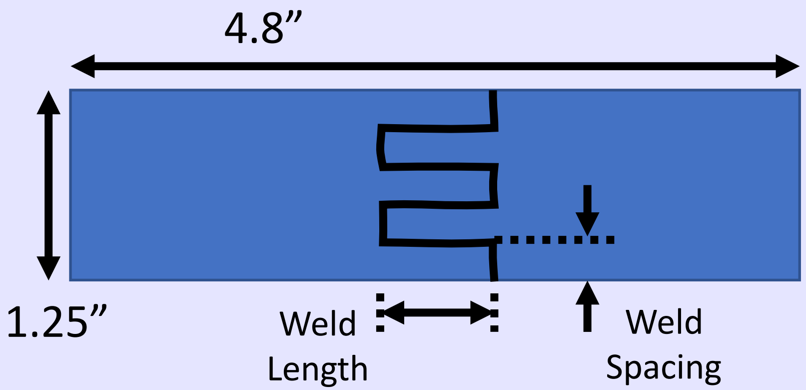
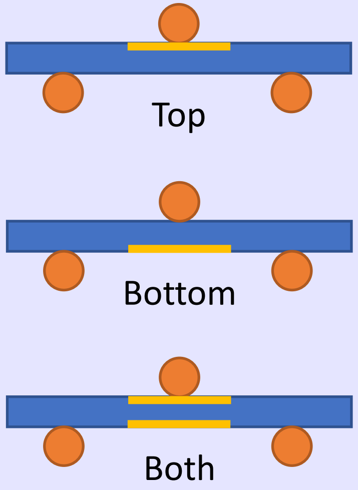
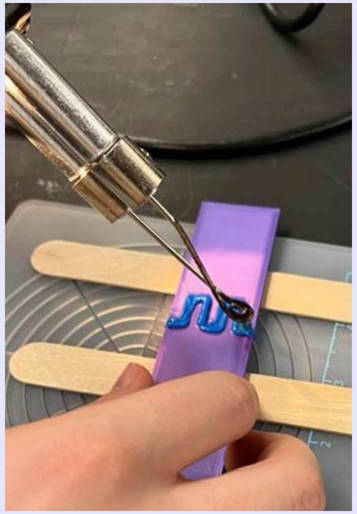
- All bars were welded with 3D printing pens and smoothed with a soldering iron
- Baseline comparison bars were printed with no weld at 20% fill with 0.15 mm layer height and 4 walls/tops/bottoms
- Each group had 5 specimens tested (135 total)





		Spacing		
		0.25"	0.3125"	0.4167"
Weld Length	0.25"	Top	Top	Top
		Bottom	Bottom	Bottom
		Both	Both	Both
	0.50"	Top	Top	Top
		Bottom	Bottom	Bottom
		Both	Both	Both
	0.75"	Top	Top	Top
		Bottom	Bottom	Bottom
		Both	Both	Both





Flexural Testing 3D Printed Welds - Results

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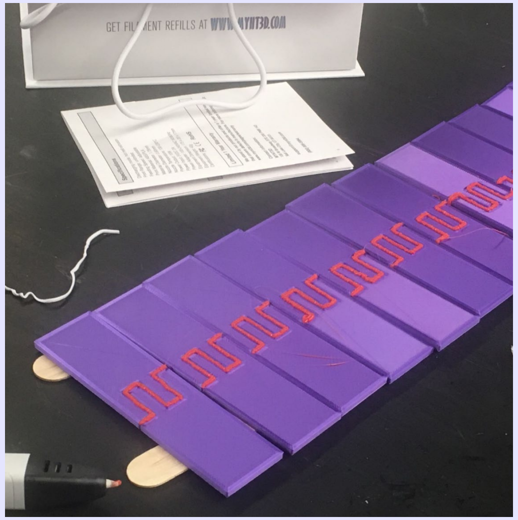
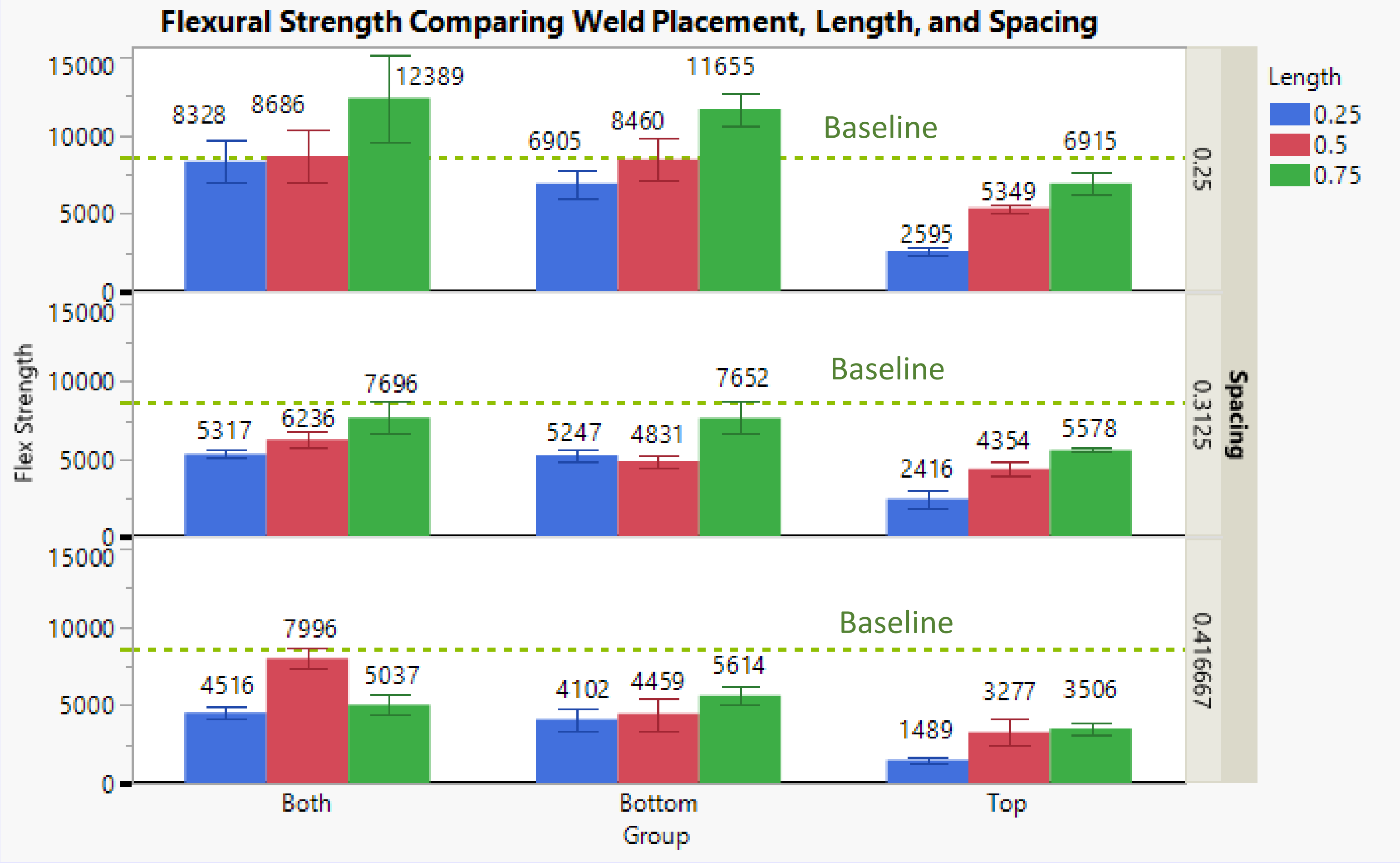
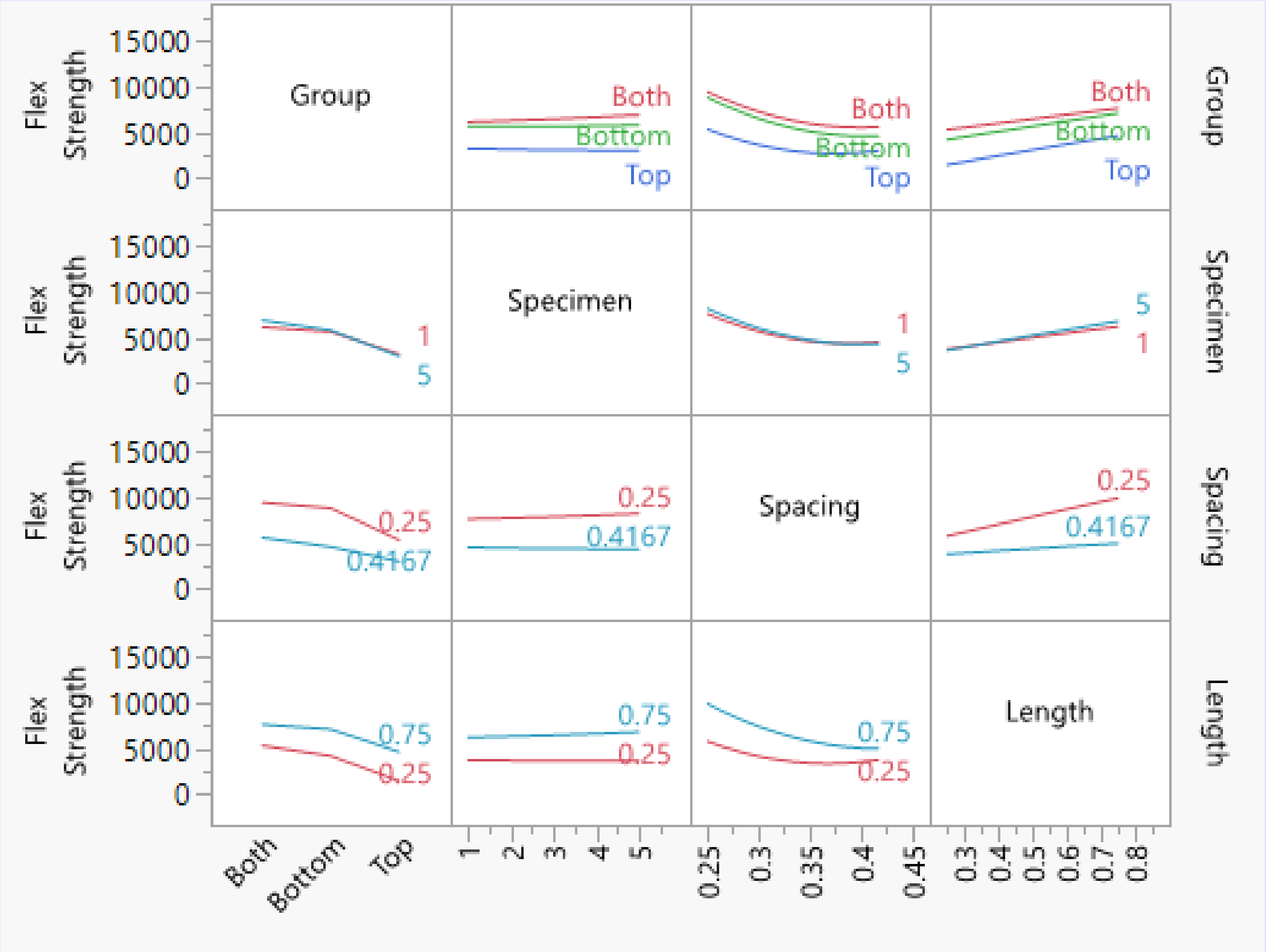
It was found that a weld length of 0.75” and spacing of 0.25” with the weld on the tensile side of the bend exceeded the strength of a standard 3D printed bar without welds.





Interaction of position, length, and spacing

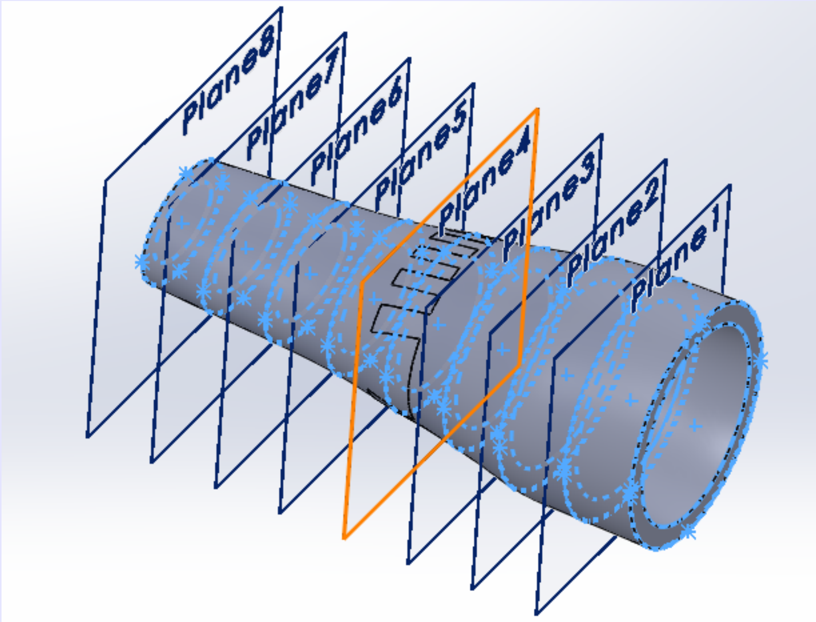
- Flexural Strength increased:
  - As weld spacing decreased
  - As weld length increased
  - As weld was placed on the tensile side of the bend

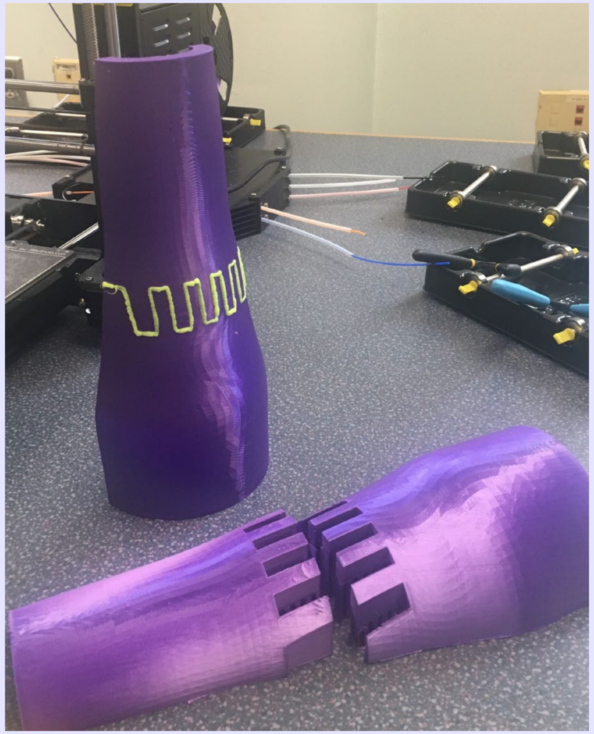


- There was no significant run effect or specimen effect

Modelling a Kyle Arm

- Rubber bands were used to space out the measurements at 1” increments
- Caliper was used to determine principal dimensions of the ellipses
- Offset planes were used to create a lofted extrusion in Solidworks





Printer size, cost, and timing

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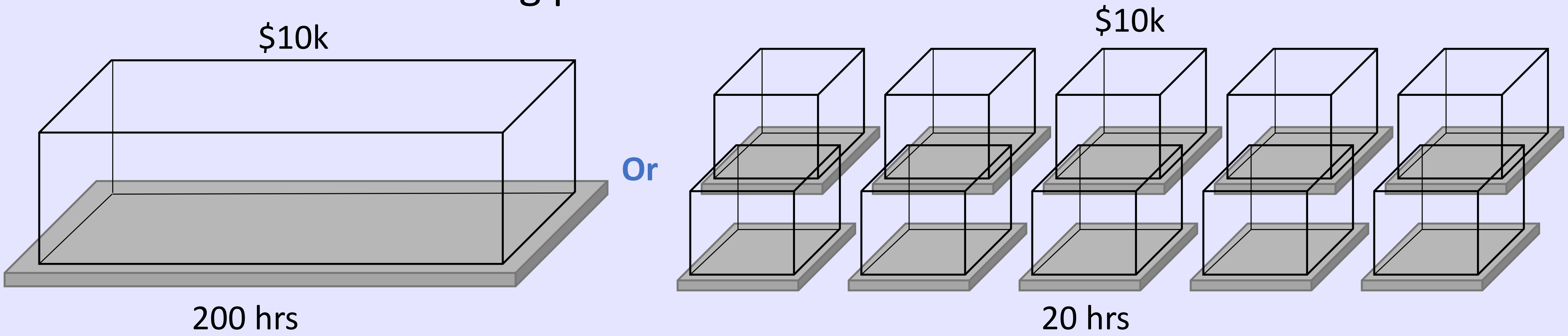
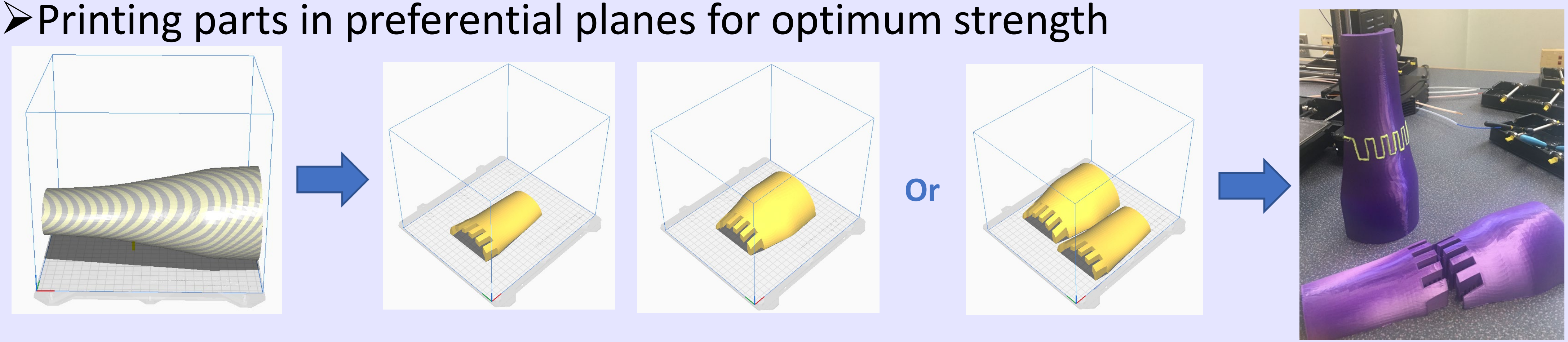
- Several pieces of a part printed on cheaper smaller printers simultaneously will be much faster than one big part

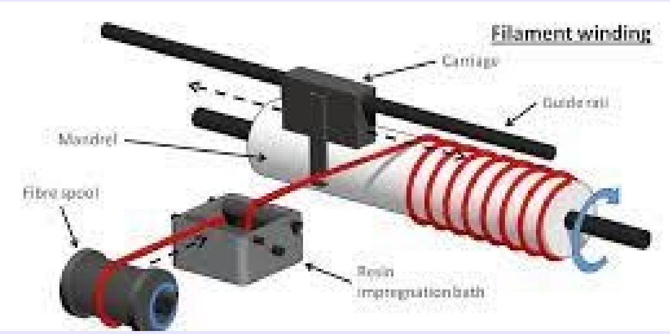


- Printing parts in preferential planes for optimum strength

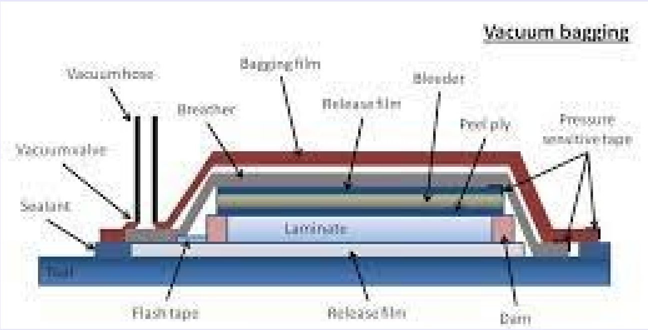


Sacrificial Tooling

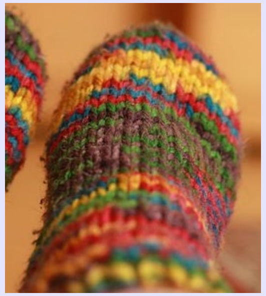
- Traditional tooling requires forming, machining, and polishing of metal with release agents to ensure resin does not adhere to tool. (Multiple parts produced)
- Sacrificial tooling is used to make fast, unique prototypes by either leaving the tool form in the part after production or cut/melted out of the part after production. (One part produced)
- Tooling can be used to wind filament, vacuum fabric, or pull braided fabric over while the resin cures and the composite is created.



Filament Winding



Vacuum Assisted



Braided sock

Future Work

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- How many layers are needed on walls, top, and bottom relative to part thickness and fill %?
- What part thickness is required for structural support during Vacuum Assisted processing?
- What material selection is compatible with Epoxy?
- How to program an auto generated puzzle piece parting of a large structure?

Questions?

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First Year Research and
Creative Mentoring

COMPOSITE MATERIALS
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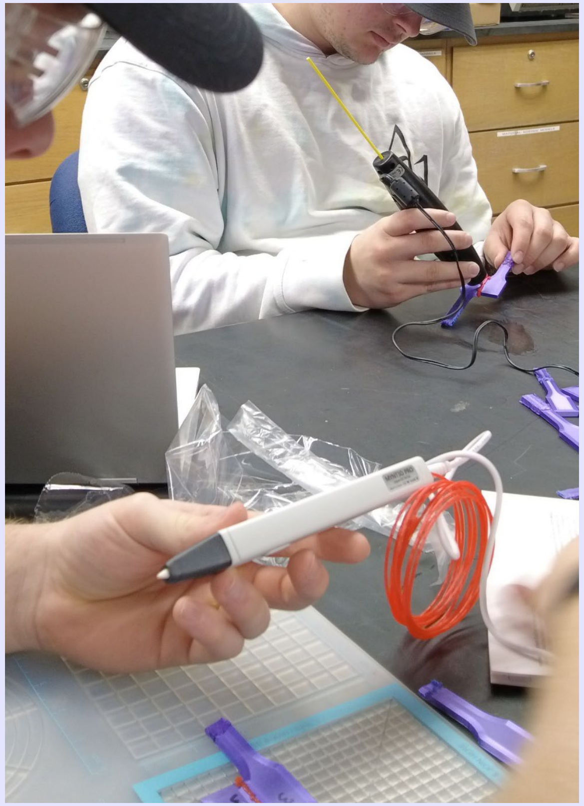

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