SLA vs. FDM Bulk Order Comparison

Purpose

The purpose of this experiment is to compare the performance of SLA printing to FDM printing when it comes to bulk orders. This was done by having the RPL's Elegoo Saturn 4 Ultra 16K and the AFL's Prusa i3 MK3S+ print 20 testudo statues each. The results of this experiment will be used to determine if it is a viable option for the AFL to switch its bulk order production to SLA printers from FDM printers. The performance of the printers will be measured by time (both printing and post-processing), material cost, and quality.

Procedures

SLA

In ELEGOO SatelLite Slicer:

- Change printer settings in the "Prepare" tab to the following*
  Resin (SUNLU)
  - $10.5/1000g
  - 1.001g/ml

  Parameters
  - 12 second bottom layer exposure time
  - 5 bottom layers
  - 10 Transition Layers
  - 1 second wait before cure
  - 0 second wait before release
  - 0 second wait after release
  - 2.25 second normal exposure time
  - 1 second wait before cure
  - 0 second wait before release
  - 0 second wait after release
  - Layer height: .1mm
- Upload STL of Testudo
- Hollow the model using the following parameters*

  Hollow Parameters

  - Thickness: 3 mm

*Any parameters not mentioned should be left on their default settings

- Precision: 1 mm
    - Hollow Type: Inward
    - Filling Structural Type: BCC
    - Filling Structural Dimensions: 15 mm
    - Support Radius: 1 mm
- Tilt model by 20 degrees w/ nose pointing up
- Add 2 drainage holes on the bottom making the first one as close to the first layer of meaningful printing as possible*
- Make a custom support region only allowing supports to build on the bottom of the pedestal
- Arrange up to 5 models on the build plate so they all fit completely on it
- Add supports using the following parameters*

  Supports

    - .35mm tip measure
- Slice and export to micro USB

  Slicer Estimates per 1 testudo
    - Volume: 69.725 ml
    - Weight: 69.795 g
    - Price: $0.733
    - Time: 3h 08m 28s

  Slicer Estimates per 5 testudo
    - Volume: 349.663 ml
    - Weight: 350.013 g
    - Price: $3.675
    - Time: 3h 08m 28s

Starting print (use gloves)

- Level build plate (if the previous print failed)
- Ensure LCD screen is clean
- Ensure integrity of FEP film
- Fill the resin vat with resin
- Ensure the build plate is secure
- Plug in USB with the sliced file
- Select the file and allow the printer to run

Post-Processing (use gloves)

- Use metal scraper to remove prints from build plate
- Remove supports
- Perform 1 IPA wash in used IPA/resin bath to clean the inside of the model of loose resin
- Perform 1 IPA wash in fresh IPA/resin bath to clean the inside of the model of additional loose resin
- Wash in Anycubic Wash and Cure 3 Plus for 5 minutes (make sure models are filled with IPA in the tank)
- Shoot compressed air in one of the drainage holes to force the remaining IPA/resin out of the other drainage hole
- Place the model in the Anycubic Wash and Cure 3 Plus and cure for 20 minutes

FDM

In PrusaSlicer

- Upload STL of Testudo
- Fill buildplate with the max amount of Testudos
- Apply 15% infill
- Ensure supports are off
- Set print settings to 0.20mm SPEED (used for build plates of 8 Testudos) or 0.15mm SPEED (used for build plates of 4 Testudos)
- Ensure filament is set to Generic PLA

Starting Print

- Ensure buildplate is clear and PLA is full
- Send slice file to printer over PrusaConnect or using the USB

Finishing Print

- Take print off build plate

Results

SLA

The front of the print shows a warping of the base as well as the clear detail on the lettering. It also shows the smoothness of the print.

The back of the print also shows warping of the base and continues to show the clear detail on the lettering. It also shows the smoothness of the print as well as the support points along the base.


The sides of the print show the smoothness of the print along with the slight visual shine that follows the layer lines.

The top view of the shell displays the details and the slightly visible layer lines of the print.

This picture shows the details in the skin and shell while highlighting the lack of stringing that comes with SLA printing.

Time & Cost

Build plate/ Date started	Printing time	Post-processing time	Total time (rounded up to nearest m)	Grams used/cost of TW to buy resin only [$.0105/gram]	Additional Notes on individual prints
5 March 26	2h 18m 24s	54m	3h 13m	350.013 $3.675	.1mm layer height, 5 models

6 March 26	2h 18m 22s	49m	3h 08m	350.013 $3.675	.1mm layer height, 5 models
7 March 31	2h 18m 26s	44m	3h 03m	350.013 $3.675	.1mm layer height, 5 models
8 March 31	1h 30m	30m	2h	262.5 $2.756	failed
9 March 31	2h 18m 25s	48m	3h 07m	350.013 $3.675	.1mm layer height, 5 models
Combined (round up to nearest m)	10h 46m	3h 45m	14h 46m	1662.552g $17.456	Add 15 minutes to the total time for the slicing time

Notes: build plates 1-4 were used to discover optimal build plate formations for bulk orders and were therefore excluded from the mock bulk order data.
Slice saved on flashdrive so there is a one time cost of 15 minutes for that.
Expecting a failure rate of about 10%.

Record of Errors:

Build plate 8 had prints falling off of the buildplate mid print and was found about 1h 30m into the print leading to the following:

March 31

- Emptied resin vat and removed resin that was stuck to film
- Restarted print
- Caused about 2 hours total of time to correct the failure and restart the print

Additional Costs:

- IPA: 2 gallons per 50 testudos
  - 1 gallon of IPA is $23.99
  - $4.80 per 5 testudos
  - $0.96 per 1 testudo
- Gloves: 1 pair per buildplate
  - 1 box of 50 pairs is $10.59
  - $0.212 per build plate
- masks : 1 per day per technician (assume 2 build plates printed per day)
  - 50 masks is $19.95
  - $0.400 per day

- FEP film replacements: 1 per 10 buildplates (about 9000 print layers)
    - 5 replacement screens is $29.99
    - $0.600 per buildplate + 45 minutes after 10 build plates have been ran

Total additional cost of batch of 20: $23.24

Final Total cost of batch of 20: $40.696

Per Unit Cost & Time of Testudos Based on # of Models on a Build Plate

Note: Assume 2 build plates are printed per day as this is a realistic estimation of the amount of prints an operator could run per day.

Number of models per build plate	1	2	3	4	5
Total cost of resin used	$1.47	$2.94	$4.41	$5.88	$7.35
Total cost of IPA used	$1.92	$3.84	$5.76	$7.68	$9.60
Total cost of gloves used	$0.42	$0.42	$0.42	$0.42	$0.42
Total cost of masks used	$0.40	$0.40	$0.40	$0.40	$0.40
Total cost of film wear	$1.20	$1.20	$1.20	$1.20	$1.20
Per unit cost	$2.71	$2.20	$2.03	$1.95	$1.90
Per Unit Time	2.3 hours	1.15 hours	.77 hours	.58 hours	.46 hours

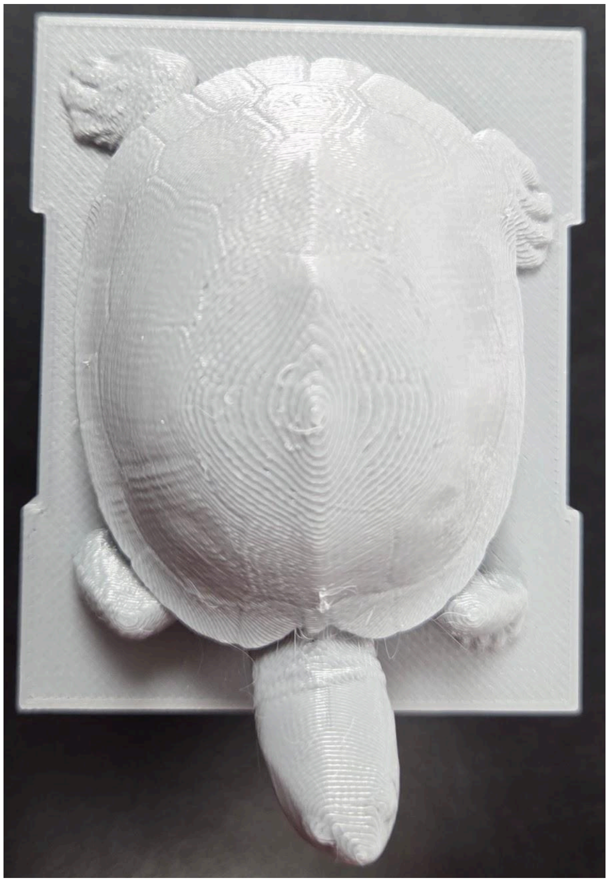
Since the cost of gloves, masks, and the wear on the FEP film does not change when adding more models onto the build plate, it is more cost effective to print the maximum number of models on each build plate.

FDM Using Prusa MK3 (Order #8511 on PaperCut)

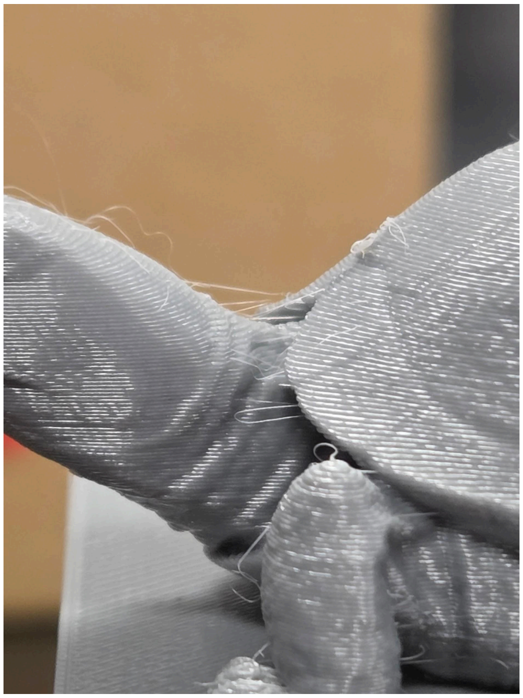
The front of the print shows no warping of the base as well as the moderately detailed lettering. It also shows the layer lines and shiny finish of the print.

The back of the print also shows no warping of the base and shows poor detail on the lettering. It also shows the visible layer lines of the print and the shiny finish.


The sides of the print show the shine and layer lines of the print.



The top view of the shell displays the lack of fine details and visible layer lines of the print.



This picture shows the lack of fine details in the skin and shell while highlighting the stringing that can come with FDM printing.

Time and Cost Link to Report

Notes: Each print done on a different printer causing a recurring time cost for slicing/preparation

Build plate	Slice/Prep Time	Printing time	Total time	Cost of Material for TW ($.02-$.013/ gram)	Additional Notes on individual prints
1	3m	25h 3m	25h 6m	413.2 g $8.27-$5.37	8 models, .20mm SPEED setting
2	3m	25h 3m	25h 6m	413.2 g $8.27-$5.37	8 models, .20mm SPEED setting
3	3m	16h 30m	16h 33m	210.78 $4.22-$2.74	4 models, .15mm SPEED setting
Combined	9m	66h 36m	66h 45m	1037.18 g $20.75-$13.48	None

Record of Errors:

Build plate 1 failed on “Dwight” causing the following (direct quotations from order comments):

February 24

- batch 1 failed due to not sticking to the buildplate. using a different buildplate, adding glue, and restarting on dwight

February 25

- dwight is not extruding correctly. restarting on Jerry

February 26

- 8 testudos - 24 hours 43 mins print time, slice time 3 mins (8 in one plate), $.1 per gram of plastic, no fails, harvest time 2 mins

March 11

- Report was created and shared in order comments
- Corrected data to what is found in the above table

Build plate 2 failed due to filament tangling/running out (direct quotations from order comments):

March 12

- Batch 2 failed due to a tangled spool, untangled spool and restarting
- Ran out of filament halfway through- check quality when done

Per Unit Cost & Time of Testudos

The unit cost of testudos is the same for FDM since PLA is the only cost consideration.

Per unit cost: $0.67

Per unit time (Best): 3.14 hours using .2mm layer height

Per unit time (Worst): 4.13 hours using .15 mm layer height

Discussion

Printing type	Unit Cost (best case scenario)	Unit Cost (worst case scenario)	Time per unit (best case scenario)	Time per unit (worst case scenario)
FDM	$0.67	$0.67	3.14 hours	4.13 hours
SLA	$1.90	$2.71	.46 hours*	2.3 hours

*Note that the total time to print is still 2.3 hours, but 5 testudos will be produced making the per unit time defined as 2.3 hours divided by 5 models produced giving the resulting .46 hours.

When printing 20 testudos, the Elegoo Saturn 4 Ultra 16K SLA printer showed a significant improvement in time when compared to the AFL performing the same order with Prusa i3 MKS+ FDM printers. The total time that was spent slicing, printing, post processing, and restarting failed prints for SLA totaled to 14 hours and 46 minutes which is over 4.5 times less than FDM which took 66 hours and 45 minutes of slicing and printing. The AFL's exclusive use of Prusa i3 MKS+ printers is a notable factor that contributed to such a large difference in print time. The AFL has faster printers which have the capability to speed up the production of bulk orders that are not showcased in this experiment. For SLA, another print can be started while the previous print is being post processed effectively eliminating the post processing time for all build plates that this is done for and speeding up the process even further. An additional consideration for time is that there must be an employee to post process all resin prints so if left to print overnight, there is still time in the morning where someone must finish the print.When comparing cost, FDM proved to be more cost-effective than SLA. Assuming the AFL buys all of their PLA in bulk (10+ rolls at a time) to get the best rate of $.013/g the cost of materials for FDM would be $13.48 which is over 3 times cheaper than the cost of resin plus additional supplies for SLA that totaled $40.696. The additional resources for SLA printing include gloves, masks, isopropyl alcohol, paper towels, compressed air, and wash & cure machines. Even when SLA models are printed with the most cost efficient method of filling the build plates and running 2 build plates per day, the per unit cost comes out to $1.90 which is more expensive than FDM's $0.67 per unit. It should also be noted that the price of the SLA order is also increased by resin wasted from a failed print. When the per unit cost of the two methods is compared FDM still has a clear advantage. The post processing is more complicated than anything involved in FDM printing and would take longer for employees to be trained on. It also poses a larger hazard to employees since resin is toxic and requires toxic waste management training. The resin needs a well ventilated area as well to keep the rest of the area safe. The failures can take longer to fix than in FDM as well. Print failures require emptying of the resin vat to clean the FEP film which may need to be replaced.

These films take about 30-45 minutes to replace but the time could be shrunk to under a minute if a certain replacement resin vat and custom films were bought. The SLA prints also had noticeably higher quality with more detail in areas like the text and shell, as well as no stringing. The FDM prints did have less warping and no support points on the base but overall this does not make up for the lower quality across the rest of the print.

Conclusion

This test shows that SLA printing has the potential to significantly increase the speed at which the AFL completes bulk orders while also improving the quality of the products. It also shows the large increase in complexity and cost to print in SLA instead of FDM. Despite higher costs and increased complexity of SLA printing, the time that could be saved is worth considering the switch for bulk order purposes. Before any final decision is made it should be noted that limited FDM printer capabilities in the AFL's data make the difference between the two methods extreme so further testing on the faster AFL printers should be considered to uncover the real amount of time that could be saved.