Due to the additional finishing properties of Polymaker's PolySmoothTM, Sue and I wanted to do a more in-depth testing of the PolySmooth filament. After speaking to Yulila and Tim of 3Dfilaprint they lent us a PolysherTM machine to try out the PolysmoothTM filaments range and produce a more comprehensive testing. Along with some samples of White & Transparent in 1.75mm and Coral and Electric Blue in 2.85, we also initially purchased 2 rolls of filament to use on our 2 machines, Black in 2.85mm for the Ultimaker2 and Teal in 1.75mm for the Wanhao Di3+, and later purchased a roll of Transparent in the 1.75 after Sue really liked the finish after the Polysher and wanted to try some more models out in it.

In addition to the basic test pieces we use to find the ideal printing parameters to suit our machines, we wanted to try some additional models that may prove difficult to print or may not quite give the results we expected after processing through the PolysherTM. The models that were shown in the advertising were all normal models not necessarily with fine detail or thin sections etc. and we wondered how the PolysherTM process would affect various features and dimensional stability.

The general recommended settings given for PolySmooth are:

Nozzle Temperature	210'C to 230'C
Bed Temperature	if heated bed fitted then up to 70'C
Print Speed	40mm/s to 90mm/s
Build Plate adhesion	PVA glue.

PolySmooth^{TM} is Polyvinyl Butyral (PVB) and is sensitive to moisture, when not in use it is advised to store in the provided re-sealable bag with the desiccant pack to minimise moisture absorption and ensure best printing performance.

We wanted to consider a small range of parts and models to print which we hoped as well as testing how the filaments performs and the polishing process would also look good when finished.

Ultimaker Robots, *Jet Black, Electric Blue, Teal, Coral Red, Snow White, Transparent.*

We started with a few of our standard test pieces and these are a simple *material tag* (1) then some of our standard test pieces for a standard set of files, which include the *Ultimaker Robot* (2) the *Treefrog* (3), and the *3DBenchy* (4) test piece, in addition to these four there are also a single wall *fluted vase* (5) printed in "vase mode", to check the print speed range from **3mm^3/s** to **10mm^3/s** we use a volumetric cylinder wall (6) and then some more complicated models which include the multi component articulated *'Braq'* dragon (7) printed at 75% which has some nice fine details and includes some thin sections, Sue also took a shine to a Dragons Head hair slide (8) again printed at 75% to see

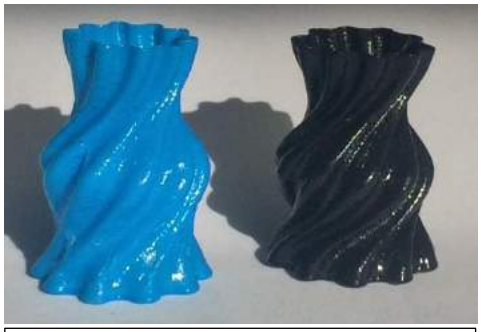
how it would look in different colours, and the last piece we wanted to try out was a *'Voronoi'* style model of a cat (9) again at 75%.

Treefrog, Jet Black, Coral Red, Transparent, Snow White, Teal, Electric Blue.

For bed adhesion, initially we tried hairspray and although it would work for the majority of the time it had to be a freshly applied layer for each print so we found that using PrintaFix was the best option and was is our preferred method being less messy than the glue stick.

We started with testing the Black on the Ultimaker2, using the '*Quick temperature filament test'(10)* by Arjan to find the preferred print temperature, it printed across the range from 230'C to 210'C but we found 220'C to 225'C the ideal, it would print down to 200'C but here we found that it could suffer from lack of layer adhesion at the lower temperatures. Having found the preferred temperature region we then moved on to the test pieces, after the material tags printing a few of each, first the *Ultimaker Robot* (2) and the *Treefrog* (3) and the *3DBenchy* (4) test pieces. There is evidence that there was not enough cooling to the antenna of the Robot and also the doors and windows on the 3DBenchy, they also appeared to show some fine wispy stringing, adjusting print temperature, retraction settings and fan speed did not seem to improve things.

When printing the *fluted vase* (5) in "vase mode" the fine wispy strings were evident in the fluting and as there were no retractions just a constant spiral build mode it could not have been due to the retraction settings, and adjusting the fan speed from 0 -100% again had no real noticeable effect on the wisps, varying the temperature from the bottom to the top of the printing range reduced it at the upper range but did not eliminate it completely.



Fluted Vase

Printing some more complicated parts to investigate how it handled the features, including supports, retractions, finer structures and details, the *'Braq'* dragon (6) in general printed well but again these parts showed some signs of the fine hair wisps in the black, as did the *'Dragons Head hair slide'* (7) and the *'Voronoi'* style model of a cat(8), in the other colours this fine wisping was not as evident.

Dragon Hair pin.
Polished at the back, Unpolished at the front.

LASER CAT - Voronoi Style

On addition we noticed during printing on both printers was the amount of filament residue on the nozzle, some materials leave little or no evidence of residue on the nozzle, but PolySmooth from our testing, left the nozzle coated and in the case of the Ultimaker2 the heater block splatted in residue which needed cleaning off almost after every print. Initially we thought that it was due to printing the black to hot and it was carbonising on the nozzle but we found the same effect with each colour across the temperature range and on both printers.

There was very little difference between printing the various colours, they all would produce wisps to some extent and we could not find a retractions setting that eliminated them, although there were fewer wisps on a direct feeder compared to a Bowden tube feeder. All filaments left the nozzle with a residue which would need cleaning off after about eight hours of printing.

The printed parts now needed cleaning up to remove the various small blobs and hairy wisps, in the main this was fairly easy although we had not planned for this amount of post printing clean up, and did a few test, using the Polysher without removing the wisps etc. and also cutting and filing the parts before putting them through the Polysher.

Print speed, PolySmooth printed well over 3mm^3/s to 6mm^3/s at 225'C and up to 10mm^3/s at 230'C although there was evidence of errors occurring at 8mm^3/s and above, I would stay below 6mm^3/s this works out at about 150mm/s at 100um layer height or 75mm/s at 200um layer height, although I'd stick to 50mm/s print speed to reduce vibrations etc. so well within the recommended range.

Support structure, on two comparison parts printed with the same file, one in PLA, the PolySmooth part's support structure was more difficult to remove cleanly being a little more brittle on fine detail more care is needed to remove the supports so as not to damage the main piece.

Processing in the Polysher™.

'Braq' pieces suspended on wire frame in PolySher.

The *Polysher™* machine uses a mist of 'Isopropyl Alcohol' to smooth the printed *PolySmooth™* model and is to be used in a well ventilated room we also found that towards the end of the cycle the surface beneath the Polysher on which it was standing would be wet so we placed the machine on a small tray with a paper towel to absorb any moisture.

A point to note is that the maximum part size that can be treated in this machine is 150mm in Diameter and 180mm high, ideally the model will have a flat base and be large enough to span three or four dimples to stand atop the dimpled platform. For some of our parts without a suitable base I made a small scaffold to hang parts from using copper wire, this worked well allowing the mist all-round access to the components, although they would need to dry on the hanger or a similar drier support for several hours to fully vent off any moisture. If they didn't have a flat base to stand on they would still need to remain on the hanger for a few days to harden as if rested on a surface the bottom edges may deform as they are soft.

In use, the time needed to expose the parts to the mist is initially trial and error and in general about 20-40 minutes worked well. However, the isopropyl alcohol misting process melts the outer surface and we found that fine edges would disappear and on very fine single layer areas then holes could appear if processed for too long, and that a single wall build item such as the vase became soft and pliable and may deform or collapse. I would also not mix different colours in the machine at the same time, I wasn't 100% sure if there was a slight colour bleed in the vapour from the red, you are able to see a hint of colour in the liquid residue on the platform after finishing and needs to be cleaned or peeled away.

So how do some of our test pieces hold up, testing with a 20 minute cycle time in the Polysher to start with, the majority of the thin wisps that we had not removed did dissolve away, and the visible print layers had in the main disappeared. There was no noticeable difference between the two items for which one was printed at 100um (0.1mm) steps and the other at 200um (0.2mm) steps after processing.

Before handling the parts need to air and dry so as not to leave finger prints etc. on them and keep spaced apart so as not to contact each other or they will stick together. When you first handle them the parts have the feel of a flexible material and any thin parts are flexible almost to the same extend as Ninjaflex, although over the next 7 days this diminishes and they will re-harden again as they dry further. Be aware that any small parts that are too small to sit on the dimples of the platform should be suspended as if they sit on the bottom of the platform the bottom of the parts will dissolve away in the liquid isopropyl alcohol and leave a thin gel layer. Also remember any thin or fine elements will dissolve away, so a fine filigree model will not survive the PolySher™ process.

The gloss shine on the parts is really nice and if you have taken extra time to clean up the parts with a fine file etc. before putting them in the Polysher they look fantastic, initially testing with the black the finished parts really do look the bees knees and the 'Braq' Dragons will look and feel amazing, as well as well the other parts we were really taken by the treated parts printed with the Transparent

sample, these look so good Sue ordered a reel of Transparent to run additional tests and print a pair Transparent Dragons and a couple more Dragon Head Hair slides, but as mentioned during PolyShere process fine details will be lost.

Shrinkage or Expansion.

Using the 3DBenchy test piece and its measurements, (all dimensions in mm) and measuring the part first after it had been printed and then again after it had been polished we could see how it changed, the results are below Although a little change in dimensions was observed it is no more than may be observed in some other filaments.

3DBenchy

Model True. Length = 60.00, width = 31.00, Total height = 48.0, height top of Box to Chimney 32.5

Printed,. Length = 59.99, width = 31.45, Total height = 48.2, height top of Box to Chimney 32.47

Post Polysher. Length = 59.76, width = 31.09, Total height = 48.01, height top of Box to Chimney 32.39

Conclusion

Polysmooth^{TM} is not as perfect as some PLAs to actually print as fine detail will be lost and its limited to just 7 colours in the range at the moment depending on availability from your filament supplier, for normal solid prints the resulting post *Polyshere*^{TM} processing parts are really nice, allow them to dry for at least 12 hours and then there shouldn't be any finger prints left on the soft surface.

A word of warning, I would allow seven days to fully dry and the soft feel surface to re-harden before assembling an articulating model similar to the 'Braq' dragon. Initially in a little of a rush to finish some of the models for this test I assembled a Teal 'Braq', just a couple of days after Polyshering and when handling it I found that a few of the parts were sticking together and a couple have fully bonded together, so allow to fully harden again before assembling, this adds time to your completed model timescale but is worth the wait. Models that have a variety of features of different thickness's again will need to allow time to fully dry out as some of the features remain pliable for a long time, on the hair slides the combs remained flexible for a couple of weeks. The build-up of residue on the nozzle was frustrating and happened across the temperature range, you would need to clean the nozzle at regular intervals and on long prints pause to then clean the nozzle else risk a dark drip contaminating your part, definitely not wanted on the Transparent models.

Test Print
A volumetric flow test piece, showing collapse after polishing

We wanted to test both the material and the *Polysher*^{TM} with some more complicated parts and models, away from the normal basic models. We feel that in general use for average models that it gives really nice results and others we have shown the models to really like the look and feel, the dragon hair slides have been loved by the girls. Like all materials it does have limitations, fine filigree parts will not print and finish successfully but courser filigree parts will, although you will need to experiment with the *PolySher*^{TM} process timing to get the best results, but you can always polish for 30 minutes, check the results and then process for an additional 10 minutes, and repeat until happy.

'Braq' Dragon.
An articulated model.

If I had a busy 3Dhub then using *PolySmooth*^{TM} and the *PolySher*^{TM} would add another string to the bow, although an additional cost to the printed parts would be required to cover the additional costs and additional finishing. On the other hand, having shown people parts in PLA and in *PolySmooth*^{TM} in general the *PolySmooth*^{TM} was preferred, they liked the gloss finish.

It is fairly reasonable in the consumption of the 'Isopropyl Alcohol' during testing we have used approximately 3 ½ reels of filament and only used just over 1½ litres to finish all the parts. I would consider obtaining a couple of extra platforms if available so that you can cycle through more prints but leave them on the platforms for longer to dry.

Many thanks to Tim and Yuliy of 3DFilaprint for the loan of the *PolySher*^{TM} over the last few months and some sample filament to enable us to run this testing.

Models printed

1 Material Tag by Ian Hiscocks
2 Ultimaker Robot, original supplied by Ultimaker a file by Martijn is available here https://www.thingiverse.com/thing:11551
3 Treefrog by MorenaP https://www.thingiverse.com/thing:18479
4 #3DBenchy - The jolly 3D printing torture-test by CreativeTools.se by CreativeTools https://www.thingiverse.com/thing:763622
5 Fluted Vase by Ian Hiscocks
6 Test Print for Ultimaker 2 by Arthur. https://www.youmagine.com/designs/test-print-for-ultimaker--2
7 "Braq" jointed dragon by bqLabs https://www.thingiverse.com/thing:854575
8 Dragon head hair pin by harddrv1. https://www.thingiverse.com/thing:1315614
9 LASER CAT - Voronoi Style by Roman Hegglin. https://www.thingiverse.com/thing:179266
10 A quick temperature filament test by Arjan https://www.youmagine.com/designs/quick-temperature-fillament-test