Continuous Liquid Interface Production

Through Forced Oxygen Permeation

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Introduction

Everyday new forms of additive manufacturing enter the market. While everyone is excited to see these advances, few individuals can afford to purchase the latest technology.

One such technology is Continuous Liquid Interface Production (CLIP), which uses UV-cured resin to print 3D objects with no requirement to separate the object from the base of the resin pool by using atmospheric oxygen to inhibit the resin-curing process.

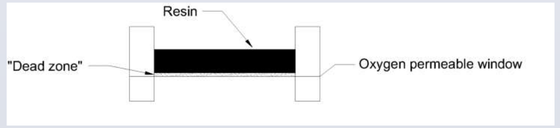
The downside is that this technology still remains out-of-budget for many individuals and institutions because the process requires specialized resins and equipment.

What is CLIP?

The term CLIP stands for Continuous Liquid Interface Production. In this form of resin based 3d printing, oxygen permeates through an optically transparent layer into the bottom of a pool of resin. As a light source of the proper wavelength is sent thought the bottom of the resin pool it breaks apart the catalyst into free radicals. Oxygen binds to free radicals causing the polymerization process to terminate until the amount of oxygen is reduced. Effectively creating a dead zone at the bottom of the pool.

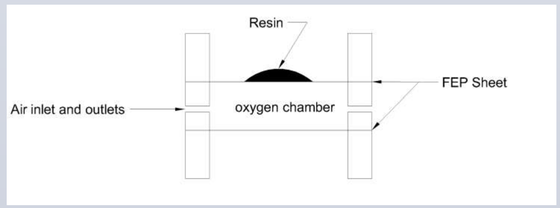
The CLIP process takes advantage of this to prevent the resin from curing to the base of the resin pool. This in turn allows for the a print to be pulled up straight out of the resin pool without having to be broken free from the base. It also allows vacuum forces to draw in the next bit of resin to be cured removing the need for a brief pause for new resin to flow in place.

With these advantages we can pull a print out of the resin with no steps and no waits and thereby greatly reducing the print times.



Our Process

In our process, instead of relying on optimal materials to make up the oxygen permeable window at the bottom of the resin pool, we will rely on pressure to force the oxygen though less than optimal materials. We are attempting to do this with FEP (Fluorinated ethylene propylene.) FEP is commonly available and is used by a lot of resin based printers for their resin pool windows. We hope that using this instead of costly specialty materials we will be able to reduce the cost and difficulty of implementing similar CLIP based printing machines.

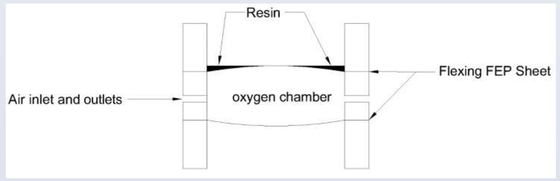


Test 1

For our first round of testing we took a simple approach. We created a small testing resin pool with a hollow chamber between two sheets of FEP film. We then added 0.2ml of UV cured resin we ran the test with 2 ways. We did the test with both atmospheric pressure in the chamber as well as with roughly 2-3psi above atmospheric pressure in the chamber. We did both 5 minutes of cure time and 7 minutes of cure time for both pressures.

At the 5 minute cure time with atmospheric pressure we found that the edges of the cured/partially cured resins stuck to the FEP sheet with a decent amount of force. It was still able to be pulled away fairly easily and near the center it took very little force to remove. At 7 minutes the edges of the resin were more difficult to remove requiring a noticeable increase in force.

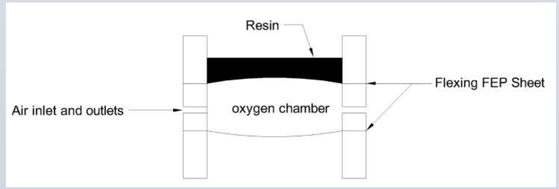
With a 5 minute cure at 2-3 psi above atmospheric pressure we encountered the resin running towards the edges of the testing apparatus. This in turn caused the edges to become thinner as it was spread over a larger area. This thinning causes the edges to adhere just as strongly to the FEP as the 7 minute atmospheric pressure cure. But, we also encountered the resin above what was on the edges not curing as much as the atmospheric pressure tests. These areas remained much more gelatinous. Although this might be due to reduced UV exposure near the edges of the testing apparatus.



At 7 minutes at 2-3 psi we noticed a much larger change compared to the atmospheric 7 minute test. While the thinner edges adhered just as tightly to the FEP the center of the resin did not adhere to the FEP. When peeled off of the FEP the bottom remained coated in uncured resin.

Test 2

Due to the issue of the resin pooling to the side, the test was repeated with 2ml of resin ensuring there was full coverage of the FEP film in both tests and an extended cure time of 15 minutes to make sure the resin was able to cure over the entire surface area for the FEP film. In both variants of this test the resin cured firmly to the edges of the apparatus due to the use of a broad targeted UV source and the edges had to be cut away.

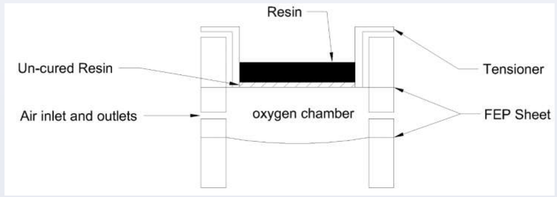


In the tests with atmospheric pressure the resin stuck very securely to the FEP film and had to be forcibly peeled off of the film.

The 2-3 psi tests had very encouraging results. Once the edges, where the resin cured to the plastic of the testing apparatus were freed, the cured resin slid off of the film under its own weight. It left behind a small layer of uncured resin.

Test 3

After the addition of a tension mechanism we repeated test 2's procedures only now the FEP film remained flat. We were very pleased to see that out results remained the same. The atmospheric pressure test still had full adhesion with the FEP while the 2-3 psi test had little to no adhesion to the FEP leaving behind a layer of uncured resin.



Conclusion

Although we ran into issues during our first test of this process with the FEP film flexing too much under pressure, our results are still encouraging. The second run using 2ml of resin presented us with positive results and seems to point that this technique might work.

After correcting the tension issues we were able to verify that out results in test 2 were not caused by the flexing of the FEP and instead appear to be triggered by the forced oxygen permeation.

We were able to have noticeable differences between atmospheric permeation and pressurized permeation. With all our current results appearing to show that we can achieve forced oxygen permeation to allow the CLIP process on a much lower cost.

We have now started construction and programming of a full printing device that will allow us to attempt to draw the cured resin up to ensure we can get new resin to be drawn in.

We will also be testing with a faster curing resin to see if the amounts of oxygen permeating will be able to inhibit more aggressive resins.

References

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