Slice Engineering®

Desiccant Activation Tests: Activated Alumina Versus Silica Gel

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***Abstract*—Moisture absorbed by 3D printing filament can cause a multitude of print quality issues. The Filament Drying Desiccant by Slice Engineering® presents a solution to removing humidity during filament storage. A desiccant is a hygroscopic material used to remove moisture from surrounding air to protect sensitive products. The most common desiccant is silica. Desiccant activation tests were conducted to observe and compare the moisture-adsorption of both silica gel and activated alumina. The change in relative humidity of the air within a vacuum-sealed container after 18 hours was utilized to determine the effectiveness of the desiccant. The tests were started at an approximate relative humidity of 43% and temperature of 23 °C. The lowest relative humidity reached by silica gel was 9.7% at the 17 hour mark. Activated alumina achieved a zero-percent relative humidity after 9.5 hours and maintained that level for the remainder of the experiment. The effectiveness of the two desiccants were determined to be 77.9% for silica gel and 100% for activated alumina. The data presented is used to determine how Slice Engineering's Filament Drying Desiccant behavior compares to an existing desiccant and whether it is a viable option for 3D printing filament storage.**

***Index Terms*—Activated alumina, desiccant, relative humidity, silica**

I. Introduction

A vital step to achieving a great quality print is drying filament. When printing with wet filament, it is likely to experience bubbles, extruder jams, poor adhesion, undesirable surface finishes, and more. All of these interfere with the success of a print. A potential solution is to dry the filament spools and properly store them in a sealed container equipped with desiccant. A desiccant is a hygroscopic material that aims to eliminate humidity from the surrounding air to create and sustain a moisture-free environment [1]. The desiccant that is most commonly used is silica. Slice Engineering's Filament Drying Desiccant is composed of 1/8 in diameter spheres of activated alumina. Activated alumina is an extremely porous form of aluminum oxide with a high surface area [2]. Both of these desiccants work through adsorption, or the accumulation of molecules at the surface, rather than absorption into the bulk of the material [3,4]. Therefore, a high surface area is ideal for adsorption allowing more molecules to attach to the surface.

Most filaments are hygroscopic materials, just like desiccant. That means they too naturally attract surrounding moisture. When this happens, hydrolysis can occur where the water molecules start to degrade the polymer chains [5]. When printing, the water in the filament heats up very quickly to the point of boiling. A high moisture content corresponds to a low viscosity and therefore, a high flow rate, which in turn contributes to over extrusion.

Relative humidity is defined as the amount of water vapor present in the air relative to the amount that would be present if the air were saturated [6]. The residual relative humidity of the air is one approach to measure the effectiveness of a desiccant.

Desiccant activation tests were conducted to observe and measure the drying behavior of two types of desiccant: silica gel and activated alumina. The change in relative humidity over a period of time was used to compare the ability of both desiccants to adsorb surrounding moisture. The tests aimed to achieve and maintain a zero-percent relative humidity in a vacuum-sealed environment. The characteristic differences were analyzed using the test results.

II. Procedure

The adsorbing ability of each desiccant was explored through the following desiccant activation tests. These findings allowed for the comparison of the effectiveness of both types of desiccants.

A. Test Method

Two Slice Engineering Filament Drying Desiccant canisters were filled with an approximately equal volume of desiccant, one with silica gel beads and one with activated alumina spheres. Due to the difference in weight per bead for both desiccants, an equal volume of each was measured rather than an equal weight.

To ensure no residual moisture was left over from previous exposure, the desiccant was restored before completing the drying test. First, the 1/8 in diameter silica gel was baked at a temperature of 120 °C for 1 hour. Next, the 1/8 in diameter activated alumina desiccant was baked at a temperature of 200 °C for 1 hour. The temperatures at which the desiccants were baked were based off manufacturer recommendations. Both were baked directly in the canister in a Whirlpool® Free Standing Electric Range kitchen oven.

The test took place in a vacuum-sealed container. The container used was a PrintDry Vacuum Sealed Filament Container. Molykote® 111 Compound was utilized as a grease to aid the sealing of the container.

A hygrometer was used to measure and record the relative humidity in the vacuum-sealed container throughout the tests. Most inexpensive hygrometers only measure down to a relative humidity of 10% or 20%, which is enough to saturate filaments over time. It is important to note a hygrometer with the ability to measure low relative humidity was necessary. The device used here was an Omega™ Pen Size Temperature and Humidity USB Data Logger (OM-HL-SP-TH) with the ability to measure relative humidity from 0% to 95%. The desiccant and hygrometer were inserted into the container. The hygrometer was set to start recording the time and relative humidity data. Lastly, the lid was secured, and the vacuum-seal was created using the PrintDry hand pump that came with the container.

After 18 hours had passed, the seal was released, and the hygrometer was set to stop recording. The data was transferred to a computer to be analyzed. These steps were completed for both silica gel and activated alumina.

III. Results

The relative humidity versus time data was plotted using MATLAB for both desiccants (Fig. 1). Both tests started at approximately the same percent relative humidity, 43%, and the temperature remained at approximately 23 °C.

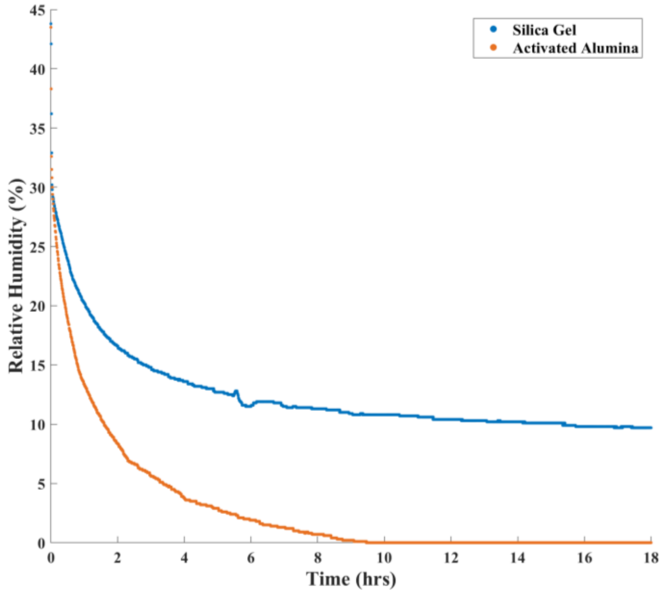

Fig. 1. Relative humidity versus time test results for both desiccants: activated alumina and silica.

A. Silica Gel

In the first hour, the humidity dropped from 43.8% to 20.2% when using the silica gel beads. After a period of 16.9 hours, the silica gel beads had reached what would be its lowest relative humidity of 9.7%. The relative humidity fluctuated between 9.7% and 9.8% for the remainder of the 18 hour experiment.

B. Activated Alumina

In the first hour, the humidity dropped from 43.5% to 13.4% when using the activated alumina desiccant. The environment in the container reached a relative humidity of 0.0% in 9.5 hours. This zero-percent humidity was maintained for the remainder of the test.

IV. Discussion

The desiccant activation tests allowed for the comparison between silica gel and Slice Engineering's activated alumina desiccant.

A. Performance Comparison After 1 Hour Elapsed

The first hour was observed to be the steepest decrease in moisture for both of the desiccants' behavior. After 1 hour had elapsed in the vacuum-sealed container, the silica gel desiccant had decreased the relative humidity by 23.6% resulting in an initial adsorption rate of 0.39% per minute. The activated alumina desiccant had reduced the relative humidity a total of 30.1% resulting in an adsorption rate of 0.50% per minute. This reveals that activated alumina is 1.28 times faster-acting in the first hour than silica gel.

B. Overall Performance Comparison

After the full 18 hours had passed, the silica gel had not reached zero-percent relative humidity. It fluctuated between 9.7% and 9.8% for the last hour indicating that the silica gel beads had reached their maximum limit of moisture-adsorption.

The activated alumina eliminated all moisture from the environment after 9.5 hours, while silica gel was only at 10.8%. The 0.0% relative humidity was maintained by the activated alumina for the following 8.5 hours. Further testing should be conducted to measure the maximum limit of adsorption of the activated alumina.

The overall change in relative humidity created by the silica gel was only 34.1% versus activated alumina at 43.5%, which corresponds to a 77.9% effectiveness for silica gel and a 100% effectiveness for activated alumina. Effectiveness is defined as the ratio of the achieved change in relative humidity to the desired change in relative humidity. A summary of the performance of the desiccants, and the accompanying uncertainty, is shown in Table I.

Table I
Desiccant Performance Summary

Metric	Value	
	Activated Alumina	**Silica Gel**
Adsorption rate (%/min)	0.50 ± 5	0.39 ± 5
Lowest Achieved Humidity (%)	0.0 ± 5	9.7 ± 5
Change in Relative Humidity (Δ%)	43.5 ± 5	34.1 ± 5
Effectiveness (%)	100.0 ± 5	77.9 ± 5

C. Limitations

Environmental limitations are present when repeatability is considered. Tests were conducted in the month of July in Gainesville, Florida. The average relative humidity under these conditions ranges from 60% to 89% throughout the day [7]. Performance of both desiccants may vary slightly depending on the climate they are being used in.

An equal volume of each desiccant, filling up the same size canister, was measured for the tests. This method has the potential for accompanying error. Future tests should measure out the same number of beads for each desiccant to eliminate this error.

It is likely that both desiccants were exposed to moisture in the air during the transfer between the oven and the vacuum-sealed container. The transfer time was assumed to be small compared to the overall length of the experiment. The moisture that could have been adsorbed was determined to be negligible.

Finally, the vacuum-sealed atmosphere inside the container was limited by the hand pump used to create the seal. This introduces human error in removing air from the container. An electric pump may have produced a tighter seal. Ultimately, this limitation did not affect the data collection as the period before the seal was created was not included in the analysis.

V. Conclusion

Activated alumina achieved and maintained a zero-percent relative humidity in a vacuum-sealed environment. This adsorbing behavior was compared to that of silica gel. Activated alumina is a useful option for a desiccant when storing 3D printing filament. Further testing could be done to explore the ability of activated alumina to extract and adsorb additional moisture from filament once the surrounding air has reached a relative humidity of 0.0%. Research has been done on forms of desiccant drying plastic pellets used for injection molding, including the use of circulating air and the effect of applying heat [8,9]. These methods could be followed to determine if storing filament with activated alumina desiccant can further dry the internal moisture and compare the results to active drying methods. The impact that desiccant effectiveness has on print quality could be investigated, as well.

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