Development of a Visual Humidity Indicator for 3D Printed Cores for Metal Casting

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Abstract

During metal casting, cores are emplaced in the mold. Cores with high moisture content give rise to porosity in the cast part therefore impairing quality. The project goal was to create a visual humidity indicator to determine moisture content of a 3D printed core. We accomplished this by successfully incorporating phenolphthalein into the sand based powder used in the 3D printing process. The success of our project will optimize digital manufacturing and metal casting by ensuring high quality cast products and improved productivity.

Phase 1: Choosing an Indicator

Indicator Requirements
1. Visually unique with humidity absorption
2. Reversible color change with addition and removal of moisture
3. Physically compatible with 3D printing technology
4. Relatively cheap to implement
5. Safe for direct human contact

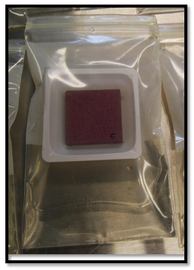
Considering these five requirements, preliminary testing compared a variety of pH indicators and silica gels in order to narrow down and identify the best possible moisture indicators. Two pH indicators, phenolphthalein and thymolphthalein satisfied requirements 1,2,3,and 5 the best. Because the cost of thymolphthalein is 10 times the cost phenolphthalein, it was more economical to use phenolphthalein as a potential indicator.

Phase 2: Incorporation into 3D-Printing

When incorporating the phenolphthalein into the ink, it did not dissolve completely. This posed a problem in the printing process because the solid particles in the ink clogged up lines in the print head, which caused streaky unreliable printing patterns.

A small concentration of phenolphthalein into the sand based powder yielded viable print tiles. The phenolphthalein in the powder reacted with the ink solution immediately; giving the printed tiles a very noticeable pink color and portraying great promise for the project.

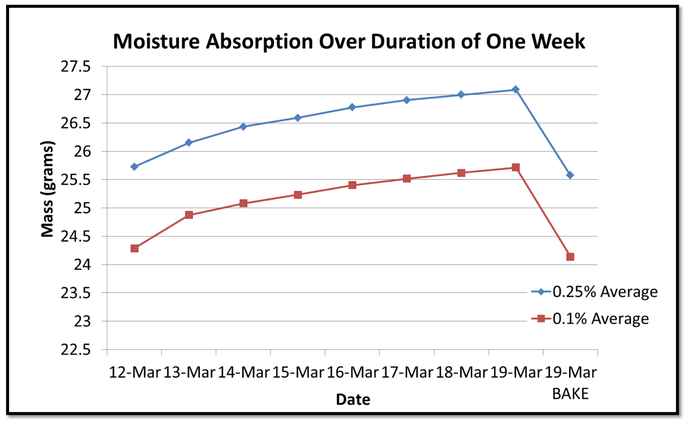
Phase 3: Humidity Testing

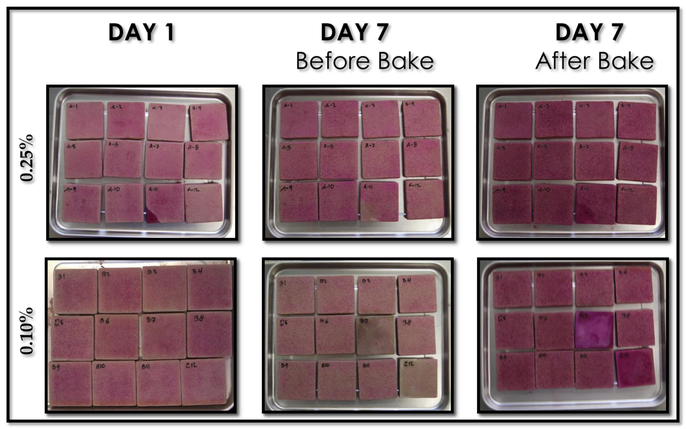


To test the potential of the phenolphthalein powder, an experiment was designed to measure color change vs. moisture content in printed pieces. Experimental procedures were as follows:
1. Bake tiles until no moisture is present and take mass measurements and photographs.
2. Place tiles in humidity environment (tiles were placed in plastic bags with 100mL of water as seen to the left).
3. Record mass and take photographs of tiles every day for one week.
4. At the end of one week, bake tiles until no moisture is present, record mass and take photographs.
5. Analyze results (color change vs. moisture absorption).

Results: Moisture and Color Change

From performing this experiment, it was evident that as the tiles absorbed moisture, the color of the tiles changed. After being baked, the tiles had a vibrant pink/purple color. After a week in the humidity environments, the tiles lost this vibrant color and became more of an opaque grey color. Again after the final bake, the tiles regained their vibrant colors, thus proving the reversibility of the process. Color change vs. moisture absorption in two different concentrations of phenolphthalein can be seen below.



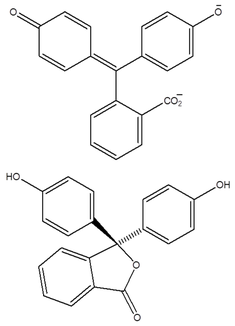


Phenolphthalein: Interaction with Moisture

Phenolphthalein can be seen in 3 different forms:

The first form of phenolphthalein is shown to the right; phenolphthalein takes this form when it is dry. This molecular structure provides the indicator with its pink color.

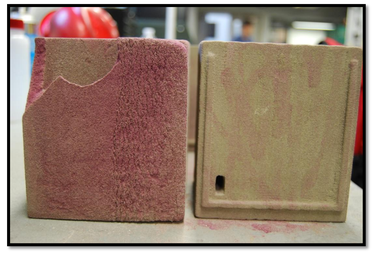
Phenolphthalein will take one of 2 forms when saturated with moisture. One of these structures is shown to the right. These molecular structures provide the indicator with a clear color.



Scale Up

The last step in the project was to create full sized molds and perform a full scale metal pour. Through this we hoped to demonstrate the capabilities of our formula to indicate the presence of moisture in a mold. Three identical molds were created for the experiment – all printed with our moisture indicating formula but varied the treatment between each:

1. Dried to remove all moisture prior to pour.
2. Dried after printing, then rehydrated.
3. No treatment.



After the pour we inspected the quality of the final cast parts. We observed that mold 2 and 3 produced very porous, low-quality parts in comparison to mold 1. This proves that molds 2 and 3 out-gassed due to the presence of excessive moisture, which our formula successfully indicated. The photograph below shows the final aluminum parts from molds 1, 2, and 3, from left to right.

Industry Applications

DO NOT POUR IF the color of the mold does not match the color of this card. If the color of the mold does not match the color of this card please dry until it does so.

In the metal casting industry, all 3D printed indicator molds will be accompanied by a color card with instructions. This process will ensure that foundry workers bake out all moisture in the mold and core prior to casting. This in turn leads to higher quality castings. Overall, the success of our project will optimize digital manufacturing and metal casting by ensuring high quality cast products and improved productivity.

Acknowledgements

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