A Brief Look into MetalTek Wisconsin Investcast's Shell Drying Process

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Abstract

This trial focused on determining the effectiveness of the shell drying practice on a lost wax mold following normal practices for simple parts. The mold was processed as a normal part of similar size and complexity would be in production. Temperature was tracked through all dips and drying using KPI-Dry™. These results will be used, along with additional trials, to determine if internal passages of this size need additional drying time.

Introduction

The dryness of shells is a key process variable of shelling. If a shell is not thoroughly dry it can result in many defects or issues such as spalling. These defects can reveal themselves during any of the remaining steps of the shelling process, starting with the next dip and extending to when molten metal contacts the shell. As a result, ensuring that shells are dry is something that many foundries go to great lengths to ensure before the next coat or further processing. However, as most foundries have limited shell capacity, shell dryness is typically balanced with production rates, ensuring that the shell is strong enough to endure the next coat but not necessarily completely dry. Using a KPI-Dry™, trials can be run on sacrificial molds to determine drying rates of various shell complexities both internally and/ or externally. These sensors can measure both temperature and relative humidity in two locations allowing for multiple options to determine shell condition. Determining the required shell dryness for a quality shell is the objective of this trial.

Testing Procedure

The trial was conducted using two sensors on a small but thick-walled T-body. The part is approximately 5” tall, 3.5” wide at the base with a 1.75” opening, extending down to the T which is 4” wide with two 2” openings. The sensor was placed using a cold 7/16” drill bit at the approximately center of the intersection wall and along on outer edge, please see below photos. The sensor was flush with both surfaces and was set to collect data every five minutes.

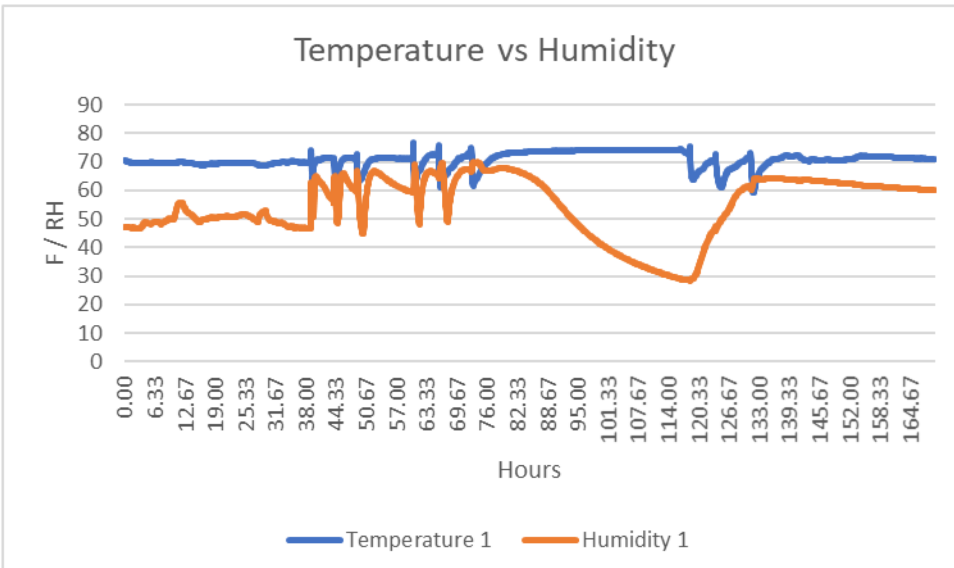
The part and sensor were then welded to a 2x2" spru and pour cup to function as a carrier during shelling. The cable slack and logger were then placed in a plastic bag and tapped to the top of a hanger. Shelling was done following a standard dip cycle including one prime coat, two intermediates, five back up coats, and a seal coat to complete the shell. Dips were at a minimum of four hours apart but followed the normal flow of production. A 40-hour delay occurred between the 3rd and 4th back up coat due to the backup tank needing to be remade. Dipping was completely automated and utilized drying rooms with monitored and maintained humidity and temperature, with continuous fans on both sides of the drying rooms.

Figure 1-3: Three photos depicting the size of the sample part.

Figure 4-6: Both sensor locations flush with the surface of the part and the staging rig.

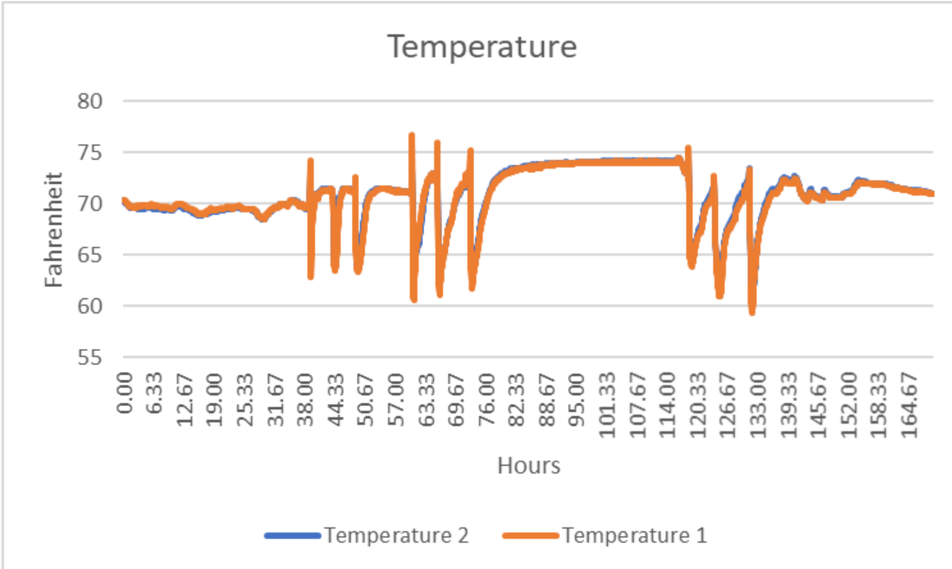
Results and Analysis

The data shows each of the dips clearly when looking at temperature variation, but they are harder to discern looking at relative humidity, specifically on the later back up coats, Graph 1. Looking at the graph it is easy to confirm the difference in variation between temperature and relative humidity that KPI refers to when encouraging relative humidity as the basis for measuring dryness. Looking at temperature, the readings return to room temperature (70-72 degrees Fahrenheit) before each consecutive dip, even the final back up coats. However, the relative humidity only just achieves 60% (typical room humidity) after the prime coat and both intermediates, it then increases over the first three backups and increases even more rapidly with the final two back up coats and seal coat. Having both temperature and relative humidity allows for the determination that a minimum 4 hour drying time is right on target for this part; if the analysis was done with only temperature, the results would misleadingly suggest that the part could be shelled faster. Between hour 75 and 115 no dips occurred due to the shell tank needing to be remade.

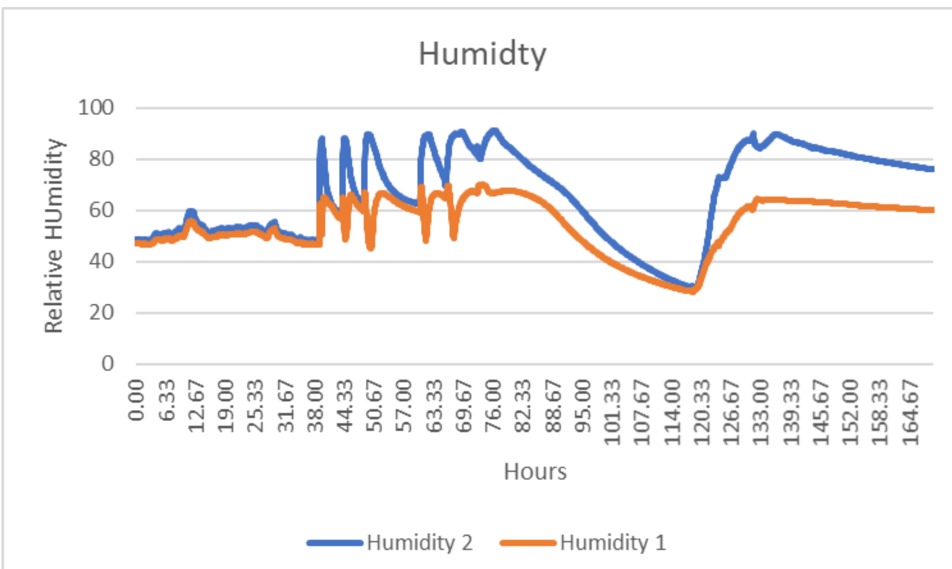


Graph 1: Comparison between temperature and relative humidity readings.

When adding the variable of an internal passageway the importance of looking at relative humidity only increases. Looking at Graph 2 below, sensor 1 was reading the outside of the shell while sensor 2 was reading the inside, the sensor number correlates with temperature and humidity, 1 and 2. Graph two shows that there is very little difference in temperature despite the location on the shell. Graph 3 however, looking at relative humidity, shows a very significant difference between the two locations. While the prime coat and intermediates return nearly to the room level humidity of 60%, as the backup coats are applied the difference in relative humidity levels separates greatly. Looking at the 4^{th} through 6^{th} dips, as the internal passageway reduces in size rapidly with the thicker back up material build up, the drying rate also begins to slow down. Due to the extended dry time in between the 6^{th} and 7^{th} dips it is difficult to predict how this trend would have continued. Looking at the final three dips, the shell quickly returns to 60% humidity as the system and tank come back online and further demonstrates the difference between internal and external shell dryness.



Graph 2: Temperature variation between sensor location.



Graph 3: Humidity variation between sensor location, the blue line (sensor 2) was place in the internal passageway.

Conclusions

While the results suggest that the shell was not completely dry between back-up dips, there does not seem to have been any impact on the final shell quality. Dips were applied with relative humidity ranging from 60% all the way up to over 80%. Furthermore, it is standard practice at Wisconsin Investcast to unstage, autoclave, and burn out shells as soon as 24 hours after the final dip. This would have put the external of the shell at approximately 60% relative humidity (room level) but around 80%

relative humidity at the center of the internal passageway. The shell was unstaged and destructively inspected 20 hours after removal from the producer when then internal passageway of the shell was still around 74%. Figures 7-10 show the results of the inspection; no flaking was visible and the surface finish and strength were as expected.

Figures 7-8: Completed part after shelling and the external shell wall.

Figures 9-10: Surface of the internal passageway shell and wall thickness showing backup dip quality.

Future Work

Additional trials utilizing various internal cavity sizes with sensors on the outside and inside would allow to build a guideline relating drying time to internal passageway width and depth. Relative humidity levels should be varied between dips to determine the impact on shell quality and determine a process threshold. Shells should also be tracked closely through the end of shelling and continue through additional processing at various degrees of relative humidity and temperature to determine a similar threshold. Trials should also be conducted to determine if there is a different relative humidity threshold regarding prime coats, intermediates, and backups. It would be critical to determine what relative humidity is permissible between coats and before additional processing to maintain quality but maintain respectable production levels. This initial trial would suggest that relative humidity under 90% between back up coats is permissible, as is a relative humidity under 80% before further processing.