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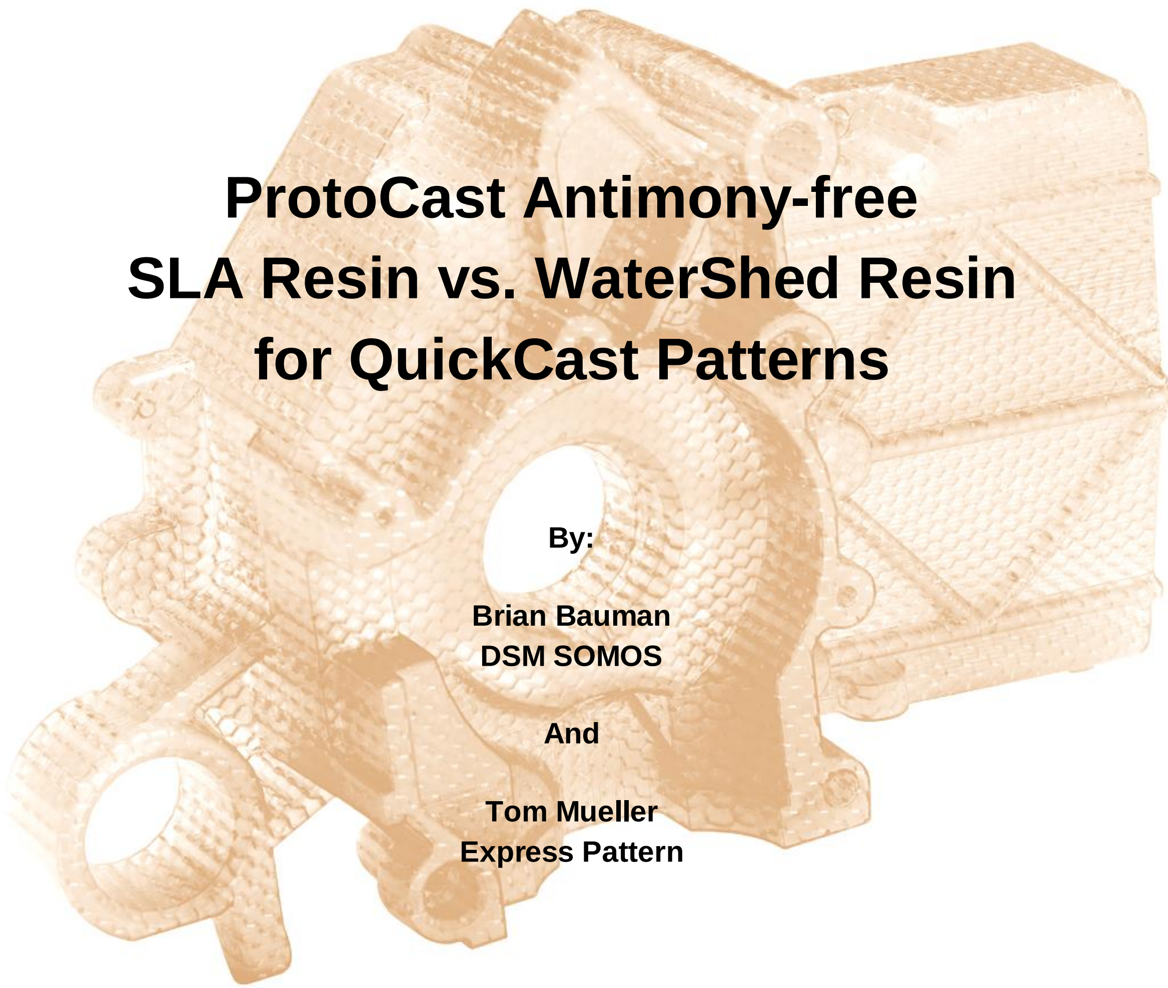

ProtoCast Antimony-free SLA Resin vs. WaterShed Resin for QuickCast Patterns

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Title:

A Comparison of the DSM SOMOS® ProtoCast™ 19120AF Antimony Free Stereolithography Resin and the DSM WaterShed® 11120Resin for QuickCast® Investment Casting Patterns

Speakers:

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Abstract:

The industry standard stereolithography resin for QuickCast investment casting patterns has, for the last several years, been the DSM WaterShed 11120 resin. DSM has now developed and released a new resin, the ProtoCast AF 19120 resin, the industries first completely antimony free stereolithography resin and the first developed specifically for investment casting applications. The new resin is designed to provide significantly less ash than previous resins and eliminate the risk of antimony contamination.

This paper reports the results of laboratory and foundry testing of both resins in areas critical to investment casting performance. In addition, the results of testing to identify critical burnout process parameters are reported.

Background:

Soon after stereolithography was developed in the 1980's, its potential for use as a means of developing prototype investment casting, patterns was recognized by foundries looking for a means of creating prototype castings without the cost and lead-time required by wax pattern tooling. Initial efforts with solid SLA parts only had minimal success, typically requiring five patterns to yield a single casting. In the early 1990's, the QuickCast build style was developed, creating a hollow pattern with an internal rib structure to provide strength. The QuickCast patterns had the advantage of significantly less mass to burn out of the shell, and because it was hollow, it could collapse inward as the patterns expanded with temperature instead of cracking the shell.

In the nearly 15 years since the introduction of the QuickCast build style, QuickCast patterns have become the most popular method of creating prototype and low volume production investment castings. To date, general purpose stereolithography resins have been used for QuickCast patterns. Enterprising foundries have, primarily through trial and error, developed methods to build shells using such patterns and to burn the patterns out cleanly.

Currently, DSM Somos is beta testing a resin specifically for investment casting known as ProtoCast AF 19120 which is the industries first completely antimony free SL resin. All previous stereolithography resins used trace amounts of antimony in the photo-initiator component of the resin, an element which can seriously degrade material properties in titanium and some superalloys. In addition, testing shows that the residual ash of the new resin is significantly lower than previous resins.

At this point, there is only generic information that could be useful to foundries to increase the probability of successfully casting the pattern. Consequently, it is a significant risk for them to use QuickCast patterns, especially for foundries with little experience using them. If more information were available, casting yields could be improved and it would be easier to convince inexperienced foundries to take the risk of using QuickCast patterns.

Consequently, we are presenting results from a test plan that will allow us to evaluate both the current QuickCast resin (WaterShed 11120) and the new resin (ProtoCast AF 19120) on measures that are critical to their performance as investment casting patterns, and compare them to investment casting waxes. In addition, we hope to provide suggested procedures to foundries for burning out the resin.

Objective

1. Identify material properties critical to the performance of the resin in direct pattern investment casting applications.

2. Identify or develop tests that will allow us to measure those properties on DSM ProtoCast 19120 resin and on DSM WaterShed 11120 resins.

3. Draw conclusions about whether DSM ProtoCast 19120 resin has significant advantages over DSM WaterShed 11120 and how either of them compare to typical investment casting waxes.

4. Develop guidelines for burning out patterns.

Discussion

There are two areas in which the use of QuickCast patterns presents the greatest challenges for foundry in investment casting; building the shell and evacuating the pattern.

Shell Building - The biggest concern in building the shell (aside from assuring that there are no leaks that will allow slurry to enter the pattern) is to ensure that there is good first coat adhesion. While most people don't seem to have a major problem, we have heard that the use of a pre-wash and the finish used on the pattern can have an effect on adhesion. A test method was developed with Remet to test the material for adhesion. A simple test bar about 1.0" x 0.25" x 6.0" will be used for testing

Specific questions to be addressed include:

1. What affect do the various finishes (as built, honed, and clear coat) have on adhesion?
2. Does ProtoCast 19120 have better or worse adhesion than WaterShed 11120? How do both compare to typical pattern waxes?
3. Does the use of a pre-wash on the pattern affect adhesion?

Ash Content – Any ash or other residual material remaining in the shell after the pattern was burned out can cause inclusions and poor casting quality and the less ash that remains, the lower the chance that there will be resulting casting issues. ProtoCast was designed to be a very low ash resin.

The ICI Standard test procedures for pattern materials in "Determination of Total Ash" were used. Crucible tests were conducted to determine residual ash levels for both the ProtoCast 19120 and the WaterShed 11120 resins. To determine whether burnout temperature or time had an impact on the level of residual ash, tests were done at a variety of times and at two different temperatures as illustrated in the following table.

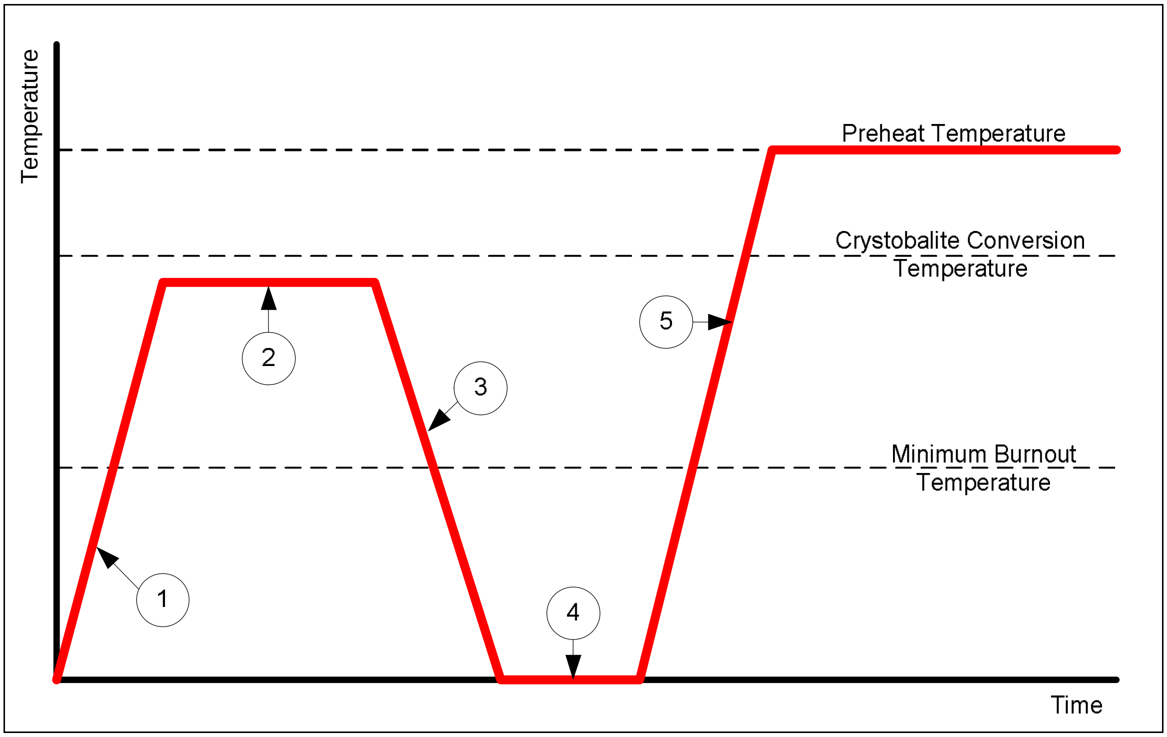
Time in Minutes	19120 Ash % at 1500 deg F	11120 Ash % at 1500 deg F	19120 Ash % at 1800 deg F	11120 Ash % at 1800 deg F
30	3.127	0.101	2.747	0.093
60	0.887	0.094	0.602	0.090
90	0.016	0.092	0.025	0.089
120	0.015	0.093	0.017	0.089
150	0.013	0.092	0.016	0.089
180	0.013	0.093	0.015	0.089

Specific questions to be addressed include:

1. What is the residual ash level for the ProtoCast 19120 and WaterShed 11120 resins? How does that compare to typical casting waxes?
2. Does the amount of residual ash vary with temperature and oxygen content? (If for example, the amount of ash is less if the oven temperature is higher, keeping oxygen level the same, or if ash is less if oxygen content is higher, then it may be possible to minimize ash by specifying the appropriate temperature and oxygen level. On the other hand, if higher temperatures only mean that the burnout will be faster, but the amount of ash will be the same, then there is likely not an ideal temperature and oxygen level to minimize ash.)

Pattern Burnout – Because the pattern is made of a thermoset material, and will not melt, it must be burned out of the shell. The burnout phase presents two difficulties that the foundry must encounter. First, like any material, the pattern expands with heat and will exert a force on the shell. The QuickCast build style is designed to allow the pattern to collapse inward as it expands; none the less, it is possible for the expansion of the pattern to crack the shell during burnout. Secondly, any material remaining in the shell after combustion will impact the quality of the casting. The minimal effect will result in additional finishing of the casting (welding, polishing). In the worst case, it will cause the casting to be rejected.

Most foundries using a fused silica shell system use a process similar to that illustrated in the figure on the following page.



Burnout Process

Step	Description
1	The shell and pattern are heated to a temperature above the minimum burnout temperature but below the crystobalite conversion temperature.
2	The shell is held at that temperature for a time sufficient to complete the combustion of the pattern. Often, outside air is added to the shell to aid combustion.
3	The shell is allowed to cool to near room temperature.
4	Ash is removed from the shell, usually by blowing out the shell with compressed air. Some foundries rinse the shell with water, a citric solution, or even boiling water to remove ash.
5	The shell is reheated to preheat temperature prior to pouring.

The specific temperatures and times of the above process are usually developed by the foundry with a trial-and-error process. Some are much more successful than others which leads us to believe that there may be an optimum process. The trial was performed at two operating temperatures and burned-out at 30 minute intervals with three sets of shells. First observations were made of shell integrity and completeness of burnout. The second observation was following standard foundry procedures of blowing out the shells followed by a wash and then metal pour. A third observation was made of pouring directly into the shell without cool-down to clean out any residual ash.
Specific questions to be addressed include:

1. Are patterns built with the ProtoCast 19120 resin less likely to result in cracking from thermal expansion than those built using the WaterShed 11120 resin?
2. Does burnout temperature have an impact on casting quality?
3. Does the time allowed for burnout have an effect on casting quality?

Conclusions:

Based on the following results, conclusions were made.

Lab testing results:

- ProtoCast 19120 showed the lowest ash % overall
- WaterShed 11120 contained much higher ash % at 1500º F vs. 1800º F
- ProtoCast 19120 took longer to reduce mass vs. WaterShed 11120
- WaterShed 11120 ignited and flamed much brighter then ProtoCast 19120 resulting in faster mass reduction

Foundry testing results:

- Shells burned at 1800º F were easily sawed in half
- Shells burned at 1500º F were very difficult to cut requiring a new saw blade for each shell
- No evidence of incomplete combustion in any of the shells
- No evidence of shell damage, even in thin sections which were built solid
- All ash appeared to be fine, loose powder
  - No tarry residue
  - No clumps that would be difficult to remove
- Shells directly poured without ash cleanout showed negligible surface pitting

From the results, ProtoCast AF 19120 is a significant advancement in SL resin for investment casting patterns. Based on its antimony free chemistry, there were no risk of detrimental effects on material properties as well as environmental issues or antimony oxide formation.

ProtoCast 19120 displayed significantly reduced residual ash content after burnout. The material also is more accurate as a pattern material based on its lower differential shrink. Since it is lower in viscosity then WaterShed 11120, it has lower pattern mass also resulting in thinner hollow walls.

ProtoCast AF19120's lower residual ash content may allow a caster to skip the cleanout step for many applications when using fused silica shell systems.