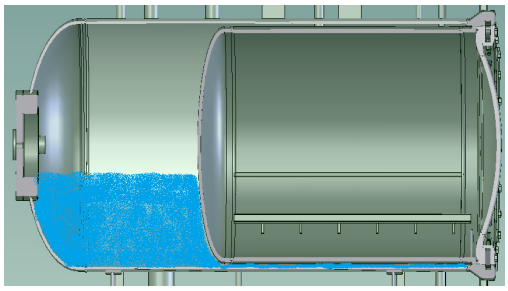
Best Practice Dewaxing.

Howard Pickard
h.pickard@lbbc.co.uk
LBBC Technologies

The removal of the wax pattern from the ceramic shell is a key part of the investment casting process, however, it is often seen as the 'necessary evil' that is responsible for cracking all the shells and leading to, at best, costly repair work or, at worst, the scrapping of the shell. There are many arguments as to where cracks originate from, however, the best way to identify the cause is to ensure that the dewaxing equipment is performing reliably to the current standards. This article aims to provide a straightforward guide to what those standards should be and the best practice LBBC Technologies, originating as Leeds and Bradford Boiler Company Limited, have been involved in the investment casting industry for over 50 years. Originally supplying the separate autoclave, accumulator and boiler combination, the company then developed the Boilerclave™ concept of combined boiler and autoclave which immediately became the industry standard due to its significantly improved performance, reduced footprint, low maintenance and increased efficiency.

Boilerclave™



Boilerclave™ concept

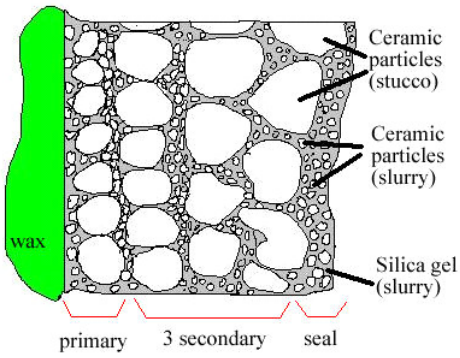
Although the fundamental concept has remained unchanged (and suffered from many cheap imitations) the operation, performance and reliability of the Boilerclave™ has been continually improved.

Through LBBC Technologies involvement in the industry, particularly with the blade and vane manufacturers, the company has also developed the core leaching autoclave system which again has become the industry standard for removing the complex ceramic cores used for aerospace components. The safety requirements of this equipment are even more critical due to the use of caustic.

Objective

The main aim of the dewaxing process is to :

Transfer heat to the wax/shell interface layer as quickly as possible



The purpose being to melt the wax at this point, allow the surface wax to be absorbed into the prime coat and create the space for the remainder of the wax to expand and melt. When reviewing the performance of this stage always use this factor as the benchmark against which all variables are judged. This applies both to the selection of equipment and shell materials.

Pioneers of the investment casting process recognised the advantages of using steam as opposed to air as the means of transferring heat to the wax pattern and so, due to the need for achieving temperatures above atmospheric pressure, autoclaves became the most commonly used method for wax removal and therefore the method subsequently considered.

The process.

Safety:

It is firstly important to remember that when using a steam autoclave or Boilerclave™ then it is a pressure vessel with a fast operating door and, as such, has mandatory safety interlocks which are fitted to ensure the safe operation of the equipment. These should be built into the control system in such a way that the equipment cannot operate in an unsafe condition nowadays incorporating dual redundancy. Unqualified personnel should not be permitted to make any adjustments or modifications to the safety systems and any maintenance routine should include verifying the operation of the safety systems.

Secondly, the manufactured integrity of the pressure vessel should be evidenced by a legitimate independent inspection agency who has witnessed the stage inspection and hydrotesting during the manufacture. With the cyclic loading duties and rapid movement of steam, it is important that only quality certified steel and approved welding techniques are used during manufacture.

Maintenance of equipment:
It may sound obvious but having acknowledged that speed of operation of the equipment is critically important, it follows that the condition of the equipment should be adequately maintained to ensure that when the dewaxing process is started the equipment operates effectively and reliably.

Loading system:
The method for loading the shells into the dewaxing chamber must be simple and reliable. As soon as the shells are presented up to the chamber, they are beginning to warm up and therefore the wax will start to expand without any room for expansion within the fragile ceramic shell. So load them into the chamber and close the door as quickly as possible. This part of the process is often viewed as unimportant.

Door closure:
Once the shells are loaded into the chamber it is critical to lock the door and pressurise the chamber rapidly. The LBBC Technologies Boilerclave™ is fitted with the uniquely designed Quicklock™ door system which is recognised for its speed of operation and is ideally suited to this application. The use of pneumatics for powering the door assists this speed of closure (less than 1 second) and, through push button operation, ensures consistency whoever the operator. Manually operated doors are not acceptable as they allow too much variability in the ease and speed of closure. There is little point in having a rapid pressurisation time if it takes over 5 seconds to lock the door.
The additional benefit of powered door operation is that the safety circuits can be integrated within the operation therefore ensuring that if the unit is not safe to operate then the pushbutton for either locking or unlocking is disabled – manual operation doesn't always ensure this.

Rapid pressurisation:
It is critical in the first phase of the pressure cycle to achieve 6 bar in the fastest possible time as steam at this temperature (165 ^{o}C) is sufficient to cause heat transfer across the shell and melt the wax/shell interface layer. Current Boilerclave™ systems pressurise from the closure of the door to 6 bar in under 3 seconds therefore enabling the heat to be transferred to the interface layer in the fastest possible time. Factors that could adversely affect the speed of pressurisation could be

- Low boiler pressure prior to cycling
- Build up of 'waste' in the bottom of the dewaxing chamber absorbing steam/heat
- Overfilling of chamber with shells (this can also lead to mechanical damage)
- Poor maintenance of air vents which automatically release the air from the chamber as the steam enters
- Poor or damaged insulation of the external surfaces and pipework leading to excessive heat loss
- Poor maintenance of valves leading to slow operation or excessive steam leaks

Steam provides the most effective method of transferring heat to the shell. There is little need to direct this flow of steam into the chamber due to the rapid pressurisation other than to ensure it doesn't flow directly at the shells potentially causing physical damage. With the Boilerclave™ concept ensuring that the chamber wall temperature is the same as the steam entering, there is little condensate produced and therefore the need for internal equipment to separate the condensate from the wax.

Cycle dwell and depressurisation:
Now that the chamber pressure has rapidly increased beyond 6 bar, heat should have transferred through to the interface layer and a small amount of wax should have been absorbed into the primary coat creating a space for the remaining wax to expand without cracking the shell. Factors that can adversely affect the heat transfer are

- Excessive backup coats slowing heat transfer
- Low porosity of prime coat reducing ability to absorb wax

The pressure should continue to rise to approximately 9.5 bar (182^{o}C) so that further heat is transferred through the shell and the wax pattern gradually melts and drains out. This dwell time depends on the volume of wax and the geometry of the pattern and is established through trials, however, around 15 minutes is typical.
At the end of the dwell, the system should automatically open the exhaust valve and begin depressurisation. With the developments in shell systems over the last 10 years, it has been important to control this rate of depressurisation through a programmable control system. The rate, normally between 1 – 2 bar / min, can vary according to the shell system and it's geometry but the purpose is to gradually release pressure pockets from the porosity of the shell keeping the differential from the overall chamber pressure to a minimum.

Wax collection:
During the depressurisation stage of the cycle, it is now common to use the residual steam pressure (approximately 1 bar) to 'blow' the wax from the dewaxing chamber into an external container. There are not many manual collection systems remaining where the wax simply drains by gravity from the chamber into a bucket as they are generally uncontrolled, dirty, a health and safety risk and require excessive manual handling.
The pipework through which the wax is blown should be steam jacketed. If wax solidifies in the pipework then it is a big problem. The external 'tank' can vary in design depending on how the customer will deal with the wax from this point but the most popular method is to have an enclosure in which a 'Big Bag' is hung as this is a cheap item which wax recyclers can easily remove and break up the block as they wish. An important point is that the enclosure should be safety interlocked to ensure that no-one can open it up if the Boilerclave™ is under pressure.

Door opening and unloading:
With the wax removed and, hopefully, a batch of uncracked shells inside, the process of unlocking the door and removed these shells is straightforward. However, as stated earlier, the integrity of the safety systems should ensure that the door is never allowed to be unlocked unless the unit is in a completely safe condition – again a situation where control is most important.

Performance measurement:
As with all equipment in today's foundry, there has been an increasing need to obtain performance data to assist in assuring an improved level of quality and consistency. It is important, however, to understand what are the critical parameters in each stage of the process and what is appropriate for each particular foundry. There is little point in obtaining data that is irrelevant to the causes of scrap. The knowledge for selecting the data to be recorded only comes through a thorough understanding of the process and the experience of working with many foundries.
The Boilerclave™ is offered with various levels of performance measurement right up to advanced SCADA and batch monitoring systems. However, whatever the foundry's requirement, the main parameter that must be measured is the speed of pressurisation. Beyond that, the data is primarily used for traceability and process analysis.

Summary
Compared to many aspects of today's investment foundry, the dewaxing equipment is relatively simple, therefore, it is necessary to monitor just a small number of key factors

- Rapidly achieving 6 bar pressure including loading time
- Controlling the rate of depressurisation
- Maintaining the integrity of the safety systems
- Ensuring the reliability of the equipment

However, by understanding the complete process as described, today's process engineer will be able to quickly establish whether that recent batch of cracked shells was really caused by dewaxing or had actually been created during the build up of the shell.

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