THE PROBLEMS OF POROSITY IN CASTINGS AND THE SOLUTION THROUGH DESIGN AND VACUUM IMPREGNATION

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Introduction

Casting Porosity is an unfortunate, renowned phenomenon in the manufacturing process when dealing with the changing states of materials and castings. For manufacturers this is an extremely detrimental issue where the component quality and function are undermined by the defects that casting porosity causes.

Here, we present comprehensive solutions for designers. It is through this white paper that we hope that designers can further help manufacturers to achieve the optimum quality casting through the control and management of porosity.

The characteristic that is unintended casting porosity

In its simplest terms, when materials change from a liquid to solid state during the manufacturing process, casting porosity arises and this results in core imperfections whether this be on the surface or as a leak path. The reason why there is porosity is typically due to shrinkage or gas.

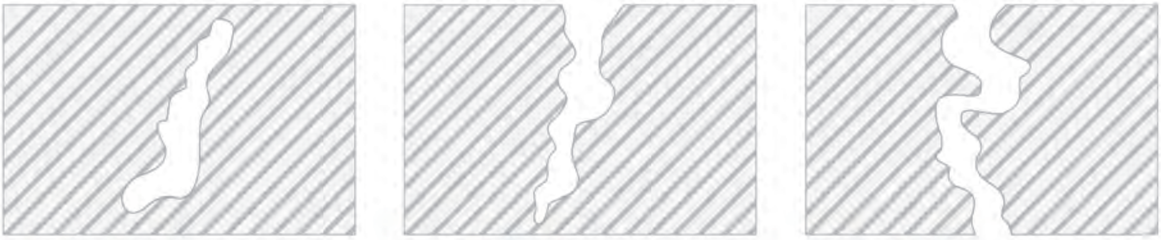
Jagged pores are a signifier of shrinkage porosity and are formed at a lower liquid fraction. This is a mechanism where a volumetric contraction of a material solidifies and the jagged edges form when there is not enough liquid to fill the shrinkage.

Smooth pores are a signifier of gas porosity and are caused by trapped gases of various kinds in the die. In comparison to shrinkage porosity this forms under high liquid fractions.

Porosity is extremely common in both aluminium and magnesium die castings. A recent survey revealed that 35% of the participants when asked what the main problem with die casting was, believed that it was porosity. 32% stated it was another defect which in fact stems from the same underlying problems, these being the physics and characteristics of the process which are found within the causation of porosity. Thus, over 65% of all concerns within die casting and manufacturing are directly attributed to porosity.

What makes porosity an even greater inconvenience is the various forms in which it manifests; porosity appears as a collection of voids in a structure. The three main forms are as follows:

Figure 1: Types of porosity



This further accentuates the problems which face manufacturers and their products.

The impregnation process – one key solution for casting porosity

Figure 2: Component with porosity

Vacuum impregnation is a reliable and permanent solution to the eternal problem of porosity in casting, a phenomenon that can ultimately lead to the failure of a finished component if porosity leads to a leak path forming. Whilst this white paper attempts to inform the reader further about how the occurrence of porosity can be reduced through design, vacuum impregnation is now a globally used process to successfully treat porosity and provide leak free castings. By developing an understanding and awareness of both these factors, it will assist any designer in the aim to reduce casting porosity.

Many companies around the world which embrace sealant impregnation of die cast components as routine, now favour modern methods of vacuum impregnation. These methods employ high quality sealants to maximise quality in low-cost, fast cycle time processes, which dispense with the need (in the majority of instances) for added pressure. Subsequently increasing efficiency with shorter cycle times.

The concept behind vacuum impregnation is simple: the porosity is filled with a liquid sealant which is then set into a hard plastic. Modern impregnation sealants are methacrylate-based and set within minutes at 95°C. First, parts are placed in an autoclave and a vacuum applied in order to draw out air from any porosity. Liquid sealant is then introduced and drawn into the porosities. During the final, "hot cure" stage the sealant is turned into a solid but flexible plastic by immersing the parts in

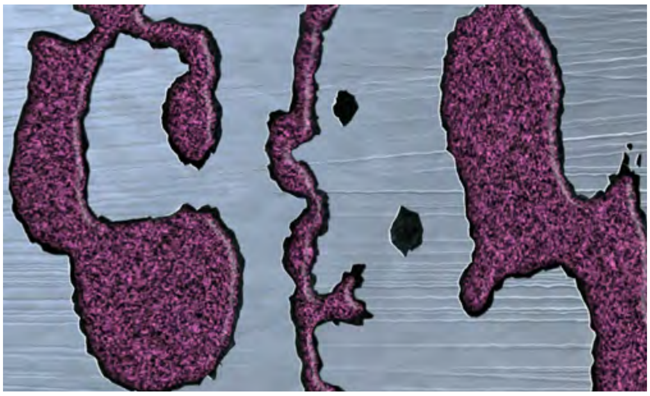


Figure 3: Component filled with impregnation sealant

hot water at 95°C. The result is a pressure-tight part.

The process is “sub-surface” and does not dimensionally change or alter the surface of the part. Parts impregnated with modern methacrylate-based sealants are instantly sealed after the impregnation process and available for immediate use.

Cutting edge sealants

Two sealant technologies now dominate vacuum impregnation: these are anaerobic and thermocure sealants. Both these types use similar base chemicals, but with different curing systems; the performance and ease of use of each are significantly different:

Anaerobic

These sealants are formulated so that curing of the resin occurs at room temperature. As such curing times are typically very long, up to 24 hours, rendering the process unsuitable for modern JIT (Just in Time) production facilities, with pressure testing not possible until curing is complete. Additionally, the sealants are unstable and require significant maintenance to ensure unwanted bulk polymerisation in the autoclave does not occur (constant refrigeration, aeration and reactivity checks). Typically, this technology is limited to sections of North America and Mexico.

Thermocure

Thermocure sealants now dominate the global impregnation market. Introduced in the 1970s, they were rapidly adopted due to their fast curing times. These products are based on methacrylate monomers that cure in the presence of heat. Development of this technology since its introduction means this class of product can be subdivided into two groups:

- non recycling sealant
- recycling sealant

Non-recycling sealants were the first thermocure products to be introduced to the impregnation market. They are now a relatively old technology, having been used for the past 40 years. However, they still offer reasonable sealing performance and are widely used in particular markets. Thermal resistance of these products tend to be limited and some formulations can also lack the correct adhesion and flexibility characteristics required to give optimum performance.

Cutting edge modern sealants are recyclable

The cutting edge of sealant design is represented by recycling thermocure sealants. These give high sealing rates, last longer in service through increased thermal stability and reduce the costs and environmental impact of the impregnation process. This being due to the fact that far less effluent is produced when compared to non-recycling thermocure sealants.

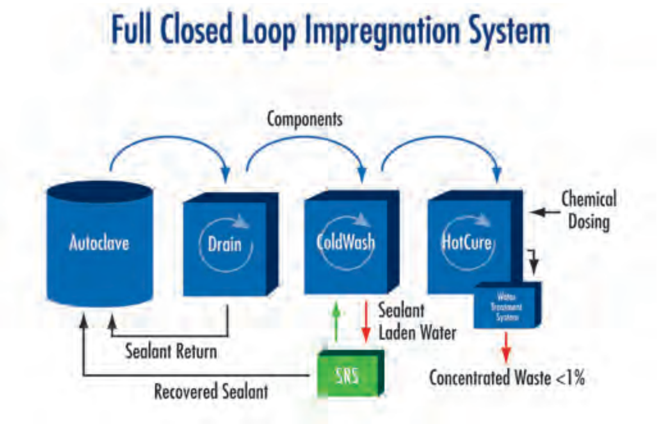


Figure 4: Ultraseal fully closed loop impregnation system

Recycling sealants combine high performance with marked environmental benefits: the majority of the sealant which is removed from the surface of treated components in the cold wash stage is recovered and returned to the autoclave for immediate re-use in the first stage of the impregnation process.

This drastically reduces the consumption of sealant – by up to 90% - and eliminates up to 95% of the effluent stream.

There is no need for compromise in performance with recycling sealants – indeed some, such as Rexeal 100™, offer exceptional efficiency, being effective at temperatures of up to 220ºC (428ºF) and being independently verified as achieving US military specification MIL-I-17563C (Class 1 and 3), an internationally recognized quality standard.

Figure 5 shows the Ultraseal Sealant Recovery System (SRS) where the sealant which has been collected from the wash tank is passed through the system for retrieval and reuse.

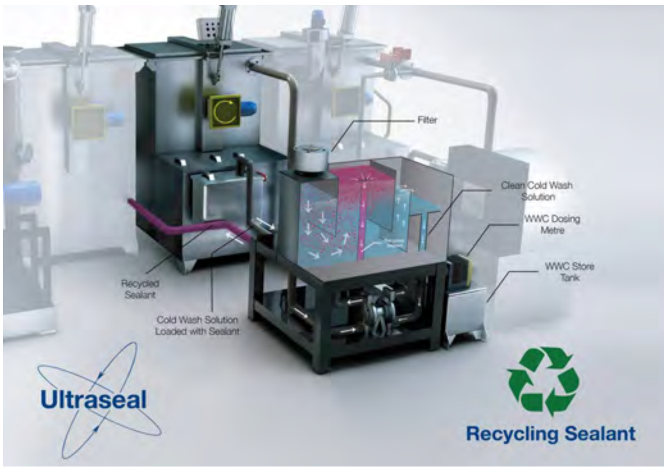


Figure 5: Ultraseal Sealant Recycling System (SRS)

Casting and tooling design - the second key solution

It is through the casting and tooling design that an optimum success rate of minimal porosity can be achieved.

The main cause of porosity is actually the casting design. The effect that the tooling design has on the porosity in casting also has a negative effect on the porosity within it. It is these two crucial aspects that need to be taken into consideration at the design phase.

Density and die casting

Generally, when looking at a uniformed thin wall casting, the designer must consider the high pressure die casting process, take advantage of the skin effect and find a dispersed and smaller porosity. Conversely, when looking at thicker sections, squeeze casting or semi-solid process is needed for the large sections. This is because a large gate is required in order to pressurise and feed the amount of shrinkage.

It is vital within the casting process to address the concern with porosity and pick the die casting processes and secondary operations (such as impregnation) in the upfront design of the part.

Porosity tolerance and vacuum impregnation benefits

What has already been established is that porosity is a characteristic of the process and is prominent at all times due to the way the casting process works. However, it can be controlled and sometimes eliminated.

In terms of design, expecting and tolerating porosity is vital wherever possible. Fatigue, life and ductility depend on porosity; as a result having a high concentrate of porosity would be detrimental in the critical areas. However, most of the other casting properties are less sensitive and so designing to accommodate this porosity instead of trying to eliminate porosity would be a much more cost effective approach. This is where the economic benefits of impregnation are apparent.

Vacuum impregnation is used on a long list of parts – including air compressor units, cam carriers, cam covers, clutch cases, cylinder blocks, cylinder heads, fuel pumps, fuel rails, inlet and fuel system components, oil pans, oil sumps, thermostat housings, timing chain covers, thermostat housing, torque converter cases, transmission cases, transmission pump castings, transmission valve body castings, turbo chargers and water pumps.

Vacuum impregnation today is increasingly being viewed as a routine quality enhancement, especially for parts that have to withstand pressure. It is no longer regarded merely as a remedial process to be used in the last resort only on individual parts which have been identified as having porosity.

There is a strong economic argument for routine impregnation of whole production runs of parts. For some components leak testing cannot be effectively carried out until a very late stage in production, by which time a large amount of added value has been invested in the part. Scrapping it – or even disassembling the component at that late stage – can be very expensive.

Dealing with porosity at this late stage in production is often many times more expensive than routinely using vacuum impregnation at an earlier stage; this makes vacuum impregnation extremely cost-effective.

Not only is it much less expensive than scrapping parts, it also gives a manufacturer the assurance that all of the production run will be of a high quality, with no porosity that could cause a part to fail in service, or possibly provoke a warranty issue.

Casting shape

There are a lot of decisions on casting shape that cannot be adjusted for controlling porosity. However, there are many shapes that need to be produced. Below are some general rules which can help control porosity.

Uniform wall thickness

The strongest casting is the thinnest casting, as the metal that is first injected into the mould and the die are very cold in comparison to the metal, thus leads to a very rapid solidification. The solidification happens very quickly and there is little time for defects to arise.

Flow porosity

The primary issue with flow porosity is that there are certain shapes and geometries that may affect the flow and fill of the molten metal. So when designing the casting it is crucial to visualise the flow of the metal and to avoid design features that might encourage hotspots.

Core pin

Core pins are subjected to high thermal stresses during the die casting process. Due to ineffective heat dissipation, core pins are subject to frequent breakdowns/ washout/soldering, and can be common trouble spots for shrinkage porosity in the casting.

When taking into consideration the design, the length of the pin will have a strong control over the porosity as well as the material. Thus, to minimise porosity when using high thermo conductivity material, a short pin is advised. In terms of casting design, the shortest hole and the biggest pin that will fit in the hole is the most efficient design.

General rules

- Wherever possible design thin walls and uniformed wall thicknesses
- Long, slender features such as core pins create porosity, so minimising these features is critical to reducing porosity

The benefits of impregnation to eliminate porosity

Porosity is an extremely detrimental problem which affects the quality of the product and the service. Controlling and eradicating this problem to improve services and products is of utmost importance. The recommendations which have been articulated in this article provide a solution and can potentially enhance manufacturers' products in a drastic way.

When selecting a vendor for this endeavour it is vital that the company chosen will match the expertise in both the casting impregnation process and the sealant technology. As this is such a vital element in the manufacturing process a reputable porosity and impregnation specialist with experience, research and knowledge of all world class casting processes is recommended.

Ultraseal

Ultraseal is recognised as the global leader in providing casting impregnation equipment and impregnation sealant as a solution to the universal problem of porosity in castings, powered metal components, and electronic components.

It has pioneered vacuum impregnation developments for casting porosity for over 40 years by continually being first to market with products such as recycling sealants, front loading and automatic vacuum impregnation equipment.

Few companies worldwide can match Ultraseal's experience and expertise in both casting impregnation equipment and impregnation sealant technology and this combination has led it to partnering many of the global players in the automotive, die casting and general manufacturing sectors.

Backed by a highly responsive worldwide service support team that is unmatched by other industry suppliers, Ultraseal's position as the world's leading provider of impregnation solutions remains unchallenged.

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