FINDING A SOLUTION TO THE ETERNAL PROBLEM OF POROSITY IN CASTING

porosity? **Ultraseal** it!

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Definition of Porosity

Porosity in castings is a major problem for die casting engineers the world over which leads to a host of defects ranging from poor surface finishes to critical failures of pressure-tight components. Significant improvements in product quality, component performance and design reliability can be achieved if porosity can be controlled or eliminated (Munroe, 2005). The use of impregnation as a standard quality enhancement process step with a sealant such as Rexeal 100 will lead to substantial savings through the avoidance of material wastage. The financial benefits have increased significantly in recent times due to the rapid increase in material commodity prices.

Often invisible to the naked eye, the tiny holes that are micro-porosities can undermine the quality of castings to a critical degree by providing a path for gases or liquids to leak through the finished part.

Unfortunately porosities are formed during the die casting process and whilst steps can be taken to reduce the risks, it is extremely difficult to eliminate them altogether.

Figure 1: Component with Porosity

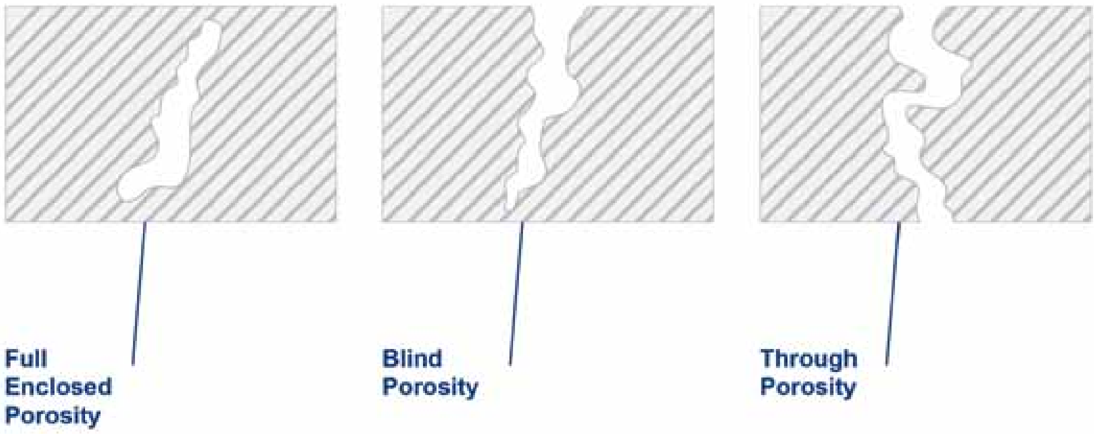
The most common, and the most difficult to control, is Shrink Porosity which is caused by the change in volume when the molten metal changes back to its solid state within the die casting mould. Flow Porosity occurs when the molten metal does not flow well around the mould and when pressure conditions are poor. Finally, the presence of die release agents and water used for cooling during the die casting process can lead to porosities. Gas Porosity occurs when vapours are trapped in the molten metal: these can be air, steam or residues of the die-release agents used to ensure the casting is easy to free from the mould. The volume of die lubricants and cooling water should be kept to a minimum to reduce this risk, however porosities can still form.

> “Rexeal 100 will lead to substantial savings through the avoidance of material wastage”

Types of Porosity

Regardless of how they are formed, porosities fall into three categories – enclosed, blind and open. Enclosed porosities are, as the name suggests, entirely enclosed within the metal and will only pose a problem if they are subsequently exposed when a raw casting is machined. Blind porosities are open on only one surface of a component, leaving a relatively large internal surface area of metal open to attack by chemicals or water. They are often the cause of the “spotting out” of paintwork and internal corrosion of parts. The worst problems are caused by open porosities which are microscopic holes stretching right through a metal part from one side to the other. Open porosities allow leaks and can contribute to the failure of components such as automotive compressors which operate under high pressures.

Figure 2: Illustration of Types of Porosity



The Need To Treat Porosity

Treating porosity is more important than ever because of acute new economic pressures operating in modern supply chains. It has always been the case that scrapping fully machined parts is expensive, given the work invested in them, however if a machined part is found to fail after it has been incorporated into a component such as an automotive compressor the costs associated with scrapping it at that stage are significantly higher. Increasingly, suppliers are being charged penalties for faulty parts, often in excess of the cost of the part supplied, by their customers as compensation for the wasted further production costs customers have incurred. Penalties can be prohibitively expensive. Pressure-testing each individual part is one option, but it is neither practical nor costeffective for high volume production.

"Impregnating with sealants as a matter of course ensures that every part being produced meets the high quality standards required"

Impregnation

A reliable, safe and permanent solution to the eternal problem of porosity in casting is to impregnate parts with sealants as a quality enhancement that is an integral part of the production run. Impregnating with sealants as a matter of course ensures that every part being produced meets the high quality standards required.

Impregnation is used in a wide range of pore sizes and even as small as 100nm and up to approximately 0.5mm. Larger pores may be sealed through multiple impregnations but are susceptible to loss of resin in washing and curing stages of the impregnation process.

The success of impregnation depends on the size of the porosity and not dependent on the volume of porosity.

The graph represents the typical pore size distribution which can be sealed by impregnation based on laboratory data on sintered metal test pieces. Pore sizes of identical test pieces were measured. Some were impregnated and someunimpregnated using a process called mercury prosimetry and then checked using powder and helium pycnometry.

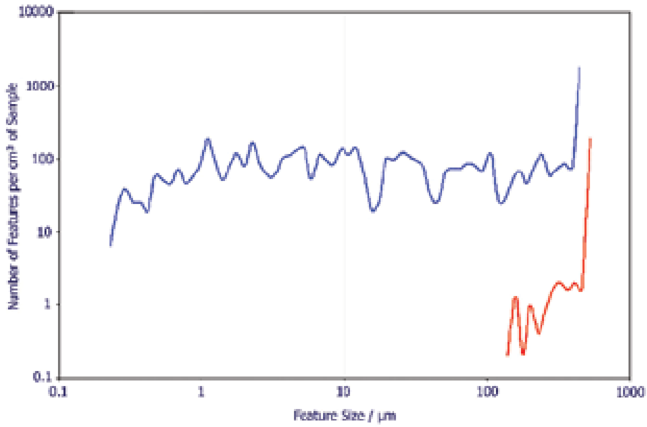


Figure 3: Porosity Diagram

These processes show the number of features (porosity) and the feature size (size of the porosity), whichare the 2 axis on the graph. The graph uses a logarithmic scale.

The blue line on the graph represents the unimpregnated test pieces. It can be seen that there are:

* 10's of pores measuring below 1µm (0.001mm)
* 10's - 100's of pores measuring below 500µm (0.5mm)

The red line shows the impregnated test pieces. It can observed that:
* All features under 100µm (0.01mm) have been sealed
* And now there are only 1 or 2 pores at 500µm (0.5mm) where as the unimpregnated test pieces had about 100 pores of this size.

Benefits of Impregnation

Automotive compressors, transmissions, brake systems and engine blocks are all examples of components where the failure of an individual part after assembly leads to excessive cost and where manufacturers are increasingly turning to impregnation with sealant to ensure quality.

Figure 4: Section of Casting Impregnated with Sealant (Under UV Light)

Compressors are traditionally cast in aluminum in three separate sections and have to be pressure-tight at pressures of up to 18 Bar and at temperatures of up to 150°C.

If there is the slightest leak or contamination the compressor will not work correctly. If a leak is detected once the entire compressor is assembled manufacturers face two costly options: either scrap the compressor or disassemble it and impregnate the faulty parts. However,this is not straight forward - the specialised PAG oil used inside the compressor, the refrigerant gas, the O-rings, the seals and the bearings would all have to be disposed of and replaced.

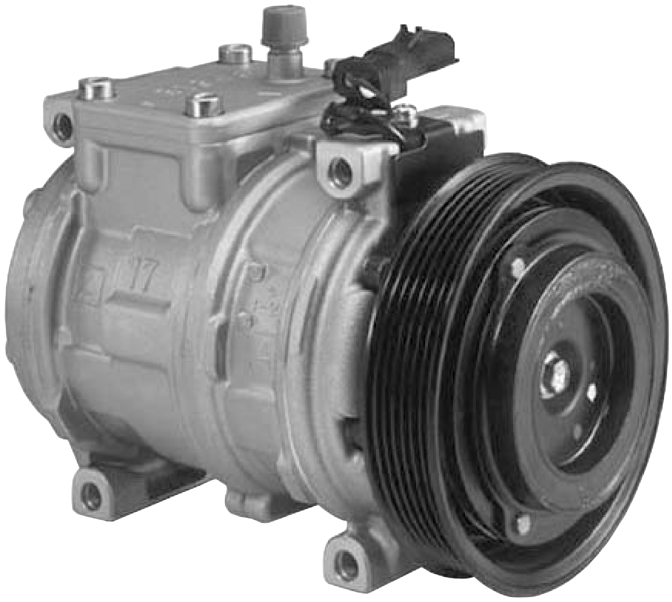
In contrast, impregnating 100% of a production run guarantees results and is easy to achieve with modern recyclable sealants and impregnation machinery that can be easily incorporated into a production line. The reliability of the results has led to manufacturers impregnating as a matter of course for parts such as automotive compressors.

Impregnation Process

There are three key stages in the impregnation process:

* sealant is applied to the casting under a vacuum in an autoclave to draw the sealant into any micro-porosities. Depending on the casting, the overall cycle time can take as little as two minutes (engine block) or as long as 30 minutes (compressor parts).
* Cold Wash Module – removes excess sealant from external surfaces and by Washing
* Hot Cure Cycle – ‘cures’ the sealant by applying heat.

Figure 5: Automotive Compressor



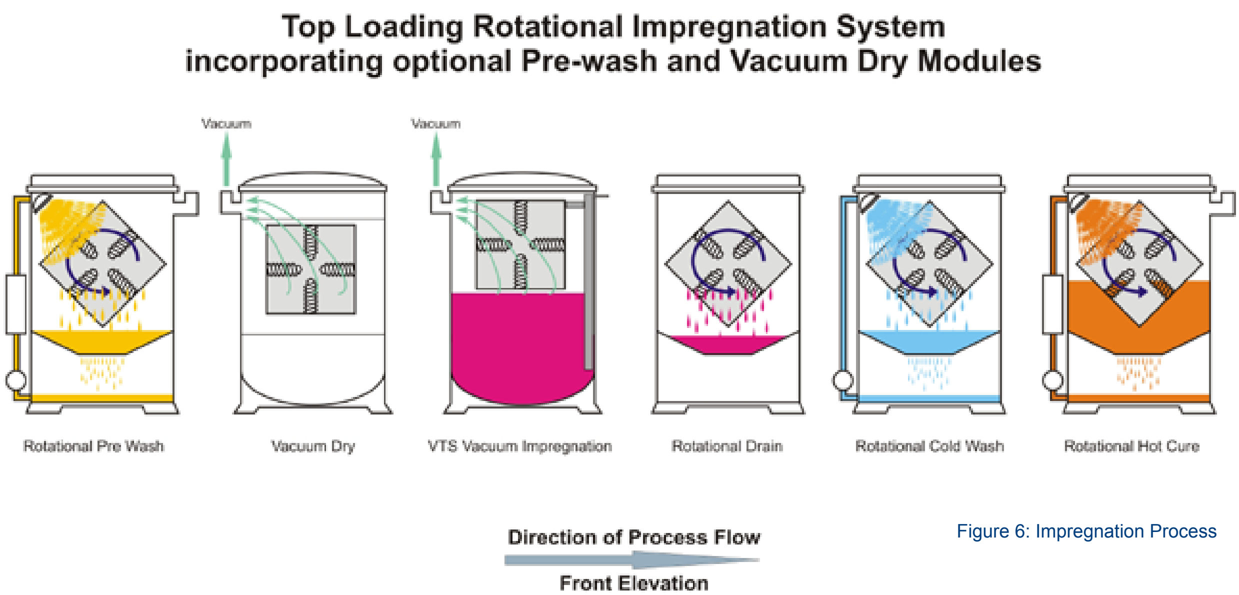


Figure 6: Impregnation Process

Impregnation Sealants

The principle behind impregnation is simple: to fill up the porosities with sealant which will not adversely affect the finished product. Sealants are liquid chemicals which, when heat is applied in the hot cure cycle, polymerise and turn into solid plastic. The uncured liquid has to be easily drawn into porosities, so has to have low viscosity. The cured sealant has to be flexible, resistant to attack by heat, oils and chemicals, and stable under high pressure for the lifetime of the component. Sealants have been used since the 1950s, beginning with the original sodium silicate and polyester and then in the 1970s anaerobic sealants. These have been superseded by more effective and more environmentally-friendly thermocure methacrylate-based products. However, there is a lot of waste even with these: up to 95 per cent of the chemicals are simply washed away in the cold wash stage of the impregnation cycle, leading to high consumption of sealants, high levels of effluent, and the associated costs of dealing with that, and high energy consumption.

> "Sealant impregnation is a safe, reliable and permanent solution to the problem of porosity in casting"

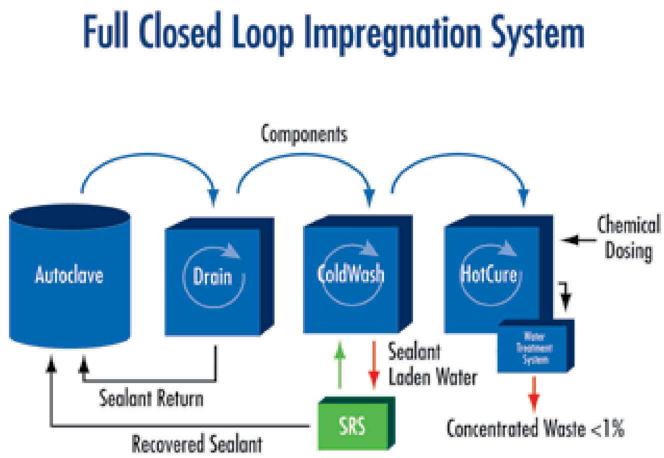
The impregnation process was further transformed by the introduction of recyclable sealants which outperform conventional sealants as well as reducing costs, effluent and carbon footprint.

Recyclable sealants, as their name indicates, can be used over and over again. Up to 95 per cent of the sealant can be recovered from the cold wash cycle and returned for immediate re-use in the autoclave where parts are being impregnated. Clearly substantially less sealant is consumed and less effluent produced – an important consideration in places where there is a high cost associated with treating waste water or disposing of effluent, and one which will become increasingly paramount as environmental legislation tightens around the world.

Further environmental benefits can be achieved if the water is recycled from the hot cure stage of the process. The latest innovation is the introduction of a closed loop impregnation system that recycles the water via an energy-efficient distillation system linked to the hot cure tank and which produces so little effluent it does not even need to be attached to a mains sewer system. The system can operate almost continuously around the clock, offering other benefits over a conventional hot cure cycle.

Recyclable sealants have higher thermal resistance than conventional methacrylatebased sealants. Thermal resistance is particularly important for parts that have to undergo thermal cycling, such as engine and transmission castings. The leading recyclable sealant can operate in temperatures from -76°C to 220°C (-105°F to 428°F).

Figure 7: Closed Loop



Sealant Performance

There can be startling differences in performance between the conventional and recyclable sealants. The table below shows the wide gulf in performance between one conventional methacrylate-based sealant and a leading recyclable sealant on the market. An aluminum test ring impregnated with conventional sealant started to leak after four hours at a temperature of 40°C (104°F) and after just half an hour at temperatures of 100°C (212°F) and above. In contrast, an identicalring impregnated with recyclable sealant experienced no leakage even after 24 hours at 220°C (428°F).

Product	Alternative Producers of Non-Recycling Sealant					Leading Recycling Sealant		
Temperature	40°C	100°C	180°C	200°C	220°C	180°C	200°C	220°C
Initial Seal	0	0	0	0	0	0	0	0
0.5 Hours	0	1	2	2	3	0	0	0
1 Hour	0	2	3	3	3	0	0	0
4 Hours	1	3	3	3	4	0	0	0
8 Hours	2	3	4	4	4	0	0	0
24 Hours	3	4	5	5	5	0	0	0

Where 0 = pressure tight (leak free) and 5 = bad leakage

Table 1: Comparison of Performance between Non-Recycling and Recycling Sealants

Thermal resistance is not the only enhanced quality of the leading recyclablesealant: it also has greater resistance to chemical attack. Moreover, it has greater hydrophobic qualities, ensuring the sealant rejects moisture more quickly, and it is easier to wash excess sealant away after impregnation, leading to cleaner finished components. Process stability is improved, resulting in more easily maintained systems. The sealant is highly flexible and can withstand vibrational environment such as those experienced by engine components.

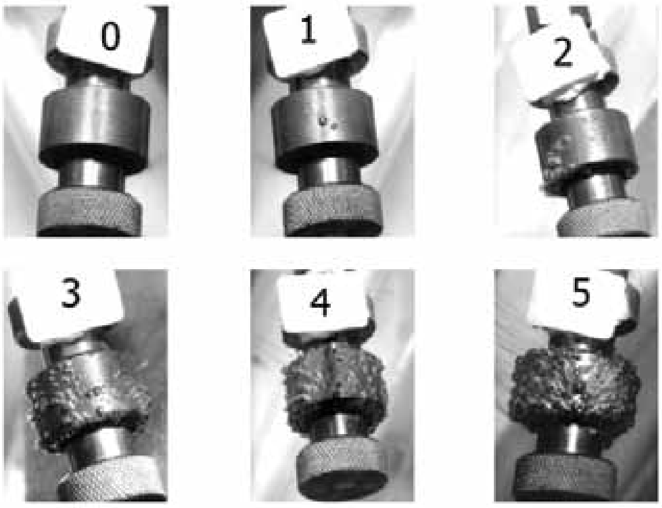


Figure 8: Test Ring Leak Parameters

When selecting a sealant, the end use has to be considered, and there are sealants especially manufactured for use on electrical equipment, where flexibility is a necessity, and for powdered metal components.

In summary, sealant impregnation is a safe, reliable and permanent solution to the problem of porosity in casting and is becoming widely used as a quality assurance process in the production of parts that are required to operate under pressure. Modern recyclable sealants such as Rexeal 100 can perform to higher standards than conventional methacrylate-based sealants, as revealed by tests to the US military spec MIL-I-17563C (Class 1 and 3), as well as delivering cost benefits and being more environmentally-friendly by using less energy, less sealant, less water and producing less effluent.