

Types of Vacuum Impregnation Processes

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In the November issue of DCE, we discussed the basics of vacuum impregnation, the essential fundamentals and variables in establishing a vacuum impregnation program. In this issue we take a deeper dive into one of the selection variables, the impregnation process types used to seal a casting.

To say that all vacuum impregnation processes are equal would be to say that every die casting process is the same, and nothing could be further from the truth. In practice, the type of vacuum impregnation process will have a direct impact on the quantity of pressure tight castings produced.

In general, all impregnation process types follow the same steps:

1. Impregnation of the sealant into the porosity/leak path using vacuum (and pressure)
2. Recovery of excess impregnation sealant
3. Removal of sealant from casting surfaces and features where sealant is undesirable
4. Curing of the sealant within the casting wall

The impregnation process type is defined by the first step, and this step will largely determine if the castings are sealed. Steps 2-4 will have a greater impact on assembly characteristics than on sealing performance.

With this understanding we can look at the three commercially viable impregnation process types.

1. Wet Vacuum (WV)
2. Dry Vacuum (DV)
3. Dry Vacuum & Pressure (DVP)

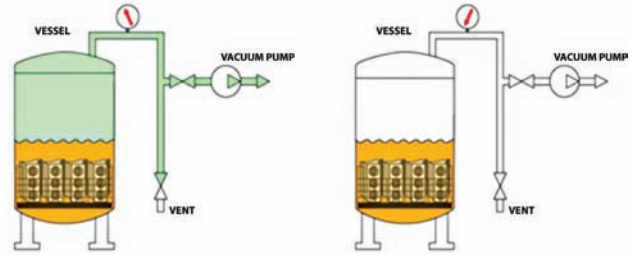
These three process types represent over 95% of the global applications. There are always exceptions. The internal pressure process for large castings and wet vacuum & pressure process for electronics are two that will not be covered here.

Wet Vacuum (WV)

In the wet vacuum (WV) process, the castings to be impregnated are immersed directly into the sealant contained within the impregnation chamber. Once the castings are covered and the chamber is sealed, a vacuum pump evacuates air from the chamber and the porosity within the castings. It is worthwhile to note that since the castings are in a bath of sealant, the air within the porosity must be evacuated by not only overcoming the friction of the pores inside the casting but must also be pulled through the sealant.

• *Processes: Impregnation Chamber*

- *Wet Vacuum Only - un-equalized vacuum, least thorough, suitable for large open leak paths*

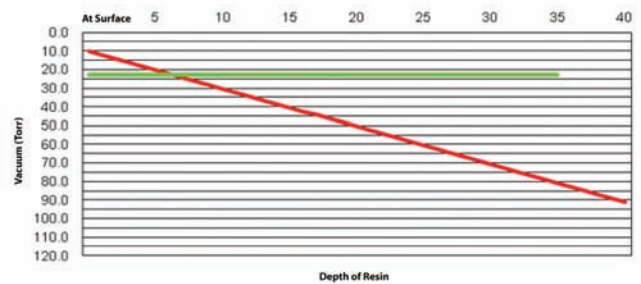


1. Parts loaded, Chamber Wet

2. Vacuum, evacuate air, 2-15 Torr

3. Release Vacuum & hold

Loss of Vacuum



- *25 mm of sealant depth results in 2.1 Torr loss of vacuum*
- *Penetration of sealant decreases with increasing depth of vessel*

Following the vacuum cycle, the vacuum is released and the chamber is returned to ambient, atmospheric pressure.

Due to the hydraulic pressure of the impregnation sealant, castings in the impregnation chamber experience different vacuum levels depending on their location in the chamber. Castings near the top of the bath will see a better vacuum than those at the bottom. The effective vacuum level is reduced by 2.6 mbar per 1" of sealant depth. Therefore if the impregnation chamber is 40" deep, the effective vacuum level at the top could be 10 mbar and the level at the bottom > 100 mbar, a significant variation in the process. Thus, a customer may find the process produces a higher percentage of pressure tight castings near the top of the chamber vs. the bottom.

This process is capable of achieving good results for powdered metal parts and electrical components (e.g. plastic connectors) and has become the preferred method of impregnation for these items. These parts typically have large, open leak paths which can be sealed very effectively with the wet vacuum process.

The primary advantage of the wet vacuum process is cost. This process is simple and the equipment used to apply the

process is economical to acquire. But the attractive initial economics has a trade off and that tradeoff is pressure tight castings. The wet vacuum process consistently delivers a lower recovery rate than DVP or DV processes, and a percentage of castings processed will continue to leak adding to the ongoing operational cost of the process.

Dry Vacuum (DV)

While the wet vacuum process is best used for powdered metal and electrical parts, the dry vacuum process may be used when impregnating castings. Castings generally present finer and potentially blind porosity, and require a more effective impregnation method.

The process begins by placing castings to be impregnated into a 'dry' impregnation chamber. Once the chamber is sealed, a vacuum pump evacuates the air from the chamber and the porosity within the castings. This dry vacuum creates an equalized vacuum in all parts regardless of the position in the chamber. This is unlike the wet vacuum where the vacuum level varies in the impregnation chamber.

The advantage is that all parts in the impregnation chamber experience the same vacuum level, creating a uniform negative pressure in the casting porosity. Once the dry vacuum cycle is complete, sealant is transferred into the chamber, covering the parts. The negative pressure created in the casting porosity 'pulls' the impregnation sealant into leak paths.

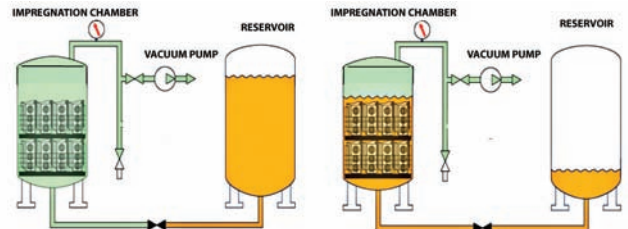
Perhaps the only downside to the dry vacuum process is the lack of positive pressure to assist the sealant in penetrating the porosity. The vacuum creates a maximum pressure differential of one atmosphere from the vacuum created in the pores and the ambient hydraulic pressure of the transferred sealant.

The question is often asked, "Does it take more energy to push liquids into the porosity than it takes to pull air out?" The short answer is yes. But if the penetration of sealant is deep enough to seal a leak path then the appropriate amount of energy was applied.

Impregnation with the DV process is an effective method to seal porosity and is frequently used by European manufacturers as a cost effective method for recovery up to 90-95% of porous casting.

Process: Impregnation Chamber

• *Dry Vacuum Only - Equalized vacuum, less thorough (no pressure cycle)*



1. Parts loaded, chamber dry
2. Vacuum, evacuate air, 2-15 Torr

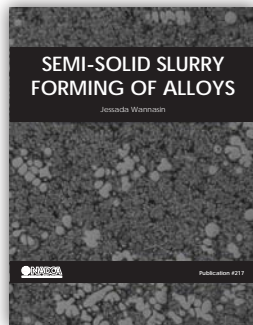
3. Open transfer valve
4. De-gas sealant
5. Release vacuum & hold, transfer

Semi-Solid Slurry Forming of Alloys

Semi-solid metal processing has been known for many years to have several benefits that could change the way the industry produces metal parts. The focus of the exploitation of the technology in the early years has been on forming semi-solid metals by the thixocasting route. In the last decade, however, the focus has been shifted to a more cost effective and less complex forming route, called rheocasting. During the attempts to commercialize a rheocasting process in the die casting industry, it has been found that the needs to modify the current processes, machines, and dies have prevented prompt interests and collaborations from the industry.

A new forming approach called semi-solid slurry forming has been applied. This process involves producing semi-solid slurries at a low solid fraction so that they can simply be poured into a shot sleeve.

This publication covers a historical introduction to the subject and then moves to the formation of the slurry, its fundamentals and its practice. In addition forming processes are addressed as well as characteristics and benefits of the cast products. This publication also provides insight into the intimate relationship among processing, structure and properties, and also shows how relative processing costs influence processing route to be chosen.



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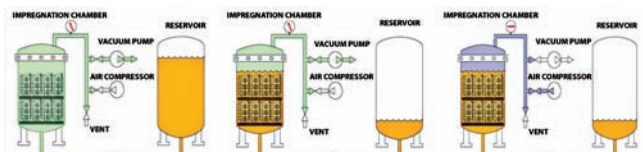
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Dry Vacuum & Pressure (DVP)

The dry vacuum and pressure process (DVP) is well-established as the most thorough and reliable form of the vacuum impregnation processes. It differs from DV only in the application of overpressure. This overpressure provides the energy required to allow for thorough penetration of the sealant throughout the casting. The overpressure value is typically 90 PSI. So looking at the DVP process as a natural progression of the DV process, a dry vacuum is created in the pores of the casting, sealant is transferred to cover the parts and the P is the 90 PSI overpressure. What is now created is a seven atmosphere pressure differential, one negative atmosphere in the pores and 6 positive atmospheres pushing the sealant throughout the casting. This significantly improves and/or accelerates the penetration of the impregnation sealant.

Process: Impregnation Chamber

• *Dry Vacuum & Pressure - Equalized vacuum, most advanced and thorough process.*



1. Parts loaded, chamber dry
2. Vacuum, evacuate air, 2-15 Torr

3. Open transfer valve
4. De-gas sealant
5. Release vacuum
6. Apply pressure, 70-90 PSI
7. Hold
8. Release pressure & transfer

Theoretically, the depth and speed of sealant penetration may be traced back to a law of physics - **the law of the French physicist Poiseuille from 1846**. He discovered and described the interactions of viscosity (of the impregnation sealant), pore size and length, and pressure difference (see more on Poiseuille's Law in our blog article on our website titled "What size holes can be filled using vacuum impregnation?").

Using the positive pressure forces the impregnation sealant to penetrate even deeper and faster into the fine porosities and improves the sealing results accordingly.

Establishing a pressure difference of seven atmospheres can reduce the time to impregnate by approximately 80% and produces higher sealing results as compared to the dry vacuum only process. The DVP process is largely used to impregnate very fine porosity and components with very stringent leak test requirements (e.g. A/C compressor, high performance engines and transmissions) and high-quality, high-value machined components.

The disadvantage of the DVP process is the need for the use of a pressure rated impregnation chamber. However, this extra cost is very quickly recovered through increased production of pressure tight castings and a virtual elimination of scrap.

The Search for the Right Impregnation Process

To engineer a successful impregnation process, a few basic questions should be answered.

- What type of porosity?
 - Macro porosity or micro porosity? Cast metal, sintered metal or multi-material?
 - Note that cracks and visible through-porosity are not candidates for vacuum impregnation.
- What is the leak test specification for the component?
 - What is pass/fail criteria in cc/min at a given PSI?
- Component information? (material, size, geometry)
- Current machining status of the component?
 - Completely finished, machined components are best suited for impregnation.
- What sealing rate is expected?
 - What is the customer's expectation for a pass/fail rate after impregnation?

By "letting the parts talk" and collecting the answers to the above questions you can begin to determine which of the three commercially viable impregnation processes will most likely meet both your part specifications and program expectations.

Confirming your Process Choice

Although this subject could be an entire article of its own, developing a Design of Experiment or DOE is the best way to confirm your choice of an effective impregnation process for the components or program. The data collected from a DOE will validate that the selected process meets the parts' leak test

specification. An important item to note – any DOE should take place in the production environment, not a laboratory.

Performance Guarantees

For the most part, companies, whether they provide outsourced impregnation services or complete turn-key, in-house systems, have been reluctant to guarantee performance or recovery results. However, when the process selection and sealant choices are supported by sound analysis and confirmed results are documented through a DOE, it becomes possible to anticipate process performance and provide some guarantees that impregnation will recover a projected percentage of castings. Of course, the incoming castings for impregnation process must also be of uniform quality in order for the process to deliver the projected results. However, if testing in advance of impregnation is possible and if the parts moved into the impregnation process are within the parameters established prior to the DOE, then it is not unrealistic to require the selected impregnation process or source to deliver a repeatable range of recovery.

Yielding a sustainable 95-99% recovery rate is an excellent benchmark for impregnation system operators when the quality of castings is held constant and verified by pre-impregnation testing and DOE data supports that an effective combination of process and sealant has been used. The impregnation service provider or system manufacturer should be able to refine the process yielding even higher results of 99% or better.

When guaranteed results are required, attention to process parameters, operational procedures and chemical control is essential to success.

Conclusion

For many manufacturers vacuum impregnation has been a "black box" operation – more of an art than a science. In fact, impregnation includes a lot of science. The three commercially available processes (WV, DV, DVP) each have unique elements that follow understandable physical and scientific principles. In the same way, component manufacturers have engineered parts and developed specifications and program requirements. By "letting the parts talk" and evaluating the specifications and requirements, an impregnation process choice can be made, comparing and contrasting the scientific principles of the impregnation process with the specifications and requirements of the manufacturer.

Part manufacturers want sealed components that meet their pressure test specifications and their customers' program goals. The impregnation process can deliver guaranteed results when manufacturers make their process decisions and selections supported by science, physics and engineering and confirmed by data.

Godfrey & Wing Inc. is a vertically integrated company offering vacuum impregnation equipment, sealants and processing. We welcome the opportunity to discuss any project or product that requires vacuum impregnation. ●