REDUCING CORE DEFECTS

White Paper Series
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REDUCING CORE DEFECTS
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WHITE PAPER TAKEAWAYS
• Define the proper core process
• Tooling design considerations
• Core machine and ancillary support equipment selection
• Record keeping, recipes and process data collection
• Maintenance (Cleanliness) programs
Since the first castings were poured, foundry men have been working to eliminate scrap castings and improve product quality. This white paper will concentrate on one area of reducing casting defects and scrap by outlining the important aspects of a reliable sand core production process.

There are many different sand core processes that metal casters can utilize. These can include; cold box, shell, warm box, in-organic, no-bake, and most recently printed cores among others. Any of these core processes can be used for just about any alloy. Selection is typically based on the size of the core, the production rate required, quality requirements of the casting process, tooling investment, and generally the skills and competency of the foundry.

1. CORE PROCESS

The castings and process that require cores will need to be thoroughly defined up front. For example, what kind of finish is the customer looking? Is this a high production job, a periodic runner, or a 1-up prototype casting job? Will venting of the gas from the cores adversely affect your cast product? Is shake out of the cores from the finished casting going to be restrictive in any manner? By defining the economical limits of your decision making matrices, this also will typically lead to you the core process that will satisfy your requirements.

Shell cores can be solid, smooth with high definition. These can also be molds where a foundry casts right into them for an excellent casting finish with minimum cleaning room requirements. The solid shell cores, when proper cured can provide excellent finishes internally for smooth casting requirements. This process can be cured with either electrical heated platens or gas fired systems, and the uncured sand can be re-used after collection.

Cold box cores provide good quality finishes in a rather fast fashion, and finishes with better quality for surface or shake out can be improved with several types of core washes. Cold box cores can be easily stored for long periods of time, and are solid enough to undergo normal handling or transporting. These core solutions require EPA considerations, including collection of sand and gases, as well as a scrubber.

Hot box, Warm box or Inorganic cores are more popular today for their low toxic gas emissions during casting, as well as excellent shake out properties. These processes require an external heat source, such as electrical heaters, gas or combustion systems, warm air purge, or a combination thereof. Cure rates can be comparable to cold box, whereas Warm box would be slightly longer to cure and inorganic cores can be shorter or longer cure times, depending on the core. Inorganic cores are hydroscopic and require some specialized storage considerations for long term buffers.
No bake cores can be blown or hand rammed. Typically, this can be done with low cost tooling of wood and resin, and can be manipulated with mandrels, inserts, loose piece in a relatively easy manner due to the simplicity. The No Bake cores can cure conventionally after filling of the core box, a dwell time for cure before stripping is required or depending on the binder a gas catalyst can be used to accelerate the cure rate.

Capacities of very small to extremely large cores can be considered with the No Bake process. The core blowing process for the no bake cores typically does not allow for the repeated blowing of the sand in discharge magazine, as in cold box or other process. After blowing, the remaining sand is discharged and not re-purposed.

Printed cores can be utilized and are basically sand and resin layers that are accurately printed. Unique shapes, negative draft, lattice type patterns, and other internal considerations that cannot be considered with conventional tooling are all possible with this process. As costs come down and technology improves, this methodology is becoming increasingly more prevalent.

Another process consideration is the quality of the sand and the choice of the binder system for the core making processes. Shell sand should be sourced from a quality vendor with strict quality control. Some companies chose to put in a sand plant and run several different recipes of shell sand.

Cold box can use new or reclaimed, or blend of both. Chromite or iron oxides can be added during the sand preparation. Sand grain finest can be a fine grain silica for smooth lacy cores or lake sand for a more rugged, porous core.

Depending on your process, you will require some type of curing methodology to hardened your core after filling. Shell is melted or heated to a finish. Final cure is based on color or how much the core has been cured in the machine. Some solid shell core products require further post processing through an oven.

When using the cold box process, the choice of a binder coupled with the catalyst is extremely important. The binder maybe a 1 part or two part, or may include a 3rd part such as a bench life extender. Additions to the sand may include veining or iron oxides (red, black).

Hot and Warm box require some type of external heat source, as does the Inorganic process, whether it is heated through a box or cured via hot air passed through the core cavity. Even a combination of external heat with temperature elevated purge air can be effective. Heat source can include a combustion system with burners, electrical cal rod heaters embedded in the tooling or as flat iron plates, and even warm air through an external heater can be incorporated.

Printed cores are cured up in a similar fashion to the No Bake cores. With today's technology, some of our industry vendors are delivering cores the very next day requested when printed. Even plastic tooling can be printed as well!
2. TOOLING DESIGN

With any of the core processes, (other than printed cores which require an electronic file of the model) the tooling design is a critical consideration for accurately filled and well-defined cores that can meet the casting process requirements. A comprehensive understanding of the tooling design is really required in order to design a complete core making solution, which makes up not only the core machine but also the auxiliary systems required to make the entire system work seamlessly.

With any of the core processes, other than printed cores, the tooling design is a critical consideration for accurately filled and well defined cores that can meet the casting process requirements. The tooling can be made from a variety of materials, and needs to take into consideration not only the tooling design itself, but how it stacks up and interacts with the filling and cure system it will run on. From a wood and resin coated core box for low production or no bake, or aluminum machined tooling for the cold box, inorganic or no bake cores, to the iron/steel boxes that are machined for medium to high production core runs, or shell, hot or warm box considerations.

Depending on the core box tooling and the design, the life of the tooling can vary for the materials, depending also on the core accuracy required. For example, printed core boxes, or wood and resin made boxes maybe good small runs to a few thousands. Aluminum tooling packages may run from the tens to hundreds of thousands of shots. Iron tooling can run hundreds of thousands to half or more of a million runs. Of course, these are generality dependent on a lot of factors and many tools are repaired and reused over the course of their lives.

Minimizing core defects and improved reliability begins with your tooling design. The filling and curing analysis can be done with trial and error, pattern shop, resin supplier or foundry experience, or with commercial simulation software such as ASK Chemicals Arena Flow (R) with a very high degree of accuracy. Success at launching a new tooling requires a combination of these design steps noted above, as well as a firm understanding of the core machines capacities and distribution systems that interface your tooling.

First consider the experience level of your tooling engineer. Understanding the core making process and using years of experience to get the tooling design close is a critical first step. A clear understanding of venting, temperatures, sand blow dynamics, and proper gassing (catalyst introduction and exhaust) is necessary for success. Commercial simulation software as mentioned above not only takes into consideration your tooling package, but can also evaluate the sand magazine delivery as well as the curing process for effectiveness and efficiency.

The tooling engineer often times will work with the chemical binder suppliers who have the experience in developing the tooling design with many of their customers. Often, the combination of art and science can help speed the design process and help to insure successful core production.
There are many rules of thumb, formulas, and general design criteria for the tooling design. Blow tubes can be slots, holes in plates, plastic blow tubes, metal tubes with rubber tips, water cooled blow plates and blow tubes. All these exit points usually have a tapered hole of some type on inlet side of the blow plate that they are mounted to. The goal is first to allow for the smoothest transition of the sand from the magazine into the core box, then we can concentrate on curing it.

The tooling will typically have vents, which can be holes, screened, slotted, or other mesh like materials that will allow the air to escape during blow effectively, yet allow the most efficient cure after filling. Although critical to both parts, filling is the first most important requirement that must be established. Some areas don’t allow for vents, are too small of any area, or cannot allow for any defect in the casting in that particular area. Rules of thumb are typically twice the vents in the cope than the drag in horizontally parted tooling scenarios. Never put a vent directly below a blow tube.

Vertical tooling may have several vents at the bottom of the box, with minimum along the vertical sides and a few at the top perimeter. This allows for not only good filling, but forces the cure amine to push through the entire core to the bottom vents for passage out. Sometimes, where vents are not possible, the parting line can be slightly cut, providing what is called a scratch vent. Seals may or may not be used at the parting lines.

Other design considerations include seals, (material types, size, shapes), pin and bushing arrangements, eject pins and support plates, parting line pins, gas windows and tamper pins are important to the overall operation of the core box. Flatness and how the tooling mounts in the machine are key factors, and care should be taken in the box construction so that it can adequately take the machine forces applied.

Tooling mounting and change out should be considered up front, especially with a new machine or retrofit. Any quick change tooling mounting features, either automatic or manually interfaced need to be reliable and easily accessible, as well as safe. Consideration as to how the sand is dumped and cleaned, how the tooling is loaded (correct orientation as well), connection of cure inlet and box outlet (non-enclosure), picker fingers are changed out, and how loose piece connections are made are important design criteria as well.

Even the best designed tooling will need some periodic attention during production. Intermediate blowing off of the parting line, cleaning of vents, or parting line spray application is important. Not to mention the importance of all the ancillary systems that will be covered below.

With any new core box, the core room operator must remember that patience and perseverance pays off in the end. (See Record Keeping below) Keep in mind that every core machine and tool has nuances that cannot be planned or avoided. Just about every tool may require some modifications and only through patient trial and error will the tooling engineer be able to deliver consistent, high quality cores.
3. CORE MACHINE AND ANCILLARY SYSTEMS

Just as important as good tooling design for your process is choosing a core machine that is properly sized for your tooling to achieve your production goals. But your success will not be dependent on tooling and machine alone, but will require the complete core cell to be properly specified, designed and installed to meet your requirements.

As your core machine vendors will tell you, not all core machines are the same. Of course, like many decisions a foundry will make, this is also based on production requirements and economical considerations.

There are many core machine solutions to choose from, from entry level prototype machines, semi automatic, automatic, and all the way up to complete core machine cells with full production amenities to satisfy the highest production levels.

A first step to determine the proper core machine solution is to understand the size and complexity of the core. Larger core sized are typically attempted to be lightened with mandrels or loose pieces to hollow areas. A core is typically desirable to be made in one piece, however multi-piece cores may be made into one-piece assemblies. Each machine must be considered for total cost of ownership (LCC), including a thorough review of initial capital costs, productivity, uptime, downtime, MTTR, utilities, PM maintenance, and competency of your core room operators.
When analyzing your core machine requirements, you must consider the entirety of your core production, the number of cores per tool (or core box), the number of cores per year, and your operating hours. With this basic data in hand an analysis of production times and potential improvements can be made that will help to identify the correct size (blow capacity and box size) core machine meets your foundry’s needs for today and the future.

When choosing your core machine, a key feature (and difference) in machines will be the sand magazine and blow/exhaust system. Different manufactures have different solutions and capacities. You can look for a 50 pound, 100 pound, 300 or 800 pound solution. Some manufactures describe their capacity in liters (10, 25, 40, 80, etc.) Basically, 10 liters is about 35 pounds of sand capacity for reference.

You should also give careful thought to the compressed air systems that will supply your new core machine. The blown air, as well as the gas or purge air is an important aspect that needs addressed for core quality as well. When compressed air is blown in the core making process, even minute quantities of moisture (even in vapor phase) can result is core defects. Moisture can affect every machine and product a little differently. Air for the blow process should be dried to -40 F minimum.

The dynamics of air drying can be complex, and needs to be sized to meet the CFM requirements of your machine. You may consider consulting experts in this are to help eliminate compressed air as potential core defect creator. Most foundries use large compressors for plant wide use. Consider the addition of having a localized desiccant drying system for the blow circuit is highly recommended.

Another important point is the sand itself. The sand entering the mixing system will typically be introduced from a storage silo, either a localized silo (enough for several hours) or larger storage silo (days). It is important to supply sand to the mixing system that is in the range of 75-90 F for optimum sand cure characteristics. The sand should pass through a sand heater before entering the mixer. Depending on your location geographically, you may want to include a properly sized sand heater (22.5-300 Kw for 100-2000 lbs/minute) that are set up and maintained (many are non functional in the field and clogged), along with resin binder heaters are critical process considerations.
The preparation and mixing of the sand will come from a batch or high speed continuous mixer. A batch mixer can be an open type S blade mixer, vibratory or a side mounted Stator type. Similarly, like the mulling of green sand, you will need a predetermined amount of time to optimize the mixing the sand and binders to provide a homogenous sand mixture. Today, many foundries also utilize the continuous mixer for core making which as well provides good sand mixing properties that can be on demand or batched as required.

The sand is injected or introduced into the core box via a pressurized air system that blows the sand into the box through the blow plate described above. This distribution of sand is from the sand magazine, or blow head, or sand shooter, or sand press (or whatever distribution system the manufacture choose to market it as) all are slightly different.

The geometries and shapes of these magazines affect the performance, as do the blow systems themselves. The sand magazine is blown at some pressure typically below 80 psi, in a 1-2 second time frame. Immediately following this blown sand step is a dwell and exhaust of the remaining trapped air pressure. This exhaust time is dependent on the tooling vents, as well as the core machines exhaust systems.

From a process standpoint, the exhaust time is typically the second longest time consumer. This remaining air must disperse from the tooling and sand magazine in a controlled manner that does not promote sand velocities that escape or overly pack screens or vents. Some machines have dual blow/exhaust systems, while others have independent blow and exhaust systems. Other than the most efficient, it must also be maintenance friendly for periodic cleaning and servicing.

Of course, after the hard work of actually having a well built tool matched to your core machine that is capable of filling of the core box, the curing or hardening of the core is the next step which typically is the longest consumer of time from the process standpoint.

For Hot box, warm box, Inorganic or shell cores, the curing is a function of heat delivery system, the core box geometry, and the time required to properly react and cure the core for removal and handling. These types of curing methods typically are a bit more time consuming than traditional cold box system.

The Cold box core is cured via these gas generators that are designed specifically to deliver a controlled pressure and temperature of the gas, typically followed by clean air purge. A gas or amine that is introduced to start a chemical reaction that allows the mix binder atop the coated sand to harden or cure. Several types of catalyst are available, including; TEA, DMEA, DMIPA, SO2, CO2, or Methyl Formate.

Catalyst requirements are product dependent on the binder. For example, an average core may require 1.5% by weight resin. If the binder system is a two part, this may be blended at 55/45% ratio. The volume of regular amine to sand to cure will be on average about 1 cc per 1 kg (about .03 ounces per 2 pounds) of sand to cure. Core size and box design will also affect the final field results.
The ramp features are important in that you want to deliver the initial catalyst gas at a lower pressure (up to 15 psi) to skin over the core, then complete the cure with a follow up purge air (up to 40 psi). The ramp feature of the gas pressure, as well as the gas to purge, provides for excellent control of the core hardening process and minimizes defects from an air shock.

Typically, heated cure air supplies are anywhere from 3 Kw to 40 Kw heaters. Using these heaters to purge warm air in the tooling before start up is an excellent feature that provides for better core start up. Depending on the actual amine being used to cure, temperatures can range from 100 to 250 F. You will need to consult with your binder supplier to get the flash point and critical temperatures of your particular catalysts. Remember, just because you set a controller to 240 F, doesn’t mean that the internal heating elements are at 1000 F! Conventional off the shelf heaters are designed for continuous air flow, not intermittent, so be careful on this point.

An efficient gas generator, coupled with the most effective catalyst will help reduce the amount of catalyst consumed. This will pay off downstream since less gas means fewer emissions and reducing scrubbing and acid costs.

Typically for the Cold Box process, these catalysts gas choices mentioned above require that the core room capture these exiting gas and run them through a scrubber. A common scrubber provides a certain CFM pull on the core box directly or the enclosure.

This acid type scrubber bubbles the retrieved air with gas through a water/acid solution. Typically these are rated for efficiency as 99%, 99.9% or 99.99%. The numbers after the first 99 decimal are really important and should be discussed thoroughly before making a decision. The higher the precision, typically the larger or taller the scrubber tower and sump are, which is directly proportional to the cost of the units themselves.

You will need to work with the core machine manufacture, the tooling designers and the scrubber manufacture to develop a clear and concise consensus on the right size CFM scrubber. Depending on the machine and the enclosure, and how you are capturing the amine will decide if 1000, 2000 or 4000 CFM capacity is right for your application. When choosing a scrubber, you will need to consider not only current but possible future additions of machines for proper capacity. Too strong of a scrubber can short circuit your box and make the cure process inefficient.

These are the key components of a core cell system. Many more items go into your specific solution to complete the core room plan. Once that plan is complete, the engineering design, build, location and installation are all critical. Before you finalize your Gantt chart, you will need to consult your local or state laws for proper permits, as sometimes permits to install can take over 6 months to obtain!
4. RECORD KEEPING

What’s critical and often forgotten is careful recordkeeping of the sand, resin and machinery settings when a quality core is produced. The long list of variables that goes into making a quality core is amazingly complex, and easily forgotten. Ensure your attention to record keeping is as detailed as your attention to all other process. This can be as simple as developing a log book of core box parameters that can assist during set up and start up of an existing core box.

Keeping track of the system parameters is an excellent practice that should begin with the first trials of any core box. The tendency to change several inputs at one time (blow, gas, exhaust, etc) should be resisted. Of course, you can get lucky and hit a winning combination of parameters, but the best methodology is to change one thing at a time. Document and record each setting until you have picked a consistent set of parameters for good core production.

Another way to help eliminate core defects between different core products (or SKU’s) and different core boxes is to utilize the core machine’s Programmable Logic Controllers (PLC’s) with recipe functionality. This is a relatively easy add-on feature for modern core machines that use PLC and Human Machine Interface (HMI) to control the operation of the core machine. But since many foundries rely on older relay based core machines, this becomes a costly add-on.

Each core product or SKU will have unique process attributes that range from sand and resin volumes to machine settings such as; blow pressures, gas pressures, times, temperatures, number of cycles, etc. By closely recording these individual core machine settings in a receipt matrix, a skilled Engineer can pre-load these machine settings into the HMI.

The HMI and PLC will control the core machine automatically without the operator having to effect manual adjustments. Once this matrix is complete and proven operational, the core machine operator only has to enter the SKU information into the HMI and the machine will take over from there. Even utilizing RFID chips and readers for core boxes can be implemented.
By using accurately recorded process data along with current instrument and controls technology, the core room operators can deliver higher quality cores with less likelihood of defects. Just another tool that can lead to improved quality, less scrap, and higher profitability.

NOTE: Additional information about advanced control and machine analytics can be found in a previous article titled: “Process Optimization with Advanced Control Techniques”

5. CLEANLINESS AND OVERALL MAINTENANCE

Once you have solved the iterative process of core production, the most often overlooked process variable is ensuring cleanliness of the tool and the core machine before and during production. Cleaning the vents and parting lines, blowing off the cope or gas sealing areas is an important in process procedure. Pattern spray applications can also be critical, as foundries have become accustomed to using compressed air blow-off to aid in this step. But as the promulgation of the “silica rule” advances, this may create added challenges to any core room operation.

Many core machines are fully open to the foundry environment and these machines will be a first point of review under the currently proposed silica rule. One method that may be employed to medicate these particulate emissions is to fully enclose the core machine. This has serious cost and operational consequences, but a smartly designed enclosure can be employed that allows tool cleaning while working to capture silica, capture amine fugitive emissions, and provide the necessary ergonomic access during operation.

Modern core machines are routinely supplied with a full enclosure, fast acting containment windows, and automatic high pressure tool cleaning functionality. The automatic tool cleaning function adds an additional level of safety by keeping your operator away from the automatic movements of the core machine. A properly ventilated enclosure will help improve the core room environmental conditions by minimizing catalyst (amine, methyl formate, SO2, and CO2).

Beyond the obvious needs to keep the tool clean, it’s equally important to conduct routine cleaning of the core machine itself. The sand magazine, inlet hoppers, slide gates or butterfly valves should be cleaned at the end of each shift. Blow and exhaust screens will require some PM maintenance to keep them in good operating order. Seals on the tables, gas plates and blow plate sealing surfaces should also be routinely inspected and replaced. Even the machines alignment of pins, bushings or other locating features needs routine inspection and adjustment. The best alignment tool is a newer set of known dimensional tooling.
Excess sand builds up around the moving parts of the core machine will cause process and operational errors that can affect the quality of core, and lead to premature wear of guide rods, rollers and bushings. Some core processes may even require frequent cleaning throughout each shift, such as loose piece slides. In these cases, it’s helpful to record the number of cycles between cleaning and create some process steps that consider what cleaning steps may be required. This data can be made part of any receipt function as a process step requiring cleaning and may be a key contributor to improved core quality.

**SUMMARY**

Eliminating bad cores from the casting defect scenario is not difficult. But it does take close monitoring and requires a well thought out and thorough action plan that includes checklists for recordkeeping for each job. Initiating several simple process changes, maintenance procedures, and understanding your new core machine and its supporting systems can help deliver consistent core quality.

Making good quality cores is a combination of many factors. By taking control of even the simplest of changes can dramatically improve your foundry’s profitability, employee safety, and workplace environment.

Automation is now top of mind with many foundries. As you formulate plans around your next core project, today’s foundry managers are beginning to study how core room automation can play a key role in keeping your foundry front and center with your customers and improving your profitability for years to follow. Additional processes such as removal, inspection, defining, core wash, assembly, dunnage design, transfer and storage should all be candidate projects for evaluation. EMI has developed many solutions for core removal, such as drag eject pick offs, cope eject, walking beams, manual, semi-automatic or robotic retrieval and manipulation. Validation of final products with vision or test of core strength (dog bone sand validation, scratch tests, weight or destructive testing) can also be implemented into the core quality system as well.

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