



Green Sand Management – Role & Application of Carbonaceous Additives and Concept of total Carbon in a Green Sand System

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ABSTRACT

The advent of High Volume, High Density & High Pressure Molding Lines has changed the logistics of Molding Techniques and selection of additives significantly. Having 4 main ingredients, Sand, Bentonite, Water & Additives, the properties of the Sand Mold resulting from this simple mixture to deliver target casting quality is complexly variable. Modern machine molding parameters demand increasing efficiency from the additives, many of which are natural resource based; having limitations for developing their inherent properties under the speed, force and load conditions of modern foundry installations. This challenge to optimize a given natural resource escalates sand preparation and management from being an 'art' to being a 'science'. Consequently, the importance of maintaining range-bound values of the prepared Sand in addition to the promotion of a 'reducing' atmosphere in the metal-mold interface can minimize the occurrence of sand related defects.

SAND PREPARATION & IMPORTANCE OF MOLDING ADDITIVES IN MODERN FOUNDRY INSTALLATIONS:

Sand Control is an "Art" as any foundryman will willingly emphasize. It is well accepted that no two foundry sand systems are the same. Even a single foundry Unit or foundry group having two or more molding lines, along with separate Sand preparation lines, whether in the same campus or in different locations, sand preparation and sand parameters will normally differ in each sand loop.

The advent of High Volume, High Density & High Pressure Molding Lines has changed the logistics of Molding Techniques significantly. Today's foundry manager rarely gets to see the sand being mixed, or the additive being added, or the prepared sand being transported to his molding machine, physically.

The role of quality in additives has therefore become even more important than when one could "feel" the sand & make changes accordingly. Now, additives and ingredients have to be engineered precisely for the application with assured reproducibility in chemistry, grain fineness & other parameters.

INTERPLAY OF MOLDING ADDITIVES IN SAND MANAGEMENT AND CONTROL

For example, the lustrous carbon additive has to have the right grain fineness to match the GFN of the Molding sand.

Because, this for example, could affect the GFN of the sand which in turn will affect the moisture demand or "temper water" of the system sand.

Simplicity and Complexities of a Unit Sand System

Having 4 main ingredients :

- . Sand
- . Bentonite
- . Water
- . Additives,

the properties and effectiveness of the Sand Mold resulting from this simple mixture to deliver target casting quality is complexly variable & besides the quality of the inputs themselves, is, among other reasons, also a function of:

- Sand to Metal ratio
- Grain Fineness (GFN) of the sand & the Bentonite & Additives
- Molding & Mixing Machine types and configurations

The multiplicity of input sources and the complexity of newer machine molding parameters demand increasing efficiency from the sand molding additives, many of which are natural resource based and therefore have inherent, natural limitations for developing their inherent properties under the speed, force and load conditions of modern foundry installations. This challenge to optimize a given natural resource escalates sand preparation and management to being a 'science'.

The escalation of the sand mixing process from 'mulling' to 'intensive mixing' and the importance of Bentonite development to target bond conditions from 3 minutes in mulling to < 1.5 minutes in the intensive mixer is a classic example of this statement.

DIFFERENTIATING 'REAL' AND 'ABSOLUTE' VALUES

By themselves however, none of the above figures signify the "real" quality of the prepared Sand. A well formulated LCA would give more optimum results in terms of sand peel and surface finish @ 5% LOI than which an LCA which is formulated from more passive sources of carbonaceous additive; cannot give at even 6% LOI. Similarly, for example, an active Clay reading of 7.5% may be equal, in performance



terms, to a 8.5% active Clay reading, depending on the quality of Bentonite that has been used in the Sand preparation process.

An outlook for applying any additive in the green sand

Therefore, it is an accepted view that any addition to Sand for preparation of a mould should be viewed as an essential contaminant. If being termed as a “necessary contaminant” is acceptable; correspondingly its addition to the molding Sand should be as low as possible to achieve target molding properties to optimize the prepared sand mould for achieving a well dimensioned, clean and smooth casting surface, free from Sand related defects. Quality of the inputs is therefore very important to ensure that with minimal additions, maximum efficiency of intended use is achieved.

Concepts and Role of Carbonaceous Additives in improving Casting Surface Finish

- . “Gas Cushion” Concept
- . “Reducing Atmosphere” Concept
- . “Lustrous Carbon” Concept

GAS CUSHION CONCEPT

When Molten Metal is poured into the mold cavity, the radiant heat causes particles of the carbonaceous additive distributed through the mold, to both carbonize (thermal decomposition) & ignite. The particles closest to the cavity surface, volatilize faster and donate most of their volatiles between 300°C- 680° C and while volatilizing, generate gas which tries every route possible to escape from the mold cavity, either through the casting itself, if it was so possible or through the pores of the sand Mold; into the atmosphere, whichever is the route of least resistance, thereby forming a temporary cushion of Gas.

It is therefore most important therefore to ensure that the

additive has just the right amount & right temperature type of volatiles to evolve & maintain a gas cushion to match with the permeability of the mold. Otherwise the result could be pinholes, blowholes.

“REDUCING ATMOSPHERE” CONCEPT

Seamlessly, the “Fixed Carbon” starts to volatilize around 680°C & the carbon evolved from the total volatiles combines with the free oxygen in the mold cavity to form Carbon Monoxide(CO). Generation of CO reduces the availability of oxygen to create a “**reducing atmosphere**” in the mold cavity.

This prevents oxidization & metal mold reactions at metal mold interface. Possibilities of pinholes & penetration defects are also reduced.

The extent of this phenomena will depend on the Volatile Matter & the Fixed Carbon content of the Additive, to be present in the correct proportion to: match the weight & configuration of the Casting, Sand Metal ratio, permeability of the sand & its compactibility.

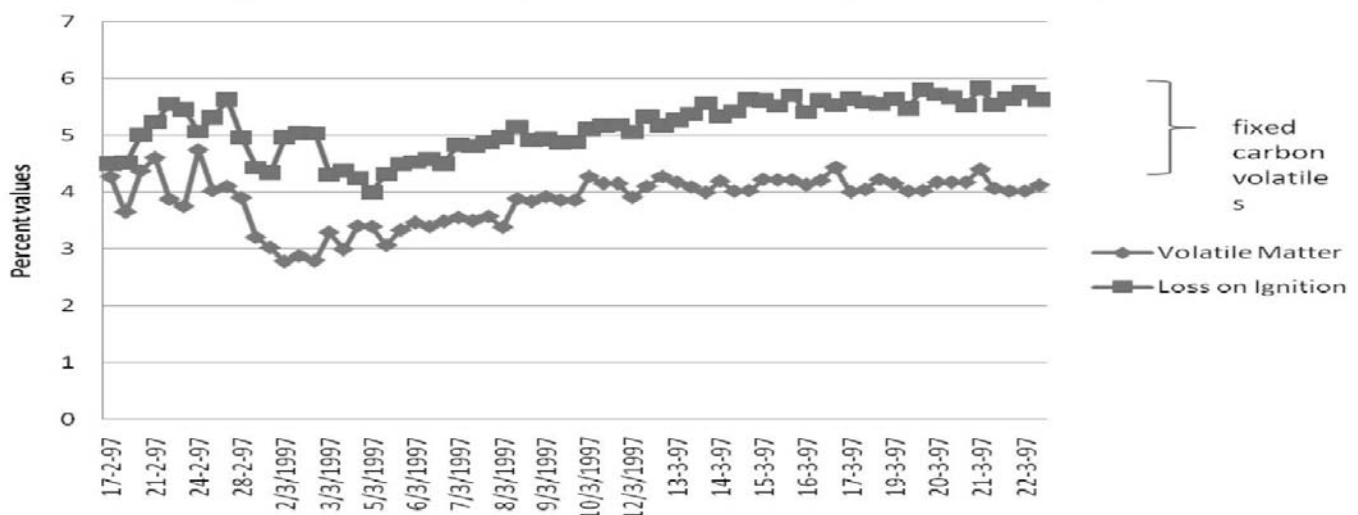
LUSTROUS CARBON CONCEPT

While the carbonaceous additive is decomposing:

- The Carbon in the Additive starts to coke, expanding in Size, filling the voids between grains of sand. At the mold’s inner surface this results in a smooth surface presentation to the liquid metal as it solidifies there against. Throughout the mold, it reduces mold wall movement & prevents expansion defects.
- Some fractions of volatile gases carry or donate particles of carbonized matter which form a thin layer of Pyrolytic Carbon, generally termed as Lustrous Carbon, on the internal mold surface. This forms a thin non-wetting barrier between sand & metal, contributing to smooth parting of the Casting from the sand.

Effects in sand parameters when using high Fixed Carbon content Lustrous Carbon additive: Example:

Development of High Carbon Volatiles in the green sand system of Example Foundry





Narration to Chart # 1

At start of introduction of high FC content LCA, target foundry was using a LCA whose low temperature volatiles were higher than the high temperature volatile. Result was that; at the commencement of trials with Higher FC content LCA, the VM and LOI readings on 17.2.97 were almost equal. Lack of adequate Fixed Carbon in the system would have been resulting in an inadequate ‘reducing atmosphere’ in the mold cavity.

Customer was facing severe sand burn-on and surface roughness on the casting surface. S:M ratio was 3:1. It didn't help that the return sand temperature was very high due to fast return sand cycles mandated by production pressures as also a lack of mechanized sand cooling facilities.

From 17.2 to 21.2, there was a distinct increase in the gap between LOI and VM readings. From 21.2 To 28.2 , that is a period of 4 days, the gap between the LOI and VM started increasing and between 28.2 to 7.3; stabilized at a ratio of VM being 65%-70% of the LOI. This gap is perceived as the development of the FC in the Unit sand.

Within 10 days, the sand peel improved and there was a perceptible improvement in surface finish on the casting surface.

Sand Control

It is emphasized that notwithstanding the Concepts of Gas Cushion, Reducing Atmosphere & Lustrous Carbon, these concepts/theories are not enough to prevent the metal from hitting the sand surface. The final quality of the surface finish as well as defect free castings will depend now on how

well the sand has been controlled to form a firm, Refractory, & smooth surface for the metal to solidify there against.

GOOD SAND MANAGEMENT - THE IMPORTANCE OF PROCESS CONSISTENCY

“A recent survey shows that there are 211 different categories of ferrous casting scrap. Of these, 42 are attributable to melting practices and melting materials. There are 126 types associated with core making and sand control. The balance of 83 categories of casting defects, are caused by molding, pouring, and cleaning. These are a few examples of what can happen when management does not give proper consideration to changes which occur in the overall scheme of operations.”¹

Having achieved/targeted the ideal Molding Sand parameters for your foundry, the next step is to ensure that each of these are range-bound. Please refer column 2 for the range parameters in Table # 1 in earlier portion of this article

IMPORTANCE OF PROCESS CAPABILITIES

The importance of maintaining range-bound values in molding Sand parameters can never be understated. It does not just reflect good Sand practice; it speaks of the underlying process capabilities developed by the foundry in managing Sand and optimizing the same for the casting process.

Normally, once a foundry has achieved this kind of process capability, the occurrence of sand related defects is totally minimized. If there are defects, it can be narrowed down to their incidence and cause, more precisely since the other variables are standardized.

CHART # 2

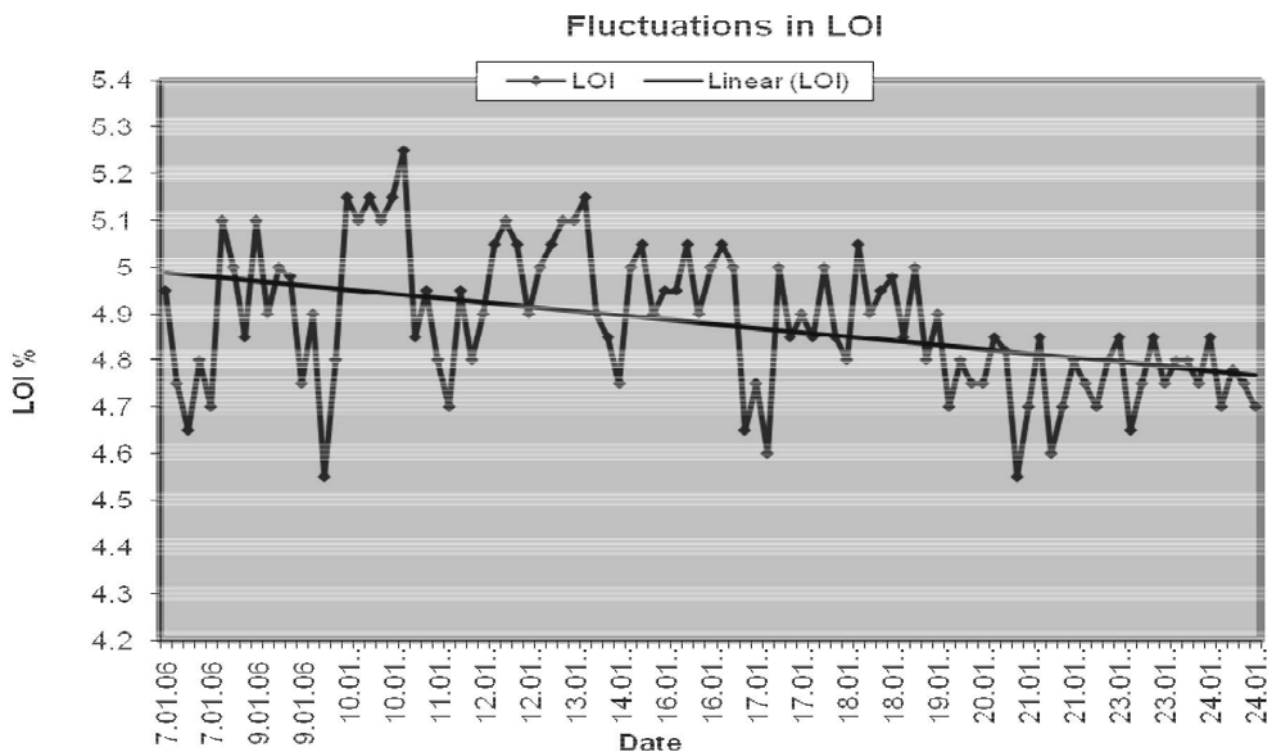




Table 1
Fundamental and Ideal Sand parameters of prepared sand

Active Clay	Tolerance range from established mean level	7.8% to 8.5% depending on the swelling Index or bonding (montmorillonite) capacity of the Clay.
Inert Fines	± 0.15	3.0% - 4%
Total Clay	± 0.20	the sum of the Active Clay + Dead Clay should normally be 11% -12%
Volatile Matter		Should normally be 60% - 70% of the LOI
Loss on Ignition	± 0.15	5.5% - 6.0% - in conventional lines 4.5 – 5.0% in high pressure lines 4.0 – 4.5% in high pressure, flaskless Lines
Moisture (at molding machine)	± 0.15	3.8% - 4.0% in Conventional Lines 3.2% to 3.7% in High pressure lines
GCS	± 0.15	Depending on type of line. Conventional lines normally operate between 1100 – 1300 gm/cm sq. Compactibility 32– 45 depending on the molding machine type

Narration to Chart # 2

Normally, an addition rate of Lustrous carbon additive is suggested between 0.2% to 0.4% depending largely on sand to metal ratio and casting shape and configuration. This range may increase due to core sand infiltration at shake out due to heavy weight cold box/ shell cores.

A study during a LCA change over program was conducted in a reputed foundry manufacturing Cylinder Blocks & Heads castings to determine reasons for a higher than normal addition rate of Lustrous Carbon additive & fluctuations in LOI on a wide range.

Observation: There were fluctuations in LOI over a wide range: 4.5% to 5.2%. Especially, when molding sand was

prepared with return sand of Cylinder block a drastic drop in LOI values was observed. A search for causes of LOI drop came up with following observations;

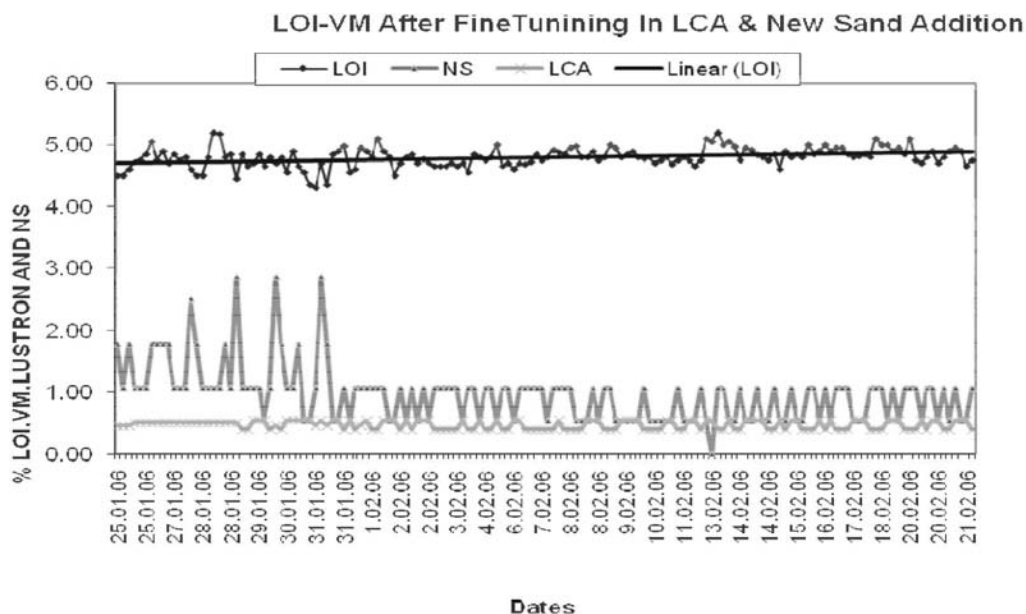
Metal to sand ratio was low, i.e., 1:3.5 causing higher than normal burn out of the additives.

Cooling time after pouring was around 2 to 2.5 Hrs. adding to extra burn out of Lustrous carbon material

Core sand introduction was high – around 105 kgs/box of cylinder block.

Range bound LOI values after fine tuning additions based on return sand and core sand calculations for different patterns.

CHART # 3





Narration to Chart # 3

The study of the system return sand pattern and core sand introduction into the system sand, estimated that core sand was being introduced from Cylinder Block cores at 8.8% which was apparently causing maximum dilution of LOI. Average core sand infusion was 3.5 to 4%. Raw sand addition rate was 1 to 3 %. Hence average, total new sand addition (core sand + fresh silica sand) in the sand system was adding up to 5%.

Action was taken to add LCA in variable amounts based on the return sand pattern. Example: it was to be higher when sand was coming in from casting of cylinder blocks and lower when tackling return sand from the brake drums and lowest when accepting sand returning from smaller casting bunch weights.

RESULT OF ACTION:

After implementation of variable addition rate and reduction in new sand addition in the cylinder block return sand; fluctuations in LOI showed reduction & a gradual rise in LOI was also observed. Most importantly the LOI variations stabilized in range bound parameter of 0.3%. Result on the casting was a considerable drop in sand burn on/fusion in several patterns.

Using a Lustrous Carbon Additive - An Outlook for better understanding of the Role of a Lustrous Carbon Additive

- The use of a Lustrous Carbon Additive should be viewed as an essential component of the Unit Sand system and not in isolation of the system. If added in a well balanced manner it enhances sand properties towards better surface finish. However, by itself a Lustrous Carbon Additive may minimize, but it cannot totally offset, effects of other imbalances of a sand system if already present due to other variables. In imbalance it could cause casting defects.

Matching the Additive to the Unit Sand Dynamics – not vice-versa

- Since each sand loop is subject to different sand metal ratio, sometimes different molding machines, different molding pressures, different density of molds & other numerous variables, by the same token of reasoning, the additives, be it clay or carbonaceous, have to match with the dynamics & parameters of the target sand system. The sand system does not & should not have to adapt or compromise itself to the additives. The development of proprietary blends is the direct consequence of the varying Unit Sand dynamics. However, wherever natural resources of required specifications are available, they are used with good results by foundrymen worldwide.

Lustrous Carbon Additive – Quality as a cost control tool

- A single percent increase in rejection due to sand related casting defect or deterioration of casting surface finish can account for the entire value of a LCA addition program of a foundry. Therefore casting cost control on

account of LCA is normally to be a function of evaluation of the following achievements of a good quality and well planned LCA program.

- Improved Surface Finish
- Reduced consumption of shots
- Reduced Fettling
- Reduced sand related casting defects
- Reduced Man-hours on pre-dispatch casting preparation = faster throughout times.
- Reduced variables in sand Control = Standardization of the sand molding process = consistent, reproducible results.

Concept and Significance of Total v/s ‘active’ Carbon in the green sand system

If we accept that most foundry sand related casting surface defects are mainly a result of metal-mold reaction, the solution to reducing these defects, if not eliminating them, is to focus on the de-oxidation of the atmosphere in mold cavity. Namely, promotion of a ‘reducing’ atmosphere in the metal-mold interface as explained in previous slides.

However, it is important to understand what is ‘total carbon’ in a system sand and which of these types of carbon are going to play the “active” role in this process.

Total carbon

Carbon content of the carbonaceous additive added in the green sand mix.

Residual/coked/partially coked carbon from the thermal degradation/decomposition of carbonaceous additive and other ingredients.

Residual/thermally decomposed carbon from the hydrocarbon resin used to bind the core

Carbon from the un-burnt refractory material of the coating such as graphite

“Active” carbon

As distinct from ‘activated’ carbon, in this article “active” is the terminology used for purposes of this presentation to emphasize the useful carbon in a green sand mixture. it is the amount of the total carbon of the carbonaceous additive, comprising the low-temperature volatiles and the high-temperature volatiles (commonly referred to as fixed carbon) which evolve as a result of the thermal decomposition of the organic carbon present in the additive.

This organic carbon is as distinct from processed carbon such as synthetic graphite.

Carbons generated during the thermal decomposition of hydrocarbon products like camphor, petroleum fuels, polystyrene, also evolve lustrous carbon quite similar to that obtained from carbonaceous compounds like coal, coal tar pitch, asphalt, etc.



The reason for using 'active' carbonaceous additives

The difference between carbonaceous additives used in greensand molding like coal dust or equivalents, and that of products like camphor and polystyrene is that the latter evolve their carbon-rich gases at much lower temperatures than required in casting process. Typically between 180-200 degrees C.

Empirically, it is reasoned that the lustrous carbon additive should start donating its carbon and precipitate lustrous carbon from 300°C onwards in order to be most effective in providing for the "reducing" atmosphere in the mold cavity to prevent oxidation defects due to metal-mold interaction.

A true carbonaceous Carbon additive

It is important therefore to ensure that the carbonaceous additive has "active" carbon element which is released in the process of thermal decomposition of the organic

matter, both as elemental carbon as well a highly pyrolytic carbon precipitating as Lustrous carbon film at the metal mold interface.

It has to be available and/or formulated to contain sufficient high temperature volatiles that evolve at 680°C in addition to the Volatile matter which volatilizes between 300-680°C

This winning combination combined with other important characteristics such as its lustrous carbon content and expansion/coking value co-efficient is what enables it to contribute its mite to better and cleaner surface finish on the casting, free from blow-holes, pinholes, explosive penetration, rough surface, sand fusion and other related defects.

REFERENCE

1. Art Spengler Lecture No.1 – Ductile Iron Society Publication"