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GREEN SAND PLANT MACHINES: STATE OF THE ART

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Sand plant (goals)

The modern sand plant must satisfy three fundamental requirements:

- production of high quality sand;
- guarantee of constant quality in time;
- production of a constant high quality at the lowest cost possible.

Production of high quality sand:

What does “high quality sand” mean?

High quality sand must have the following characteristics:

- **compactability** that allows a good molding and consequent shakeout, without causing any defects due to moisture excess / deficiency;
- **strength** that allows to produce molds resistant to handling, core laying and casting, and that does not cause any problems during shakeout;
- **temperature** below 45 – 48°C and without any sudden variations, as higher values hinder the correct activation of additives (with consequent higher bentonite consumption with equal strength) and increase water demand, causing defects on castings;
- **permeability** that enables the evacuation of gases from the mold without causing any blowholes.

Of course, it is necessary to control also other characteristics, such as moisture, bentonite and fines content, etc.. However, if above-mentioned features are kept in a limited range, the whole sand system will be stabilized.

In our experience, we have never found two foundries using the same sand parameters, even if production typologies were almost the same.

This “uniqueness” is absolutely normal and justifiable. In fact, sand is a means to obtain high quality castings and every foundry must optimize its own castings by producing a distinctive type of sand.

This specificity is not only due to different casting types, but also to the usage of different molding systems (high pressure, shot, shock wave, manual).

So, there is not one sand which is fit for all, but there are many sands of different qualities that satisfy every single requirement.

Guarantee of constant quality in time

It is of the utmost importance to maintain the same sand quality in time. In fact, if the “right” quality of sand allows to obtain a better casting, quality constancy in time extends such advantage to “all castings”.

Constant quality at low cost

Of course, it is extremely important to make the first two conditions available at the lowest possible cost so as to obtain from the sand plant the efficiency and the cost abatement which render our product more competitive.

The attainment of this goal is pursued on two levels: first of all, a constant quality of sand leads to a reduction of rejects, unpoured flasks, sandblasting times, broken flasks and to an improvement of casting “skin”.

For instance, the muller must have just one motor to reduce energy losses and to ease maintenance; the rotary sand and casting drum is to be considered as a multifunction machine, as it allows to cool both sand and castings at the same time and to pre-sandblast castings; besides lowering temperature, the cooler must homogenize sand and enable the controlled removal of fines and a preventive moisturizing.

Sand plant (theory, dimensioning)

How to design a sand plant fit for a high-pressure molding?

Sand is the key element required to obtain a good quality mold and so a good quality casting, whatever molding principle is applied.

The characteristics of the sand to be prepared change according to the type of molding machine chosen, whereas the machines necessary to prepare sand do not change.

During preparation, sand undergoes different stresses, which can be distinguished into two groups:

- mechanical stresses
- temperature stresses.

Mechanical stresses cause the breaking and erosion of silica grains which compose sand skeleton. Signs of mechanical stresses are: decrease of permeability and higher bentonite requirement.

Temperature stresses cause the increase of sand temperature.

A higher water demand causes an increase of compactability and a decrease of bulk density (this phenomenon can be explained by a higher sand viscosity at high temperature). Therefore, hot sand produces molds which are not very compact: the more compactability increases the more flowability decreases.

Sand compactability is very important. To obtain good quality molds it is required a low water addition and also a limited temperature variation.

Therefore, it is of fundamental importance that sand has always the same characteristics when returning to the molding machine. So, it is absolutely necessary to quantify the entity of above-mentioned phenomena in order to correctly dimension the various machines to be used, avoiding the mistake of undervaluing important phenomena or overestimating negligible phenomena.

We turn our attention to sand cooling: for this reason we have studied the layouts of two classic types of plant (with drum and with cooler).

For both of them we have plotted the average trend of sand temperatures. As already said before, temperature must not undergo any great variations from the mixing phase to the moment in which sand returns to the mixer for restoration of its characteristics.

In a circuit without drum or sand cooler, temperature continuously tends to increase until the heat exchange between structures (flasks, silos walls, transfers from one

conveyor to another) reaches and maintains very high values (balancing heat exchanged with the environment and heat put into the casting). Only the utilization of cooling machines allows to definitely maintain temperature below 45°C in order to avoid serious problems when molding. Moreover, carefully chosen machines must homogenize sand and avoid great variations in uniformity of sand moisture.
Therefore, we have ascertained that batch coolers are better than continuous coolers, as batch coolers always keep parameters (moisture and temperature) under control, with a higher guarantee of uniformity at the end of the process.
We produce the following coolers:

- sand and casting cooling drum TDR for sand and castings – continuous type;
- cooler and homogenizer for sand only – batch type.

Usually, the utilization of one machine excludes the other machine.
One peculiarity of our plants is that silos are considered as double-function machines:

a) sand storage mechanics that allows to empty flask storage lines, when necessary;
b) chemical phisical characterization of bentonite curing and of cooling improvement before sand returns to the muller.

So, we are convinced that silos have to be appropriately studied in order to avoid the “funnel effect” which drastically reduces effectiveness.
The silo must empty completely both for its inner shape and for the particular configuration of the emptying hopper and of the ejector feed system (belt type or with vibrating cone).
Therefore, it is important that sand inside the silo is proportionate to its volume: only in this way the residual bentonite in the sand can be activated and all other above-mentioned phenomena can take place.
The logic employed to dimension these machines starts from the determination of the quantity of heat put into the sand during casting and from the setting of the parameters that allow to complete the theoretical calculation of heat exchanges during the further processings of the sand.
The balance of the suction system is fundamental for sand reclamation. As regards such system, our model gives the hourly capacity values at key points.

Sand plant (machines, technology)

Sand and casting cooling drum

The sand and casting cooling drum has been devised to offer modern foundries the possibility to cool sand and castings at the same time, to ease castings cleaning and to control the quantity of fines by means of an appropriate suction.

Obviously, the utilization of a sand and casting cooling drum is to be valued according to the production typology and to its undeniable advantages on the process.

Poured molds are taken from shakeout to drum by means of a vibrating conveyor. The cooling process is based on the evaporation of the residual moisture of return sand and on the evaporation of the water appropriately added by a conditioning device, which is made up of two parts: one part adds water into the charging area (according to incoming temperature) and the other part adds water into the sand discharge area, if necessary.

Vapor and fines due to process are removed by a suction and filtering system. Besides easing castings cleaning and core emptying, the rolling of castings and sand inside the drum homogenizes return sand and consequently reduces mull time.

At the end of the process, clean and cooled sand and castings pass through a screen which carries out a separation.

In brief, the main advantages are:

Sand cooling: Sand is cooled (50°C), homogeneous and with a moisture content of about 1,6 – 1,8%.

Castings cooling: Castings come out at the same temperature as the sand and can immediately be handled doing without intermediate warehouses.

Castings cleaning: The rolling of castings and sand inside the drum eases castings cleaning and core emptying and consequently reduces sandblasting times.

These results are achievable thanks to the automatic control of water addition into the drum.

Batch Cooler

The cooling of sands coming from shakeout is extremely important in order to avoid problems due to excessive temperature, such as difficult bentonite activation, difficult control of prepared sand compactability, higher water demand, etc..

The aim is to obtain sand with a temperature below 45°C. We think it is likewise important to favour the maximum homogenization of the sand itself.

Operating principle:

The physical principle applied in this plant is the removal of evaporation heat of water in contact with sand by means of the forced suction of vapor formation in the tank.

Sand is continuously mixed by mixing tools. At the same time, fluidizing air is added to guarantee an increase of heat exchange surface between sand and air.

The cycle begins with the inlet of cooling and moisturizing water, then hopper opens and used sand is charged. Thus, the cooling cycle is active from the very first mixing instants.

The vapor formation due to contact between water and sand is continuously removed by the suction system.

Vapors removed must be treated with a dry filter in order to satisfy emission limits prescribed by positive law.

The cooler we usually use is a batch cooler, as we think it is a kind of process more easily controllable and less influenced by stops (for instance, change of templates, lack of cast iron, etc.).

In fact, a batch process (charge / cooling / discharge) determines incoming and outcoming parameters on defined parts of sand, so that it is extremely easy to add just the quantity of water required.

Sand storage silos

Sand storage silos are real machines and not mere containers. Their function is to allow the "curing" of bentonite present in the sand: that is, bentonite unites with water contained in the sand to generate all mechanical characteristics which are required to produce high quality sand.

Molding plants working more and more quickly and the tendency to reduce the sand/casting (+ metal in flask) ratio cause a more and more accentuated utilization of sand, reduced time of stay in silos and therefore a degradation of the bentonite.

All these problems, together with the age-old problem of the "funnel" effect in old silos, induce us to reconsider the "silo machine" under a new light.

First of all, during the planning phase of a sand plant it is necessary to project an effective capacity equal at least to twice the productivity of the sand plant. For instance, a plant with a muller supplying 80 t/h requires a 160 t silos.

Secondly, it is necessary to guarantee the effective usage of silos planned and to avoid the "funnel" effect. In this case, sand flows through one preferential channel only and forms stratified deposits which decrease of 50% and more the effective capacity of silos. The utilization of EFB uniform flow silos eliminates this problem. In fact, a particular geometry of the (stainless steel) cone structure and the introduction of two baffles connecting the interior of the silos with the surroundings allow to eliminate moisture in excess and favour a uniform and constant flow of sand.

Intensive mixer

The mixer or muller is rightly considered to be the pulsating heart of tha sand plant. Obviously, it is the most important machine where ideal conditions of molding sand are restored.

Over the years, the market has been invaded by the most various types of mixers: from the first mixers with scrapers to the actual intensive mixers. Today, a mixer must satisfy the following requirements:

1. Production of constant quality sand
2. High productivity
3. Reliability
4. Reduced maintenance.

In our opinion, to meet these requirements it is necessary to combine the activity of the mixer with a sand control which supervises its functions.

In fact, they are to be considered as two parts of the same system: arm and mind.

As regards “arm”, we have chosen a hydraulic working. In fact, our new mixers are provided with a hydraulic motor: a sturdy piston engine supplies the power necessary for the movement of all the mixing unit, which turns out to be particularly compact.
The mixing unit is composed of two rotary units rotating on their own axis and whose movement cover the whole surface of the tank. Moreover, mixing is integrated by a high speed rotor that guarantees a quick activation of additives.

The planetary driving system supplies a high speed mixing through each rotary unit. Every rotor is composed of three mixing arms provided with blades working on the tank bottom, all units are equipped with wearproof inserts. The mixing tank wall is kept clean by two scrapers provided with wearproof blades.

Used sand is put into the mixer through a measuring hopper placed on the top of the cover. Sand is put through a slide opening moved by hydraulic cylinders.

The combined action of rotary units – resulting from the sum of the speeds of planetary system, intensive homogenizer and mixing arms – allows to obtain an optimal mixing of ingredients with low specific consumption and high mixing efficiency in the cycle time.

Reconditioned sand is discharged through an opening on the tank bottom. Discharge door rotates in a horizontal plane and is moved by a hydraulic cylinder.

The main advantages of hydraulic motor in comparison with the traditional geared motor are:

1. high reliability and sturdiness with equal performances
2. possibility of optimizing mixing speed by varying hydraulic motor rpm
3. absorption of inertia due to accidental stops (blackouts) by means of the exhaust valve
4. restart of mixer at full load with the maximum torque available
5. less components to be serviced
6. possibility of positioning the hydraulic power unit in a safe and clean place.

Mixing cycle

The mixing cycle is the most interesting factor from which to obtain remarkable improvements of sand quality.

The mixing cycle consists of all operational sequences resulting in the production of molding sand. After various field experiences, we have inferred that the sequence with the best results is the following:

Inlet of water – Inlet of return sand – Inlet of additives – Mixing – Discharge

Here is a phase-by-phase analysis of the cycle:

The inlet of water must take place at the beginning of the cycle. Thus, the tank is systematically cleaned and also cooled. The quickest possible inlet of the maximum quantity of water at the beginning of the cycle allows the longest possible contact between water and bentonite and improves the activation of bentonite.

Moreover, water must be added without solution of continuity so avoiding successive additions in the middle or at the end of the cycle. This guarantees that water binds with bentonite and will not be found “free”, with all consequent damages.

The inlet of return sand must take place after water addition: for instance, if the cycle requires 60 liters of water, return sand begins to be charged after a water addition of 30 liters (50%). This percentage varies according to the tightness of mixer.

The inlet of additives must take place when all water required for the cycle is inside the mixer. This is needed to minimize any losses of additives due to suction effect. In fact, moistened sand incorporates additives more easily. The inlet of additives and water has to take place as quickly as possible so as to allow the longest possible contact between the different ingredients.

<u>In brief, it is necessary to minimize inlet times in order to maximize the mixing time, which is the real active phase of the cycle.</u>

Mixing can be divided into two precise phases:

Pre-mixing**:** washing water and return sand are inside the tank. During this phase, sand is moistened and prepared for the addition of other additives. This phase ends a few seconds after closure of the water inlet valve. This phase lasts from 4 to 12 seconds according to return sand moisture.

Intensive mixing: it is the phase during which all ingredients are inside the mixing tank and react to develop all physical chemical and mechanical characteristics of the sand. This phase lasts from 50 to 90 seconds. Lower mixing times usually cause a lower green strength value and a disomogeneity of the product; higher mixing times often do not result in an improvement of characteristics, but only in a higher expenditure of energy and in a reduction of productivity.

Discharge is to be considered a secondary phase. It must be reduced to the minium in order to recover time to be devoted to other phases or to be deducted from the total cycle.

The above-described mixing cycle is to be considered as the result of the operation of the intensive mixer and the work of the automatic bond determinator GSC.

<u>Automatic bond determinator GSC</u>

Green sand control in foundry has always been one of the main goals to be achieved in order to obtain good quality productions and to minimize scraps. So far, sand control methods were mainly based on the control of return sand moisture and on the consequent water addition to muller to obtain the desired moisture of prepared sand.

There are also control systems which determine the compactability of mulled sand and then determine the quantity of water to be added.

All these systems give a partial answer to the demand of quality sand, in particular of constant quality sand. In fact, they do not allow the automatic control of important parameters such as strength, active bentonite, total bentonite, permeability and automatic addition of additives and new sand.

The automatic bond determinator GSC controls mixer operation and addition of water and additives in order to obtain constant quality sand.

The program uses the following five input data, which are necessary to have a precise measurement of compactability:

1. <u>return sand temperature</u>
2. <u>return sand moisture</u>
3. <u>batch weight</u>
4. <u>required compactability</u>.

The instrument is essentially composed of three distinct units:

Nr. 1 Temperature, weight and moisture detecting system, with thermocouples, load cells and moisture probes.

Return sand temperature is monitored by nine thermocouples, which are installed in groups of three in opposite positions in the batch hopper. In this way, we obtain an accurate measurement of the average temperature of sand.

Return sand moisture is read as a conductive signal. The control unit controls the current supply between two electrodes placed in the mixer hopper. The value of the flow of current in the sand between the two electrodes is proportionate to the quantity of water in the sand. These electrodes are divided into three isolated sections at different depths in the hopper.

The third datum is the batch weight. It is obtained by means of load cells. The PC program is set to stop supply when the preset weight is reached.

Once temperature, moisture and sand weight are determined, the processor calculates the quantity of water necessary. All water is quickly added through a flowmeter at the beginning of the cycle in order to obtain an excellent mixing.

These three data are the main part of the control and are measured before sand enters the mixer. Further data are obtained from the setpoint.

Nr. 1 Automatic lab which takes physical measures of the sand sample taken at the mixer discharge.

The automatic compactability control TVE is designed to take a sand sample at the mixer discharge, compress it and then determine its compactability. All operations are controlled by the GSC program, that <u>provides for one test for every mixing cycle</u>. Compactability data are given by a printer which records all information acquired: the processor sends data to a base module that transfers them to the printer.

Printed data are:

1. date – hour

2. number of test or cycle
3. return sand temperature
4. return sand conductivity
5. desired compactability
6. measured compactability
7. desired water (measured with pulses)
8. batch weight
9. setpoint
10. mixer motor absorption.

At the end of the day, an abstract is printed. It indicates the summary of the day, the number of tests, the number of tests within range, the percentage of tests within range. Such data are followed by a histogram showing the deviation from setpoint.

For every single mixing cycle the following physical chemical parameters are recorded:

compactability, moisture, strength, active bentonite, total bentonite.

Of course, all process parameters are supplied, such as:

incomping sand temperature, number of cycles, mull time, water addition, additives addition, process analysis, calibrations, alarms.

Nr. 1 Processor which processes data acquired and adjusts additions of water and additives to obtain the desired compactability and strength. The PLC is connected to a touch panel, allowing for an immediate and easy display and consultation of production parameters, system performance and alarms.

Results: Thanks to the Automatic bond control GSC and to a constant high quality sand, various advantages are obtained in the production cycle, such as:

- reduction of rejects
- reduction in the number of broken flasks
- improvement of casting “skin”
- sand plant operation without supervision
- improvement of mixer performances
- optimization of the usage of additives
- extremely rapid depreciation.