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Bentonite-bonded sands – state of the art and future expectations

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State of the art

With bentonite moulding sand systems more than 90% of the used sand is immediately re-usable after mechanical cleaning and moisturization. The good re-usability is based on the reversible binding of the bentonite. In order to optimally utilize the re-usability of the bentonite, bentonite-bonded sands are moved around in a circulating system that must be kept in equilibrium. A number of requirements are placed on the sand and the sand system:

- constancy of the properties,
- optimal properties,
- low control costs,
- automatic process sequence,
- low consumption of raw materials
- small amounts of residual materials and emissions,
- re-usability (reclaimability) of the residual materials.

Constancy of the sand properties is not without reason referred to as the first point because this is a prerequisite for the production of defect-free castings. Whether a casting can be reproducibly produced is dependent on the pattern, the moulding machine and the moulding sand. Reliable production is endangered if, within the combined effects of these parameters of influence, the quality of the sand is not constant.

Constancy of sand properties

There are a number of measures available in order to maintain the properties of the sand as constant as possible:

- sand testing,
- preventive sand control (per day),
- preventive sand control (per pattern),
- homogenization of the used sand,
- cooling of the sand,
- sufficiently large amount of circulating sand
- bunker capacity.

Sand testing is described in the VDG Data Sheet – Series P. Control of the sand system by means of the characteristic values measured in the laboratory then leads to uniform sand properties if there are no excessive variations in the peripheral conditions (iron/sand ratio, core sand addition etc.) in a foundry.

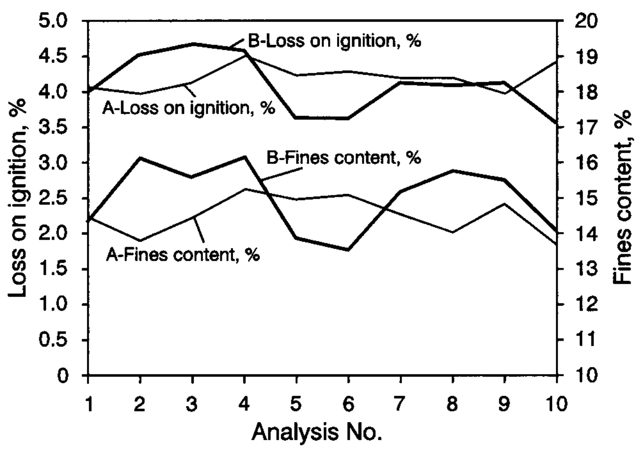

Figure 1. Comparison of the loss on ignition and fines content in foundry A with, and foundry B without, preventive sand control

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Table 1. Average characteristics of sand in iron foundries

Feature	Value	Dependent on
Sample weight	145 to 155 g	Addition of new or core sand
Water content	3 to 4,5%	Content of fines and bentonite
Fines content	12 to 15%	Addition of new or core sand, return of dust
Gas permeability	90 to 120	Grain distribution, grain size of quartz sand
Green compressive strength	approx. 20 N/cm^2	Bentonite content, water content
Wet tensile strength	> 0,20 N/cm^2	Water content, bentonite content, degree of activation
AFS number	approx. 60	
Average grain size	approx. 0,25 mm	
Loss on ignition	3,5 to 6%	
C_{aktive}	approx. 0,5%	

Preventive sand control [1, 2] has proved successful in foundries with widely varying peripheral conditions. **Figure 1** shows the characteristic values of the sand in two comparable foundries over a period of 10 months (foundry A: preventive sand control, good homogenization of the used sand; foundry B: no preventive sand control, inadequate homogenization of the used sand. With homogenization of used sand it is the state of the art to use several bunkers which are filled one after the other and simultaneously emptied. A disadvantage here is the caking of the used sand on the bunker walls, which impedes the homogenization and reduces the sand in circulation [3].

Cooling of the sand improves its properties to a considerably more constant level. Hot sand is difficult to moisturize and it "dries out very quickly" [4].

In general, the amount of circulating sand is then sufficient if the sand in the foundry does not circulate more than once in 2 h. In systems that are too small the sand is often very hot and is difficult to homogenize. With too high circulating speeds the bentonite has too little time to optimally absorb the supplied water and to optimally mature.

Sand properties

It is not possible to generally define how the properties of bentonite-bonded sands should be. Each foundry places specific requirements in accordance with the range of castings and the process. Requirements specific to the product are for example the iron-sand ratio, the pattern geometry, the tendency of certain parts to casting defects etc. Requirements specific to the process are for example the intensity of the sand preparation, cooling capacity, degree of new sand, shakeout properties, disposal of residual materials etc.

Selection of the quartz sand, suitable sand additives (bentonite, lustrous carbon producers) and the core binder systems result from these requirements. The core binder systems considerably influence the bentonite-bonded moulding sand, mostly in a negative way. **Figure 2** shows the example of a requirement profile. **Table 1** shows average values of the sand characteristic values with the production of iron castings.

The influence of the water content on the sand properties is significant. **Table 2** shows a used sand that was prepared with different amounts of water.

Amount of control and testing

Certain controls and tests are important and easy to carry out, e.g. those of the energy consumption in the sand preparation or those of the temperature of the used sand

Table 2. Preparation of a moulding sand with different amounts of water (15% fines, 5.4% LOI, AFS 61)

Water content	%	3,6	3,9	4,44
Sample weight	g	143	140	138
Compaction	%	33	39	50
Bulk density	g/l	950	850	700
Gas permeability		67	83	99
Hardness		93	90	90
Green compressive strength	N/cm^2	26,6	24,4	21,5
Dry strength	N/cm^2	42	51	67
Wet tensile strength	N/cm^2	0,27	0,3	0,35

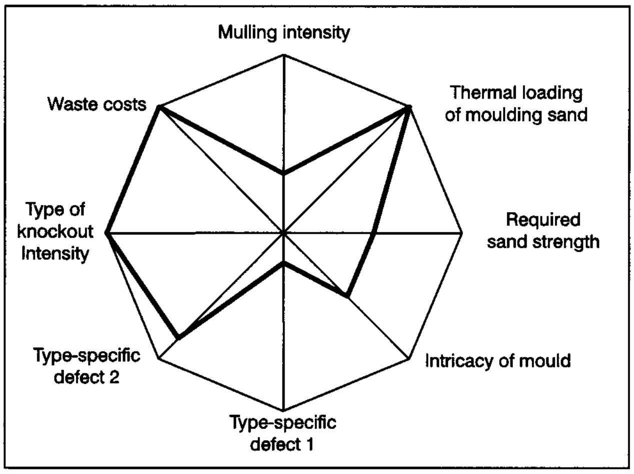

Figure 2. Requirement profile of a sand

and the finished sand respectively. The correct emptying of the homogenization bunker should likewise be regularly checked. These types of controls are easily automated by means of EDP.

Sand testing in the laboratory should be exclusively aimed at checking existing control systems (dosing systems, preventive sand control) with regard to their functional efficiency or for assisting research into the cause in the case of any defects that may occur.

Process operation

The most important factor for the control of the sand properties in the moulding plant is the compactibility, which is best measured before entry into the moulding machine. Automatic systems for on-line measurement of the compactibility have already been in use for years. **Figure 3** shows a modern moulding sand preparation plant [5]. With

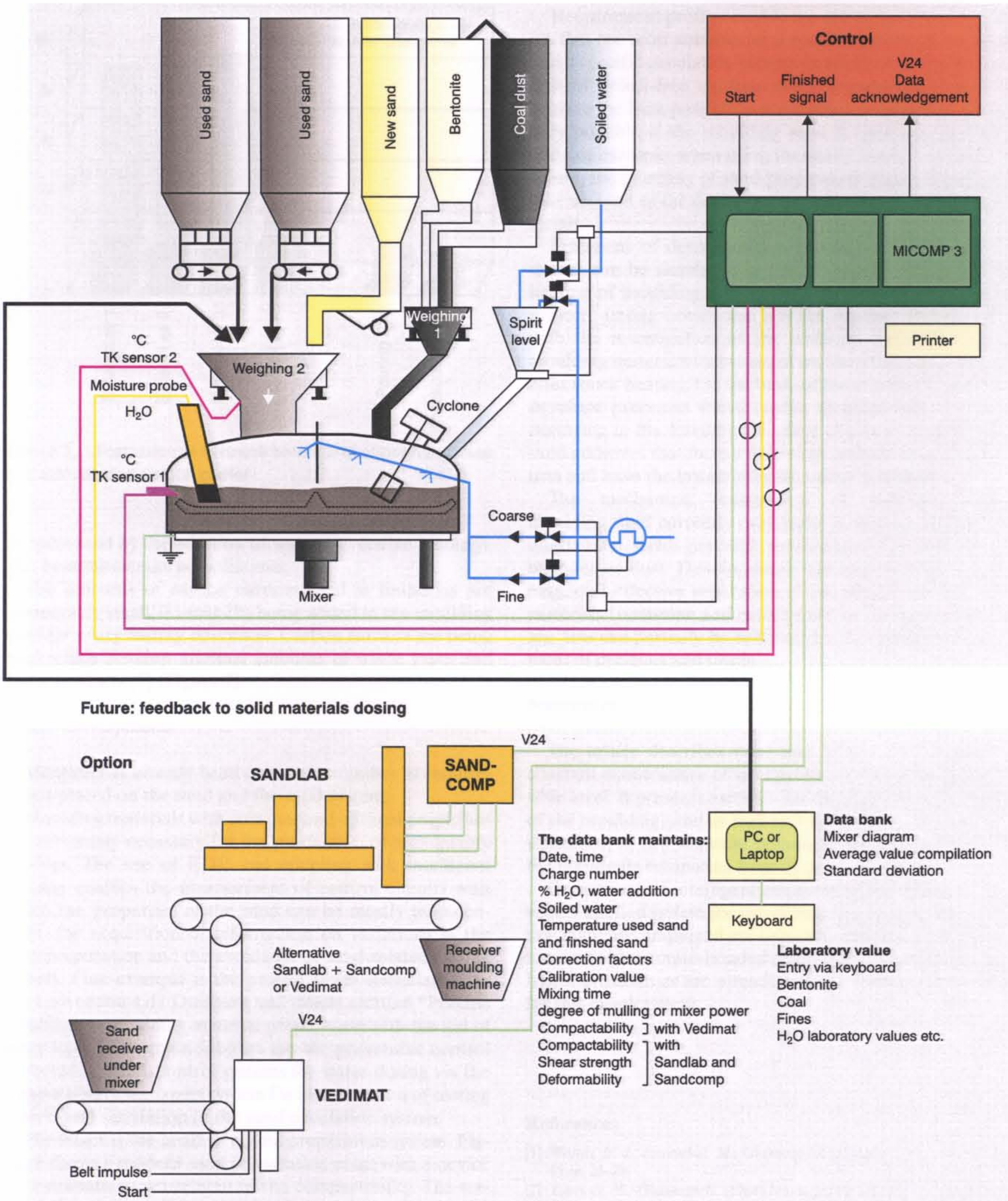

Figure 3. Modern sand preparation plant *(Michenfelder)*

the aid of EDP a modern plant can be well combined with preventive sand control.

Raw materials consumption – residual materials and emissions

Fewer residual materials and emissions is conditional upon lower raw materials consumption. On the one hand this can be achieved by the use of high quality raw materials and, on the other hand, by optimal preparation of the moulding sand. **Figure 4** shows the influence of the energy required by the moulding sand on its degree of mulling [3]. A 90% degree of mulling efficiency requires a specific energy of at least 1.0 kWh/t sand. If this is not the case, the mixing operation should be investigated. Good pre-moisturizing of the used sand likewise results in low consumption of

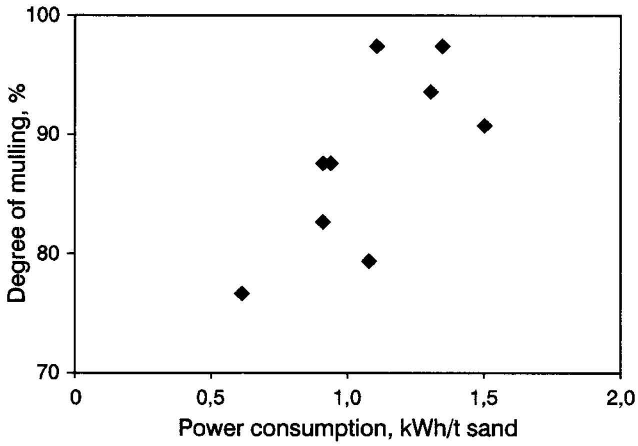

Figure 4. Energy consumption and mulling degree in 9 different foundries

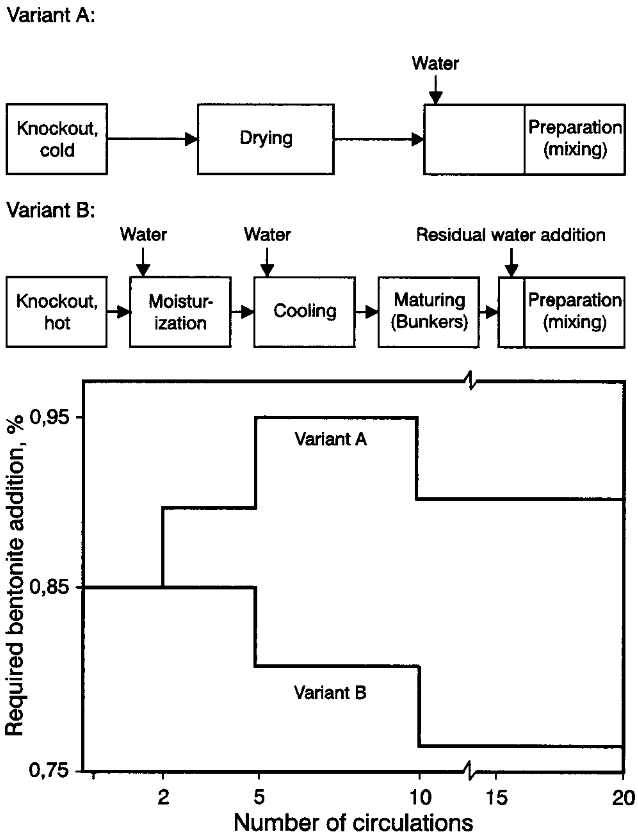

Figure 5. Reduction of the addition of bentonite through optimization of the process configuration

raw material [4] **(Figure 5)**. Finally, the thermal stability of a bentonite substantially influences the consumption [4, 6] **(Figure 6)**.

The desired properties of the sand are of considerable importance. If these properties are achieved with a low addition of bentonite this results in a lower percentage of fines which, in turn, presents the possibility of returning more dust into the sand system and the addition of less new sand. At the same time, there is less dust during the reclamation of the used sand.

Lustrous carbon producers have three main functions:
1. Improvement of the casting surface
2. Good separation of the casting from the moulding sand

Bentonite type	spec. binding capacity, N/cm²/% bentonite for cumulative preparation	Loss, % Sand-iron ration 3:1
Bentonite GUA	2.17	7.44
Bentonite B	2.23	6.94
Bentonite GQ	2.43	6.24
Bentonite G	2.47	6.22
Bentonite T	1.87	7.94

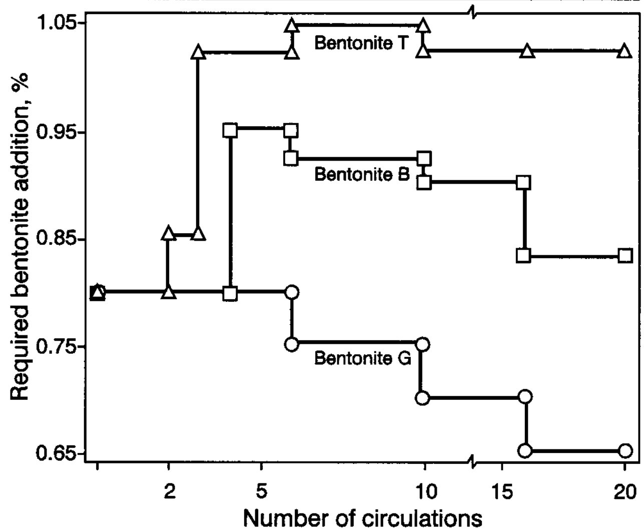

Figure 6. Influence of type of bentonite on sand abrasion

3. Improvement of the break-down of the moulding sand properties.

Additionally, lustrous carbon producers influence the stresses/expansions of the mould and can improve the flowability and compacting properties of the sand.

Today's modern low volatiles lustrous carbon producers emit fewer pollutants. **Figure 7** shows the result after changing over to such a product [7].

Organic crack products of the carbon carriers and the core binders partially absorb or condense into the sand.

Correct selection of the raw materials enables minimization of the crack products. An example is the reduction of polycyclic aromatic hydrocarbons (PAH) in the moulding sand.

Re-usability (reclaimability) of residual materials

Used sand is re-usable in many areas, such as in road-making, covering of dumping sites, the cement industry etc.

Bentonite-bonded sand can be best reclaimed by mechanical means, plants of this type having already been in successful use in foundries for many years. [8, 9] The reclaimed sands are mostly suitable for use in coremaking. By comparison with new sand, when used in the PUR cold-box process, reclaimed sand has less tendency to viening, so that fewer cores need to be coated. Today, most foundries only regain the quartz sand but there will have to be a rethink with regard to other valuable materials such as bentonite and carbon carriers.

Future expectations

The economical and technical advantages of moulding with bentonite-bonded sand are so important that there is no doubt that this moulding process has a future. Bentonite is very environmentally-compatible in its use. Up to a temperature of around 550 °C its binding capability can easily

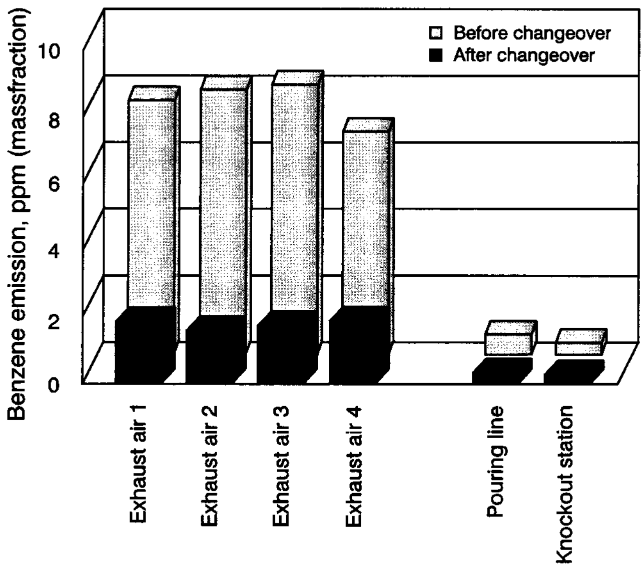

Figure 7. Formation of benzene before and after changeover to a low volatiles carbon carrier

be recovered by the addition of water (reversible binding). The bentonite emits no pollutants.

The amounts of carbon carriers used in foundries are comparably small, 0.1 to 0.2% being added to the moulding sand for every casting operation. Carbon carriers are being used which develop minimal amounts of waste gases and crack products [7] **(Figure 7)**.

Future developments

Mention has already been made of a number of requirements placed on the sand and the sand system.

Moulding materials with constant and optimal properties are absolutely necessary for the production of high quality castings. The use of EDP and coupling with intelligent systems enables the arrangement of control circuits with which the properties of the sand can be mostly held constant, the acquisition of information on variations in the sand preparation and the avoidance of sand-related casting defects. One example is the project being undertaken by the Universität-GH Duisburg and others entitled "Process reliability in moulding material preparation with the aid of fuzzy logic". The main subjects are the preventive control of moulding sand, control systems for water dosing via the compactibility, an expert system for identification of casting defects and simulation of the sand circulation system.

The mixer is the heart of a sand preparation system. **Figure 3** shows a modern sand preparation plant with a device for automatic measurement of the compactibility. The water content in the mixer is not the decisive factor for the degree of moisturization but the compactibility at the moulding machine. Furthermore, there should be more effort in developments towards improvement of the homogenization. It is possible to simulate the cooling of castings by means of mathematical models. In parallel with this the heating of the moulding sand could be calculated as a time function, with the aid of which it is possible to derive the degree of calcination and thus the loss of active bentonite.

Requirement profiles enable the selection of raw materials that are most suitable for a specific casting programme and a specific circulation system. In addition to the production of defect-free castings every foundryman strives to achieve the least possible raw material consumption. This is only possible if the moulding sand is optimally prepared and, for example, when using thermally stable bentonite. In future, the planning of sand preparation plants should also take account of the desire for low consumptions of raw materials.

Emissions of decomposition products from the carbon carrier can be simulated in the laboratory through shock heating of moulding sand carbon carriers. The Umbiform project, among others the RWTH Aachen, is concerned with the investigation of the emission characteristics of moulding materials by means of on-line mass spectrometry after shock heating. On the basis of these tests it is aimed to develope processes which enable identification of odours occurring in the foundry. The final objective is to develop sand additives that form a minimum amount of crack products and have the lowest possible odour potential.

The mechanical reclamation of bentonite-bonded moulding sand currently only leads to the recovery of the quartz sand, yields generally amounting to 75% with the remainder as dust. Developments are required that enable easy, cost-effective separation of the dust in the valuable materials (bentonite and carbon carriers) and inert materials. This can partially be achieved by the optimized adjustment of cyclones and filters.

Summary

The article describes ways and means of ensuring the constant maintenance of sand properties at the highest possible level. It presents methods for the checking and control of the moulding sand as well as possibilities of the optimal utilization of raw material potentials and minimization of the pollutants emanating from them.

Greater use of intelligent computer-aided systems and a widely applied systematic use of requirement profiles of the raw materials employed are expected with regard to the future use of bentonite-bonded sands. The technical and analytical possibilities are already today available as the basis for this development. ■

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