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High-quality, inorganically bonded cores can also be produced without a heated core box.

Inorganics for iron casting

Experiences with innovative hot-air curing binder

Water glass-bonded molding materials can achieve the strength levels required of inorganic binder systems through hot air gassing. Heated mold boxes have proven their worth in large-scale production. Hot air curing offers a cheaper alternative that is also suitable for smaller batches.

By Hartmut Polzin and Theo Kooyers

Starting at GIFA 2003, various binder manufacturers presented work on the development of new heat-curing inorganic binder systems, which is still ongoing today. The basis for these developments was the well-known fact that water glass-bonded molding materials can be brought to significantly higher strengths with tempered molding tools than, for example, with classic carbon dioxide gassing. These high strengths were a fundamental requirement for inorganic binder systems, as one of the main impulses for this development came from the automotive industry and thus from the large-scale production of sometimes highly complex and filigree cores for vehicle components. This paper reports on a hot-air-curing inorganic core production process that works without an actively heated core production tool [1].

State of the art

The current state of the art is still that a silicate-based binder system is usually mixed with the mold base material and shot into a steel core-making tool tempered to 160 - 200 °C, in which a stable edge shell is formed. The cycle times can be brought into acceptable ranges by combining this process with hot air gassing. The main disadvantage of these processes is that they can only be used in large-scale core production (usually in automotive casting) due to the high tool and energy costs. In addition, the application is limited to the production of aluminum castings due to various inadequate technological properties (e.g. residual strength/decomposition behavior). A still largely valid overview of these processes can be found in [2].

Hot air-curing inorganic cores

The development of the binder system presented is intended to provide iron foundries, which in many cases are customer foundries with frequently changing product ranges and batch sizes, with an opportunity to use inorganically bonded cores. The key aspect here is the elimination of an expensive heated steel core production tool, which can only be justified in large-scale production. The binder system used is an alkali silicate or water glass-based binder that has been modified with a whole range of oxides and does not contain any organic components [3]. The molding material is solidified exclusively by gassing with air at approx. 160 °C. The binder is a one-component binder that can be dosed without additional additives in ranges of less than 2.5 %, in many cases less than 2 %.

Practical experience

Molding material strengths in comparison

Figure 1 compares the flexural strengths of the binder system with those of three other commercially available inorganic binders (labeled B1 to B3). An initial difference becomes clear in the binder contents used, as with these binders the binder itself and at least one additive must be considered as the total binder content. Furthermore, the comparison systems are exclusively warm box systems. The process parameters of the Peak CC-VC system were as follows: 150 °C curing air temperature, curing time 45 s, sand temperature 23 °C, relative humidity 45 %.

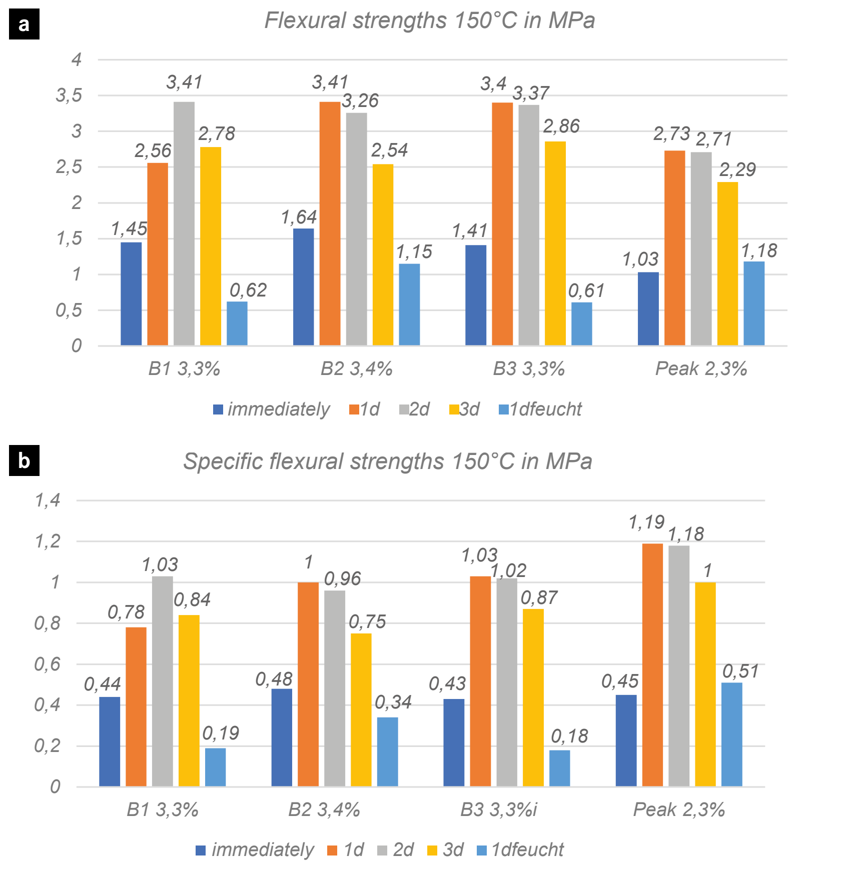

Fig. 1: CC-VC binder system compared with other inorganic systems, curing temperature 150 °C: a) flexural strengths, b) specific flexural strengths.

Fig. 2: CC-VC binder system compared with other inorganic systems, curing temperature 200 °C: a) flexural strengths, specific flexural strengths.

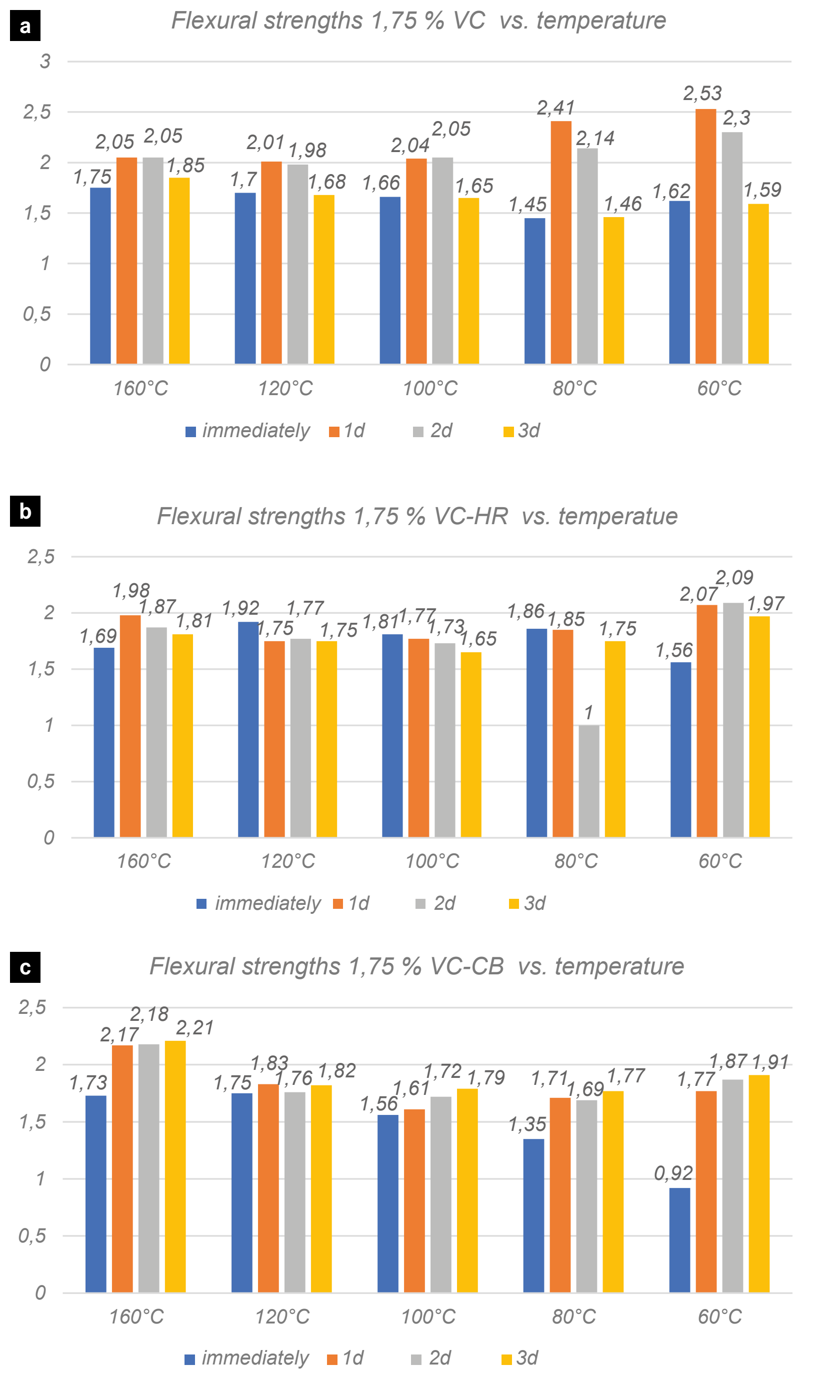

Fig. 3: Flexural strengths in MPa at different curing temperatures, binder content 1.75 %: a) CC-VC binder, b) CC-VC-HR binder, c) CC-VC-CB binder.

The strengths were determined immediately and after 1 to 3 days. The test conditions for the "1d wet" values were 25 °C and 75 % relative humidity. For binders B1 to B3, the temperature refers to the core box temperature. The strengths achieved speak for themselves:

> All binders experience increases in strength during the first few days of storage under normal conditions, which can be attributed to progressive drying.
> Two of the comparison systems react more sensitively to storage in a damp environment.
> The strengths of the peak binder system are lower than those of the other systems, which is due to the lower binder content. These values could be increased by adding more binder if necessary, but the strengths shown here are sufficient for many applications. The potential of the system becomes clear in fig. 1b, which achieves the significantly higher specific strengths determined after one day.

In principle, it is assumed that the strengths also increase when higher temperatures are used. Figure 2 shows this for a temperature of 200 °C (again core box or gassing temperature). An increase in strength actually only results for binders B1 and B3; the strengths of the Peak system remain approximately the same. This is interesting for determining the optimum gassing temperature in terms of cost and environmental protection. When cores are stored in a humid environment, the advantage of a higher hardening temperature is clearly evident. Binder B3 has the better values for specific strengths.

Influence of the gassing temperature

As the temperature of the curing air is a cost factor, tests were carried out to vary the air temperature for gassing and curing. Figure 3 shows the results of these tests for three binder systems. The binder labeled VC is the initial system, while VC-HR and VC-CB are binders designed for special applications. The following parameters were used in this series of tests:

> Gassing temperature 160 °C to 60 °C in five stages,
> Gassing time 60 s,
> Sand temperature 25 °C,
> Silica sand QQs 26,
> relative humidity 45 %.

Figure 3 shows that usable results can be achieved up to a gassing temperature of 60 °C, with a few exceptions. The very low binder content of 1.75 % is also interesting at this point! The reason for this behavior lies in the use of very dry air for gassing the test specimens. As a result, a satisfactory removal of water and water vapor from the core during curing can be achieved even at lower temperatures. These correlations will be examined in more detail in the near future.

Decoring behavior and residual strength

One of the "classic disadvantages" of water glass binder systems known from the literature is the high residual strength of cores or molds after pouring, combined with a high decoring effort. Last but not least, this disadvantage was a decisive factor in the sharp decline in process shares from around the 1970s. The aim of the development

Fig. 4: a) Core for brake disk, approx. 15 kg, b) cast brake disk made of cast iron, inorganic core, sand adhesions, c) cast brake disk made of cast iron, PUR cold box core.

of modern inorganic binder systems must therefore be to improve the decoring behavior in addition to other properties. As the binder system presented here was developed especially for use in iron and steel casting, particular attention had to be paid to this point. To this end, casting tests were carried out in an iron foundry in which coated and uncoated test cores (fig. 4a) were used to cast a ventilated brake disk made of cast iron with lamellar graphite (core mass approx. 15 kg). The standard PUR cold box cores were used for comparison.

First of all, it should be noted that there were no clear differences between coated and uncoated cores. Visual observation of the disintegration and decoring behavior showed that the channels of the castings in the inorganic cores were filled with mold material adhesions, which was not the case with the cold box cores (fig. 4b, c). After the normal sandblasting process, however, these sand deposits were also completely removed. The other cores in this series were fed into production as normal and did not give rise to any complaints.

During the evaluation of the castings, one advantage of the inorganic binder systems based on water glass that should not be underestimated became clear: the extensive absence of veining. This molding material expansion defect, which is particularly typical for the PUR cold box process, only occurs to a very small extent with water glass-based binder systems due to the thermoplastic bonding present there and with special casting ranges (fig. 5).

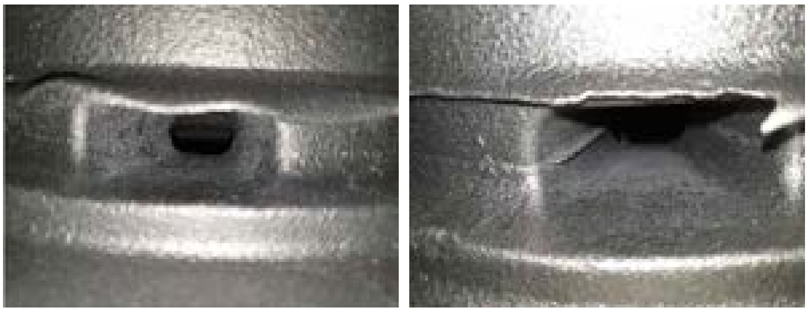

Fig. 5: Cast part from Fig. 4 after blasting: a) inorganic core without veining, b) PUR Cold Box core with veining.

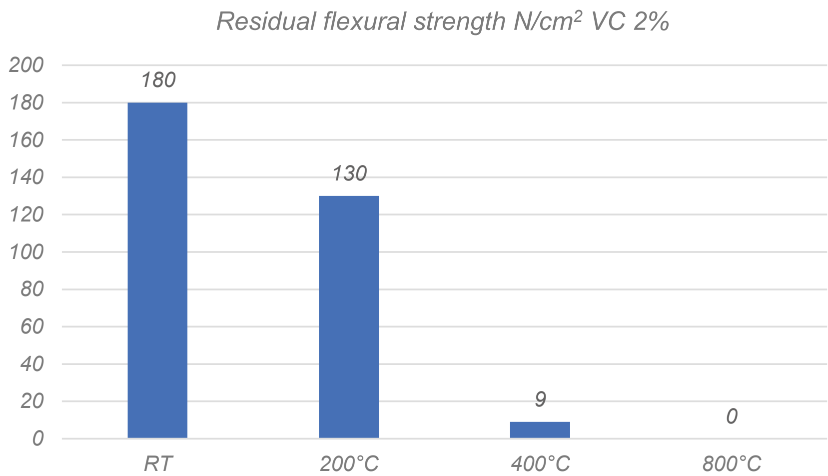

Fig. 6: Residual flexural strength at different annealing temperatures.

Fig. 7: Inorganically bonded core package cores for iron casting.

Fig. 8: Inorganically bonded intake manifold cores for non-ferrous casting.

In order to substantiate this subjectively positive behavior with figures, the decoring behavior should be evaluated on the basis of the residual bending strength:

> For this purpose, bending bars were produced which were exposed to the test temperature for 5 min 24 h after production and tested 2 h after removal from the furnace.
> The test temperatures were 200, 400 and 800 °C.

The results shown in figure 6 confirm the positive properties already evident from the casting tests in this direction. The test temperature of 400 °C is intended to represent the trend in the area of aluminum casting, while the temperature of 800 °C stands for iron casting. It can be concluded from this that the inorganic binder system presented exhibits decomposition and decoring behavior similar to the PUR cold box process.

Examples from practice

To date, cores with the inorganic binder system presented have been produced and successfully used in a whole series of foundries. The cores shown in figure 7 are exemplary for the field of iron casting. The range extends from outer cores for core packages to the aforementioned brake disk core and the filigree core for valve casting. The area of non-ferrous casting, which has not been the focus of this article so far, is impressively illustrated by the example shown in figure 8. Here, too, the range of possible applications extends from simple cores, e.g. for intake manifolds, to the highly complex core of a cylinder head. The examples shown are used in the areas of copper and aluminum casting.

Summary

The presented inorganic binder system based on water glass is an alternative to the PUR cold box process that can be used in iron and steel casting. The liquid one-component binder is dosed less than comparable binder systems: the binder quantities used to date are between 1.5 and 2.5 %, but can also be increased if required.

The single-component system facilitates binder dosing on the core shooter, and the desired strengths are ensured by comparably higher specific strengths. The curing of the manufactured cores takes place via 160 °C warm gassing air. The core production tool is not heated. When selecting the core box material, care should be taken to use thermally resistant plastics. Core boxes made of metal (aluminum or steel) offer advantages in terms of shorter cycle times.

If particularly dry air is used, curing can be achieved at lower temperatures. The binder system can of course also be used in the warm or hot box process. The fact that veining only occurs in exceptional cases with the inorganically bonded cores is certainly a welcome advantage in the fettling shop.

The residual strength and decoring behavior is very similar to that of the PUR cold box process. In addition to the binders designed for iron and steel casting, variants for aluminum or copper casting are also available.

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