Initial feasibility studies and customer projects on real component geometries underline the fundamental potential of inorganic binder systems like the Inotec technology in iron casting applications (Photo: Shutterstock)

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Inorganic binder systems in iron casting – current state of development and outlook

The Inotec technology from ASK Chemicals has previously been limited to large-scale applications in light metal casting [1]. In heavy metal casting, inorganic binder systems also have huge potential as an emission-free system alternative to organic core production processes. However, a number of materials science and technological hurdles must be overcome first. For example, the processes and sand systems are more complex and the requirements for the thermal resistance of the binder are significantly higher [2]

Motivation

Initially, the introduction of the Inotec technology in light metal casting applications was purely ecologically motivated. The market launch resulted in other valuable technological, economic, and ecological advantages. Today, ten years after the introduction in large-scale processes of light metal foundries, the Inotec technology from ASK Chemicals, Hilden, Germany, has become established as a productive core manufacturing process. This technology is mainly used in low-pressure die and die gravity casting to produce AI cylinder heads and crankcases as well as chassis components.

Also in cast iron applications, inorganic binder systems have a huge potential as an emission-free system alternative to organic core sand binders. Due to political and legislative measures, the provisions of TA Luft (Technical Instructions on Air Quality Control) in Germany have already been tightened and in the future will also be subjected to further restrictions. The use of emission-reduced or emission-free processes will be affected by this. However, there is still no large-scale application for this technology, since the transfer from light metal to cast iron is generally associated with fundamental challenges. The sand systems and processes are significantly more complex and the casting temperature is about twice as high, which is inevitably associated with higher mechanical and thermal strain of the binder system.

Nevertheless, inorganic binder systems offer significant advantages. Primarily, no harmful and volatile compounds are released during the core production, core storage, or casting processes. As a result, no complex and cost-intensive air treatment systems are necessary. In addition, the risk of traditional casting errors, such as gas bubbles or veining, is reduced through the use of inorganic binders, which eliminates post-processing steps of castings and potentially reduces scrap rates. The economic, ecological and technological benefits are offset by an initial investment volume for the core shooting machines and heatable core tools.

Special requirements for inorganic binding systems in iron casting

Various feasibility studies on the use of inorganic binder systems in cast iron applications have been carried out for about a decade. One example is the study on the manufacture of a ventilated GJL (flake-graphite cast iron) brake disc, which describes the complexity of this project in detail [3]. The incompatibility of inorganic bound sand cores with water-based coatings, insufficient thermal stability and poor decoring properties are material-specific weaknesses of inorganic binder systems that previously limited their use in iron casting. In addition, there are process-related problems that must be clarified prior to implementation in series production. These include greensand compatibility, the handling of alkaline used sand and ensuring a productivity that is comparable to cold box technology.

Coating stability

Feasibility studies of inorganic binder systems in iron casting have shown that the coating of inorganic bound cores is one of the biggest challenges. Countless efforts to coat filigree cores have failed, almost all of them resulted in core breakage. The Inotec binder coating system was systematically developed with the aim of coating even the most complex and filigree core geometries, such as water jackets, in a process-reliable manner.

In the coating-drying process, the sand core is exposed to an aggressive climate with high humidity after the ap-

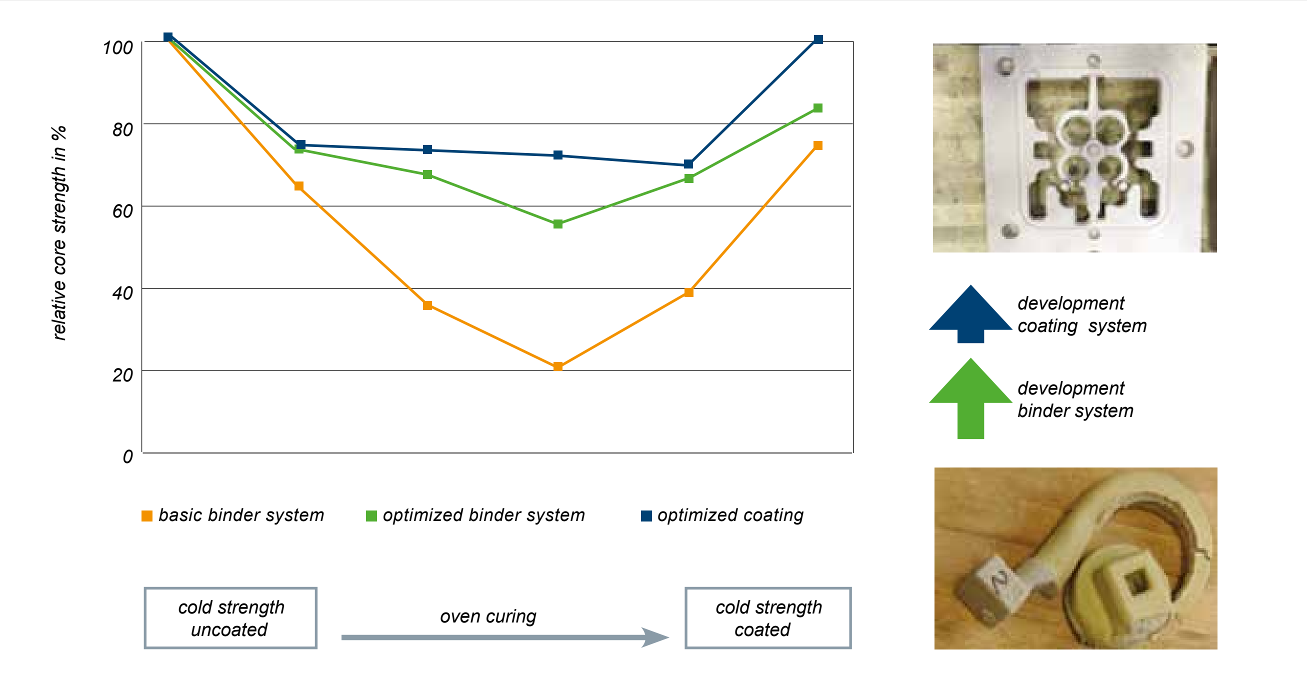

Figure 1: Development concept of the binder-coating system: Strength profile (coating stability of the binder system) in the drying process (Graphics: ASK Chemicals)

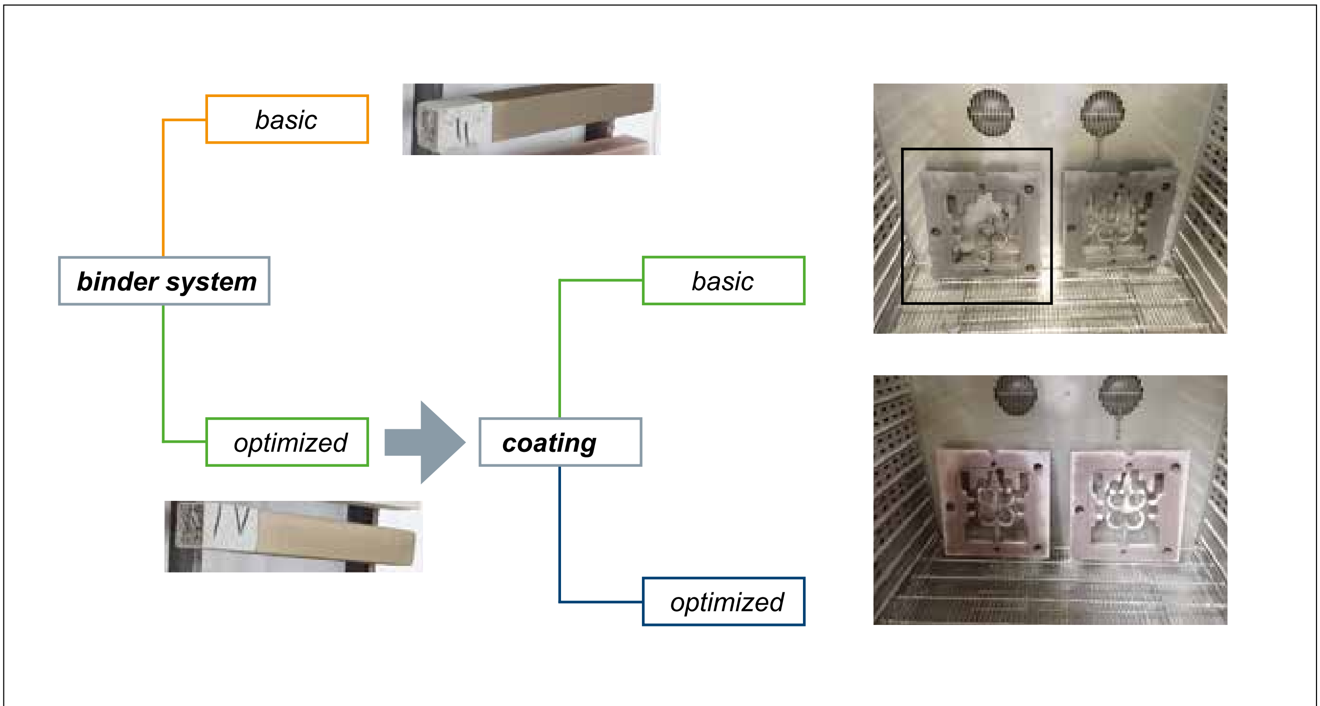

Figure 2: Two-stage optimization step of the binder-coating system facilitates a process-reliable drying process without core breakage of the delicate water jacket frame core

plication of a water-based coating and with the heat of a drying oven, which favors the back-reaction of the network formation by splitting the silicate framework. The sand core thus increasingly loses strength and is susceptible to deformation or core breakage when passing through a strength minimum. If it survives these critical phases, the sand core reaches a considerable strength level again in the further course of the drying process, but in particular in the cold strengths.

The optimization of the binder-coating system can be divided into two main steps (**Figure 1**). In a first step, the coating stability was improved by chemically modifying the binder. During the oven drying, significantly higher core strength can then be ensured throughout the entire drying process. In a second development step, a new coating was designed that was specifically tailored to the characteristics of inorganic cores. By an optimal combination of both components, an inorganic binder system and a water-based coating, the core is only slightly weakened during the drying process.

The coating formulation is basically targeted to a certain application type, such as dipping or flood application. It is sought after to develop a coating that does not unnecessarily stress the binding system already during application. In the case of an optimal coating-drying process, the inorganic sand core is only slightly stressed resulting in a high mechanical stability with a simultaneously low residual moisture. The risk of casting errors (scabs, gas bubbles, penetrations) can thus be significantly reduced and a process-reliable moisture level of the coated cores can be ensured. The use of a compatible binder-coating system first made it possible to coat even filigree core geometries such as a water jacket frame core, in a process-reliable manner without core breakage (**Figure 2**).

Thermal deformation

Complex components with low wall thicknesses (e.g. water jacket) require a high degree of thermal-mechanical resistance of the binder system during casting. [2] Due to the thermoplastic properties of inorganic binder systems, the sand core can deform under the influence of temperature and pressure from the iron smelt, which results in a significant dimensional deviation of the raw casting. Thereby, the thermal stability of the binder system describes its ability to withstand the thermal strain for a certain period of time without deforming. The thermal stability is defined by the softening point of the binder system, which is empirically determined using the hot stage microscope (**Figure 3**a).

Optimizing the binder system can increase the thermal stability and ensure the dimensional accuracy of the castings (**Figure 3**b).

The use of special water-based coatings offers another way to counteract thermal deformation. In the coating formulation, the specific thermal conductivity can be specifically controlled through a defined selection of suitable refractory components and through the rheological system. Protected by the application of a coating layer on the sand core, the binder system withstands the thermal and mechanical loads during casting, which significantly reduces the degree of thermal deformation and also improves the surface quality of the unfinished casting.

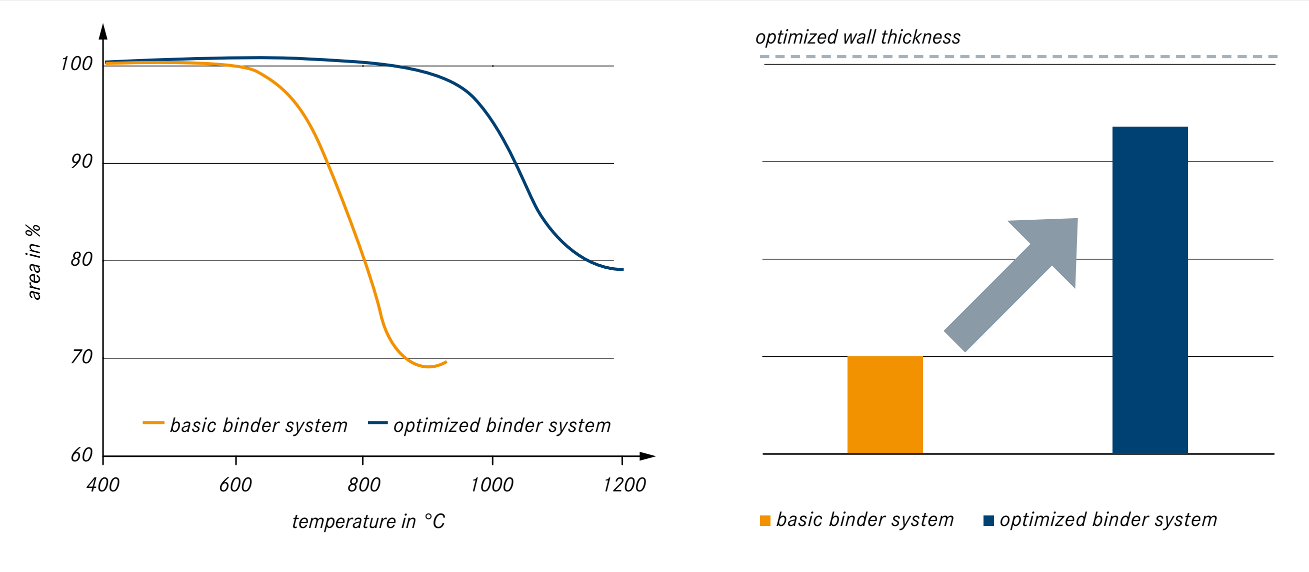

Figure 3: a) Hot stage microscope investigations of the thermal stability of inorganic binder systems. b) Increasing the dimensional accuracy of the casting through the targeted adjustment of the thermoplastic properties of the Inotec binder system

Shake-out behavior and decoring capability

The occasional poorer shake-out behavior of inorganic cores in iron casting results from the chemical nature of waterglas-based systems. Unlike organic binder systems that pyrolyze during the casting process, the inorganic binder system softens and vitrifies into the state of a supercooled glass melt during slow cooling. Taking into consideration additional sintering and sand expansion effects, this results in the poor shake-out behavior of the inorganic bound sand core. This is particularly pronounced in the filigree core geometries with an unfavorable sand-iron ratio.

While organic additives are used in traditional waterglas-ester or CO_2 systems to optimize the shake-out (such as by adding molasses), new inorganic materials were identified in the course of continued development, which significantly increase the decoring behavior, even with a low energy input (**Figure 4**).

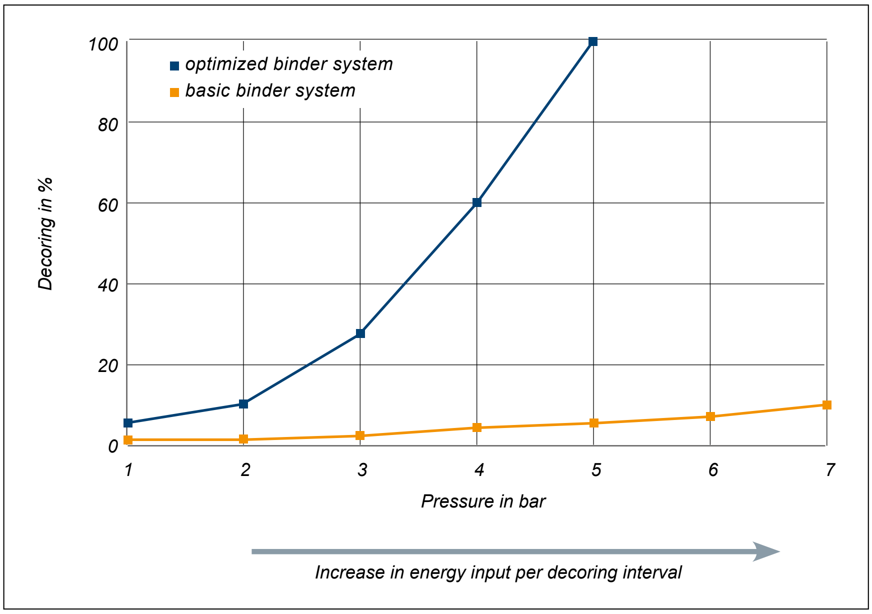

Figure 4: Decoring Study of Inotec-bound sand cores after casting (GJL: 1420 °C) – Increasing the decoring capability by inorganic core sand additives.

The application of coatings also makes a significant contribution to increasing the decoring capability. When uncoated, the liquid iron penetrates into the sand core, whereby additional sintering processes negatively affect the shake-out behavior. A coating layer can prevent smelting and sintering processes resulting in a smooth casting surface, whereby the core can be more easily removed from the raw casting.

Process engineering challenges

A technological change to inorganic binder systems also includes process engineering challenges, as already indicated. Greensand compatibility, economic cycle times and the process engineering handling of alkaline used sands are examples.

For example, the compatibility of inorganic bound used sands with bentonite-bound molding sand (greensand compatibility) is a decisive criterion for the series application of inorganic binder systems in iron casting. In every process cycle, inorganic bound used sand gradually accumulates in the bentonite-bound molding sand. However, initial studies have shown that a core sand concentration of up to 25 % is considered non-critical. However, this should be individually validated for the greensand system of each foundry.

When designing the core production processes, an economic cycle time of the entire process is very relevant. The chemical and physical curing mechanism results in a significantly higher overall cycle time in the core production in the case of very large core cross-sections or high core weights.

In addition, "inorganic used sands" have a high pH value, which drastically reduces the processing time of sand mixtures when using cold box binder systems. Inorganic used sands are therefore not compatible with a cold box production, i.e. a separation of inorganic sands from the cold box sand cycle is required.

Summary

The initial feasibility studies and customer projects on real component geometries highlight the basic potential of inorganic binder systems of the Inotec technology in cast iron applications. Already today voluminous cores and molds with moderate thermal strain can be used as a partial replacement in a cold box core package. A big challenge, however, remains the technological transfer of the inorganic binder system to the entire core package, whereby the first material-specific hurdles were already overcome through the gradual development of an optimized binder-coating system.

For a series-ready application of inorganic binder systems in iron casting, the technological findings from the laboratory must be transferred into practical operational sequences in order to evaluate and estimate the overall potential of the current developments. Strong partnerships between industry and research facilities are essential for this purpose. Increasing regulations in the field of environment (market pull) as well as the progressive development of inorganic binder systems (market push) should be drivers of corresponding development projects.

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www.ask-chemicals.com

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