Effect of additives promoting the formation of lustrous carbon on the knocking out properties of foundry sands with new inorganic binders

I. Izdebska-Szanda a,*, Zb. Stefański b, F. Pezarski c, M. Szole d

a, b, c, d Department of Technology, Foundry Research Institute, ul. Zakopiańska 73, 30-418 Kraków, Poland
*Contact for correspondence: e-mail: irsza@iod.krakow.pl

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Abstract
The article presents the results of investigations, which make a fragment of the broad-scale studies carried out as a part of the statutory activity on optimising the foundry sand technology using new, modified, inorganic binders. The results of investigations regarding the effect of lustrous carbon carriers on the technological properties of foundry sands with inorganic binders were presented in a concise manner. The selected additives were introduced to moulding sands prepared with the new, modified, inorganic binders bonded by the chemical reaction or by blowing with gaseous CO2. Attention was focussed on the effect of selected additives promoting the formation of lustrous carbon on the knocking out properties of moulds and cores prepared from sands with the new types of inorganic binders. The quality of the test castings was also evaluated along with the tendency to the formation of lustrous carbon at the metal – mould interface, basing on the results of microscopic examinations and analysis of the chemical composition using an X-ray microanalyser.

Keywords: Innovative foundry materials and technologies, inorganic binders, lustrous carbon, knocking out properties, strength

1. Introduction
The growing demands of ecology and economy promote continuous interest in the non-toxic and cheap, compared to organic, inorganic binders.

The investigations carried out by numerous research centres in Poland and abroad mainly focus their attention on extending further the applicability range of these binders to replace totally resin systems.

The investigations are of a multi-faceted character, starting with chemical modification of the most commonly used inorganic binder, which is sodium silicate (hydrated sodium silicate or water glass) [1,2,3,4,5], through the use of special additives introduced directly to sand mixture [6,7], and ending in the development of new inorganic binders [8,9].

The, developed by Foundry Research Institute in Cracow, silicate binder modified chemically with morphoactive additives of the type of polymers and copolymers enables reducing the binder content in moulding sand by nearly 20%, while maintaining the good technological properties (the residual strength) at ambient and high temperatures [10,11,12].

Similar effects were achieved with a geopolymer binder introduced to the sand [8,13]
The research carried out under the statutory work programme in year 2007 aimed mainly at optimising the composition of sands with new inorganic binders and, in the case of self-setting sands, at obtaining full control of the binding time, as having an immediate and important effect on the time when casting can be knocked out from mould [13,14].

In 2008, these studies were continued to find out if it is possible to subject the sand mixture to repeated reclamation and improve further the sand knocking out properties [15].

2. Background and aim of the research

Apart from the factors of strictly economical and ecological character and the quality requirements imposed on foundry moulds and cores, there are two other factors very important and always considered by foundry in the choice of casting-making technology. These two factors are the knocking out properties of moulds and cores and their reclamability.

Therefore, under the statutory work carried out to optimise the technology of moulding sands with inorganic binders [15], some studies were undertaken to explain, among others, the effect of additives promoting lustrous carbon formation on the technological parameters and knocking out properties of moulding sands with new inorganic binders.

The investigations were carried out on moulding sands with inorganic binders based on hydrated sodium silicate modified with morphoactive additives (150MC and 145MC water glass) and on mineral polymers of low polymerisation degree (Rudal A), hardened with both liquid and gaseous hardeners (liquid self-setting sands and CO2 process, respectively).

Owing to these investigations, it has been possible to improve further the knocking out properties of moulding and core sands without any more serious damage to their beneficial ecological characteristics.

3. Investigations of the effect of lustrous carbon carriers and other additives on the quality and knocking out properties of moulding sands

3.1. The choice of lustrous carbon carriers and other additives improving the knocking out properties of sands with new inorganic binders

The investigations carried out formerly on sands with inorganic binders containing the addition of a lustrous carbon carrier, which in this case was Kormix, raise hopes for a considerable improvement of the knocking out properties of these sands. For this reason, at the next stage of studies continued in 2008, it was attempted to better investigate this field of knowledge, raising in the programme of investigations also other lustrous carbon carriers and organic release agents.

The following materials were selected for the investigations:

- LK phthalic resin,
- Ekosol novolak resin,
- KHD III novolak resin for the coated sands,
- Kormix S lustrous carbon carrier of enhanced grade,
- pure calophony,
- dextrine.

For selected additives, the lustrous carbon content was determined first, and trials on the possibilities of mixing these additives with the investigated inorganic binders were made next. The lustrous carbon content was determined using an automatic analyser. The measurements were made with an NDIR probe of infrared radiation absorption, installed in the apparatus, analysing the gaseous CO2 content in products of the sample combustion.

The conducted investigations have proved that in the lustrous carbon formation, the most powerful additives are „Kormix S” and dextrine. The LK, Ekosol and novolak resins are all characterised by a similar level of the lustrous carbon content, as shown in Figure 1.

![Fig.1. The results of measurements of lustrous carbon content in the examined additives](image)

3.2. Effect of lustrous carbon carriers and other additives on the quality of sands with new inorganic binders

A series of tests was carried out on the selected additives used to improve the knocking out properties of sands. Each time, the sand mixture was prepared and basic technological parameters, i.e. permeability, compression strength and bending strength, were determined.

Tests were carried out on both self-setting sands and sands hardened with CO2. Self-setting sands were prepared with 2,5 parts by weight of binder and 0,25 parts by weight of the hardener. In the case of CO2-hardened sands, the content of binder was 3,5 parts by weight.

The sand components were mixed in an LM-R2 ribbon-type laboratory mixer. Before adding the liquid components (hardener and binder), special additives in an amount of 0,5 (0,25) parts by weight were introduced to the new sand during mixing operation. The sequence in which the sand components were added was determined by experiments.

From thus prepared sands, specimens were made for testing of the mechanical properties and permeability measurements. For compacting of the sand a vibration device was used.

The results of the mechanical tests are plotted in Figures 2 and 3, taking as an example the bending strength of the sands with 145MC binder, hardened by chemical route and with gaseous CO2.
Fig. 2 Bending strength of self-setting sands with additives improving the sand knocking out properties

Fig. 3 Bending strength of CO₂ hardened sands with additives improving the sand knocking out properties

The conducted investigations have proved that, as regards the mechanical parameters, the best effects are obtained using the following additives:
— to self-setting sands – Kormix S, calophony and LK and KHD III resins,
— to CO₂ hardened sands – dextrine and, though to a smaller extent, the LK phthalic resin.

3.3. Tests and evaluation of the knocking out properties of sands with new inorganic binders and special additives improving mould life and sand knocking out properties.

For full evaluation of the effect that the added sand components have on the knocking out properties of sands with the selected binder (MC145), moulds according to PN-85/H-11005 Standard were made.

Moulds were prepared for simultaneous determination of the sand knocking out properties (test casting for determination of the knocking out properties) and casting surface quality (stepped test casting) when made in moulds prepared of the same sand mixture. The sand compositions were identical as in the case of technological tests.

The ready moulds were poured with iron at a temperature of 1340 °C. After knocking out of castings from moulds, the part assigned for testing of the knocking out properties was cut off.

The results of the measurements of the knocking out properties are compiled in respective table. A measure of the knocking out properties is the number of blows of a bob weighing 3.3 kg.

Irrespective of the hardening process, the best knocking out properties offer sands with the new inorganic binder and an addition of Kormix S and calophony. The LK resin improves knocking out properties of the self-hardening mixtures by about 50 %, and in the case of CO₂ hardened sands, nearly three times. Still better effect exerts on these sands the addition of dextrine. The very beneficial effect of these additives on the sand knocking out properties is convergent with the best mechanical properties that the sands prepared with these additives offer.

For selected castings, the microscopic examinations were also carried out. The sand sticking to the casting was examined by scanning microscopy, and specimens were cut out from the selected castings (from the mould-casting interface area) to evaluate the quality of casting surface in terms of the lustrous carbon formation at the phase boundary.

The examinations consisted in observations of microstructure (SEM) and in local chemical analysis carried out in microregions by X-ray microanalysis (EDS)

Observations were made under a STEREOSCAN 420 scanning electron microscope, examining the surface of the specimens coated in a B30 vacuum e-beam evaporation system with a layer of amorphous carbon. The conditions of the examinations were as follows: acceleration voltage 25kV, current 250pA, detector: SE1. The qualitative determination of chemical composition in microregions was made by an X-ray microanalyser (EDS), model LINK ISIS 300.

Examples of the results obtained in the form of plotted EDS spectra are shown in Figures 5 and 6.
This proves the formation of lustrous carbon at the metal-mould sand without an addition of this carrier (the case illustrated in Figure 5). The obtained results enable a statement to be made that the tendency to the formation of lustrous carbon is definitely stronger when the LK resin and Kormix S are added to self-hardening sands (20-30 cps), compared with the same addition introduced to sands hardened with \( \text{CO}_2 \) (8-15 cps). This, in turn, may indirectly affect the knocking-out properties of these sands.

The above examples show that in the specimens cut out from the castings poured in moulds made from the sands with an addition of the lustrous carbon carrier, the content of carbon is much higher than in the castings poured in moulds made from the sands with an addition of the carrier (the case illustrated in Figure 5). This proves the formation of lustrous carbon at the metal-mould interface.

The obtained results enable a statement to be made that the tendency to the formation of lustrous carbon is definitely stronger when the LK resin and Kormix S are added to self-hardening sands (20-30 cps), compared with the same addition introduced to sands hardened with \( \text{CO}_2 \) (8-15 cps). This, in turn, may indirectly affect the knocking-out properties of these sands.

## 4. Conclusions

The above presented results of investigations concerning the knocking-out properties of sands with the new, modified, inorganic binders enable selection of special additives that can improve the knocking-out properties of these sands, while preserving the required high level of mechanical properties, necessary to produce moulds and cores, first, and castings, next, characterised by the required high quality.

Among the examined carriers of lustrous carbon added to the sands with new binders to improve their knocking-out properties, and consequently the quality of the casting surface, the best effect had the additives of Kormix S, LK resin and calophony. In the case of \( \text{CO}_2 \) hardened sands, dextrine also had a beneficial effect on the knocking-out properties, mechanical properties, and permeability.

## References


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**Fig. 6. EDS spectrum of the casting surface (casting made in mould with inorganic binder with an addition of the lustrous carbon carrier)**