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THE MEASUREMENT OF HIGH-TEMPERATURE EXPANSION AS THE STANDARD OF ESTIMATION THE KNOCK-OUT PROPERTIES OF MOULDING SANDS WITH HYDRATED SODIUM SILICATE

POMIAR EKSPANSJI WYSOKOTEMPERATUROWEJ JAKO KRYTERIUM OCENY WYBIJALNOŚCI MAS FORMIERSKICH Z UWODNIONYM KRZEMIANEM SODU

The necessity of receiving high quality castings forces undertaking research to elaborate moulding and core sands ensuring obtaining the materials with relevant technological parameters and also with high environmental standards. The most important group here are moulding sands with hydrated sodium silicate. Unfortunately, their fundamental disadvantages are weak knock-out properties. The article presents the most commonly used methods of measuring the knock-out properties of moulding and core sands. The authors propose a new method for estimation this parameter. The method is based on the measurement of high-temperature expansion.

Keywords: moulding sand, hydrated sodium silicate, knock-out properties

Potrzeba uzyskiwania wysokiej jakości odlewów wymusza podejmowanie prac badawczych dla otrzymania mas formierskich i rdzeniowych zapewniających uzyskanie tworzyw o odpowiednich parametrach technologicznych, jednocześnie spełniających wysokie wymogi ochrony środowiska. Najważniejszą grupę stanowią tutaj masy z uwodnionym krzemianem sodu. Niestety jedną z ich podstawowych wad jest słaba wybijalność. W artykule zostały przedstawione najczęściej stosowane metody pomiaru wybijalności mas formierskich i rdzeniowych. Autorzy zaproponowali nową metodę oceny wybijalności opierającą się na pomiarze ekspansji wysokotemperaturowej.

1. Introduction

The necessity of receiving high quality castings forces undertaking research to obtain moulding and core sands providing to obtain materials with relevant technological parameters and also with high environmental standards. Many national and foreign scientific centers [1-12] undertake scientific research aiming to elaborate new binding systems based on nontoxic inorganic binders. The most important group here are moulding sands with hydrated sodium silicate. Unfortunately their main disadvantage are low knock-out properties and low ability to mechanical reclamation.

For estimation of actions improving moulding sands' knock-out properties it's fundamental to use the appropriate measurement procedure. In the article there are presented the most commonly used methods of measuring the knock-out properties of moulding and core sands. There is also proposed a new method based on measuring high-temperature expansion of tested moulding sands.

2. Knock-out properties of moulding and core sands

The knock-out properties are defined as moulding or core sand's ability to easy smashing out (pouring out) from mould (moulding sand) or from cast (core sand) after cooling the cast to knocking-out temperature [13]. The knock-out properties are estimated by technological methods and according to retained strength R_c^{tk} measurement.

2.1. Technological methods – the method recommended by Polish Standard no PN-85/H-11005

In technological method recommended by Polish Standard there are used standard cylindrical samples (ø50×50 mm) prepared from tested moulding sand [13]. The samples are treated exactly as moulds and cores being produced from the tested sand. The samples are not covered with any protective coatings. The samples (cores) are put inside the mould with usage of special model (sampler). The liquid foundry alloy is poured into the mould. The alloy temperature should be the same as it is while producing casts in tested moulding sand. After cooling the cast to ambient temperature, it is put – with the samples (cores) – in device LUW-C or LUW-CA (auto-

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matically) constructed to measure moulding sand's knock-out properties. The device is equipped with a pin which knocks the sample (core) out the cast. The work of one pin beat is 1,63 J [13]. The knock-out measurement is the work necessary for moving the sample (core) out the cast. It is calculated from the formula 1 [13].

$$L_w = 1,63 \cdot n; J \quad (1)$$

where: 1,63 – work of one weight beat, J,
n – number of weight beats till moving the core out the cast.

There are also used other technological methods for measuring moulding sands knock-out properties including Russian and French tests [13].

2.2. The method based on retained strength R_c^{tk} measurement

The method is based on measurement of retained strength R_c^{tk} change of moulding sand with hydrated sodium silicate with temperature increasing. The test begins with measuring strength of moulding sand in ambient temperature, then – beginning in 100°C – the temperature is increasing and the strength is being measured after every 100° till reaching the temperature 1000°C. After cooling the samples to ambient temperature the retained strength (R_c^{tk}) of tested moulding sand is measured. The results are put on the graph showing the influence of temperature on moulding sand's retained strength (R_c^{tk}). According to the reached graph it's possible to estimate the moulding sand's knock-out properties. Good knock-out properties has the part of moulding sand heated to the temperature in which its retained strength (R_c^{tk}) is the lowest and the part of moulding sand heated to the temperature in which its retained strength (R_c^{tk}) is high characterizes with bad knock-out properties [13].

2.3. The curve of retained strength (R_c^{tk}) of moulding sand with hydrated sodium silicate

There are three extreme points on typical curve of retained strength (R_c^{tk}) of moulding sand with hydrated sodium silicate:

– *The 1st maximum in the temperature of about 200°C,*
– *The minimum in the temperature of about 600^{o}C,*
– *The 2nd maximum in the temperature of about 800°C.*

Most of the authors [13, 15] explain occurring the 1st maximum as the result of binder dehydration process and the main role is assigned to the dehydration of unbound hydrated sodium silicate. The author [15] explains occurring the 1st maximum according to DTA curve of hydrated sodium silicate. The curve shows that in the range of temperature 350-400°C begins endothermic process with endothermic peak registered in the temperature of 600°C. The analysis proved the presence of two endothermic peaks in temperatures of 130 and 640°C is probably responsible for the compound dehydration process. According to the author [15] in case of self hardened moulding sands prepared in ester technology the 1st maximum doesn't occur – there is constant decrease of retained strength beginning with high values in ambient temperature to the minimum in temperature of 600°C [15]. Transformation of quartz $\beta\alpha$ considered previously as the cause of occurring the minimum (600°C) according to the author [15] can't be the only reason of occurring this extreme. The author proved that moulding sands with hydrated sodium silicate based on zirconium sand grains has the minimum in this temperature as well. The minimum was also reached by testing the strength of bound hydrated sodium silicate without sand grains. The author suggests that there are different factors causing this extreme which are among all – dehydration processes of disodium silicate and silicic acid gel [15]. After the minimum there is a rapid increase of retained strength with the maximum in the temperature of 800-900°C. The 2nd maximum is caused by formation of the liquid phase (melting the hydrated sodium silicate) and by the reaction of Na_2CO_3 with SiO_2 ending with formation of $Na_2O{\cdot}2SiO_2$ [15]. Beyond the 2nd maximum there is a rapid decrease of retained strength (R_c^{tk}) what J.L. Lewandowski [13] explains as a result of the violation of the binder shell structure on quartz sand grains, caused by a large change in volume of quartz. In the presence of Na_2O conversion to cristobalite can begin already above 800°C.

2.4. The proposal of new method of knock-out properties' estimation

As it was initially referred in the previous part of the article, the method of estimation of the knock-out properties of moulding sands based on retained strength (R_c^{tk}) measurement can't be used in whole temperature range.

The use of retained strength measurement for estimation the knock-out properties of moulding sands is not clear. The author [15] proved that moulding sand's expansion is responsible for retained strength decrease beyond the 2nd maximum. The process is caused by transition of α-SiO_2 phase into cristobalite which is catalyzed by Na^+ ions, quartz density decreases from 2650 to 2330 kg/m^3 with increasing the mass volume of about 40%. Despite this moulding sand's retained strength is low in temperatures higher than 1000°C. The author [15] proved that there is the typical 2nd maximum in the temperature of about 800°C on retained strength of moulding sands with hydrated sodium silicate and ester hardeners curve, but the energy necessary for knocking the sample out while using technological method increases till 1000°C. The phenomena is caused by cristobalitic quartz sand expansion which is mainly responsible for retained strength decrease beyond the 2nd maximum, increases the final moulding sand's density causing worse knock-out properties.

According to this, authors of the paper elaborated a new method of estimation of moulding sand's knock-out properties. The base was the analysis of cores or moulds behavior during pouring process – the process causes moulding sand expansion. However this phenomena is inhibited by cast surface (core sands) or by cast and moulding box (moulding sands). Strong internal stress occurs in moulding sand which inhibits its evacuation from the cast or from the moulding box. The higher internal stress is the worse knock-out properties are.

Moulding sand expansion measurement after pouring process may be useful for estimation of moulding sand's knock-out properties.

3. Own research

There were tested moulding sands with hydrated sodium silicate and liquid hardeners prepared in self hardened moulding sands technology (ester method). The research was conducted after 24h of hardening with keeping constant temperature and humidity in research room. The authors used standard and modified moulding sands with hydrated sodium silicate to prove the necessity of elaborating new method of knock-out properties measurement. As a factor modifying tested moulding sands there were used own, patented [16] additive called Glassex [17].

The following moulding sands compositions were taking into research:

- Sand grains: quartz sand 100 parts by weight
- Binder: hydrated sodium silicate 3 parts by weight
- Hardener: flodur 0,3 part by weight
- Additive: Glassex 1 part by weight.

3.1. The estimation of moulding sands' knock-out properties according to Polish Standard no PN-85/H-11005

As the first method of estimation of moulding sands' knock-out properties there was used the method according to Polish Standard no PN-85/H-11005. There were tested moulding sands with and without Glassex additive. In the experiment there were used cylindrical samples. The samples were put in experimental cast and poured with cast steel having the temperature of about 1450°C. After cooling the casts were gently knocked out the mould and the technological knock-out properties measurement were carried out. The results are shown in figure 1 [18].

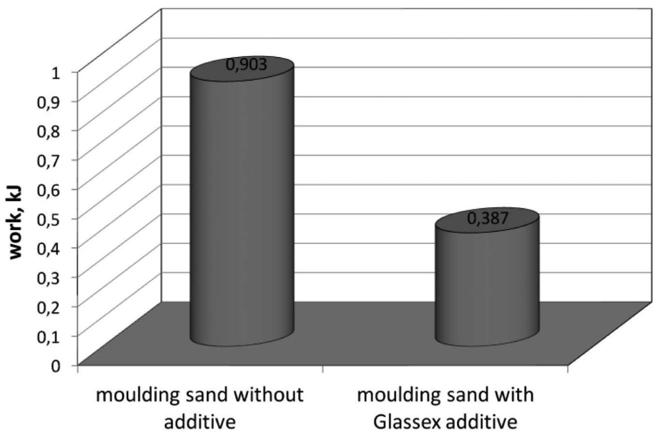

Fig. 1. Knock-out properties of moulding sands with hydrated sodium silicate with and without Glassex additive measured by Polish Standard no PN-85/H-11005 [18]

The conducted research shows more than twice reduction of work necessary for knocking the core out the experimental cast while using Glassex additive as a component of moulding sand with hydrated sodium silicate.

3.2. The estimation of moulding sands knock-out properties according to retained strength R_c^{tk} measurement

The cylindrical samples (prepared like in chapter 3.1) were heated in laboratory electrical furnace SNOL 8,2/1100 (P) in the range of temperature 100-1100°C (every 100°) and in muffle furnace FCF 7 SHM in temperature 1200°C. The samples were kept in each temperature for 15 min and were cooled with the furnace to ambient temperature. Then their retained strength R_c^{tk} was measured using testing machine INSTRON controlled with modern control system Test Star IIS. The results are shown in Fig. 2 [19].

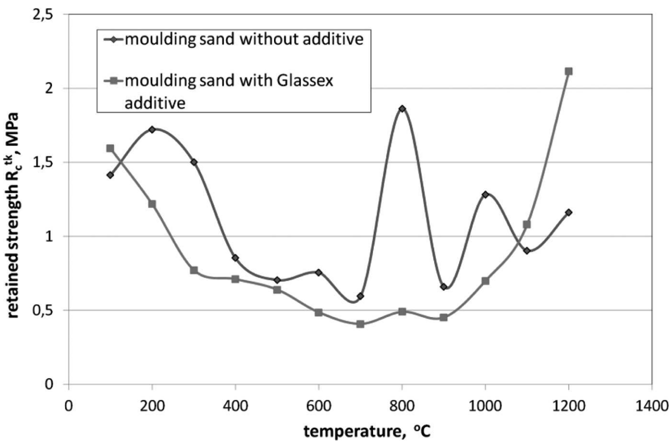

Fig. 2. Knock-out properties of moulding sands with hydrated sodium silicate with and without Glassex additive estimated according to retained strength R_c^{tk} measurement [19]

Inserting the Glassex additive to moulding sands with hydrated sodium silicate causes change of their retained strength R_c^{tk} curve shape. There is no 1st and 2nd maximum on the curve. Moulding sand with Glassex additive has lower retained strength R_c^{tk} in the range of temperature 200-1000°C. The influence of Glassex additive on moulding sands knock-out properties was described in details in previous publications [19].

The authors proved that retained strength R_c^{tk} can't be used as the criteria of knock-out properties estimation in the area beyond the 2nd maximum – which was described in the chapter 2.4. That's why there is proposed a new method of estimation of moulding sand's knock-out properties. The method is based on high-temperature expansion measurement.

3.3. The estimation of moulding sands knock-out properties according to high-temperature expansion measurement

There were used cylindrical samples prepared and heated according to methods described in chapters 3.1 and 3.2. The samples were measured before and after heating in the range of temperature 600-1200°C every 100° according to literature data [15, 20]. The results are shown in Fig. 3 [19].

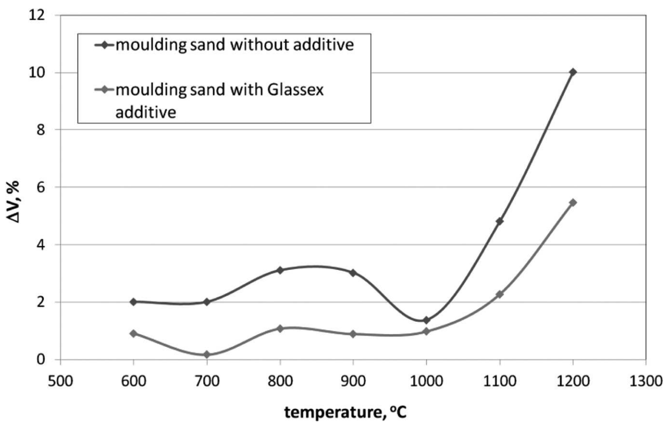

Fig. 3. Knock-out properties of moulding sands with hydrated sodium silicate with and without Glassex additive estimated according to high-temperature expansion measurement [19]

The conducted research proved that inserting the Glassex additive to moulding sands with hydrated sodium silicate causes lowing their high-temperature expansion which improves their knock-out properties. In the temperature of 600°C the high-temperature expansion is about 50% decreased; 700^{o}C – about 90%, 800°C – about 60%, 900°C – about 70%, 1100°C – about 50%, 1200°C – about 40%. The Glassex additive inhibits high-temperature expansion of tested moulding sands – reduces their internal stresses – increasing their knock-out properties.

4. Conclusions

According to literature data and own research the following conclusions may be specified:

1. The method of estimating the knock-out properties of moulding sands with hydrated sodium silicate according to their retained strength R_c^{tk} curve beyond the 2nd maximum is not reliable.
2. The method of estimating the knock-out properties of moulding sands with hydrated sodium silicate according to their high-temperature expansion measurement seems to be much more reliable.
3. Inserting the Glassex additive shows over 50% increase of tested moulding sands knock-out properties measured according to their high-temperature expansion. This is consistent with the results of conducted technological method.
4. The measurement of high-temperature expansion may be one of the standards of estimating the knock-out properties of moulding sands with hydrated sodium silicate.

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