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The Tendency of Moulding Sands to Generate Core Cracks

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Abstract

The constant growth of foundry modernization, mechanization and automation is followed with growing requirements for the quality and parameters of both moulding and core sands. Due to this changes it is necessary to widen the requirements for the parameters used for their quality evaluation by widening the testing of the moulding and core sands with the measurement of their resistance to mechanical deformation (further called elasticity). Following article covers measurements of this parameter in chosen moulding and core sands with different types of binders. It focuses on the differences in elasticity, bending strength and type of bond destruction (adhesive/cohesive) between different mixtures, and its connection to the applied bonding agent. Moulding and cores sands on which the most focus is placed on are primarily the self-hardening moulding sands with organic and inorganic binders, belonging to the group of universal applications (used as both moulding and core sands) and mixtures used in cold-box technology.

Keywords: Innovative foundry technologies and materials, Moulding sand, Binder, Elasticity, Cracking

1. Introduction

Contemporary casting has been strongly enriched by mechanization and production automation processes that have begun to generate opportunities for new foundry defects to surface, including irreparable faults. This article covers the disadvantages observed in the little-described mould assembly processes and the possibility of the mould or core to crack. These defects will be described in detail later in this paper, and are mainly related to the quality of foundry cores.

Moulding and core sands should ensure that castings assumed usability, high dimensional accuracy and high surface smoothness are obtained. While the first of these conditions depends mainly on the type of casting alloy and more specifically its structure, the other two are a function of mould and core quality.

Moulding sands are also required to have high process economy and low environmental impact. But the economics of the process is not just the cost of buying the ingredients. It also: the efficiency of the moulding process, binding time, ease of moulds and cores manufacturing, their knockout and reclamation properties.

During the preparation process moulds and cores are subjected to the influence of many mechanical factors related to particular technological operations, such as extracting cores from the core boxes, inserting the cores in moulds, closing of the moulds, moving the moulds to the pouring area, applying weights on the upper mould surface, etc. Those operations can become a cause of cracks in moulds and cores that can later lead to defects in castings, especially in highly mechanized foundries, where such operations are often performed by manipulators.

The phenomenon of elasticity of moulding sands has been recently studied by P. Gröning, S. Schreckenberg, K. Jenrich [1-2] on cold-box moulding mixtures. The resin type was as well as amine flow time influence on elasticity were measured. Research conducted by the above mentioned group was carried out on the device from JUNG Instruments GmbH Company.

The problem of the lack of flexibility of foundry moulds also appears in J. Zych's studies [3-4], where this parameter is determined on based on the analysis of changes in the velocity of the transient ultrasonic wave in the moulding sand sample.

The following article focuses on deformation of moulding samples under pressure of force. The influence of the type of binding agent on the elasticity and the morphology of the crack surface is also taken into account. The main factor affecting the moulding sands elasticity and bending strength is their binding process (type of the binder and hardener used, amount of the binding agents used, curing time and conditions (temperature, humidity), use of additives etc.). In this article different kinds of moulding sands, which have different bonding mechanisms, were tested.

2. Methodology

All moulding sands that were chosen for this research were prepared according to the resin/binder manufacturer instructions, using standard compositions (table 1). Four representative moulding mixtures that are widely used in the foundry industry where chosen for the research.

Following resins/binders were used:

- sands manufactured in cold-box technology - GASHARZ 6966 and AKTI-VATOR 7624 [5-6],
- self-hardening moulding sands with furfuryl resin – XA-20 resin and 100T hardener [6],
- alkyd moulding sands – SL2002 resin and KL1 catalyzer [7],
- Inorganic moulding sands – 145 hydrated sodium silicate and Flodur3 [7].

Quartz sand from the Szczakowa Sand Mine S.A was used in all of the conducted tests. According to the Polish standard PN-85 / H-11001, it classifies the tested sand as medium. In the studied matrix, the value of the main fraction is 84%, which determines the sand as homogeneous (the granulation 0.20/0.32/0.40; d 50 = 0.31 mm; pH= 7).

Table 1.
Moulding sands composition.

Name	Matrix	Binder/resin [p.p.w.]	Hardner [p.p.w.]
Cold-box	Quartz sand 100 p.p.w.	0,8	0,80
Furfuryl resin		1,1	0,50
Alkyd resin		1,0	0,25
Hydrated sodium silicate		3,0	0,30

2.1. Bending strength

Bending strength (R_g^u) as well as elasticity are measured on standard longitudinal bending samples made on the vibration device LUZ-1. Both parameters are measured on calibrated equipment after 24h of curing in room temperature.

2.2. Elasticity

In the study of polymeric materials [8-9] elasticity is defined as a property to make reversible shape change under the influence of external forces. It should also be noted that as a rule we are not dealing with materials showing only one kind of deformation. In foundry moulds various shares, both spring and plastic deformation, can occur. They may depend on different parameters, e.g. temperature or deformation speed.

The elasticity measurement is based on the analysis of the deflection pattern of the standard longitudinal fitting during bending. The tooling allows to perform measurements of the indentation force in time while recording its displacement. This allows the user to determine the bending strength (R_g^u) and deflection arrows. The details concerning the elasticity measurement are described in earlier works [10-11].

2.3. SEM analysis

The study was conducted on the HITACHI S-3500N scanning electron microscope- EDS NORAN 986B-1SPS analyser.

Sample preparation included cutting off and marking the broken end of a standard longitudinal moulder subjected to the elasticity test. Due to the fact that the moulding sand is a non-conductive material, it was necessary to cover the surface of the samples with a layer of gold using Turbo Dual Head Vacuum Sputter Coater, type K575XD. The surface of the breakthrough from the bottom side, which is the place where the sample is subjected to bending forces, was photographed.

3. Own research

Presented results are a continuation of ongoing authors' research described in detail in previous works [10-11].

The research was carried out on a universal measurement device LRu-DMA by MULTISERW-Morek Company. The research was carried out in the laboratory of the Department of Moulding Materials, Mould Technology and Cast Non-Ferrous Metals at the Faculty of Foundry Engineering AGH.

3.1. Bending strength

Test samples shown analogical behaviour in the bending strength test (Fig. 1) as they did in elasticity tests (Fig. 2).

The samples which achieved the highest results belonged to the moulding sands prepared in the cold-box technology, and reached 4,23MPa, which was 69% more than for the moulding sands with hydrated sodium silicate, which achieved the lowest value of 1,30MPa. Two following results reached 2,71MPa for furfuryl resin and 3,68MPa for alkyd resin bonded sand, being accordingly 36% and 13% lower than the obtained maximum.

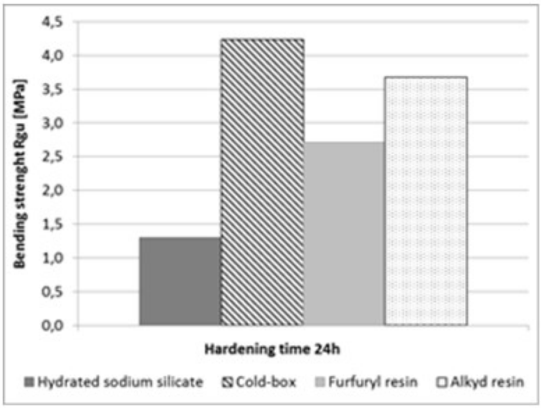

Fig. 1. Bending strength of chosen moulding sands

3.2. Elasticity

Results of elasticity measurements give two types of information, the first being the maximum load (F[N]) a sample can withstand which is analogical to the bending strength of a sample (R_g^u[MPa]), and maximum deformation (D_E[mm]), the other is related to deformation of different samples under a set force value (relating to the way automated core assembly is realized).

The obtained curves (Fig. 2) visualize few stages of the elasticity test. Firstly we can observe a nearly linear propagation of the deformation with the growth of the force. Secondly we can observe the bend in the curve which is the moment of sample breakage. The short growth of the curve after the maximal strength the sample can withstand is not taken into analysis, it is correlated with the eversion of the indenter.

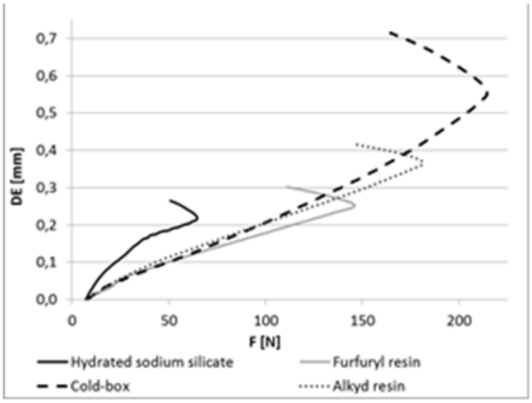

Fig. 2. Elasticity of chosen moulding sands

As can be seen on the graph above (Fig.2), moulding sand samples based on hydrated sodium silicate as the binder achieved both the lowest deformation of 0,21mm and load resistance of 64N. Following the trend to higher values next was the moulding sand bonded with furfuryl resin obtaining values of 0,25mm deformation and withstanding 146N of force. The second highest result of 0,36mm in bend under the force of 181N belonged to moulding sands bonded with alkyd resin. The highest obtained results both in deformation and load size were achieved in cold-box moulding sand samples. Deformation reached 0,55mm under the force of 214N just before the sample destruction. The resulted deformation was nearly 62% bigger than moulding sands with hydrated sodium silicate, under more than 70% greater force.

Based on both elasticity and bending strength it can be easily deduced that the greater the bending strength and overall strength resistance of the moulding sand the greater deformation the sand will undergo and withstand. But this is only the analysis of the final outcome, after the destruction of the sample. What has to be pointed out is the deformation of the sample made from different moulding sands under the same force. If for example impact of the force of 50N on the deformation of chosen moulding sand would be taken into account, it can be seen that the highest deformation under this pressure is 0,19mm for moulding sands with hydrated sodium silicate. At the same time the moulding sands with organic type binders reaches very similar results of 0,11mm under the same force of 50N, which is roughly half of what was obtained for the inorganic sand mixture.

What is more, when assessing the size of the obtained values of elasticity it should be borne in mind that they relate to moulders/profiles of predetermined geometry and length (170 mm). For samples or cores of larger size and different geometry the results might differ. This method illustrates differences between chosen types of moulding mixtures.

3.3. SEM analysis

The collation will be done on two moulding mixtures representing the inorganic (Fig. 4) and organic (Fig. 6) groups of binders. The presented images were chosen from a wide asset of samples, based on the frequency of their occurrence.

The differences in the morphology of cracks originate in the distribution of adhesion and cohesion forces in the resin itself and between the resin and the sand grain.

As author, St. M. Dobosz [12], points out in his thesis, the destruction of inorganic moulding sands runs through the binder – which means that the adhesion forces between the binder and the grain surface are greater than the cohesion forces, which promotes the breakage in the weakest place inside the binder layer (Fig. 3-4).

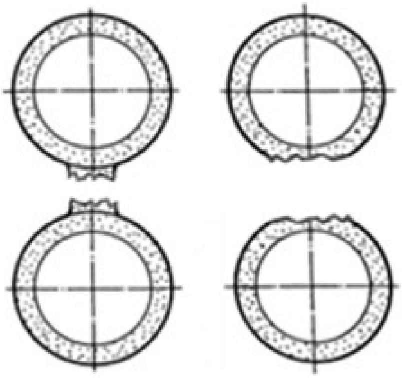

Fig. 3. Cohesive breakage

The border (Fig. 4.) and further propagation of the crack in the inorganic binder can be observed on the pictures below.

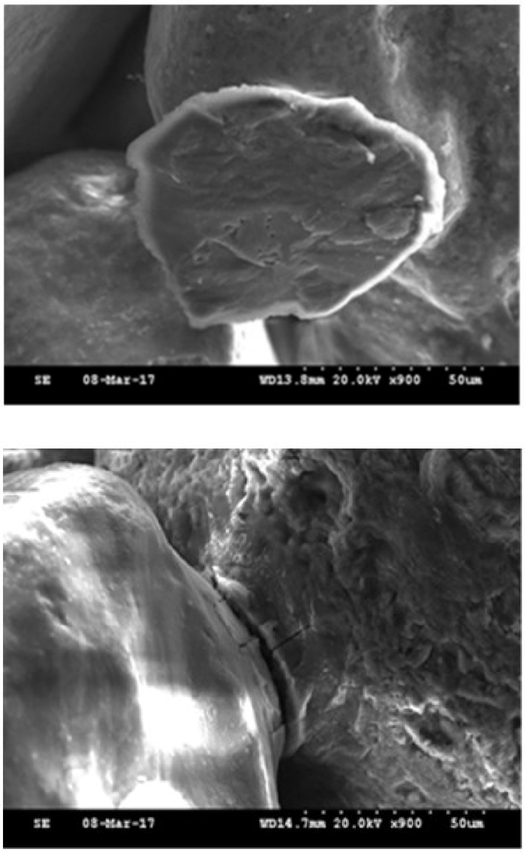

Fig. 4. Moulding sand with hydrated sodium silicate

The situation is completely different when we look up close on the destruction surface of the organic type binders, here the moulding sand bound with furfuryl resin. In this case, based on the literature [12] and SEM analysis of the crack surface (Fig. 6), we can assume that the cohesion forces in the binder are larger than adhesion forces of the binder to the sand grain, which results in the destruction between the cured resin and the grain surface (Fig. 5-6).

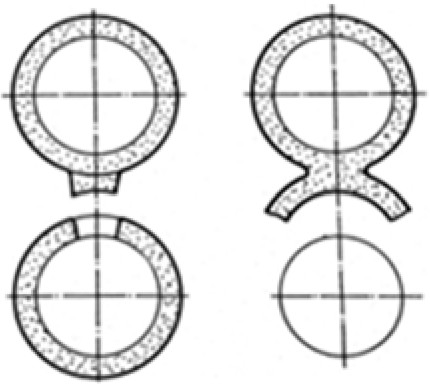

Fig. 5. Adhesive breakage [12]

The border (Fig. 6) and further propagation of the crack in the inorganic binder can be observed on the pictures above.

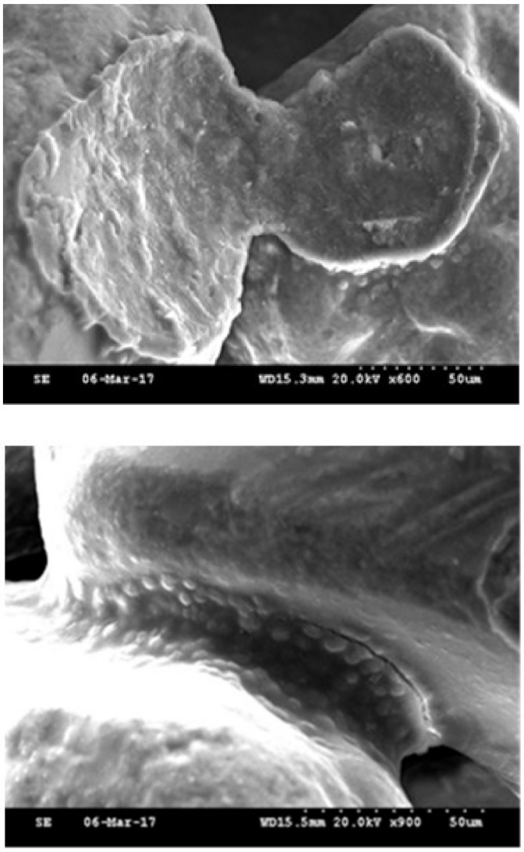

Fig. 6. Moulding sand with furfuryl resin

The differences it the destruction types between organic and inorganic sand mixtures can be another cause of the distinctions in their elasticity, since the cohesive forces are about ten times larger than the adhesive forces [12].

4. Conclusions

Own research presented in the paper showed that there are various differences, in the behaviour of moulding sands exposed to bending forces, depending on the type of binder used.

Presented research proves that with the change of used binder influences the level of deformation of the sample.

Conducted research shows that moulding sands with inorganic binders, that tend to have cohesive type of breakage, achieve lower values in both deformation and bending strength compared to organic binders, whit adhesive type of breakage.

The SEM analysis confirms the assumptions about the nature of the mechanical destruction of different binders.

Presented article shows only a fragment of broader research on the topic. The need of seeking new testing methods is clearly visible and the parameter can prove to be a valuable asset in choosing optimal moulding sands for highly mechanized foundries.

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