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Improving the Knock-Out Properties of Moulding Sands with an Inorganic Binder

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Abstract

Moulding sands with an inorganic binder are mainly used in non-ferrous metal casting employed in the automotive industry. The disqualifying factor for their use in iron alloy casting is their high final strength, associated with further solidification of the water glass as the temperature rises. The subject addressed in this study aims to improve the knockout properties of moulding sands with water glass. In this case, a foundry sand additive of geological origin was used. This additive is a reclaimed waste from the construction industry. The moulding sand was made with a binder, which was water glass R145 (3.5 parts by weight), and as a hardener, Flodur 1 was used in a ratio of 5% to the binder and additionally, 2 and 3 parts by weight of an additive with grain sizes of 0.2mm, 0.16mm, and 0.10mm were used. Research was conducted on the impact of strength on bending and stretching, as well as permeability. Subsequently, a test was carried out in accordance with the Polish standard PN-85/H11005 by pouring the mould with liquid metal. It was demonstrated that the investigated additive does not have a negative impact on bending strength and permeability values and reduces the amount of work required to remove the core from the cast iron casting.

Keywords: Knock-out properties, Inorganic binder, Moulding sands, Geological additive, Sand matrix modification

1. Introduction

The use of inorganic binders (hydrated sodium silicate and geopolymers) provides significant solutions for reducing toxic gas emissions in foundry processes [1]. Hydrated sodium silicate, used as a binder, has been applied in traditional foundry processes for producing moulds and cores, as well as in investment casting processes. In the latter, the issue of poor knock-out properties does not arise, as the casting is washed under a stream of liquid in which the binder is dissolved [2]. However, the use of inorganic binders in foundry processes has been hindered by their poor knock-out properties, which prevent the easy removal of the core from the casting. This is mainly due to the strength characteristics of sodium silicate-based binders, which increase with heating temperature [3, 4]. A possible solution to this problem could be the use of additives directly introduced into the matrix, which can shift the maximum strength of inorganic binders, resulting in a reduction of their final strength and easier removal of the core from the casting [5]. The authors of studies [6, 7] proposed an additive that lowers the final strength of the moulding sand based on sodium silicate, hardened with carbonic acid esters. The use of the granular additive allowed for shifting the maximum final strength and reducing the volumetric expansion of the moulding sand. This second parameter can cause casting defects related to shape, such as misalignments and flash. The authors of study [8] proposed the use of geological additives for the matrix. It was shown that the addition of geological perlite, regardless of grain size, positively affects the final strength of moulding sands with inorganic binders. In studies [9, 10], various types of matrix were proposed to improve the knock-out properties of moulding sands based on inorganic binders. Additionally, modified binders were used, but the influence of the matrix itself has a significant impact on the knock-out properties of moulding sands.

2. Methodology and materials

Simultaneous thermal examinations TG/DTG (Thermogravimetry/Differential Thermogravimetry) were conducted using a Thermal Analyzer from Jota located in Krakow, Poland. The temperature range tests ranged from 20 to 1000 °C, with a heating rate 10°C per minute in air atmosphere. The moulding sand was prepared in a disk-type LM mixer. The base consisted of quartz sand (100 parts by weight) from SIBELCO. Sodium silicate R145 (3.5 parts by weight) was used as the binder, and the hardener Flodur 1 was applied at a 5% ratio to the amount of binder. As an addition to the base, calcite marble with grain sizes of 0.20 mm, 0.16 mm and 0.10 mm was used. The reduced binder addition was due to the presence of carbonates in the additive, which accelerated the binding process, and it was determined experimentally.

The prepared dumbbell and rectangular samples were subjected to testing to deter-mine tensile strength (Rm) and bending strength (Rg). The measurement was performed using a strength testing machine Multiserw – Morek type LRu-2e. Measurements were carried out after 1 hour and 24 hours of curing. The permeability measurement was con-ducted using the WADAP apparatus, type LPiR1.

In accordance with the Polish standard PN-85/H11005, standard cylindrical specimens (φ50x50 mm) made from the tested moulding material were used for testing. Four pieces were made for the test, following the same procedure as expected for the tested material. These specimens serve as cores and are placed in the mould, the technological drawing of which, along with the model, is presented in Figure 1. The mould used for this technological test is made from the same type of moulding material as the specimens. The mould is filled with casting alloy, and after it cools down to environmental temperature, the assessment is carried out using the LUW-C device or its automatic version, LUW-CA. It is essential for the technological test to be examined along with the gating system. The measure of knock-out ability is the amount of work required to remove the specimen from the casting, which is calculated using formula (1) [1].

$$Lw = 1.63 \cdot n, \tag{1}$$

where:
Lw – work required to knock out the specimen from the mould [J]
1.63 – unit impact energy [J]
n – number of hammer strikes required to remove the core from the casting.

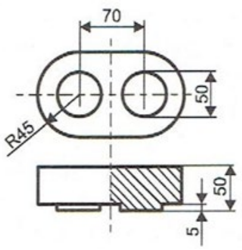

Fig. 1. The schematic diagram of the model used for mould preparation [1]

The study involved a loose, fast-setting moulding sand with sodium silicate as the binder and Flodur 1 as the hardener. For every 100 parts by weight of sand, 3.5 parts by weight of the binder and 5% of the hardener relative to the quantity of sodium silicate were added. A higher binder content was applied due to the increased use of the granular additive in the matrix. The lower than standard ratio of hardener to binder is due to the pro-environmental objectives of the study. Additionally, to improve knock-out ability, particles with sizes of 0.2 mm, 0.16 mm, and 0.1 mm were added to the moulding sand in quantities of 2 parts by weight and 3 parts by weight of powdered calcite marble from Spain. Figure 2 depicts the prepared lower half of the mould, which will be filled with liquid iron at a temperature of 1350°C. The study also included measurements of the tensile and bending strength of the tested material.

Fig. 2. The prepared drag of the mould with the placed specimens

3. Results and discussion

3.1. Thermal analysis

Figure 3 shows the results of thermal analysis for geological additive. From that figure it can be observed that the TG curve follows an initial increase, followed by a three-stage decomposition of the sample. The first stage begins at a temperature of around 30°C, as indicated by the first peak on the DTG curve. This is associated with an increase in moulding sand at the beginning of the process, followed by a gradual decrease in moulding sand. The second stage of sample decomposition begins at around 550°C, as indicated by a clear minimum on the DTG curve. On the TG curve, this is depicted as a more pronounced decrease in moulding sand. The next stage of sample decomposition is indicated by a second minimum on the DTG curve. It starts at a temperature of approximately 675°C. From the TG curve, it can be inferred that from this temperature until the end of the process, the further decrease in mass is gentler than in the previous phase of the studied process. The sample's mass decreased by 3.95 mg, which represents 0.26% of the sample's initial value.

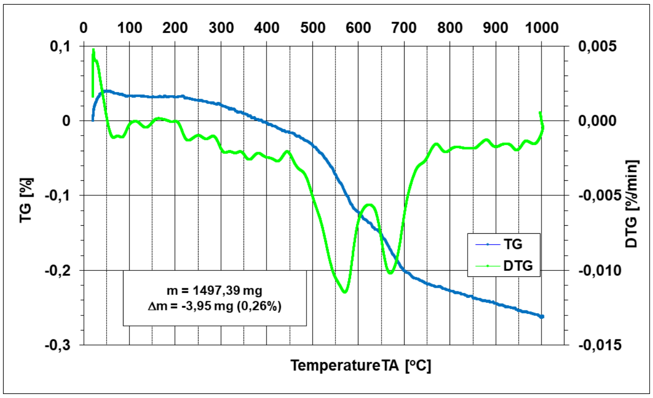

Fig. 3. TG and DTG of geological additive

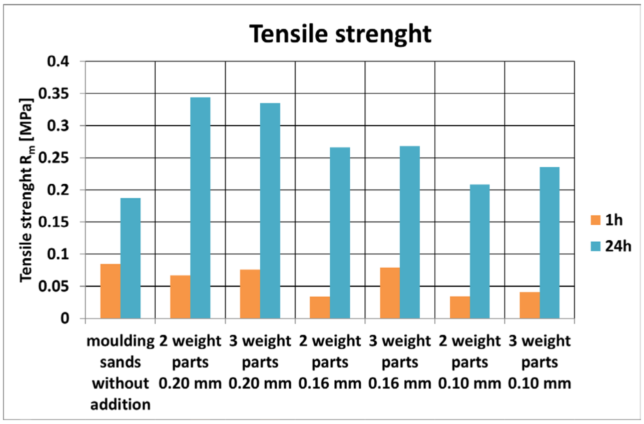

Fig. 5. Tensile strength of tested moulding sand with geological additive

3.2. Properties of tested moulding sands

On Figure 4 bending strength was presented, on Figure 5 tensile strength and on Figure 6 permeability of tested moulding sands was presented.

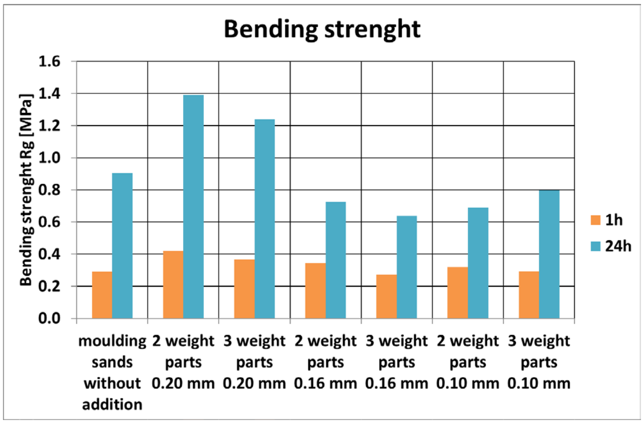

Fig. 4. Bending strength of tested moulding sands with geological additive

Regardless of the amount of additive used, after one hour of curing, the bending strength remains at a similar level in each case. After 24 hours of curing, the additive with a grain size of 0.2 mm significantly improves the bending strength values compared to the reference sample.

In the case of tensile strength, the values after a curing time of 1 hour are at a similar level. After 24 hours of curing, the applied additive has a beneficial effect on this parameter.

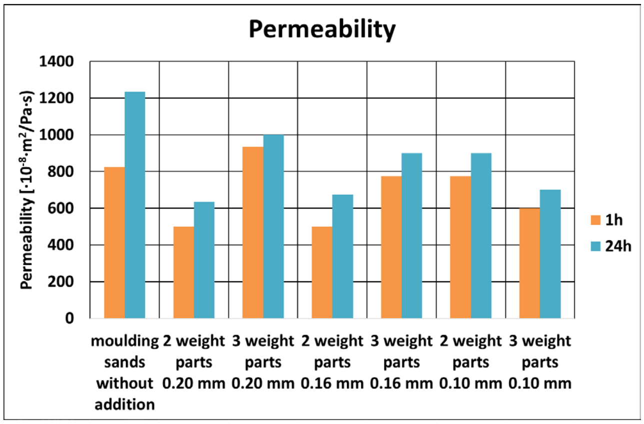

Fig. 6. Permeability of tested moulding sands with geological additive

In the case of each of the tested moulding sands, their permeability value increases after a curing time of 24 hours. The applied additive negatively affects the value of the tested parameter compared to the reference sample.

The applied additive of geological origin with a grain size of 0.2 mm in both cases of content 2 parts by weight and 3 parts by weight has a favorable effect on the strength properties of the molding sands. Unfortunately, it adversely affects the permeability of these sands, which can lead to the formation of defects of gaseous origin in the casting.

3.3. Hot distortion parameter

On Figure 7 Hot distortion parameter in time function was shown and on Figure 8 the same parameter in temperature function.

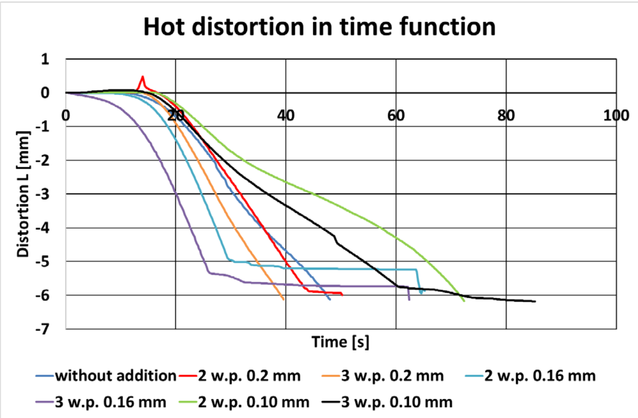

Fig. 7. Hot distortion parameter in time function

Based on Figure 7, it can be observed that the moulding sands exhibit almost 20 seconds of thermal stability under deformation, with the exception of the sand with the addition of 3 wt.% and a grain size of 0.16 mm, where the sample begins to deform after 4 seconds of heating. The sand with the addition of 2 wt.% and a grain size of 0.10 mm has the smoothest curve and also one of the longest thermal resistance times.

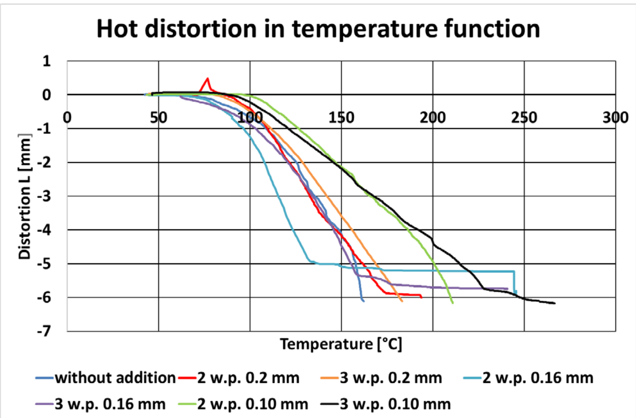

Fig. 8. Hot distortion parameter in temperature function

Most of the tested moulding sands exhibit temperature stability up to a heating temperature of around 100°C, after which they begin to deform negatively. The moulding sand with the addition of 2 wt.% and a grain size of 0.10 mm shows the smoothest deformation behaviour.

3.4. Knock out properties

On Figure 9 the amount of work, converted from equation (1), needed to remove the shapes made of the tested molding sands from the test casting is shown.

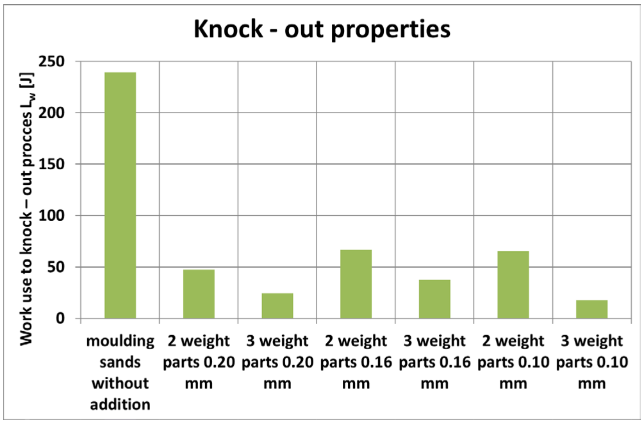

Fig. 9. Work use to knock-out properties of tested moulding sands

It can be observed that the proposed additive reduces the work re-quired to dislodge the sample. When comparing the work values, it is evident that an in-crease in the amount of additive improves the parameter being tested. The highest work value required to dislodge the sample for the mixture with the additive was obtained with 2 weight parts of grain size 0.16 mm, while the lowest value was observed with 3 weight parts of grain size 0.10 mm. The knock-out ability of the tested material improved by an average of 81.9% compared to the work value needed to dislodge the sample.

4. Conclusions

Based on the research, the following conclusions were drawn:

1. The addition of calcite marble improves the knock-out ability of loose, fast-setting materials with an inorganic binder in the form of sodium silicate.
2. The grain size of the additive used in the tested materials has a minimal effect on the work value required to dislodge the core from the iron casting
3. The grain size of the additive affects the values of bending and tensile strength
4. The addition of geological additive reduces the strength values after a short curing time

Taking into account all the developed parameters of the tested molding compounds, the mass with the addition of 3 parts by weight with a grain size of 0.2 mm can be considered optimal.

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