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Mechanical and Thermal Deformation of Hot-box Moulding Sands

A. Grabarczyk *, K. Major-Gabryś, St. M. Dobosz, J. Jakubski
AGH University of Science and Technology in Cracow, Faculty of Foundry Engineering,
Department of Moulding Materials. Mould Technology and Cast Non-Ferrous Metals,
Reymonta 23 Str., 30-059 Kraków, Poland
* Corresponding author. E-mail address: agrab@agh.edu.pl

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Abstract

The constantly developing and the broadly understood automation of production processes in foundry industry, creates both new working conditions - better working standards, faster and more accurate production - and new demands for previously used materials as well as opportunities to generate new foundry defects. Those high requirements create the need to develop further the existing elements of the casting production process. This work focuses on mechanical and thermal deformation of moulding sands prepared in hot-box technology. Moulding sands hardened in different time periods were tested immediately after hardening and after cooling. The obtained results showed that hardening time period in the range 30-120 sec does not influence the mechanical deformation of tested moulding sands significantly. Hot distortion tests proved that moulding sands prepared in hot-box technology can be characterized with stable thermal deformation up to the temperature of circa 320^{o}C.

Keywords: Innovative Foundry Technologies and Materials, Mechanical Properties, Moulding sands, Hot-distortion, Deformation

1. Introduction

The growing demands placed on moulding and core sands create the need to seek further solutions in terms of their properties. There are several requirements that a modern core mixture has to face, among them are: high resistance to humidity and temperature (mainly during storage), sufficient strength (both for handling and mould assembly), high resistance to erosion and penetration by molten metal, low thermal deformation. What is more, modern moulding and core sands should be easy to shake-out from the finished casting, and need to have good reclamation abilities followed by low emission [1-5].

This growing requirements create the need to develop elements of the casting production process, which so far haven't been fully researched. These include two types of technological processes. The first is the moment of setting the cores inside the moulds, where, especially in the case of highly mechanized foundries [1-3, 5], core damage can occur, sometimes without the possibility to remove the defective mould from the processing line. This process has been analysed in this work under the term of mechanical deformation. The second process that can affect the accuracy of the casting is the deformation of the core during the initial pouring process. The deformation during this process is referred to as hot-distortion parameter [5].

The aim of this paper is to show the influence of hardening time of moulding sands prepared in hot-box technology on mechanical deformation tests done in ambient temperature and thermal deformation analysis.

The classic hot-box process is a development of the shell-forming process [6]. Due to the high strength and resistance of the cured moulding sand, this technology is used to produce the most responsible cores, such as cores used for detailed internal engine cooling parts. The shell-forming method for making thin-walled castings is still widely used, especially in the automotive industry [6-8]. Although the most popular version is based on organic resins, the inorganic technology developed on the basis on hydrated sodium silicate is gaining interest in companies as well as researchers [9-12].

2. Methodology

The paper presents tests of the mechanical deformation in ambient temperature and thermal deformation of moulding sands prepared in hot-box technology. Tests were carried out on moulding sands with phenolic resin, prepared in accordance with the recommendations of binder manufacturer [13], in a Vogel & Schenmann laboratory mixer, with a capacity of 6 kg. The hydrothermal conditions in which the mixtures were prepared and the fittings were stored ranged between 22-26°C and 30-32% humidity. The hardening process was conducted in the temperature of 220°C in different time periods (30 s, 60 s, 90 s, 120 s), detailed sample symbols were placed in Table 1. The mechanical and thermal deformation tests were performed immediately and after the samples have reached room temperature. A minimum of 3 samples was used for each test.

For the mechanical deformation and bending strength tests, the indenter velocity was set for 20 mm/min.

The heating temperature for hot-distortion tests was set to 900°C.

Table 1.
Samples

Sample symbol	Hardening time [s]
A (sample tested immediately - hot)	30/60/90/120
B (sample tested after cooling - cold)	

The studies investigated the influence of the hardening time of the samples on: bending strength R_g^u and sample resistance to mechanical deformation, in two variants "hot" – referring to tests carried out immediately after removing the sample from the heated core-shooter, and "cold" – after the samples have reached ambient temperature. Thermogravimetry studies of moulding sands were also carried out, as well as the thermal deformation (i.e. hot-distortion parameter analysis) after 24 hours from the preparation of the samples.

2.1. Mechanical deformation tests

Measurement of moulding sands resistance to mechanical deformation has been tested on a universal apparatus for studying hot-distortion phenomena and bending strength R_g^u, produced by Multiserw-Morek Company.

Standard longitudinal samples are used in this test. The measuring equipment (Fig. 1) as well as the whole process has been described in detail in previous works of authors [7, 15].

Fig. 1. Universal Hot-Distortion and Bending Strength Machine [14]

2.2.Thermal deformation tests

Measurements of the hot-distortion parameter are carried out on rectangular samples which measure 114x25.4x6.3 mm (Fig. 2), on Multiserw-Morek Company measuring equipment.

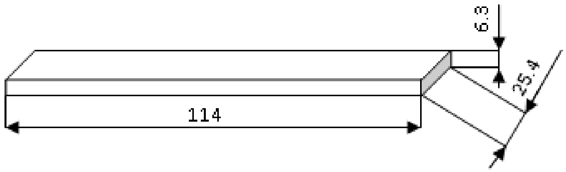

Fig. 2. Hot-distortion sample[16]

Moulding sand samples have been compacted on LUZ-1 vibration device and placed in a preheated furnace (220°C) for 10 min (sample no. 1, Fig. 6) and 15min (sample no. 2, Fig. 6). The thermal deformation tests were performed after the samples have reached room temperature.

The measuring device as well as the methodology has already been described in previous works of authors [5, 15].

3. Own research

The following paper focuses on the analysis of the influence of hardening time periods on mechanical and thermal deformation of hot-box moulding sands. Obtained results were divided into two groups – mechanical deformation in ambient temperature and thermal deformation.

Organic resin in the amount of 2.0 parts per weight (p.p.w.), accompanied with 0.4 p.p.w. of hardener, were used in moulding sand composition. 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.

3.1. Mechanical deformation

The first stage of the research were mechanical deformation tests (conducted in ambient temperature) of chosen moulding sands. The tests were carried out according to the methodology presented in point 2.1 of this paper. The obtained results are illustrated in Fig. 3-5. All tested moulding sand samples showed similar tendencies in growth of deformation accompanied by the growth of applied force. The results obtained in the tests carried out immediately were characterized by a large discrepancy depending on the time of samples hardening in the core box. The lowest result was recorded for the moulding sand heated for 30 seconds (s), reached 0.25 mm for 144 N of pressure. The remaining samples were achieved values of 0.23 mm deformation at 115 N for samples heated for 60 s, 0.27 mm for 130 N pressure - samples hardened for 120 s, and 0.33 mm at 155 N for samples kept in the core box for 90 s.

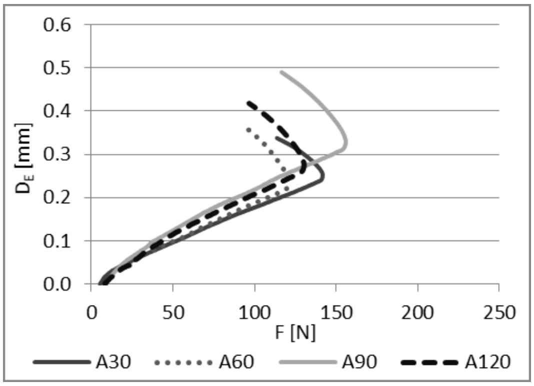

Fig. 3. Mechanical deformation curves (A-immediate tests)

Assuming the pressure was constant, the moulding sands did not exhibit large discrepancies in deformation. For the deformations for a set pressure of 50 N, the analyzed samples ranged from 0.11 mm to 0.13 mm.

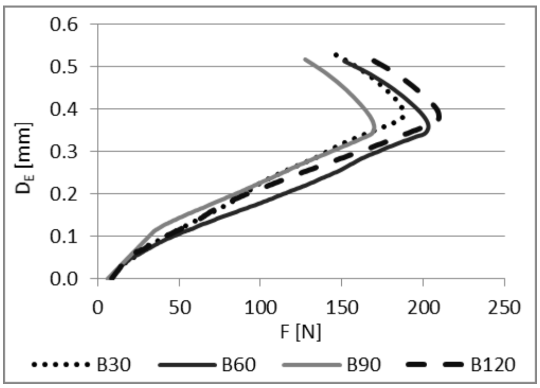

Fig. 4. Mechanical deformation curves (B-tests performed on room temperature samples)

The results obtained in B-tests (carried out on samples which reached room temperature) are different. The maximum deformation for all tested moulding sand samples was between 0.32 and 0.40 mm, under pressures of 170-222 N. The strain at constant force of 50 N was 0.10 mm, for all samples with the exception of the one with the curing time of 90 seconds.

Fig. 5 shows the influence of hardening time on bending strength of tested moulding sand. Bending strength of samples tested immediately – hot, increase with the increase of hold-up time, from 2.4 MPa for samples hardened for 60 s, to 3.07 MPa in samples hardened for 120 s. The exception is the moulding sand heated of 30 s, for which the average results reached 2.9 MPa.

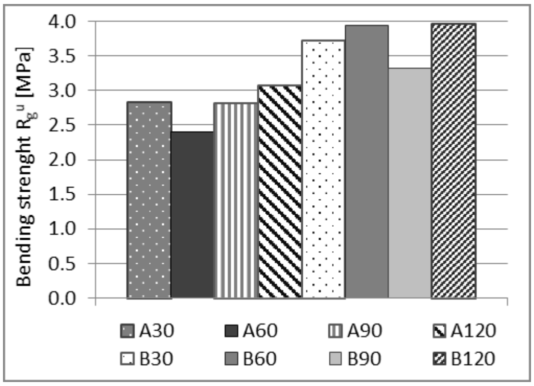

Fig. 5. Bending strength results (A and B)

The results of the bending strength tests (Fig. 4) of cooled down samples (B) oscillate around 4 MPa, the lowest result of 3.32 MPa was obtained for the moulding sand heated for 90 s, while the highest 4.45 MPa for the sample heated for 120 s.

3.2. Thermal deformation

The second stage of the research was focused on thermal deformation tests of chosen moulding sands. The tests were carried out according to the methodology presented in point 2.2 of this paper. The obtained results are illustrated in Fig. 6-7.

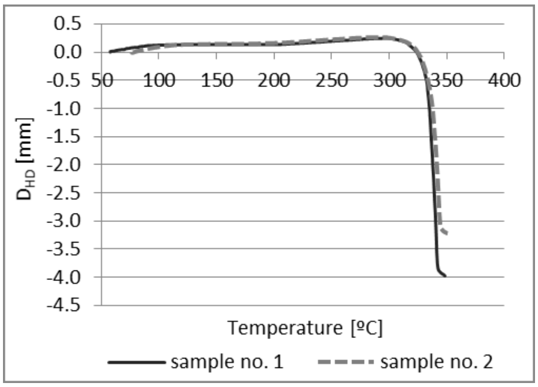

Fig. 6. Thermal deformation of the sample as function of temperature

The obtained thermal deformation graphs of the hot-box moulding sands (Fig. 6-7), show a slight increase in sample deformation, that can be observed as the temperature rises. Its maximum value reached 0.3 mm for the temperature of 320°C. The sample heating time was within 70-80 seconds.

The stable course of the hot-distortion parameter tests is the most desirable result. The situation in which the sample does not deform under the influence of high temperature and sustains it's original shape, is the most desirable one. This result is not affected by the difference in sample hardening time (sample no. 1 and 2, Fig. 6-7).

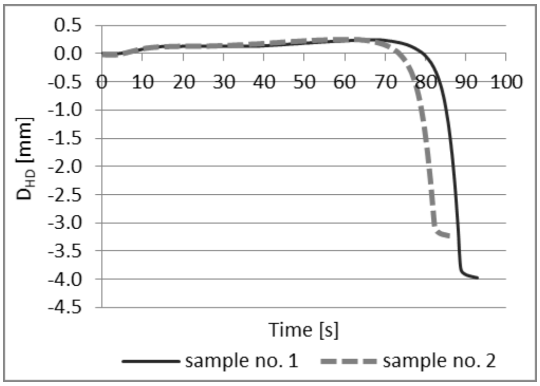

Fig. 7. Thermal deformation of the sample as function of time

The observed moment of destruction is related to the plasticity and deflection of the fitting, not its violent fracture, as is the case with loose, self-hardening moulding with furfuryl resin [17-19].

5. Conclusions

The conducted research allowed to formulate the following conclusions:

- The hardening time in the range 30 – 120 sec in temperature of 220°C does not impact significantly the mechanical deformation and the bending strength of tested moulding sand. It seems enough to harden moulding sands
- Moulding sands prepared in hot-box characterize with good heat stability up to the temperature of about 320°C.
- Long time (about 75 sec) needed for hot-box samples destruction can be advantageous in terms of the time of contact of the moulding/core sand with elevated temperature during and after the pouring process.

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