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THE INFLUENCE OF MOULDING SAND TYPE ON MECHANICAL AND THERMAL DEFORMATION

Casting industry has been enriched with the processes of mechanization and automation in production. They offer both better working standards, faster and more accurate production, but also have begun to generate new opportunities for new foundry defects. This work discusses the disadvantages of processes that can occur, to a limited extend, in the technologies associated with mould assembly and during the initial stages of pouring. These defects will be described in detail in the further part of the paper and are mainly related to the quality of foundry cores, therefore the discussion of these issues will mainly concern core moulding sands. Four different types of moulding mixtures were used in the research, representing the most popular chemically bonded moulding sands used in foundry practise. The main focus of this article is the analysis of the influence of the binder type on mechanical and thermal deformation in moulding sands.

Keywords: foundry engineering, moulding and core sand, organic and inorganic binder, mechanical deformation, thermal 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, have good reclamation abilities and low emission [1-4]. Meeting all those requirements is a thought issue on its own, but lately it is not enough.

The constantly developing and the broadly understood automation of production processes in foundry industry (Fig. 1), creates both new working conditions and new demands for previously used materials. Those high 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], core damage can occur, without the possibility of removing the defective mould from the processing line. This process has been analysed in this work under the term of mechanical deformation.

Fig. 1. Automated core and mould assembly [3]

The second process that can affect the accuracy of the casting is the deformation of the core during the initial pouring process. The process begins with the first drop of liquid metal that is poured into the mould cavity, and ends when the mould is filled. The pouring process can be divided into two: the first part when only radiation heating from the metal surface occurs, and the second – when the whole core is surrounded with liquid metal. The deformation of the core can affect the casting most in the initial stage of pouring. Due to temperature differences on the top and bottom of the core, a gradient of temperatures forms,

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and becomes the driving force of occurring deformation. The deformation during this process is referred to as hot-distortion parameter [5].

2. Research methodology

The moulding sands chosen for the research are self-hardening moulding sands with organic and inorganic binders belonging to the group of universal applications (used as mould and core compounds), like furfuryl resin moulding sands, and also cold-box, hot-box and hydrated sodium silicate moulding sands.

All of the tested moulding sands were prepared in accordance with the recommendations of the manufacturers of given binders [6-7] in a Vogel & Schenmann laboratory mixer, with a capacity of 6 kg. The hygrothermal conditions in which the mixtures were prepared and the fittings were stored ranged between 22-28°C and 30-34% humidity. The mechanical and thermal deformation tests were performed after 24 h, and minimum of 3 samples were used for each test.

The indenter velocity was set for 20 mm/min. The heating temperature for hot-distortion tests was set to 900°C.

2.1. Mechanical deformation

Measurement of moulding sands resistance to mechanical deformation has been realized on a universal apparatus for studying hot-distortion phenomena and bending strength, produced by Multiserw-Morek Company (Fig. 1) [8].

The measurement of mechanical deformation is based on the analysis of the deflection curve of a standard longitudinal sample (Fig. 2) during bending. The device allows to make measurements of the pressure course of the indenter during its displacement. This allows the user to determine both bending strength R_g^u and deflection of the tested sample. The measurement range is 0 to 900N [8].

Fig. 2. Universal apparatus for studying hot-distortion phenomena and bending strength, produced by Multiserw-Morek Company [10]

Test parameters were chosen on the basis of previous research done on the device, to determine the optimal velocity of the indenter [9].

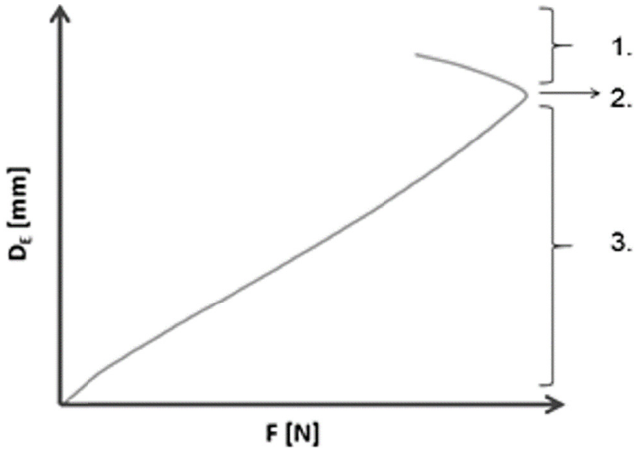

Fig. 3. Analysis of the mechanical deformation curve [9]

The performed elasticity tests are analogical to standard bending strength tests, that are popular among foundry industry. They have been developed and well described in domestic and foreign literature [11-12]. The bending test maximum strength can be calculated from the maximum force that the sample has reached, since it is the moment (Fig. 3, point 2) of sample destruction under the applied bending force. Points 1 and 3 on Fig. 3 diagram refer to 1-fragment of the curve connected with the return of the indenter, 3-the indentation pressure on the fitting, that causes the deflection in form of a rising curve. This allows the user to test one sample and derive two parameters from the test outcome.

2.2. Thermal deformation

The thermogravimetric analysis was carried out on the derivatograph of the Hungarian company MOM system F. Paulik-J. Paulik-L. Erdley, according to standard procedures [13]. The heating velocity was set to 10°C/min and the maximum temperature reached 1000°C. The TG analisys in moulding sands, usually is focused on determining certain sample properties of binders and sands, for example parameters of moulding sand reclamation, binder degradation etc. [14-15].

Measurements of the hot-distortion parameter were carried out on rectangular fittings (114×25; 4×6.3 mm) (Fig. 4), on Multiserw-Morek Company apparatus. Measurement is performed slightly differently from the previous version of the apparatus designed to determine this parameter. The device is a development of it's previous version described in detail in earlier works [5,16]. A few changes have been made in the device's heating system, allowing the heating temperature to be stabilized independently for the upper and lower heating elements which constitute of ceramic heaters with the power of 2×400 W. Additionally the heating power control has been introduced in the

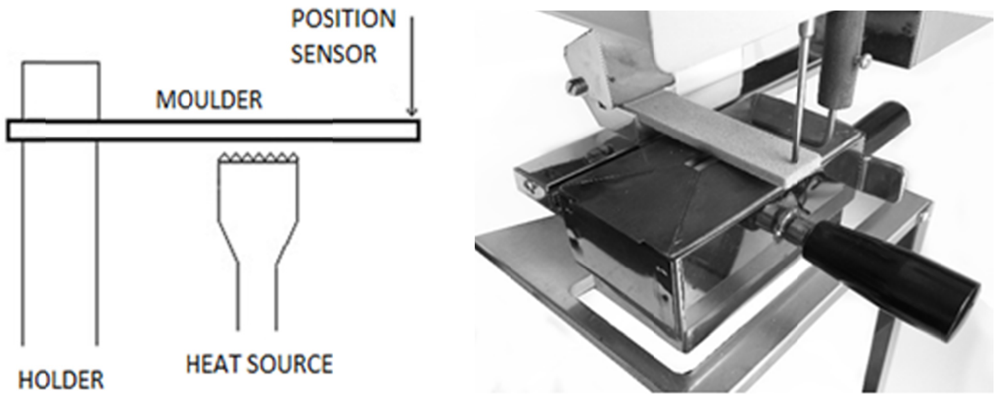

Fig. 4. Hot-distortion test scheme and sample mounted with the lower heating plate placed below [16]

range from 0 to 100%, with a step of 1%. The heating temperature ranges from room temperature to 900°C with a step of 1°C, while the maximum deformation can range up to 10 mm.

3. Own research

The following paper focuses on the analysis of the influence of the binder type on mechanical and thermal deformation in moulding sands. Obtained results were divided into two groups – mechanical and thermal deformation.

All moulding sands that were chosen for the research were prepared according to the methodology presented in point 2 of this paper. 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.

Detailed moulding sands compositions have been presented in Table 1. The obtained results are illustrated on Fig. 5-9.

TABLE 1

Composition of tested moulding sands.

Signature	Sand	Binder	Hardner
Furfuryl resin technology	Quartz sand 100 p.p.w.	Furfuryl resin Kaltharz XA-20 1.1 p.p.w.	100T3 0.55 p.p.w.
Col-box technology		GASHARZ 6966 0.8 p.p.w.	AKTI-VATOR 7624 0.8 p.p.w.
Hot-box technology		Thermoset 2000 2.0 p.p.w.	Härter AT7 0.4 p.p.w.
Ester technology		Hydrated sodium silicate 145 3.0 p.p.w.	Flodur 3 0.30 p.p.w.

3.1. Mechanical deformation tests

The first stage of the research were mechanical deformation tests 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 on Fig. 5-6.

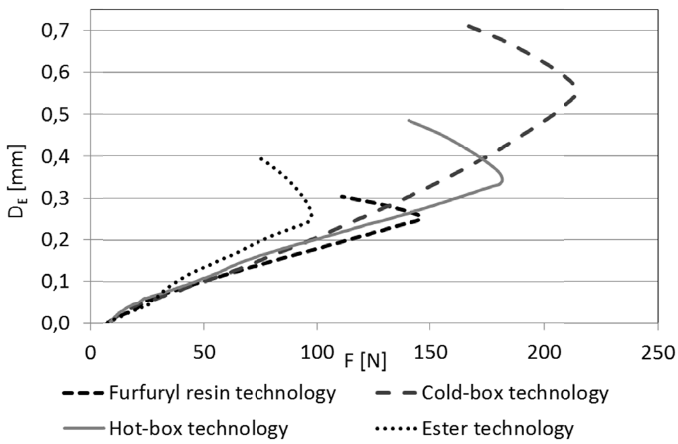

Fig. 5. Mechanical deformation of chosen moulding sands

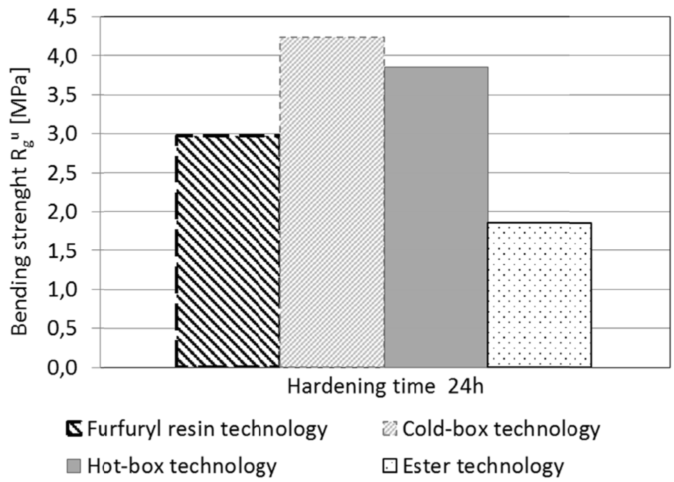

Fig. 6. Bending strength R_g^u of chosen moulding sands

All tested moulding sand samples showed similar tendencies in growth of deformation with the growth of applied force (Fig. 5). The highest deformation has been noted for the cold-box moulding sands, and it reached 0.56 mm under the force of 215 N. Under a slightly lower force of 180 N, hot-box moulding sands showed deformation of 0.33 mm, which was almost 41% less the deformation achieved for cold-box sample. Considering the obtained bending strength results (Fig. 6), the outcome is similar to the highest obtained force achieved by the samples during the deformation tests (Fig. 5).

Furfuryl resin moulding sands resisted the bending force of 145 N followed by 0.25 mm deformation. The same deformation but accompanied with a lower force was measured for inorganic moulding sands, bonded with hydrated sodium silicate with ester binder. The deformation for this mixture reached 0.25 mm under the force of 97 N, being 67% lower than the organic furfuryl resin moulding sand.

The highest bendng strength in the conducted tests was obtained for cold-box sand sample, and reached 4.3 MPa. Hot-box moulding sand followed this result reaching 3.85 MPa, being 11% less than cold-box. Two lowest results belonged to furfuryl resin moulding sand – almost 3.2 MPa, which was 27% less than cold-box, and inorganic hydrated sodium silicate moulding sand – 1.85 MPa, being less than a half of what was achieved by cold-box samples.

3.2. Thermal deformation tests

The second stage of the research were 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 on Fig. 7-9.

Termogravimetric analisys was performed for all of the moulding sand samples (Fig. 7). The analysis was performed to determine the loss of sample mass during heating and to distinguish the temperatures in which the weight procentage of the sample drops rapidly (Fig. 8).

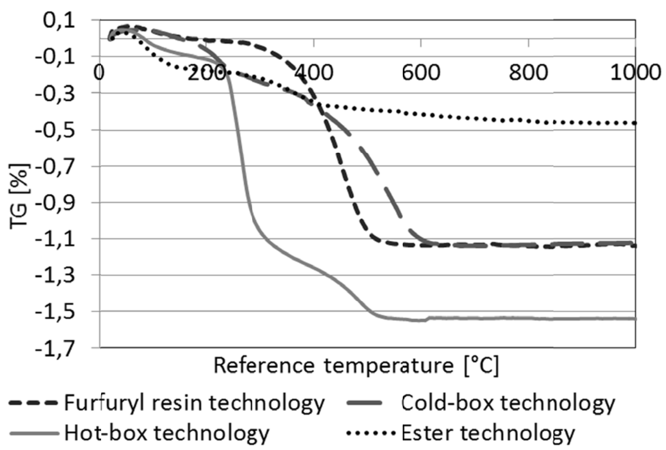

Fig. 7. Thermogravimetric curves for chosen moulding sands

The results of thermal deformation test, also known as the hot-distortion parameter, are shown on Fig. 8-9.

The thermal deformation of the moulding sand with furfuryl resin has a typical pattern with intense deformation reaching 5.3 mm in 495°C of the sample and its sudden destruction in temperature of about 495°C – the deformation was in the opposite direction to the heat source. Thermal deformation tests (hot-distortion parameter) showed that moulding sands prepared in ester technology and moulding sands prepared in cold-box and hot-box technology characterize with better heat stability than the moulding sands with furfuryl resins. Both tested mixtures exhibit almost no thermal deformation in the temperature range of 0 – approx. 160°C. After crossing the above mentioned temperature samples are subjected to mild deformation until they are damaged. Hot-box moulding sand is the most stable of all of the tested samples. It shows no deformation up to 315°C, when the sample starts to bend towards the heat source, causing a uniform and quick deformation.

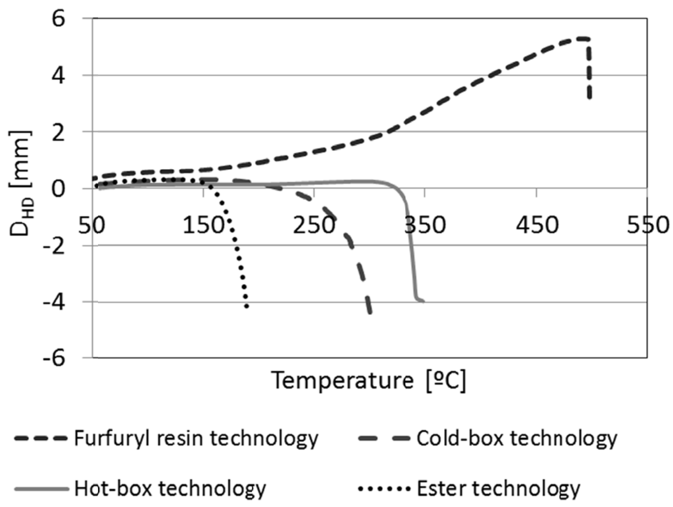

Fig. 8. Thermal deformation of chosen moulding sands (in temperature) function

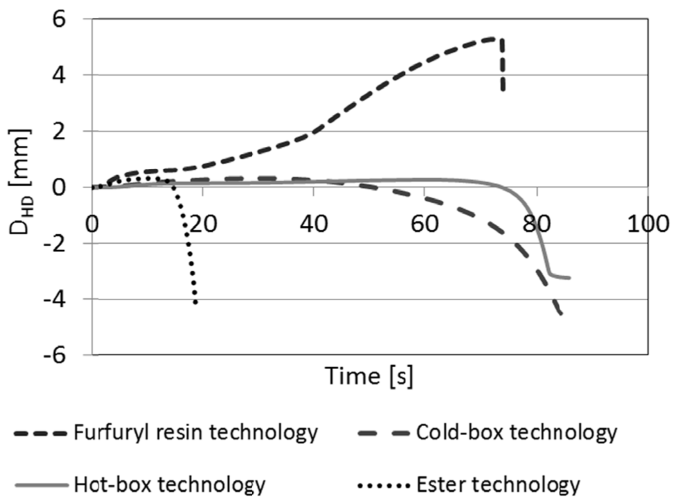

Fig. 9. Thermal deformation of chosen moulding sands (in time) function

The moulding sands prepared in hot-box and cold-box technology characterize with a longer time needed for the sample destruction – about 75 seconds – hot-box and 45 – cold-box, while the sample made in ester technology begins to degenerate after about 15 sec (Fig. 9). This can be advantageous in terms of the time of contact of the moulding/core sand with elevated temperature during and after the pouring process.

4. Conclusions

Literature analysis and own research allowed to formulate the following conclusions:

- There are significant differences in both deformation extend and bending strength levels of moulding sands, depending on the binder used.
- Presented research proves that the change of used binder and moulding technology influences the level of moulding sand mechanical deformation in ambient temperature.
- Moulding sands prepared in cold-box, hot-box and ester technology characterize with better heat stability than moulding sand with furfuryl resin.
- Longer time needed for hot-box and cold-box samples destruction than achieved for moulding sand prepared in ester technology, can be advantageous in terms of the time of contact of the moulding/core sand with elevated temperature during and after the pouring process.

The presented results are part of a broader, ongoing research concerning mechanical and thermal behaviour of various types of moulding and core sands.

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