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ELASTICITY OF CORES MANUFACTURED IN COLD BOX TECHNOLOGY

In the foundry industry, as in many other fields we seek to achieve the best quality with the least losses and the lowest cost. To meet these demands numerous plants increased automatization of their manufacturing processes. However, with changes in the production process it is necessary to change also the materials used. Not only casting alloys that are used in production, but also applied moulding and core sands are important. Proper selection and evaluation of the properties of used moulding mixtures is crucial in order to achieve a highly efficient production. In this article a new issue concerning the use of flexibility in foundry molding and core was mentioned. It explains the principles of measurement and interpretation of the obtained results for the cold-box moulding sands.

Keywords: moulding sands, cold-box technology, elasticity of moulding sands

1. Introduction

Foundry is one of many industries that undergo the processes of significant mechanization and automation. Those processes are necessary for the foundry development and stabilized production. The metallurgical industry focuses on the production of more complex high quality castings. In addition to cast parts properties, aspects such as the cost of mould making and fettling are extremely important in the production. They depend directly on the quality of moulds and the applied molding technology. One of the most sensitive components in the mould, irrespective of the material used, are cores. Not only are they often the thinnest elements in the mould, but they are also exposed to the most intense influence of liquid metal. Under such conditions, they must provide adequate representation for both the dimensions and the inner shapes of the casting.

An important element in determining the quality of the casting are processes occurring in the course of core setting operations and mould assembly, and at the initial time of pouring. These processes are only partially explored and rarely reported in the literature. Moulding materials are exposed to a variety of forces during preparation, transport or moulding. Additional steps such as removing the cores from the core box, moving cores, storage and installation of core in the mould, to the process of pouring liquid alloy, expose the cores to damage. Even small cracks or dimensional changes may later become a source of flaws in castings. The importance of this issue is being noticed more and more, especially in foundries with a high degree of automation, aimed at high production with the use of manipulators.

Another important issue are the processes of occurring in the initial stage of pouring. They can cause thermal deformation of the core generating hard to repair or even irreparable casting defects. The evaluation of the moulding material tendency to deform in heat (hot distortion parameter) and the results of these studies, together with a detailed description of the device were presented by the authors in separate publications [1].

In this article, the authors would like to introduce a new method of measurement, including an assessment of the flexibility of chosen molding sands, which determines the tendency of cores to break during installation. The studies relate to one of the moulding mixtures with synthetic resin – precisely cores manufactured in cold-box technology.

2. Deformations in moulding sands

In the polymer field, which is closest to the casting resins, flexibility is sometimes correlated with elasticity. Perfectly elastic material after being stretched should always come back to its original state without absorption (loss) of mechanical energy, just as the perfectly elastic body. In practice, however, we are dealing with real materials that deviate from the ideal assumptions. Thus, in the physics of polymers the term viscoelastic strain is used [2].

The polymeric materials may have different proportions of both the elastic (elastic) and plastic (permanent) deformation. The shares of these deformations depend on many parameters, for example strain rate, temperature, deformation range [3-5].

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Straightening of swirled macromolecular chains of the polymer during the elastic deformation causes a reduction in entropy, resulting in heat generation in the material. After removing the force which caused the deformation the flexible material tends to increase the entropy – accompanied by absorption of heat [2].

At lower stresses moulding sands show some flexibility. However, it decides the resiliency of moulds and cores during installation forms. It is preferable to keep it as large as possible. After crossing the maximum stress the process of cracking and irrevarsable damage initiates.

To fully answer the questions about moulding sand flexibility and its mechanical destruction, we must first focus on the bonding process. The mechanical strength of moulds and cores is one of the most important properties of these materials and it not only determines the quality of the casting, but also influences the economic side of technology. Moulding sands initial strength, strength after curing or at elevated temperature, is mainly an outcome of to the interaction between the binder and the sand matrix. In this analysis adhesive-cohesive properties of the binder surrounding quartz grains appear. During mechanical destruction of the bond between the grains, the plane of the destruction may take place in different places, depending on the relative values of forces of cohesion – force between the layers and the binder, and adhesion- force between the binder and the surface of the grains of quartz matrix. Here you can extract the following cases:

- Cohesion forces are greater than the forces of adhesion. Occurs when the destruction of the surface of the matrix grains of the quartz. This is known as the so-called adhesive nature destruction. An example of this are the moulding sands with synthetic resins (organic binders).
- Cohesive forces are smaller than the adhesive forces. The destruction extends inside the binder layer, it is expressed as a so-called cohesive nature of destruction. An example of this the moulding sands with hydrated sodium silicate (inorganic binders).
- The forces of adhesion and cohesion are in balance. The destruction can run both on the surface of quartz grains and inside the binder, it is expressed as a so-called mixed character of destruction. An example of this are moulidng sands with bentonite (green moulding sands).

In this study, moulding sand samples were considered as a heterogeneous material composed of quartz sand matrix bonded with resin. Due to the nature of the two components any changes on the level of a single quartz grain were not considered, for the purposes of this analysis it is assumed that the grain is not subject to deformation or any breakage does not occur through the center of the quartz grain. The testes element is the resin surrounding quartz grains and the nature and course of the breakage plane in the sample. Since the cohesive force of the resin is several times higher than the strength of adhesion (connections between binder and matrix in the case of moulding sands with synthetic resin) initiation of the cracking process after the threshold of flexibility occurs on the surface of the sand matrix.

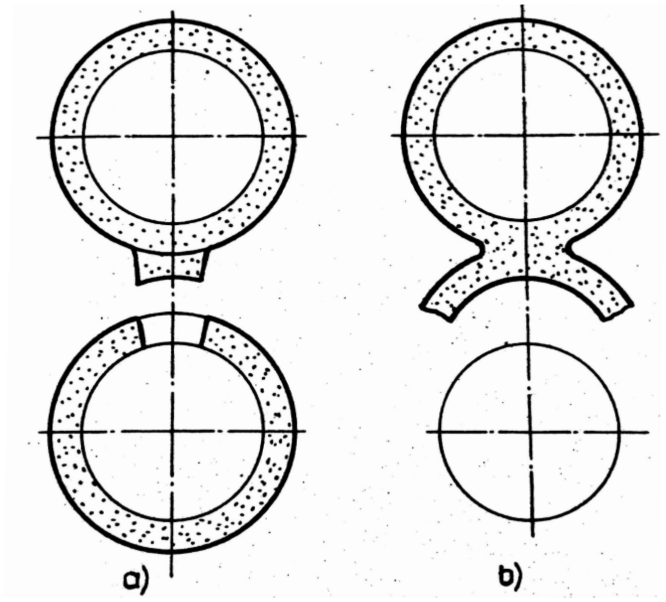

Fig. 1. Breakage plane in moulding sands with synthetic resin – adhesive character of destruction [6]

This article describes ongoing research of moulding sands in the technology of amine cold-box process. The effect of the amount of the binder and the ratio of both parts of the binder on the flexibility of moulding sands was analyzed. Moulding sands compositions are detailed in Table 1. The moulding sands were compacted on a laboratory scale core shooting machine type LUT and cured with amine GH6 2,47 ml/kg of moulding sand.

3. Measurements

The research was conducted on a new prototype testing appliance LRu-DMA produced by MULTISERW-Morek company, at the Department of Moulding Materials, Mould Technology and Cast Non-Ferrous Metals at Faculty of Foundry Engineering, AGH University of Science and Technology in Krakow.

The new measuring equipment consists of two incorporated modules: hot distortion – dedicated for measuring thermal distortion [7], and D_E – dedicated for elasticity measurement (local bending radius and maximum force detection).

In this article authors focused on determining the elasticity of chosen moulding mixtures (Table 1).

TABLE 1

Compositions of tested moulding sands

Name	Resin	ppw	Hardener	ppw	Sand	ppw
0.8-0.8	phenol-formaldehyde resin	0,8	polyiso-cyanate	0,8	quartz sand	100
1.0-1.0		1,0		1,0		100
1.2-1.2		1,2		1,2		100
0.8-1.2		0,8		1,2		100
1.2-0.8		1,2		0,8		100

4. Elasticity of chosen moulding sands

Measurements of the elasticity were made on a new prototype device. The measurement were based on an analysis of the course of the longitudinal deflection of the standard moulders during bending. The unit allows you to make measurements the indenters force in time with the registration of its movement. Based on the results bending strength R_g^u can be calculated. The measuring range reaches from 0 to 900 N, in addition it is possible to adjust the speed of the indenter in the range of 0 to 70 mm / min in steps of 1 mm. Built-in database allows you to determine the size of the moulders for different types of strength testing from R_g1 to R_g9, there is also a possibility of introducing any dimension of tested moulders. There are two types of supports included, they can be secured to two different distances – 10 and 15 cm apart.

Obtained measurements of elasticity are shown in Fig. 2. The plot represents the force growth with its impact on elasticity, which is represented by the bend of a standard linear moulder. The force increase is nearly linear as well as the bend growth on the sample. The destruction of the sample occurs at the bending point on the curve – 222 N and 0,42 mm for moulding sand 0.8-0.8, 230 N and 0,44 mm for moulding sand 1.2-0.8, 310 N and 0,54 mm for moulding sand 1.0-1.0, 324 N and 0,55 mm for moulding sand 0.8-1.2, and 325 N and 0,63 mm for moulding sand 1.2-1.2. The remaining line is a representation of the device reversion. It was left on the graph to better show the movement of the indenter and the bend of the sample.

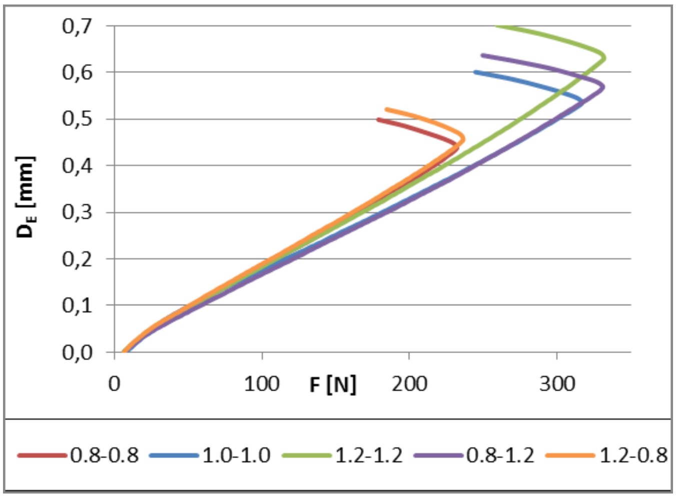

Fig. 2. Elasticity D_E of chosen moulding sands (Table 1) after 24 h of hardening

Moulding mixture containing 1.2 ppw. of phenolic resin and 1.2 ppw. polyisocyanate (Table 1) showed the highest flexibility (Fig. 2), reaching 0,63 mm, at the same time the highest force equal 325 N. Moulding sand 1.0-1.0 and 0.8-1.2 reached similar levels of elasticity amounting to 0.5 mm at a pressure of 300 N. Significantly lower results were obtained for the moulding sands 0.8-0.8 and 1.2-0.8. Both tested mixtures reached maximum flexibility of roughly 0.45 mm at a force of 230 N. These relationships are also shown in (Fig. 3).

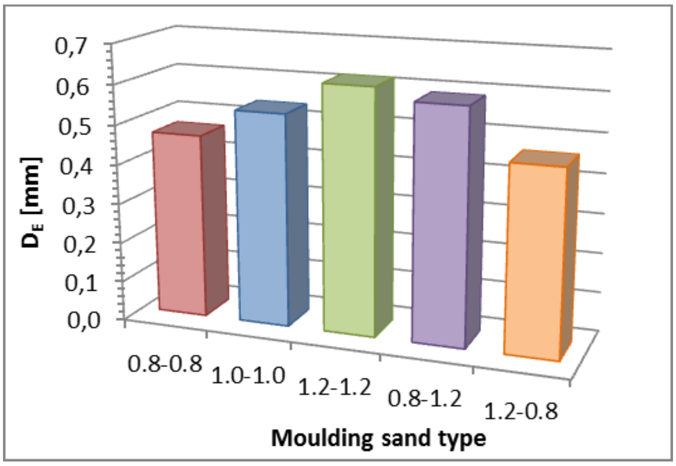

Fig. 3. Elasticity D_E of chosen moulding sands (Table 1) after 24 h of hardening

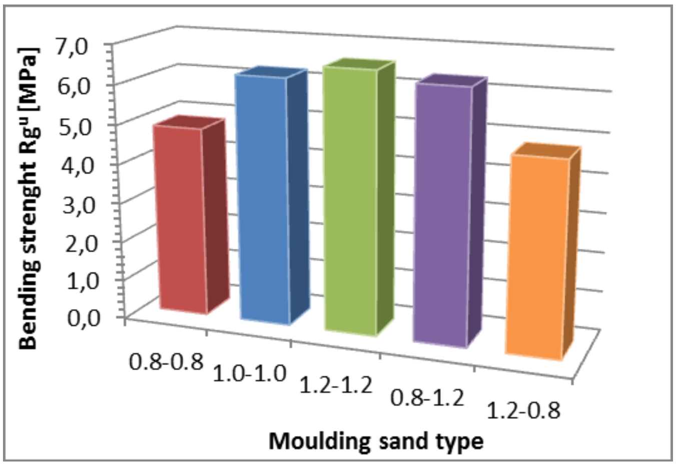

Fig.4. Bending strength R_g^u of chosen moulding sands (Table 1) after 24 h of hardening

The test results of bending strength R_g^u are shown in Fig. 4. They present a similar trend. The strength of 1.2-1.2 moulding sand reached 6,70 MPa, where 0.8-12 moulding mixture had 5.5% less (6,33 MPa), and 1.0-1.0 moulding sand reached 6.5% lower bending strength than the highest obtained result (6,26 MPa). Similarly to the flexibility the lowest rates were recorded for moulding sands 1.2-0.8 – 4.83 MPa (8% less); and 1.2-0.8 – 4,84 MPa (7.8% less).

Analyzing the results of the research it can be seen that – for the tested moulding sands – flexibility is associated with bending strength. The more a moulding sand is durable the greater the flexibility of the moulder is.

5. Conclusions

1. Studies have shown that the new device is very useful for determining the elasticity of moulding sands, which can be very helpful to evaluate the susceptibility to cracking of cores during the assembly operations and transport.

2. 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 cores of larger size and different geometry the results might differ. This method can however be used to compare different types of moulding mixtures.
3. The studies include the properties of the cold box moulding sands. Other moulding sands may behave differently. Therefore, studies should be regarded as preliminary.

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