www.czasopisma.pan.pl PAN www.journals.pan.pl

ARCHIVES
of
FOUNDRY ENGINEERING

DOI: 10.24425/118805

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (2299-2944)
Volume 18
Issue 1/2018

19 – 22

4/1

Research on the Energy of Destruction of Bindings of a Core and Moulding Sand Based on Quartz Sand Grains

R. Dańko *, G. Dajczer
AGH – University of Science and Technology, Faculty of Foundry Engineering
Reymonta 23 Str., 30-059 Kraków, Poland
*Corresponding author. E-mail address: rd@agh.edu.pl

Received 26.08.2017; accepted in revised form 22.10.2017

Abstract

In the knock-out process, as well as in the preliminary phase of moulding sand reclamation, the issue of energy demand for the process of crushing used sand agglutinations, preferably to single grains, is particularly important. At present, numerical values of moulding sand impact resistance, which would allow energy-related aspects of this process to be forecast, are not known, as such research has not been carried out. It seems that impact resistance tested on very small cross-section samples, which allows us to very precisely reveal some unique features of a moulding sand with organic and inorganic binders, is an important parameter, which so far has not been taken into account for evaluation of mechanical properties of moulding sands.

Preliminary attempts to determine impact resistance of moulding sands have been carried out as part of own research of the author. The conducted investigations aimed at determining the relationships between the obtained values of tensile strength and impact resistance of moulding sands. In addition, the effect of holding samples at temperatures of 100^{0}C, 200^{0}C, 300^{0}C on the value of impact resistance was determined, both for sands made with fresh and with reclaimed sand grains.

Keywords: Moulding sand, Deformation energy, Impact resistance, Tensile strength

1. Introduction

At present, processes concerning energy consumption of crushing processes, covered by loose medium mechanics, have been analysed on the basis of model investigations [1-6]. However, these investigations do not give a direct answer to the question about the relationship between the values of tensile strength of moulding sands obtained at the ambient temperature and other quantities known in strength tests of materials, which may more precisely bridge the existing gap. This paper presents results of moulding sand impact resistance tests, carried out with devices fitted with sensors allowing this parameter to be precisely determined.

Samples with dimensions of 6 x 4 x 60 mm and an active clearance between the supports of 40 mm were prepared for Charpy impact tests. The diagram and the view of the test stand is presented in Fig. 1. The test was carried out with a Charpy tester RESIL 5.5 by CEAST. The hammer with an energy of 4J was equipped with a piezoelectric transducer, to enable forces and strains during a collision with the sample to be measured continuously. The sensor operation range was selected so that the minimum force value to be recorded was 0.5N. The measurement of the force and strain with the piezoelectric sensor resulted in obtaining a digital record of impact energy as a function of time and sample strain. The impact resistance value was determined on the basis of recorded values of impact energy at which the sample was broken, and the area of the sample fracture.

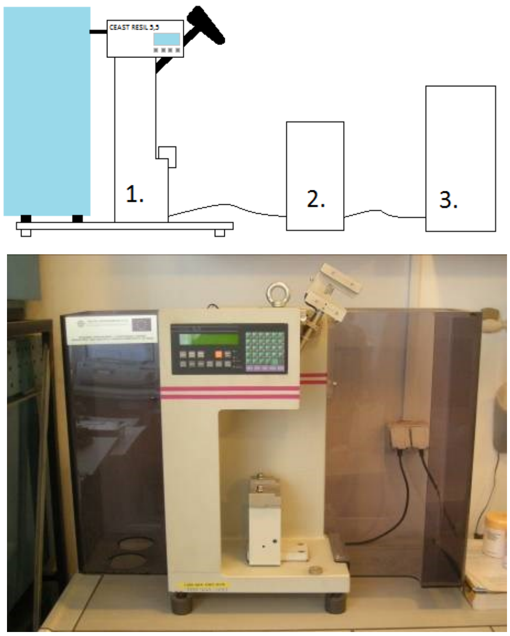


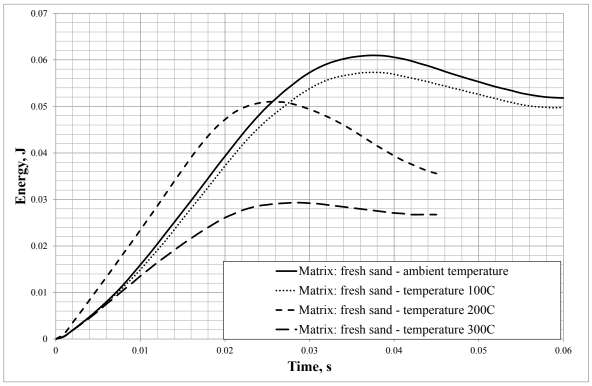
Fig. 1. Diagram and measurement system for testing impact resistance of moulding sands: 1 – Charpy tester equipped with a force sensor, 2 – digital transducer, 3 – recorder (PC)

2. Determining the influence of temperature on impact resistance of moulding sands

The investigations of the influence of temperature on impact resistance were carried out on two test groups of foundry sands, in which the binder was furfuryl resin Kaltharz 404 (1%) and curing agent 100T3 (0.5%). In the first group the sand grains were quartz moulding sand 1K 0.20/0.16/0.32 J89-WK1.26->14000C PN-85/H-11001. The second group of sands was made with sand grains obtained by recycling of used sand [7-9] with the same initial composition as for the first group. The used sand was reclaimed in a rotary test apparatus [10] for 15 minutes at a rotor speed of 420rpm, followed by removing dust from the reclaimed sand in a fluidized bed column for 4 minutes with an air flow velocity of 1m/s. The reclaimed sand showed an ignition loss of SP = 1.35 – 1.40%, and the grain composition with partially eliminated 0.1mm fraction and fully eliminated fine fractions collected on sieves 0.071 and 0.056mm and dust (bottom).

Figure 2 presents a collective comparison of averaged values of recorded changes of impact energy versus time (Fig. 2a) and strains (Fig. 2b) of samples made of self-curing, organic moulding sand, made with quartz sand from Szczakowa and held at the ambient temperature until fully cured (24 h). Some samples were heated after curing, by putting separately a specific number of samples to a furnace heated to the assumed temperatures of 100^0C, 200^0C and 300^0C and holding them at this temperature for 60 minutes. After removing the samples and cooling them to the ambient temperature, the samples were stored in a sealed container until the test. An analogous comparison of test results for samples made of sands with mechanically reclaimed sand grains with the Kaltharz resin at the ambient temperature and held for 60 minutes at a temperature of 100^0C, 200^0C, and 300^0C is presented in Fig. 3.

a)



b)

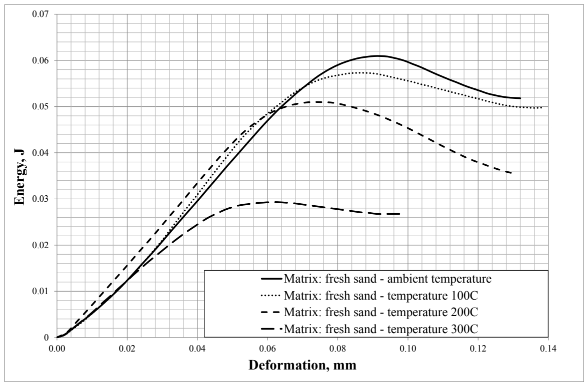
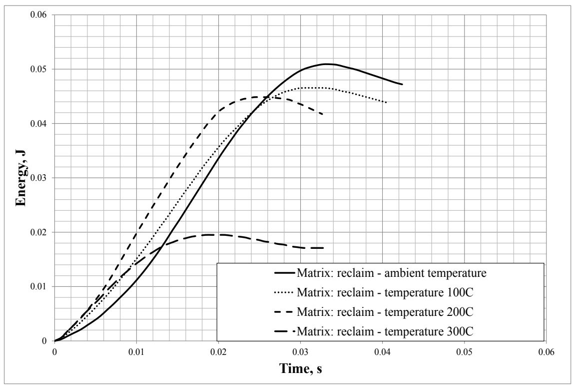


Fig. 2. Averaged values of impact energy changes as a function of time (a) and deformation of samples (b) made of a self-curing, organic moulding sand with the Kaltharz U404 resin with quartz sand grains of Szczakowa at the ambient temperature and held for 60 minutes at a temperature of 100^0C, 200^0C, and 300^0C

a)



b)

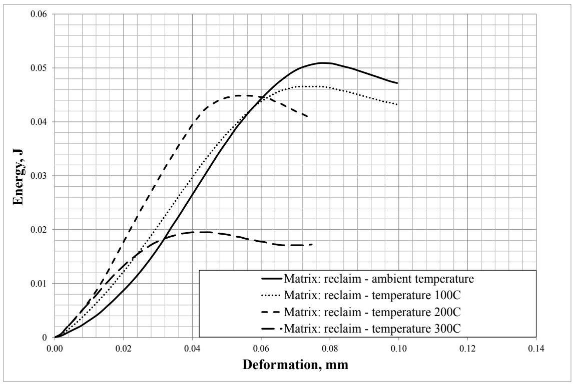


Fig. 3. Averaged values of impact energy changes as a function of time (a) and deformation of samples (b) made of a self-curing, organic moulding sand with the Kaltharz U404 resin with reclaimed sand grains at the ambient temperature and held for 60 minutes at a temperature of 100^0C, 200^0C, and 300^0C

The average total work used for fracturing the samples was computed on the basis of the recorded data and showed that the strain rates for the moulding sand samples made with sand grains increased up to 2.75 mm/s for the ambient temperature, and for the subsequent temperature values of 100, 200 and 300^0C achieved 2.80, 3.0 and 3.33 mm/s respectively.

The strain rates of the sand samples made with reclaimed sand grains were slightly lower (as the holding temperature increased: 2.30, 2.27 and 2.22 mm/s respectively) and did not show an explicit dependence on the sample holding temperature. The change in the average deformation (fracture) energy of samples made of both types of moulding sand is presented in fig. 4. It can be observed that within the temperature range from 23°C – 200°C the average energy of binding destruction decreases by from about 5% to 10%. A significant decrease, of about 50% of the initial value, occurs for sands with both types of grains held at a temperature of 300^0C, and the energy for the reclaimed sand is already lower at the ambient temperature and reaches about 80% of the value for the sand with quartz sand grains.

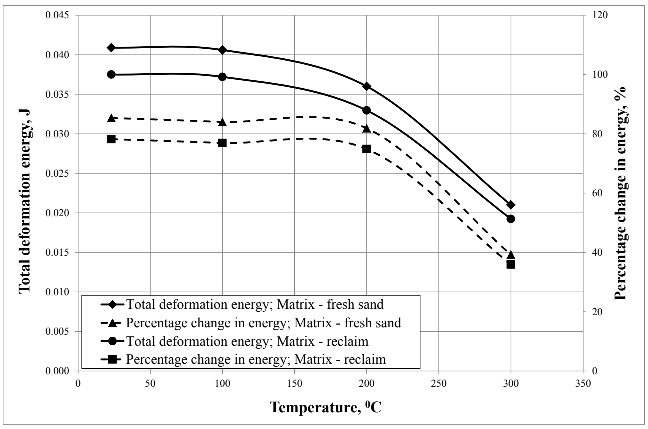


Fig. 4. Impact of holding temperature on the change in the average value of deformation (fracture) energy of samples with the Kaltharz 404 resin made with quartz sand or reclaimed sand

Results of tests of deformation energy, impact resistance and tensile strength R_m^u (UTS) versus holding temperature of moulding sand samples with the Kaltharz U404 resin made with quartz sand or reclaimed sand are presented in Table 1.

The relationship between the impact resistance and tensile strength versus holding temperature of moulding sand samples made with quartz sand or reclaimed sand are presented graphically in Figure 5.

Table 1.
Results of tests of deformation energy, impact resistance and tensile strength R_m^u(UTS) versus holding temperature of moulding sand samples with the Kaltharz U404 resin made with quartz sand or reclaimed sand

No.	Sand grain type	Holding temperature	Average deformation energy	Impact resistance [kJ/m²]	R_m^u 24h
		^{0}C	J	kJ/m²	MPa
1	Quartz moulding sand	23	0.0409	2.535	1.29
2		100	0.0406	2.411	1.17
3		200	0.0360	2.126	1.09
4		300	0.0210	1.222	0.76
5	Reclaimed moulding sand with resin Kaltharz 404	23	0.0320	2.184	1.02
6		100	0.0315	1.953	0.95
7		200	0.0307	1.70	0.64
8		300	0.0147	0.813	0.35

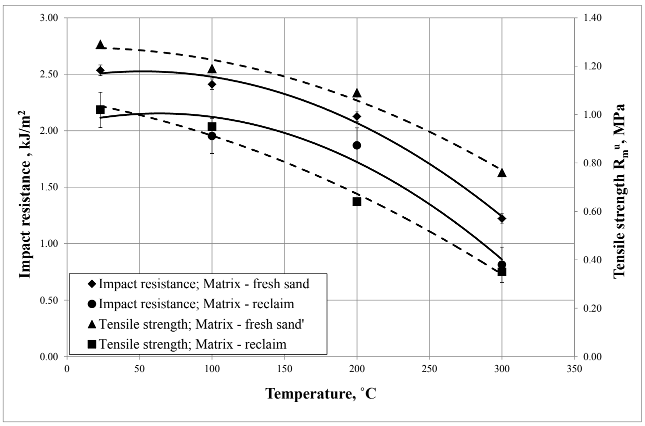


Fig. 5. The relationship between the impact resistance and tensile strength versus holding temperature of moulding sand samples made with quartz sand or reclaimed sand

Results of tests of dependence between tensile strength of moulding sands with resin Kaltharz U404 and their impact resistance are presented graphically in Figure 6 for the temperature range from 23°C to 300°C for sands made with fresh sand grains and those with reclaimed sand grains. As can be observed, for sands with fresh grains the obtained dependence is rectilinear, which allows us to conclude that for a given mass the impact resistance measurement also clearly characterises mechanical properties of the sand. The impact resistance of the sand with reclaimed grains may be treated as a value approximately linearly characterising the strength, as factor R^2 is much lower $R^2 = 0.9303$.

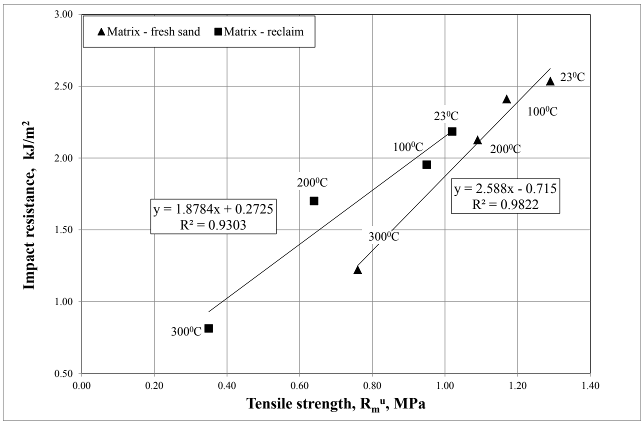


Fig. 6. The dependence of impact resistance of moulding sands with resin Kaltharz U404 on tensile strength for sands made with fresh sand grains and with reclaimed grains, held at a temperature between 23 and 300^0C

5. Summary

The analysis of results of the presented tests allows us to observe a significant similarity in the nature of changes of impact resistance and tensile strength of moulding sands prepared with the fresh quartz sand and with the reclaimed sand. The impact resistance of moulding sands with an organic binder decreases approximately linearly as the sample holding temperature increases.

Tests of moulding sand impact resistance may be applied for evaluation of operation of knock-out grates and systems for preliminary reclamation in terms of energy, and for the correct selection of this equipment for moulding or core sand technology for a specific mould. These tests can also make possible mathematical modelling of knock-out processes and specific reclamation of used sand.

The established linear relationship between the tensile strength and impact resistance of moulding sands allows us to develop a method of indirect determination of impact resistance of various types of moulding and core sands.

Acknowledgements

This work was supported by the Polish NCN project UMO-2014/15/B/ST8/00206.

References

[1] Brach, I. (1968). Crushing of fragile bodies. *Przegląd Mechaniczny*. 27(15), 15-25. (in Polish).
[2] King, R.P. & Bourgeois, F. (1993). Measurement of fracture energy during single particle fracture. *Mineral Engineering*. 6, 353-367.
[3] Hutera B. (2009). Boundary cases of matrix-bonded bonding in molding blocks. *Archiwum Technologii Maszyn i Automatyzacji*. 29(1), 21-28. (in Polish).
[4] Leidel, D.S. (1994). The influence of sand and binders on reclaimability. *Foundry Trade Journal*. 3497(168), 384-387.
[5] Dańko, R. (2007). Development of energetic model for dry mechanical reclamation process of used foundry sands. *British Cast Iron Research Association*. 20(4), 228-232.
[6] Jakubski, J., Malinowski, P., Dobosz, S. (2013). ANN modeling for analysing green moulding sand properties. *Archives of Metallurgy and Materials*. 58(3), 961-963.
[7] Grabowska, B., Malinowski P., Szucki, M. (2016). Thermal analysis in foundry technology. *Journal of Thermal Analysis and Calorymetry*. 126(1), 245-250.
[8] Łucarz, M. (2015). Thermal reclamation of the used moulding sands. *Metalurgija*. 54(1), 109-112.
[9] Lewandowski, L. (1991). *Materials for foundry moulds*. Akapit Publishing House.
[10] Dańko, R. (2012). *Strength model of self-setting moulding sands with synthetic resins in an aspect of the of the integrated matrix recycling process*. Gliwice. Archives of Foundry Engineering Publishing House, 193 pages. (in Polish).