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POTENTIAL OF THE APPLICATION OF THE MODIFIED POLYSACCHARIDES WATER SOLUTIONS AS BINDERS OF MOULDING SANDS

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The results of preliminary tests of selected properties of the moulding sands with the binder in the form of a 5 % water solution of the sodium salt of carboxymethyl starch (with a degree of substitution (DS) of 0,2 and 0,87) are presented in this study. The moulding sand properties such as permeability, abrasion resistance, tensile and bending strength - after curing - are shown in series of tests. The cure process was conducted in a field of electromagnetic radiation within the microwave range. The effect of the microwave treatment on the moulding sand was evaporating of water (solvent in a binder) and cross-linking of the polymeric binder. As a result the cured moulding sands with particular properties, essential in the context of its application in the mould technology in the foundry industry, were obtained.

Key words: foundry, moulding sand, microwave, binder, modified starch

INTRODUCTION

Currently the moulding sands technology is dominated by synthetic, often toxic, organic binders. For ecological reasons, the aim of researches is to develop new binders for moulding sands with biopolymers, originated from natural renewable resources, with a reduced impact on the environment [1-8]. In the research cycle aimed at developing new binders and determining the ability to binding moulding sand by biopolymers examinations of physicochemical properties [9], thermal stability [10], and possibility of used sand reclamation [11, 12] were carried out. The choice of the hardening agent and determining the polymer cross-linking mechanism in moulding sand are very important.The knowledge of binder properties allows to predict the quality of the casting [13].

The example of such ecological biopolymer is the modified starch in the form of sodium salt of the carboxymethyl starch (CMS - Na), commonly used as adhesive in the textile, paper, pharmaceutical industries, etc. There are also indications that the CMS - Na is a suitable matrix binding material in moulding sands used for casting [14, 15].

The CMS - Na is a starch derivative obtained in the etherification reaction of monochloroacetic acid. Depending on the reaction conditions in preparing the carboxymethyl starch, substances of different properties are received. The changes in the starch molecule are determined by the degree of substitution (DS), which is defined as the average number of substituted hydroxyl groups in each glucopyranose ring. Such properties of the CMS as solubility in water and hygroscopicity increase in proportion to the degree of substitution [16, 17].

The aim of the presented study was to investigate the selected mechanical properties of the microwave cured moulding sands with binders based on a water solutions of the CMS - Na having a low and high degree of substitution. The binding efficiency of the matrix grains was determined based on the results of permeability, abrasion resistance, bending strength and tensile strength of the cured moulding sands. The preliminary evaluation of the effectiveness of the microwave curing of moulding sands with the starch binder of various degrees of substitution, was performed.

MATERIALS

Two samples of the biopolymer as sodium carboxymethyl starch (CMS - Na) with a low DS (0,2) and a high DS (0,87) were used, CMS - Na_L (Polvitex Z, Xenon, Poland) and CMS - Na_H (West Pomeranian University of Technology, Szczecin, Poland), respectively. These materials were used to prepare 5 % water solution for application as a binder of the moulding sand of the determined composition. The starch-based binder in an amount of 3 parts by weight was introduced into 100 parts by weight of the silica sand matrix (BK 5 D 0,16 – 0,32 MM; Sibelco Poland). The mixture was stirred for 3 minutes in the roller type laboratory mixer (LM-R1).

Moulding sand was formed into different shapes: octal, longitudinal and cylindrical. Curing of the shaped moulding sands was carried out by physical agent (evaporation of the water solvent) under a microwave

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radiation with a power of 800 W in the microwave apparatus INOTEC MD 10940. The radiation time for the longitudinal and octal shaped samples was 60 s, while for the cylindrical ones 120 s. The temperature in the microwave device was approx. 100 °C.

METHODOLOGY

The determination of the moulding sands permeability was performed by fast method in electrical apparatus type LPiR1. The permeability values are expressed in the SI unit $10^{-8}\,\frac{m^2}{Pa \cdot s}$. The permeability was determined for uncured cylindrical samples and for microwave-cured samples after 1 h and 24 hours of the storage.

An abrasion resistance was determined by means of the special apparatus (Huta Stalowa Wola production). Due to the expected high abrasion of the tested moulding sands, only half of the recommended weight of steel shots, i.e. 875 g, was used in measurements. Abrasion (S) in % was determined from the formula (2):

$$S = 2 \cdot \frac{Q_1 - Q_2}{Q_1} \cdot 100\ \% \qquad (2)$$

where:

Q_1 - mass of the sample before the test / g,

Q_2 - mass of the sample after the test / g.

Abrasion was examined after 1 h, 4 h and 24 h storage.

The bending (R_g^u)and tensile strength (R_m^u) were tested - after 1 h, 4 h and 24 h of the storage - by means of the universal apparatus for measuring the strength of cured moulding sands, LRU-2c type produced by MULTISERW – MOREK, (according to the standard PN 83 H-11073/EN).

RESULTS AND DISCUSSION

The results of permeability tests of uncured and cured moulding sands with the binder based on the CMS - Na_L and CMS - Na_H are shown in Figure 1. It was noticed that moulding sands permeability after the microwave hardening significantly increased due to the evaporation of water contained in the binder solvent.

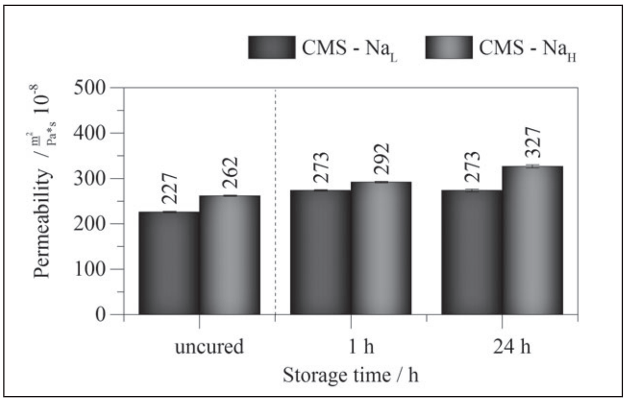

Figure 1 Permeability of moulding sands, in uncured and cured states, after 1 h and 24 hrs storage time

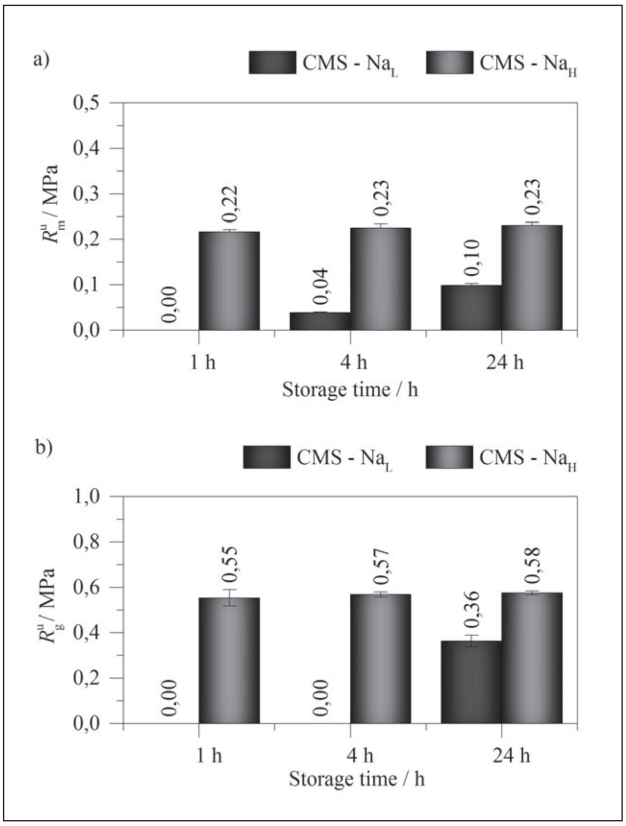

Figure 2 Strength properties of microwave-cured moulding sands: a - Tensile strength of moulding sands in the cured state; b - Bending strength of moulding sands in the cured state

Depending on the DS of the applied CMS - Na the increase of 46 units after 1 hour storage of the moulding sand with CMS - Na_L and 30 units for the moulding sand with CMS - Na_H was observed.

During 24 hours storage time of the microwave-cured moulding sands with the CMS - Na_H an increase in permeability by 35 units was found. The permeability of the moulding sand with the CMS - Na_H binder was constant, regardless of the sample storage time.

The results of the tensile strength R_m^u (Figure 2a) and bending strenght R_g^u (Figure 2b) of the moulding sand cured by microwaves after 1, 4 and 24 hours of the storage, are shown in Figure 2.

On the basis of the results of strength properties of the microwave-cured moulding sands, it was found that the moulding sand with the CMS - Na_L in the first hours of the strength measurement was characterized by a slight tensile strength, (after 1 and 4 h storage 0,0 MPa and 0,04 MPa - respectively) and the measured - at the same time range - bending strength R_g^u was each equal 0,0 MPa. Measurements of R_m^u and R_g^u made after 24 h showed little strength of moulding sand with CMS - Na_L, 0,01 MPa and 0,36 MPa - respectively. The R_m^u strength of the CMS - Na_H examined after 1, 4 and 24 hours of the storage time remained constant and was equal 0,23 MPa, while R_g^u was equal 0,57 MPa (slight differences between the results were within the range of measurement uncertainty ± 0,04 MPa).

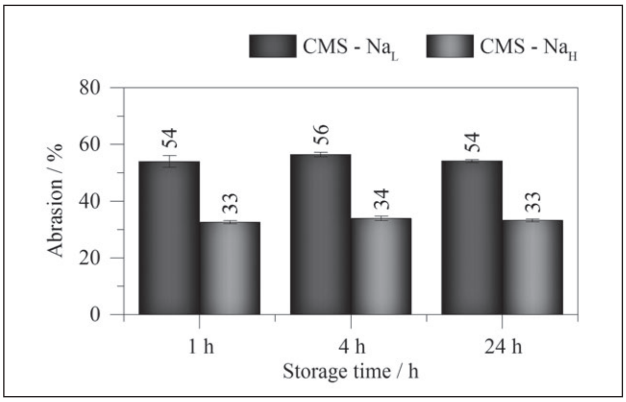

Figure 3 Abrasion of moulding sands in the microwave-cured state

On the basis of results of the abrasion resistance tests of moulding sands (Figure 3), it was found that both binders, CMS - Na_L and CMS - Na_H, caused a significant susceptibility to the surface damage of the hardened samples, which indicated a low bond strength of grains. This, in practice, is a disadvantage of moulding sands. However, when comparing both moulding sands it was noticed that the samples with the CMS - Na_H were characterized by a greater abrasion resistance than samples with the CMS - Na_L binder. The measurements carried out after 1, 4 and 24 hours of the storage showed abrasion of the moulding sand with the CMS - Na_L being 54,0 (± 2,0) %, while the moulding sand with the CMS - Na_H was characterized by a much lower abrasion, being 33,0 (± 1,0) %.

CONCLUSIONS

Based on preliminary studies of the applicability of aqueous solutions of the sodium salt of the carboxymethyl starch - with different degrees of substitution - as a binder for moulding sands, it was found that:

- it is possible to dry and cure the moulding sands prepared with water solutions of the CMS - Na, both with a low and a high degree of substitution, but clearly the material more susceptible to the influence of the curing agent is the CMS - Na with a high DS,
- the water evaporation from the moulding sands occurs efficiently in a very short time, as a result of the microwave curing method,
- there is the proportional increase in permeability, strength and resistance to abrasion with increasing DS of the CMS - Na,
- long storage time is conducive to the growth of the strength of the cured moulding sand with the CMS - Na of a low DS,
- the obtained results of selected properties of the moulding sands with binder CMS - Na_H cured by microwaves are a promising, although it is not are not fully satisfying when compared to the properties of the moulding sands with the commonly used binders [15-18]. However, the composition and method of preparation of moulding sands with the CMS - Na, proposed in this paper, is not optimal and further research are considered in the future in order to optimize the proportion of the biopolymer and sand grain, including e.g. increasing the binder share in the moulding sand or replacing 5 % water solution of the CMS - Na by other concentrations.

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Note: The responsible translator for English language: „ANGOS” Translation Office, Kraków, Poland