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Determination of application possibilities of microwave heating in the curing process of water glass molding sands with fluid esters. Part 2

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Abstract

This article, constituting continuation of the subject discussed in the first part, presents results of the experimental trial of water glass molding sands' curing method modification with application of fluid esters and innovative microwave heating. The research objective was to determine possibilities of microwave application for curing of water glass molding sands prepared with addition of hardening agents sold under the trade name of Mach. After initial chemical curing molding sands, prepared with addition of the above mentioned hardeners, have been heated with microwaves in order to determine their influence on changes of basic technological and strength parameters of the sands, and indirectly on the quality of quartz grains binding. Studies aimed at determination of water content changes in the sands have also been undertaken. As our studies demonstrated, microwave heating allows for quick reduction of water content, thus resulting in improvement of strength parameters such as bending and tensile strength. Application of the combined methods of ester curing and innovative microwave heating facilitates production of high quality foundry moulds and cores, while simultaneously improving mould and core preparation procedures at the foundries and as a result reduces their time to an indispensable minimum.

Key words: innovative foundry materials and technologies, ester curing, water glass, molding sand, microwaves

1. Introduction

Quality of the forming glassy film on quartz grains and binding bridges between them in water glass molding sands depends mostly on the way of orthosilicic acid zol transformation into silica gel [1]. They also depend on final effects accompanying this physico-chemical phenomenon constituting the result of chemical binder curing process [2]. Binding agents called Mach, currently available on the market and being mixtures of fluid esters, allow for obtaining of satisfactory, and significantly exceeding those obtained in CO_2 process, strength parameters of the sands when added in proper proportions [3]. However, the results of studies in case of water glass molding sands cured only with microwave heating process, demonstrate significantly higher strength values for identical binding agent content [4,5]. These are comparable to corresponding ones and obtained as a result of conventional curing. For this reason application of microwaves for curing of the sands containing hydrated sodium silicate positively influences quality of the formed quartz grains' bonds. The presented study objective was an attempt at determination of the changing quantity of water contained by the sand as well as the influence of additional microwave heating on the quality of quartz grains' bonds formed during chemical process of ester curing of molding sand.

2. Materials used for research, preparation of molding sands

Similarly as described in the first part of our article a silica sand 1K from Nowogród Bobrzański sand mine of 0.32/0.20/0.16 main fraction has been used for experiments. The molding sand composition have been determined basing on the recommendations contained by information card for fluid hardening agents, constituting mixture of esters and bearing the trade name of Mach 2 and Mach 3, for various curing times. Specification of these products is presented in table 1. Sodium water glass is a binding agent recommended for this group of fluid esters. Water glass manufactured by Zakłady Chemiczne "Rudniki" S.A., whose properties (according to certificate) are also contained in table, has been used for preparation of the sand. According to manufacturer's information, the given times of intense action of Mach hardening agents are similar to those of Flodur 1 and Flodur 3.

Edge runner mixer has been used for preparation of the sand [6,7]. The individual components have been batched in portions: quartz sand 100%, fluid hardener 0.4% and water glass 3.5%. Proper sequence of component addition has been maintained while mixing. First, quartz sand has been mixed for about 120 seconds with one of Mach hardeners, next binding agent added and mixed for another 120 seconds.The samples for determination of bending and tensile strength, permeability and wear resistance have been prepared in a standard rammer from the above described molding sands [1].

Concentration degree of the tested samples have been determined on the basis of the conducted initial testing and it has been found that triple ramming of the prepared sands with standard rammer ensures their sufficient consolidation. Their apparent density remained within the range of 1.56 up to 1.62 g/cm^3.

The obtained results have been compared with the previously conducted studies in order to evaluate efficiency of various methods [4,5,8]. The sand containing 3.5% of the binding agent and 0.5% of water but without fluid hardener, has been prepared for comparison. The samples made of this sand have been cured using only the innovative method of microwave heating.

3. Influence of water glass curing method modification on molding sand water content

The first part of our work [8] mentions, among others, possible methods of reduction of final water content in water glass molding sands. Water added during component mixing and water contained by water glass can be removed by application of suitable curing methods. As it is commonly known, the economical microwave heating can be used for very quick drying of various substrates [9,10]. For this reason we attempted to evaluate efficiency of fluid hardening agents and microwave heating. Cylindrical moulds have been used for studies of curing method modification on water content. Our choice has been dictated mainly by their greatest volume and transverse diameter. The layers of material farthest away from the cylindrical sample surface, similarly as in real foundry moulds and cores, have limited abilities of H_2O particles release during evaporation process [11]. The closer to the sample core, the smaller loss of water contained by the molding sand. It is also possible to reach such sand state, where water amount before and after the curing process remains unchanged.

The prepared cylindrical samples have been stored at stable temperature of 26^{o}C. In order to evaluate efficiency of curing process intensification the samples have been heated in microwave gravimeter until reading became stabilized [12]. Mass loss resulting from intense evaporation in relation to duration of fluid ester influence has been shown in Figure 1.

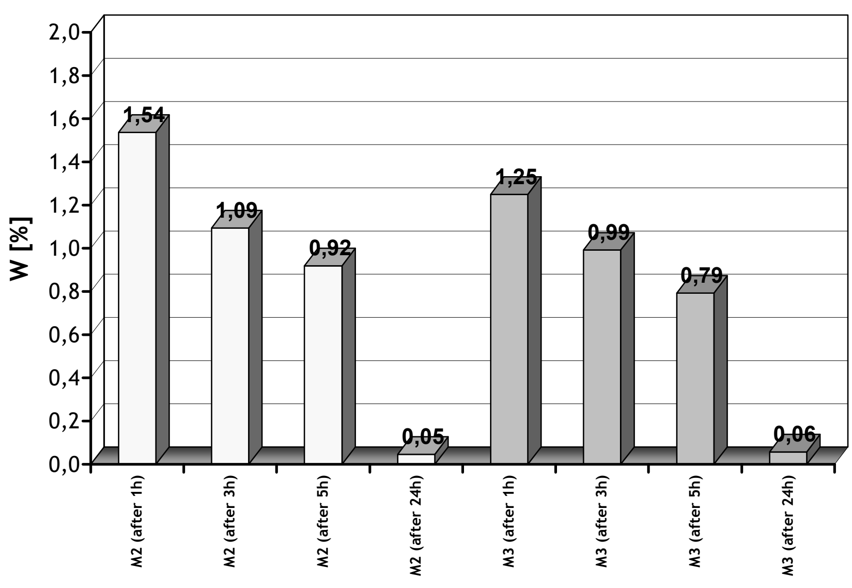

Fig.1. Influence of microwave heating on water content in molding sand depending on storage time

As can be seen (fig.1) a residue water content, established during microwave gravimeter heating process, can be found even after 24 hours from component mixing of the sands containing hardening agents.

4. Intensification and modification of ester curing process of water glass

All the samples of molding sands (cylindrical, octal and oblong) have been taken out from the moulds 50 minutes after addition of the binder to the mixture. Next, after 1 hour, 3, 5 and 24 hours, their resistance and technological parameters have been measured. The samples, initially cured in the ester process, have been subject to heating for 4 minutes in order to investigate microwave influence on formation of silica gel. Measurements of parameters have been conducted at identical time intervals (after 1, 3 and 5 hours).

A microprocessor controlled device has been used for microwave heating [8].

Bending and tensile strength measurements have been conducted with LRuE-2e apparatus. Permeability has been measured using LPiR-2e device, while wear resistance with E. Janicki method.

5. Research results

Comparison of research results of curing methods' influence on molding sands containing Mach 2 hardener has been presented in figures 2, 3 and 6. The remaining figures: 4, 5 and 7 constitute graphic illustration of measurement results of molding sands' parameters containing Mach 3 hardener. Measuring points are mean values of three measurements. The last column of each figure contains, for comparison, the results of microwave heating studies of the sand prepared without addition of fluid ester curing agent.

The results of bending strength studies presented in figure 2 demonstrate a significant curing method influence on this parameter. Application of microwave heating following first 1 hour of Mach 2 hardening agent action allowed for obtaining strength of about 1 MPa higher than after 24 hours of storage of the samples. This disproportion between the applied curing methods is especially visible in figure 3, presenting results of tensile strength measurement. The application of additional microwave heating allowed for obtaining of R_m^U strength at the level of about 2.3 MPa determined for water glass molding sands without addition of hardening agent. A downward trend of this strength value, increasing with duration of chemical binding with esters, has also been observed.

Introduction of additional microwave influence on the sand has no significant impact on permeability in case of Mach 2 binding agent. Method modification also had no significant influence on wear resistance change (fig. 6).

Figure 4 presents the results of bending strength studies for the sands prepared with Mach 3 hardening agent. In this case the results of combination of both curing methods have also been satisfactory. The sand subject to microwave effects already after 1 hour had higher bending strength than the one stored for 24 hours. Method modification had similarly positive influence on tensile strength increase (fig.5).

The applied methods had no influence of permeability changes of the sands in case of Mach 3 addition. However, decrease of wear resistance of the samples additionally cured with microwaves has been observed after 3 and 5 hours (fig.6). Rapid evaporation of water could have negatively influenced quality of the bonds created during ester process in case of this hardening agent.

Table 1. Physical and chemical properties of sodium water glass and ester curing agents

Water glass kind	Mole module SiO_2/Na_2O	Oxide content (SiO_2+Na_2O) %	Density (20 °C) g/cm^3	Fe_2O_3 % max	CaO % max	Dynamic viscosity (P)
145	2,4÷2,6	39,0	1,45÷1,48	0,01	0,1	1
Hardener – trade name:		Gelation time (minutes)	Density	Flash point [°C]	Water solubility	Composition
Mach 2		30-40	ok. 1.15	135	poor	ester mixture
Mach 3		20-30	ok. 1.15	over 135	poor	ester mixture

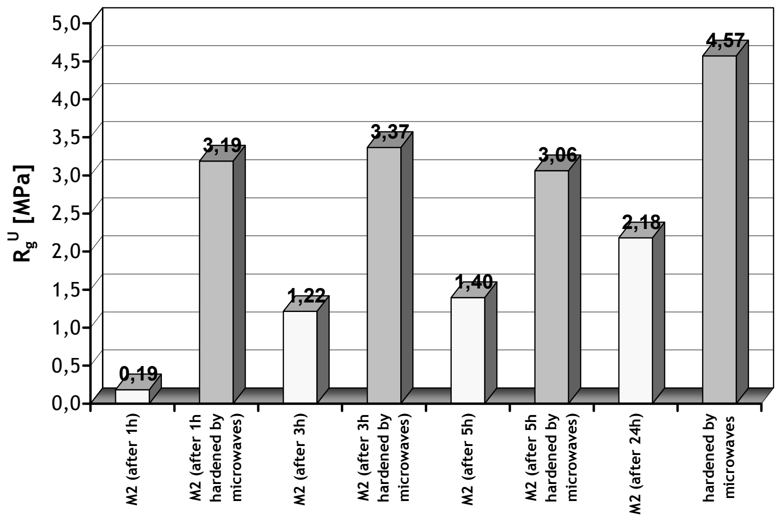

Fig.2. Influence of curing method and storage time on bending strength of molding sand containing Mach 2 hardener

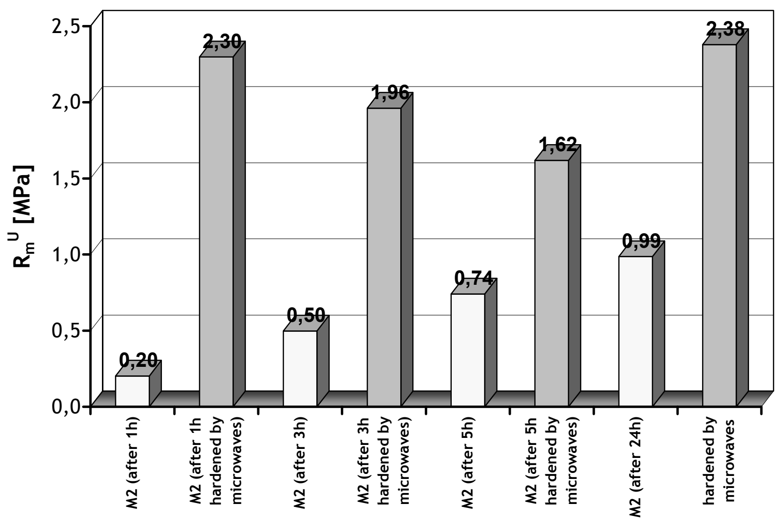

Fig.3. Influence of curing method and storage time on tensile strength of molding sand containing Mach 2 hardener

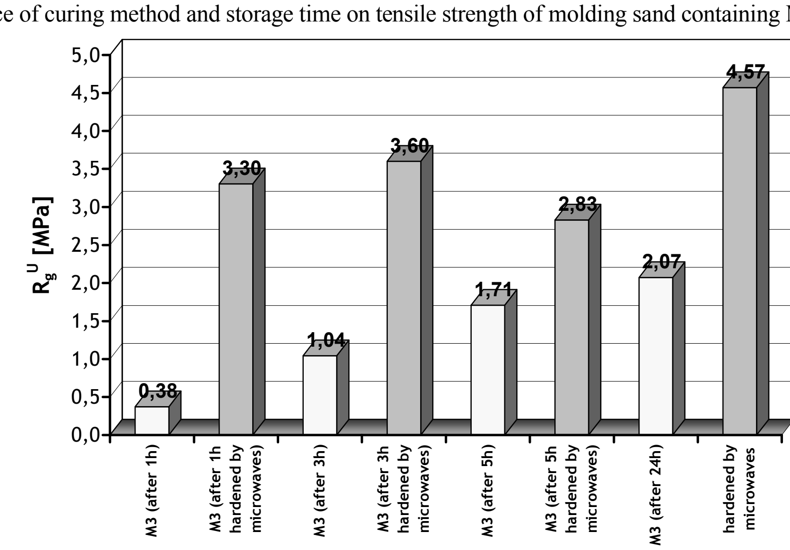

Fig.4. Influence of curing method and storage time on bending strength of molding sand containing Mach 3 hardener

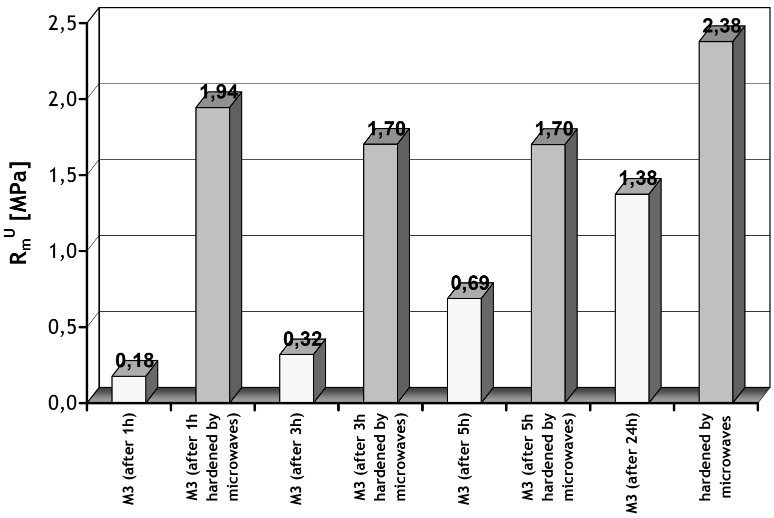

Fig.5. Influence of curing method and storage time on tensile strength of molding sand containing Mach 3 hardener

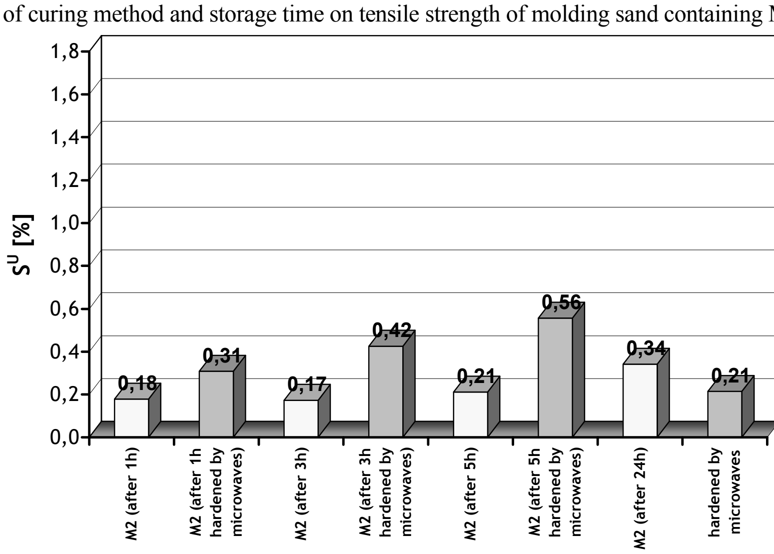

Fig.6. Influence of curing method and storage time on wear resistance of molding sand containing Mach 2 hardener

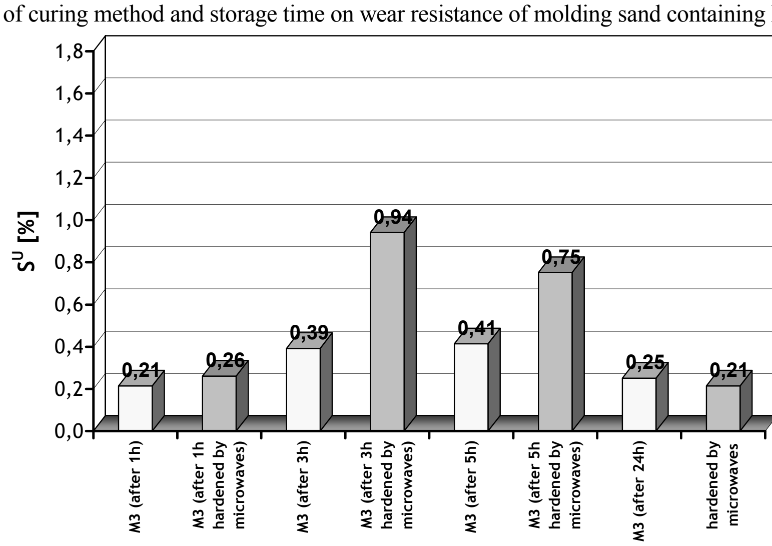

Fig.7. Influence of curing method and storage time on wear resistance of molding sand containing Mach 3 hardener

6. Final conclusions

While analyzing the results of curing methods' influence on basic properties of water glass molding and core sands it might be stated that:

- the greatest influence of microwave curing process is observed in case of bending strength (improvement of about 50%) and tensile strength (over 100%) in case of Mach 2 hardening agent,
- in case of Mach 3 hardening agent microwave heating also brought positive effects in the form of improvement of both measured strength parameters,
- in order to intensify bonding process, microwave heating might be applied optionally any time from the moment of mixing of all components of the sand,
- a two-stage curing method does not influence permeability changes of the studied sands,
- application of additional microwave heating might negatively influence wear resistance of molding sand, depending on kind and duration of the hardening agent action; the best results have been obtained while applying the microwave modification 1 hour after preparation of the sand,
- application of a two-stage curing method ensures significant time decrease of moulds and cores preparation as well as production flexibility improvement,
- in case of microwave heating there is a possibility of binder consumption reduction, reduction of the amount of the used hardener (or even its elimination) as well as reduction of final water content,
- intensification of ester curing process through application of microwaves may significantly influence time reduction of foundry moulds' and cores' preparation.

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