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DIELECTRIC HARDENING METHOD OF SANDMIXES CONTAINING HYDRATED SODIUM SILICATE

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The subject-matter of the paper covers a very topical problem of possible restriction of shortcomings like poor knocking-out properties of castings and hard reclaimability of this type sandmixes by proper selecting their components and using innovative microwave heating. It was proved that the sandmixes subject to quick dielectric process of drying/hardening show significantly lower residual strength, which gives this method priority over traditional energy-consuming processes of casting core manufacture.

Key words: foundry, moulding sand, microwaves, heating, water-glass

INTRODUCTION

Selection of proper moulding and core sands is decisive for quality of the manufactured castings. When designing technology of sand casting, several factors must be considered of which the most important are costs of moulding sand components, mixing devices, accessories and equipment for cleaning castings and disposing used moulding and core sands. Nowadays, the most important production costs of castings include also recovery of used moulding sands. Following stronger pressure on protecting environment, natural resources and human health, possibility of repeated application of used sandmixes becomes very important when selecting composition of moulding and core sands.

Currently, a search is in course of a cheap material, environmentally harmless and neutral for the persons in contact with it. Moreover, it is expected that hardening moulding sands with such a binder will be a fast and technologically simple process and the used sand will be reusable after a recovery process guaranteeing its properties from before the mould was poured with metal. Hydrated sodium silicate (sodium water-glass) fulfils the conditions of small environmental harmfulness due to its inorganic nature [1]. The practically known ways of chemical hardening, e.g. with carbonic anhydride (CO_2 process) or hardening with liquid esters do not present special difficulties when preparing moulds and cores, permit also flexible manufacture of castings. A disadvantage of such solutions are poor knock-out properties caused by high residual strength of these moulding sands [2 - 4]. This fact can restrict possibility of wide application of water-glass as a universal foundry binder. As compared to the other technologies employing organic binders used in particular in core sandmixes, hydrated sodium silicate makes much more difficulties at knocking-out cast steel and cast iron, especially at removing cores, which increases production costs. The secondary products created after applying various ways of chemical hardening can to higher or lower degree affect the process of knocking-out moulds and cores. This phenomenon was more widely described for the CO_2 process. To determine the difficulties related to removing used moulding and core sand, one can use the diagram of the relationship between residual strength and heating temperature, see Figure 1.

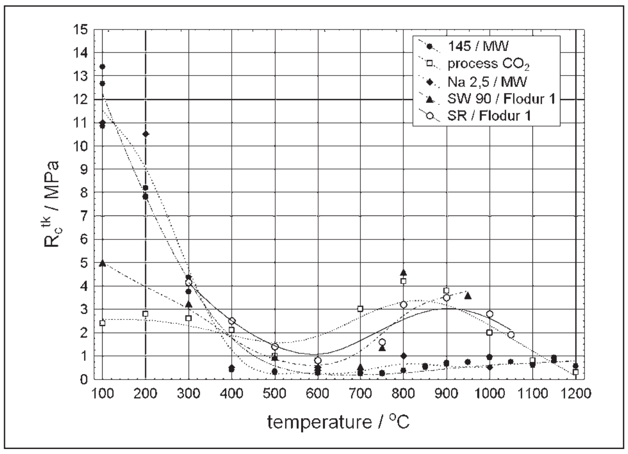

Figure 1 Influence of temperature on residual strength in ambient temperature of moulding sands prepared with various binders:
– grade 145, microwave hardened / MW (content 2,5 %), on the ground of own research,
– Na 2,5 with module 2,75 and density 1,51 g/cm³ (content 3,0 %), microwave hardened [5],
– modified SW90 with module 2,04 and density 1,504 g/cm³ (content 2,5 %), hardened with Flodur 1 (liquid ester) [4],
– SR with module 2,0 (content 2,5 %), hardened with Flodur 1 (liquid ester) [2],
– silica-type, hardened in the CO_2 process [3].

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In the case of chemical hardening methods, analysis of the curves in Figure 1 indicates occurrence of very high, secondary residual strength. After the residual strength (R_c^{tk}) drops to the level below 1 MPa at 600 °C, it starts increasing again. In the case of binders hardened with liquid esters and in the CO_2 process, after heating the moulding sands till 700 – 950 °C, their residual strength reaches values between 3 and 5 MPa. The so high residual strength makes the key problem in the case of the silica binder.

As the results of the so-far performed researches indicate, water-glass containing moulding sands can be successfully hardened with microwaves at 2,45 GHz [5 - 7]. Studies on practical application of electromagnetic waves of 2,45 GHz frequency in foundry processes have been conducted since the 80's of the previous century [8]. In foundry practice, this technology based on the dielectric drying phenomenon can bring significant benefits, resulting among others from reduced time and costs of manufacturing moulds and cores [9]. Due to low residual strength in temperature over 300 °C (see Figure 1), water-glass containing moulding sands, hardened during heating in electromagnetic field, can be also an alternative for several technologies based on organic resin binders.

The phenomenon of microwave heating of dielectric media is described in literature as the dielectric drying method [10]. The main result of the dielectric polarisation phenomenon is volumetric heating due to high-frequency polarisation of dipole-nature molecules. In the case of hydrated sodium silicate, water molecules and the created water solutions participate in the polarisation process. It should be noted that not all the phenomena accompanying dielectric drying of micellar solutions, as water-glass is deemed to be, are completely explained. Thorough recognising the results of dielectric drying can deliver information on the process of releasing water molecules from a solution of hydrated sodium silicate, as well as make its use more reasonable. It was found by analysis of the researches comparing various methods of water-glass hardening, described in [6], that the methods involving the physical dehydration process are distinguished by more profitable properties than those hardened in the traditional process of purging with CO_2 or fluid esters.

Apart from methods based on the introduction of special additives [6], the first factor that can significantly facilitate the processes of cleaning castings and knocking-out cores, as well as recovery of moulding sands is restricting the binder content. In the paper [7] presented is a research on influence of quantity of five grades of sodium water-glass on ambient-temperature strength of moulding sands prepared with their part, hardened in the quick dielectric drying process. It was evidenced that there is a possibility of significant reduction of binder quantity with maintained profitable properties of the sandmix, see Figure 1.

PREPARATION OF MOULDING SANDS

The examined moulding sands were composed of standard high-silica sand from the Nowogrod Bobrzanski mine with main fraction 0,40/0,32/0,20 and three commercially available grades of water-glass made by Chemical Plant "Rudniki", with the properties given in Table 1.

The moulding sands were prepared as follows. A portion of sand (4 kg) was poured to a laboratory runner mixer and, after starting-up, 20 ml (0,5 %) of water was added, as determined on the grounds of literature data and own preliminary results. Addition of water reduces dusting during stirring. In the case of water-glass containing sandmixes, preliminary wetting of sand is favourable for repeatability of results guaranteed, among others, by homogeneity of the moulding sand thanks to good distribution of the binder in the entire volume. After 60 seconds of stirring, water-glass was dosed in the amount of 1,5 %, 2,5 %, 3,5 % or 5,0 % and the sandmix was stirred for another 180 s. Of the so prepared sandmixes, "bone dog" shapes for tensile test 22,36 x 22,36 x 70 mm were formed on a laboratory rammer. After forming, apparent density of the sandmix ranged from 1,56 to 1,64 g/cm^3.

HARDENING OF SPECIMENS

The specimens were subject to action of microwaves at 270 W, 450 W, 630 W or 810 W. Five specimens were inserted to the oven at the same time. This number of specimens guaranteed proper operation of magnetron of the microwave oven. It was found in the previous tests that the most favourable hardening time in this process is 240 s [11]. After hardening, the specimens were cooled-down in free air till the ambient temperature. Measurements of tensile strength were carried-out on the apparatus LRuE-2e.

RESEARCH RESULTS

Measurement results of the influence of microwave heating power and amount of water glass on the properties of molding sands prepared with three kinds of this

Table 1 **Physicochemical properties of water-glass grades used in foundry practice**

Water-glass grade:	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)
150	1,9÷2,1	40,0	1,50÷1,53	0,01	0,1	1
149	2,8÷3,0	42,5	1,49÷1,51	0,01	0,1	7
145	2,4÷2,6	39,0	1,45÷1,48	0,01	0,1	1

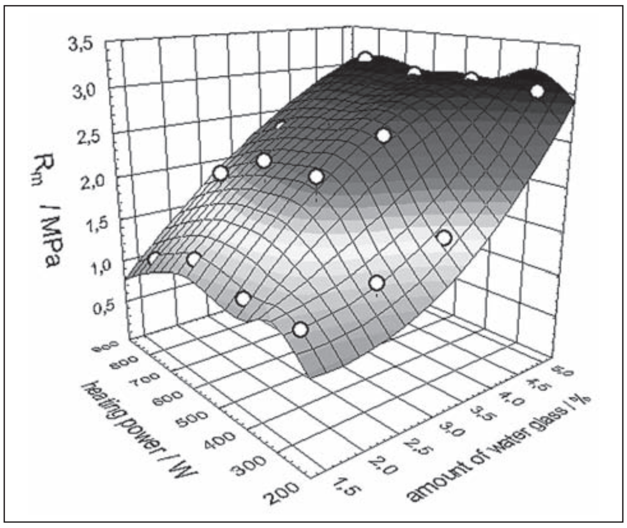

Figure 2 Influence of microwave heating power and amount of water glass kind 145 on tensile strength of molding sand

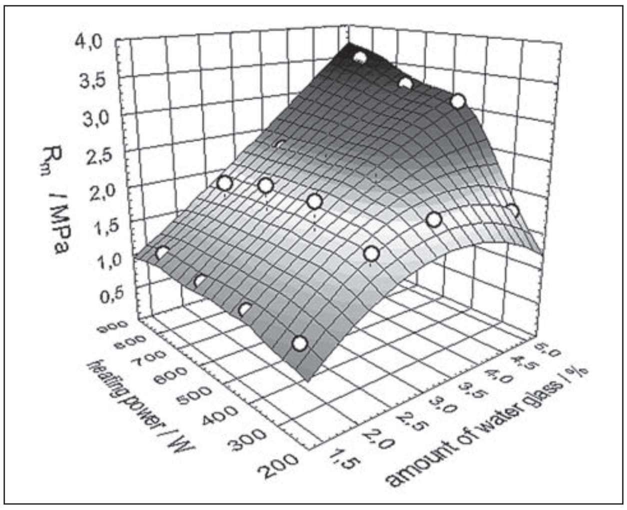

Figure 3 Influence of microwave heating power and amount of water glass kind 149 on tensile strength of molding sand

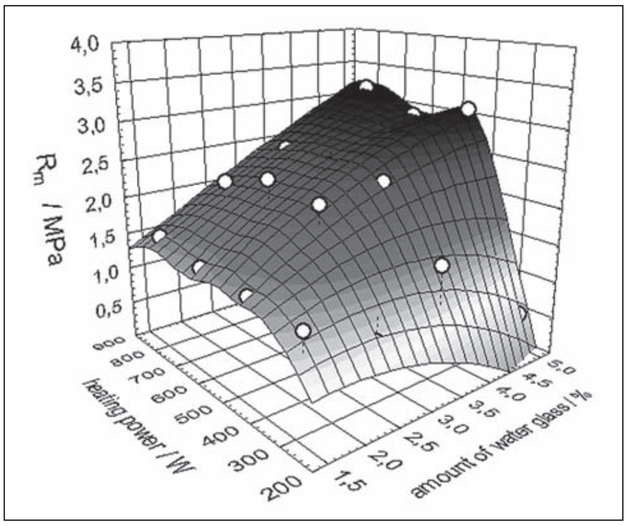

Figure 4 Influence of microwave heating power and amount of water glass kind 150 on tensile strength of molding sand

binding agent have been presented in figures 2 to 4. Measuring points constitute mean values of three measurements.

Method of least squares weighted by distances marked on the spatial graphs have been used for tensile strength visualization.

SUMMARY AND CONCLUSIONS

As appears from the analysis of Figures 2 - 4, tensile strength of molding sands with addition of three water glass kinds depends on amount of water glass and used microwave heating power. Content change of water glass in the sand from 5,0 % to 1,5 % results, according to expectations and literature data for the selected hardening method [11], decrease of tensile strength from about 3,5 – 3 MPa to about 1,0 MPa. Moulding sands with a small amount of water glass of 1,5 %, through dielectric drying, exhibit a constant tensile strength of about 1 MPa, regardless of the heating power. For examined molding sands with three water glass kinds, increasing the binder content over 1,5 % requires the adjustment of appropriate microwave power from 270 W to minimum 450 W. Otherwise, for the assumed number of specimens in the microwave owen chamber and the time of hardening, the sandmixes remains unhardened. It was noted on Figures 2 – 4 that moulding sands with amount of binder from 1,5 % to 3,5 % hardened with microwaves over 630 W, have a minimal deterioration of tensile strength. Most significant results of tensile strength achieved for the heating power of range from 450 W to 630 W used for hardening moluding sands with amount of water glass less than 3,5 %.

While analyzing the results of microwave hardening method and the amount of water glass content influence on basic parameter of tensile strength of molding sands it might be stated that microwave heating of molding and core sands guarantees obtaining repeatable strength properties at low binding agent contents of 1,5 % to 2,5 %.

Application of microwave heating in the process of water glass molding sands' hardening ensures, apart from a very significant decrease of the process duration, full stabilization of their properties and significant reduction of energy consumption as well as allows for possibility of amount reduction of the used binding agent and, as a result, improvement of knock-out properties of the sands.

Further studies concerning investigation of all factors influencing dielectric drying method efficiency shall create a possibility of precise programming of the properties of molding sands hardened with microwave heating process.

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Note: The responsible translator for English language: INTER-TK, Translation Office, Wrocław, Poland