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Possibility of utilizing thermosetting moulding sands by microwave heating

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Abstract

The paper presents a semi-industrial reactor designed for utilisation of waste moulds and cores made of thermosetting moulding sands by microwave incinerating. It was found that a possibility exists of effective incinerating residues of this kind waste cores or moulds left after casting. The research evidences that the apparatus permits effective control of the applied microwave heating process. Preliminary tests of microwave heating indicated that incinerating waste moulds and cores made of industrially used moulding sands based on phenolic-formaldehyde resins is an effective method of their utilization. Application of microwave heating for incinerating waste moulds and cores containing synthetic resins as binders guarantees significant and measurable economical benefits resulting from reduced process time.

Keywords: Innovative foundry technologies, Microwaves, Thermosetting moulding sand, Utilization

1. Introduction

Microwave radiation has found wide application, among others, in foundry technology e.g. in hardening processes of moulding sands, as well as those containing thermosetting resins or oil binders. Microwaves can be also used to solve the problems related to neutralization of foundry wastes consisting mostly of various grades of used moulding and core sands.

Neutralization of used moulding sand, with potential reuse, presents the main economical problem of each commercial foundry plant. Due to restrictive environment protection law, implemented are various technologies consisting in cleaning waste moulding sands from residues of binding materials.

The experiences gained from preliminary tests of utilizing noxious industrial wastes containing, among others, asbestos [1] contributed to the attempt of applying the electrothermal process [2], i.e. transformation of electrical energy into thermal energy of the heated materials by means of microwave-frequency electromagnetic fields. In [3], presented are laboratory tests of microwave incineration of waste moulds and cores made of moulding sands containing thermohardening resins. Residues of shell cores, separated from moulding sand after casting, were neutralised in a short time. In the examinations applied were additives intensifying the heating process and thus reducing the time necessary to reach the required incineration temperature. Moreover, it was found that in the microwave utilization process important is proper preparation of the waste moulding sand by its mechanical disintegration. To make the microwave utilization process independent, it is suggested to use the materials with suitable dielectric properties that guarantee penetration of microwave radiation efficient and sufficiently deep to transfer the energy emitted by the microwave generator to the substrate [1,2].

It should be emphasised that microwave radiation has found wide application also in other foundry processes, e.g. for drying traditional moulding sands or hardening moulding sands containing sodium waterglass or thermohardening resins [4,5,6]. So this technology is still having a great prospects for applying.

2. Measuring stand

The semi-industrial microwave reactor used in the preliminary research to determine possibilities of microwave utilization of noxious substances [1,7,8] was adapted to the needs of testing loose materials with low bulk density. In the previous design of the combustion chamber, application of the reactor to microwave utilization of sandmixes was limited by granulation of the waste materials. In order to restrict influence of refinement degree and to ensure uniform absorption of microwave energy in the whole volume of charge material in the chamber, design of the reactor was complemented with additional components permitting its rotations.

The reactor shown in Fig. 1 and Fig 2 is equipped with four microwave generators with total power output of 6.5 kW. The closures (upper and lower covers) are equipped with reactance chokes preventing microwaves from "leaking" outside. Moreover, the reactor is furnished with safety systems preventing the generators from being turned on with the combustion chamber opened.

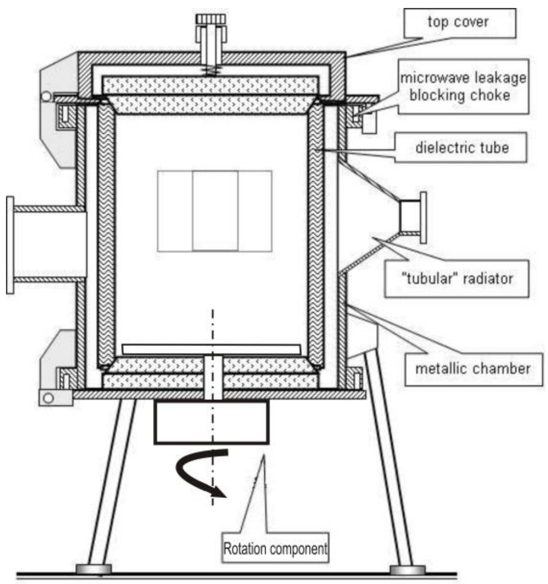

Fig. 1. Design of the microwave reactor

Radiators of the reactor are arranged on its circumstance to make possible simultaneous, failure-free operation of all the installed generators, see Fig. 2. A condition of correct operation is also homogeneity of electromagnetic field in the entire reactor chamber.

The reactor is furnished with four microwave generators of maximum microwave power up to 1.6 kW each, connected with the reactor's chamber by means of wave-guide flanges. The microwave generating lamps (magnetrons) are equipped with a water cooling system, so that each of the generators is connected to the water collecting tube. The generators system is supplied from a specially designed set of microwave power packs installed in a separate housing and connected with the generators by means of cables furnished with suitable sockets.


Fig. 2. View of the layout of microwave generator chamber with arrangement of microwave coupling systems

The charge material is loaded through the upper metallic cover. The space between the metallic chamber wall and the ceramic tube, visible in Fig. 3, is filled with insulating material, so that thermal energy of combustion can not be conveyed to the metal housing. The applied insulating material is characterised by low microwave attenuation coefficient, thanks to that practically the whole electromagnetic field energy is focused on the charge to be utilised. These requirements are fulfilled by insulating wool named SIBRAL.

The chamber is equipped with microwave chokes eliminating risk of leaking microwaves outside the reactor during its operation.

The set of microwave generators is placed in a mobile control cabinet. In addition, a set of power packs permits independent switching the generators on and off, as well as reducing power of each generator down to half the maximum value.

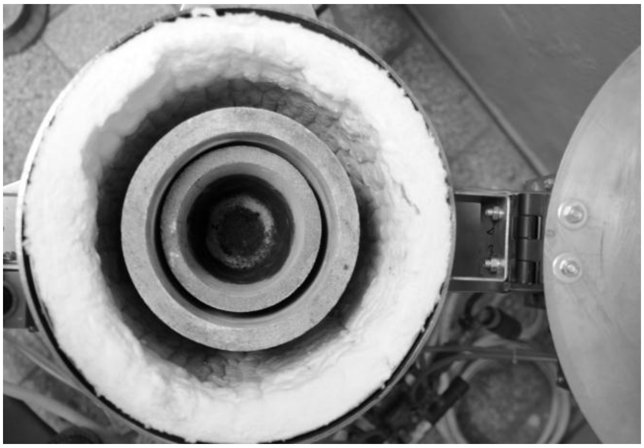
Fig. 3. View of the reactor chamber lined with thermo-insulating wool SIBRAL

3. Preparation of test material

The material used in the preliminary research consisted of non-burnt waste casting moulds and cores made in the technologies employed in foundry plants.

Two grades of thermosetting moulding sands, TMS1 and TMS2, were used in the tests.

Composition of the sandmix TMS1 (Fig. 4) was as follows:

- 96 % of high-silica sand (0.32, 0.20, 0.16)
- 3.4 % of phenolic-formaldehyde resins "Nowolak" (up to 1 % of phenol)
- 0.5 % of urotropine
- up to 0.1 % of calcium stearate.

Composition of the sandmix TMS2 (Fig. 5) was as follows:

- 96 % of high-silica sand (0.20, 0.16, 0.11)
- 3.4 % of phenolic-formaldehyde resins "Nowolak" (up to 1 % of phenol)
- 0.5 % of urotropine
- up to 0.1 % of calcium stearate.

The charge chamber was filled with ca. 750 g of the mentioned moulding sands.

Analysis of the preliminary results and their comparison with those for other materials tested for possibility of using microwave utilization [3] shows that effectiveness of heating these wastes depends on their refinement degree. Therefore, the material to be tested was subject to preliminary mechanical refinement in a laboratory roll mixer.

Microwave heating was performed after closing the chamber and starting the drive that ensured a determined rotational speed. During utilization, recorded were changes in the substrate temperature. The incineration process was finished when stabilisation of the charge material temperature was observed.

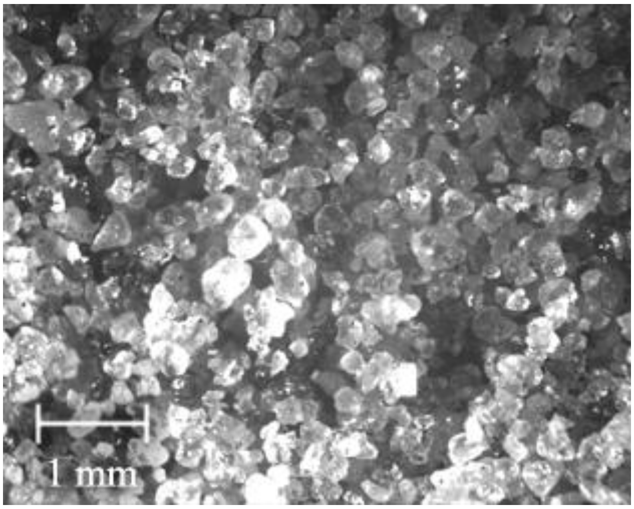

Fig. 4. Surface of TMS1 sand grains before utilization

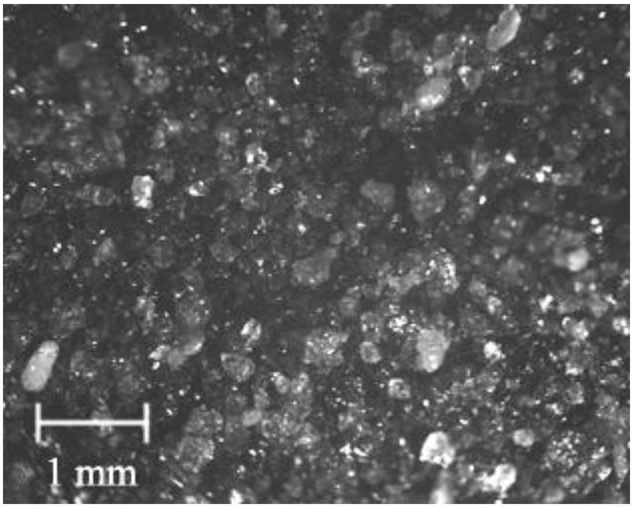

Fig. 5. Surface of TMS2 sand grains before utilization

4. Incineration process

Basic heating process parameters for the moulding sands TMS1 and TMS2, measured during the tests, are collected in Table 1. Temperature was measured on surfaces of the utilized sandmixes. Power of microwaves was 1500 W.

Table 1.
Results of microwave heating of sandmixes TMS1 and TMS2

Heating time (min)	**Temperature (°C)**	
	TMS1	**TMS2**
1	70	120
2	100	210
3	115	235
4	120	300
5	140	330
6	150	360
7	180	400
8	190	440
9	225	470
10	315	500

In the case of the moulding sand TMS1, the process stabilised after 10 minutes, reaching maximum temperature of the charge at ca. 315 °C. As a final result, obtained was very powdery, black and throughout carbonised material, see Fig. 6.

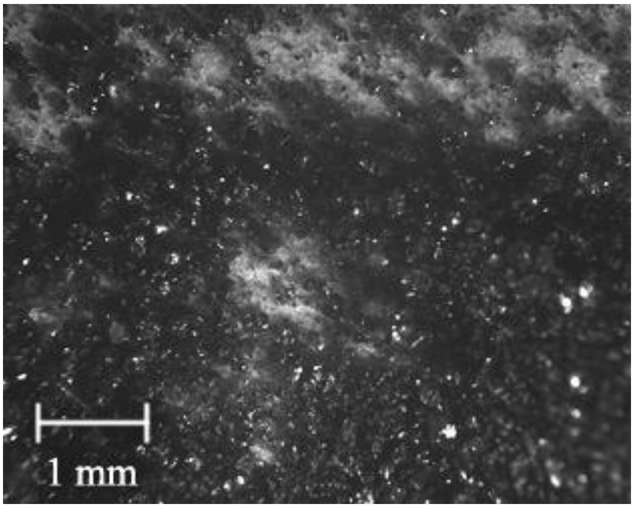

Fig. 6. Surface of TMS1 sand grains after utilization

Course of incineration process of the moulding sand TMS2 was similar to that of TMS1. However, in the case of TMS2, final temperature of the microwave heating was 500 °C. The effect of better heating is attributed to finer major fraction of the used high-silica sand than that of TMS1. The final result was also very powdery, black and throughout carbonised material, see Fig. 7.

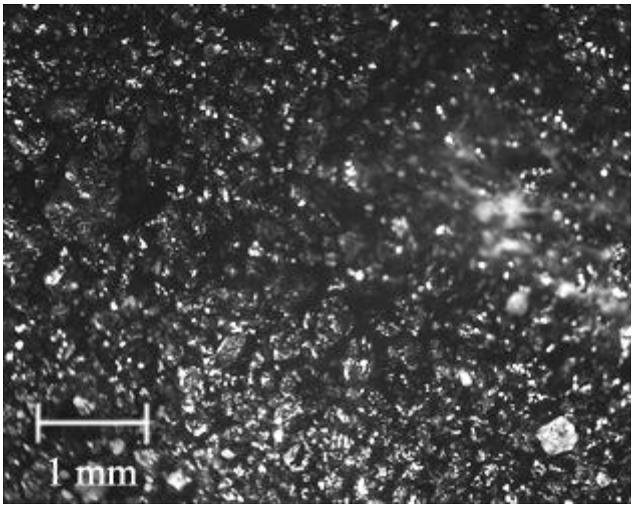

Fig. 7. Surface of TMS2 sand grains after utilization

5. Conclusions

Results of the preliminary, semi-industrial research on possibilities of thermal utilization of waste moulding and core sands based on phenolic-formaldehyde resins in the process of microwave heating lead to the following conclusions:

- Waste moulding and core sands can be effectively and efficiently incinerated in microwave ovens.
- The incineration process using high-power heating facilities is mostly influenced by homogeneity degree of the used electromagnetic field.
- Time and temperature of microwave incineration of waste moulding sands depend on power of microwave heating.
- Heating speed is determined by major grain fraction of the high-silica matrix.
- Microwave incineration of waste moulding and core sands guarantees measurable economical benefits resulting from significant reduction of incineration time.

Acknowledgements

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