ARCHIVES of FOUNDRY ENGINEERING

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

ISSN (1897-3310)
Volume 8
Special Issue
3/2008

167 – 170

35/3

Application of microwaves for incinerating waste shell moulds and cores

K. Granat[a]*, M. Pigiel[a], W. Florczak[b]

[a] Foundry and Automation Division, Wroclaw University of Technology, ul. Łukasiewicza 5, 50-371 Wroclaw, Poland

[b] Flormo S.J., ul. Strumykowa 39, 58-500 Jelenia Góra, Poland

*Corresponding author. E-mail address: kazimierz.granat@pwr.wroc.pl

Received 18.08.2008; accepted in revised form 08.09.2008

Abstract

In the paper, investigation results of microwave heating application for incinerating waste shell moulds and cores made of moulding sands with thermosetting resins are presented. It was found that waste shell cores or shell moulds left after casting, separated from moulding sand, can be effectively incinerated. It was evidenced that microwave heating allows effective control of this process and its results. Incineration of waste moulds and cores made of commercial grades of resin-coated moulding sand using microwave heating was found to be an effective way of their utilisation. It was determined that the optimum burning time of these wastes (except those insufficiently disintegrated and not mixed with an activating agent) is maximum 240 s at the used magnetron power of 650 W. It was noticed that proper disintegration of the wastes and use of suitable additives to intensify the microwave heating process guarantee significant reduction of the process time and its full stabilisation. Application of microwave heating for incinerating waste shell moulds and cores ensure substantial and measurable economic profits due to shorter process time and lower energy consumption.

Keywords: Innovative foundry technologies, Microwaves, Moulding sand, Thermosetting resin, Utilisation

1. Introduction

Microwave radiation has found wide application, among others, in foundry technology e.g. in drying and/or hardening processes of traditional moulding sands, as well as those containing water-glass or thermosetting resins [1-9]. Microwave hardening time is 10 to 200 times shorter than traditional heating time. Energy consumption at microwave hardening is also 10 to 100 times lower. This concerns all the foundry processes employing thermal energy supplied in various traditional ways. The above-mentioned advantages and successful trials of utilising industrial wastes [9] made the authors try applying microwave energy for incinerating (utilising) waste shell moulds and cores.

2. Measurement stand

In the research, a microprocessor-controlled device was applied for controlling supply power of the magnetron and adjusting amplitude of microwaves (which permits stepless power adjustment), as well as for programming heating times and cycle numbers selected for the of working chamber filling degrees [1,4,6]. Tests were carried out on the stand shown in Fig. 1, consisting of:

- adjustable power supply of the magnetron permitting stepless adjusting microwave power between 0 and 650 W, which value could be read on a digital display on the front panel;
- a microwave generator with maximum power of 800 W and frequency 2450 W;
- a length of end-shorted rectangular waveguide 100 x 50 mm with dia. 20 mm tubes on its opposite wider sides to permit

introducing ceramic boats with the material to be heated. A tube dia. 14 mm was additionally placed on the shorted end to permit immediate temperature measurements with a pyrometer and observations of the material;
- pyrometer MX2 made by Raytek.

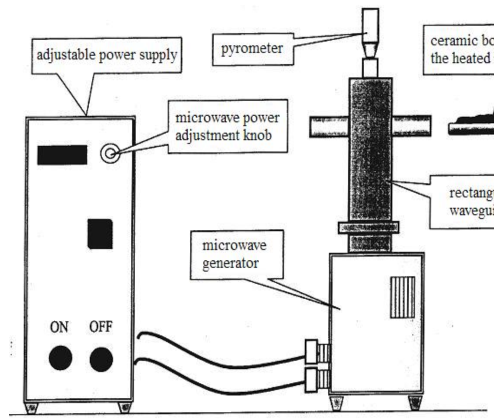

Fig. 1. Test stand for incineration using microwave heating

Thanks to high energy concentration in the specimen volume, the so completed measurement system allows testing effectiveness and dynamics of microwave heating of small specimens of various materials. It is also possible to apply varied combinations of the process parameters and to evaluate influences of different additives intensifying the heating process.

3. Material preparation

Material to be tested consisted of non-burnt wastes of shell moulds left after casting. It was found on the ground of preliminary tests that heating effectiveness of these wastes depends on their fineness degree, so the test material was mechanically disintegrated and segregated. Moreover, it was found that stabilisation, course and dynamics of the burning process are positively affected, irrespective of the material granularity, by adding some material of suitable dielectric properties ensuring proper penetration depth of microwave radiation [10]. So, in subsequent tests, the waste material was mixed with a determined, experimentally fixed, most profitable amount of the activating material. The so prepared material was placed in a ceramic boat and introduced to the heating chamber.

Starting from a minimum value, the generator's power was fluently increased while recording the substrate temperature changes. The burning process was finished at the moment when very dynamic temperature rise of the specimen was observed.

4. Burning process

As was mentioned in clause 2, effective incineration of waste shell moulds and cores in the applied test equipment depends on granulation of the charge material. With granularity of ca. 10 or more, the process in unstable, no expected temperature rise above 190 °C occurs in spite of continuous increasing the generator's power, and the substrate is heated locally only, see Fig. 2.

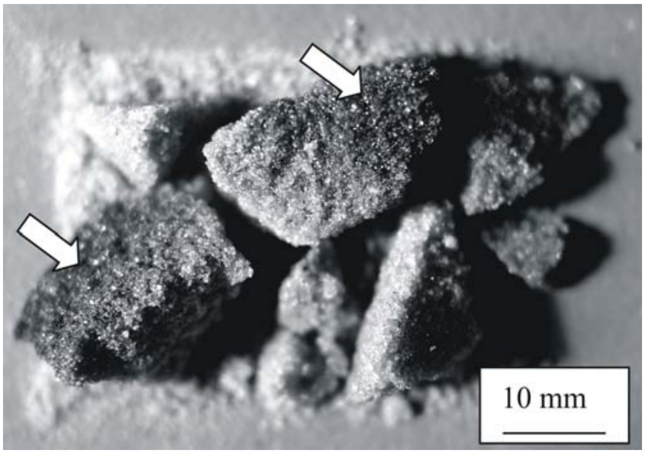

Fig. 2. Waste shell moulds and cores after burning in microwave chamber (arrows indicate partially burnt areas)

The process runs quite differently when the material granularity is below 4 mm, see Fig. 3. In this case, a stable, dynamic and quick temperature rise above 350 °C is observed even at low generator's power, leading to complete incineration of the test material, like it is observed in direct vicinity of a shell mould cavity poured with liquid metal.

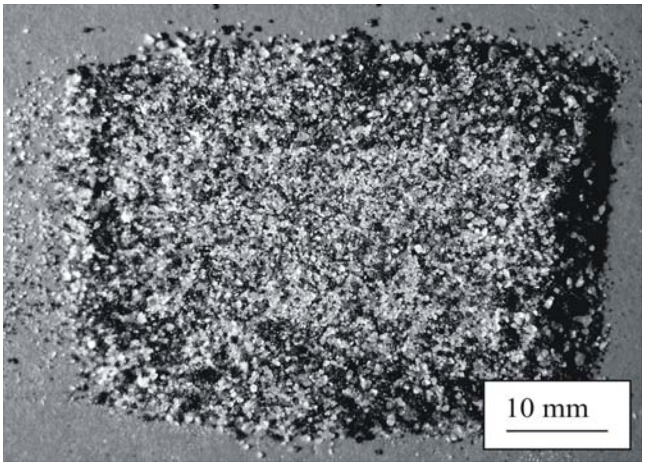

Fig. 3. Waste shell moulds and cores completely incinerated in microwave chamber

As was mentioned in clause 2, it is possible to intensify the microwave heating process by adding materials with suitable dielectric properties ensuring proper, effective and sufficient for the given properties penetration depth of microwave radiation, as well as taking up the emitted generator's power by the substrate [9,10].

So, preliminary tests were carried out, which finally allowed selecting proper quantity and kind of the most profitably acting material to intensify the burning process. Introducing a liquid additive and mixing it with the charge to be incinerated (depending on its granularity up to 25 %) permitted incinerating even large pieces of wastes used in the tests. In this case, stable, dynamic and quick temperature rise above 350 °C was observed also at low generator's power, leading to complete incineration of the test material, see Fig. 4.

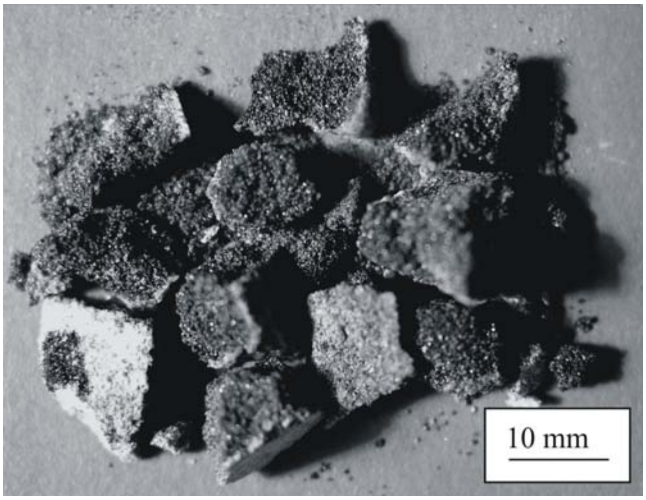

Fig. 4. Waste shell moulds and cores after burning in microwave chamber with intensifying additive

However, the carbonised material does not spontaneously spread to powder, as was when burning disintegrated wastes with no intensifying additive (Fig. 2), but it could be crumbled just under a slight pressure. Pieces of burnt material are black through, look like carbonised, and down to penetration depth of the intensifying additive are observed incinerated areas (Fig. 4) characteristic for complete incineration, as was in the case burning disintegrated specimens (Fig. 3).

Waste shell moulds and cores with granularity below 4 mm mixed with a process supporting additive (see Fig. 5), are not only subject to intensive burning (like when heating with no additive), but they additionally agglomerate (as observed in the process of burning large pieces when the completely incinerated material did not immediately spread, see Fig. 4), which can facilitate possible later transport to the place of further processing, using or storing.

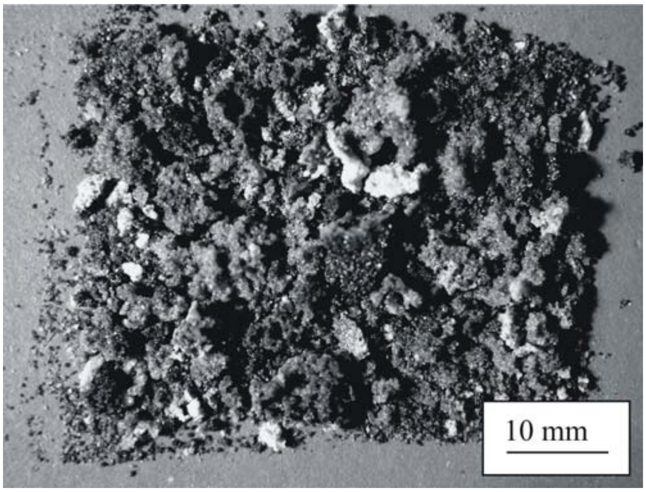

Fig. 5. Waste shell moulds and cores after burning in microwave chamber with intensifying additive

5. Conclusions

Analysis of the test results leads to the following conclusions:

- It is possible to incinerate waste shell moulds and cores in microwave furnaces.
- When using low-power heating equipment, of greatest influence for the burning process is granularity of the material to be incinerated.
- Depending on test material granularity, time of complete microwave incineration is up to 240 s at the generator's power not exceeding 650 W and recorded temperature reaches values above 550 °C.
- Adding up to 25 % of a heating process intensifying agent increases its dynamics, reducing time to reach the required process temperature, as well as favours effective incinerating the charge irrespective of its fineness.
- Intensifying additive supports the burning process to such a degree that, after initiating, a dynamic, rapid (just exothermic) process run is observed with no increase of the generator's power.
- Using the microwave heating process for incinerating waste shell moulds and cores guarantees measurable economic profits resulting from significant reduction of burning time and energy consumption.

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