MICROFLUID APPARATUS FOR FINE GRANULAR MATERIALS THERMAL TREATMENT

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Abstract

The existing equipment possibilities for the fine-grained materials thermal treatment are very limited. Therefore a significant portion of the materials is considered to be waste, even though its qualities are satisfactory. In the research of fine granular material thermal treatment the apparatus working on the fluidization principles was developed and verified on the semi-operational scale. The microfluid furnace is conceptually new solution consists of autonomous fluidization chambers, which are arranged in counter-flow. The counter-current principle provides an integrated solution for fine-grained fractions thermal treatment including individual process phases in one equipment. Experimental microfluid furnace has 9 fluidization chambers providing drying, heating, calcination and cooling of the material. The magnesite calcination experiments were carried out on the furnace. Within the experiments a high quality product at low specific energy consumption was obtained.

Keywords: Microfluid, dust material, fluidization, furnace

Introduction

The thermal treatment of granular materials is connected with rheological, hydro mechanical and, thermodynamical limitations, which implicate low effectiveness and efficiency. Classical thermal apparatus as rotary furnaces, shaft furnaces, fluidized layer furnaces have almost exhausted their possibilities and their improvement has generally not decisive technological, economical and environmental impact. In the last few years the new technologies as integrated thermal apparatus, microfluid furnace and high-revolution furnace in the area of granular materials thermal treatment have emerged. For all of these technologies the high intensity of heat transfer enabled a significant specific volume capacity increase and a decrease in fuel consumption is characteristic. Basic improvement is in significant increasing of heat exchange area, heat distribution and hydrodynamics. The microfluid furnace and high revolution rotary furnace are working with fluidized materials.

1. Experimental materials and methods:

The research of microfluid furnace was realized by physical and mathematical modelling. The isothermal physical model is presented in Fig. 2c. Modelling research was performed on equivalency principles which enable a direct transfer of the modelling results on the full scale equipment.

1.1 Microfluid furnace

The microfluid furnace consists of autonomous fluidization chambers having the character of a perfect mixing (Fig. 1). The material in each chamber can be considered as homogeneous. The individual chambers are arranged in the counter-current.

From the thermodynamic point of view, the maximal number of chambers is optimal, because of the increased number of chambers the process is close to the net counter-current.

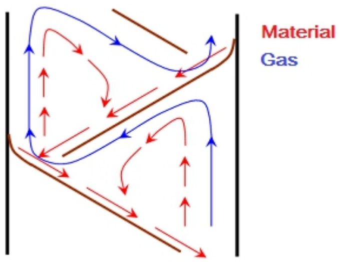

Fig. 1 Fluidization chamber

A gaseous medium at the entrance of the chamber provides a fluidization of the material, which is located at its lower end. The fluidized material is drifting into the upper part of the chamber, where it is re-circulated and is adding the material from the higher located chamber. The gaseous medium proceeds into the higher located chamber. Each chamber is an autonomous reactor, which input - output section must be adjusted to the specific conditions of the process, since the amount of media for each chamber is not individually adjustable. The flow has been validated on a physical model (Fig. 2).

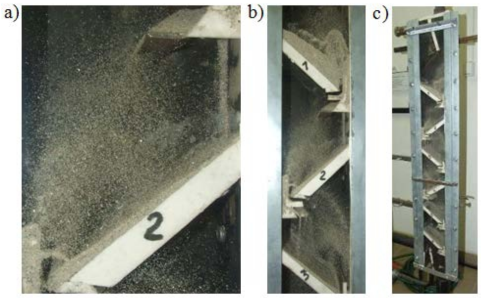

Fig. 2 Physical model of microfluid furnace a, b) detail of the process chamber c) physical model

The fluidization process can be influenced externally by media supply. Internal control is carried out on self-organization principles by embedded elements in the individual chambers.

1.2 Microfluid furnace control system

The control system consists of hardware and software parts that are using the appropriate interface effectively and functionally linked into a coherent system. The task of this system is to allow the operator to make an optimum device control and also an ongoing processes control. The scheme of control system of microfluid furnace is shown in Fig. 3.

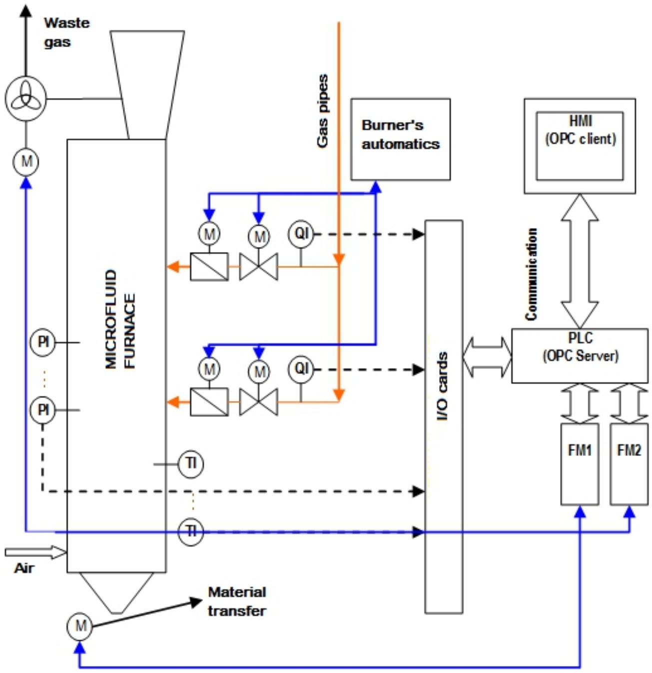

Fig. 3 Microfluid furnace control system scheme

Hardware part of the control system consists of a microfluid furnace PLC automated machine with input-output modules (analogue, digital) located in the switchgear of control system and PC with HMI interface for technology and control system visualization (Fig. 4).

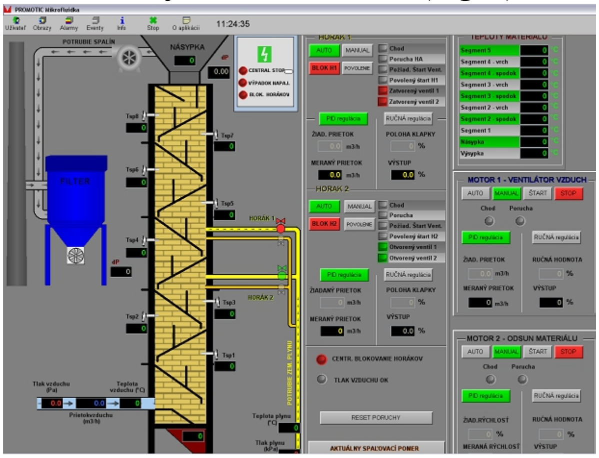

Fig. 4 HMI for technology visualization

For the technology of material processing in microfluid furnace we used two drives. The first is the fan motor intended to fluidization (create the desired air flow and uplift material). The second drive is a motor of screw conveyor for material removal. Both drives (their speed) are controlled by a frequency converter. The Frequency converters are connected through I/O to the control and monitoring system of microfluid furnace.

2. Results and discussion:

Experimental microfluid furnace has 6 fluidization chambers that provide drying, heating, calcination and cooling of the material.

The magnesite calcination experiments were conducted on the furnace. The conditions of the experiment are presented in Tab. 1. The furnace filling during the experiment is shown in Fig. 5.

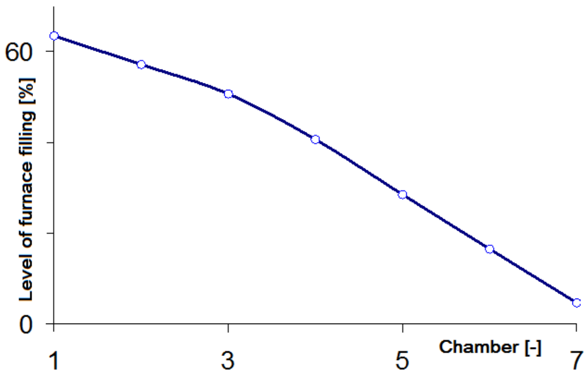

Fig. 5 Furnace filling during the experiment

The functionality verification of the operating parameters was carried out on the furnace. The results were used to calibrate the mathematical model.

Functionality of self-regulation has been fully confirmed. Specific output and thermal efficiency were assessed from the operational parameters. The production coefficient of 652 kg of product per 1m^3 of equipment was achieved.

Tab. 1 Experiment conditions

Volume of 1st chamber	2,7	l
Filling the chamber	18,5	%
Cross section of 1st chamber	0,023	m^2
Charge	30	kg/h
Production performance	15	kg/h
The air flow rate	21	m^3/h
The gas flow rate	1,9	m^3/h
Specific gas consumption	126,7	m^3/t

A specific gas consumption was 126,7 m^3/t. The course of temperatures during the experiment is shown in Fig. 5. The semi-operational microfluid furnace has been designed by the calibrated measuring model. The furnace has 11 chambers on height; burner is placed in the 7th chamber. The course of temperatures is shown in Fig. 6. The microfluid furnace capacity is 1,88 m^3/t.

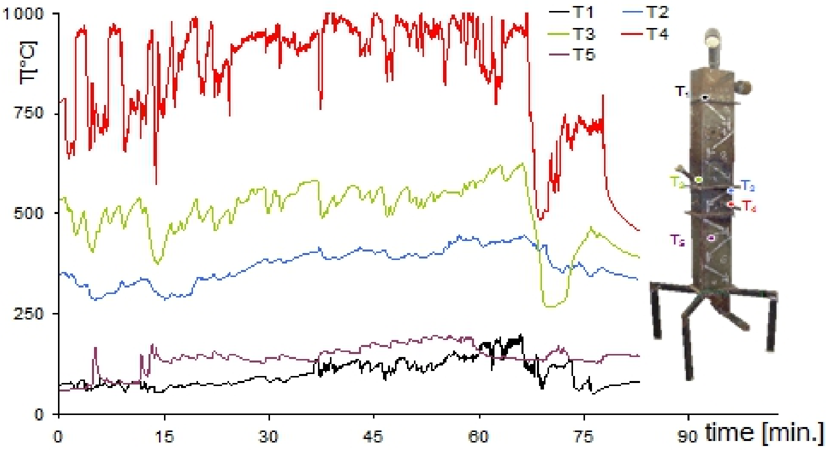

Fig. 6 The course of temperatures during the experiment on experimental equipment

On Fig 7 is presented gas and material flow in the fluidization chamber and between individual chambers.

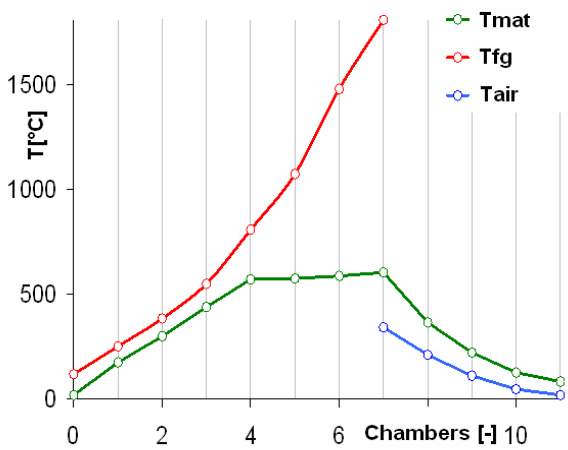

Fig. 7 Gas and material flow in the fluidization chamber

The amount of flue dusts may be affected by the chambers sizes and degree of recirculation by dimensions of input-output openings. The dependence of the amount of drifting particulates from the gas velocity in the chamber is shown in Fig. 8. Pressure losses are significant and occur mainly by energy consumption for fluidization. In the individual chambers can pressure losses reached the value in the range of 500 - 1500 Pa.

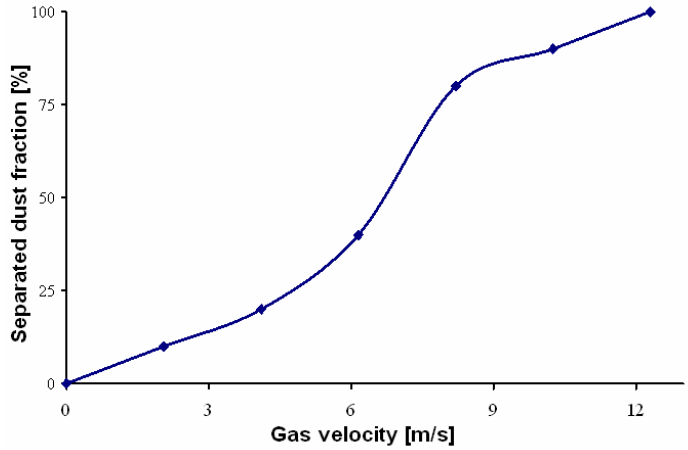

Fig. 8 Dependence of dust particles dragged from the gas velocity

Specific to the microfluid layer is that for combustion it is used secondary air and the multi-stage combustion in several combustion chambers is possible inside it, where the combustion medium in the following combustion chamber are flue gases from the previous combustion chamber. For the low-temperature processes, e.g. drying process, it is not possible to perform drying directly in the material chamber, but separately in the combustion chamber. In the high-temperature processes the combustion can be performed directly in the material section.

2.1 Microfluid furnace prototype

Prototype microfluid furnace (Fig. 9) consists of 9 fluidization chambers. Number of chambers in the different process zones depends on the process. Proposed furnace is designed for the caustic magnesite production. In the furnace is carried out the following process operations: drying (2 chambers), heating (2 chambers), calcination (2 chambers) and cooling (2 chambers). Air is supplied to the process through the last chamber. Fluidization chambers are built from refractory materials with thermal insulation and the outer shell.

Parameters of the proposed facility:

- magnesite charge of 50 kg/h,
- grain size from 0,2 to 3 mm,
- caustic magnesite product - 19 kg/h,
- 6 chambers (3 heating, 1 burning, 2 cooling).

Fig. 9 Microfluid furnace

3. Discussion

The knowledge gained from the laboratory experiments and physical modelling of the processes of fine-grained material treatment in a fluidized layer and mainly the knowledge gained from mathematical modelling of microfluid furnace indicated potentially technological and operational possibilities of the prepared solution. Microfluid furnace based on achieved knowledge was proved as an operationally and technically very effective solution.

Application possibilities of hydraulic uplift are mainly in the field of the materials heat treatment with a non-permeable compact layer. The implementation of these processes is slow, resulting in low power devices and high heat loss. This layer occurs in fine-grained and dust materials. Therefore, the fine fractions often become waste material even if the site is a valuable resource. Fluidization is becoming a breathable layer, thereby increases heating surface many times, thus the intensity of the process and reduce the size of the device.

Physical and mathematical modelling methods can significantly contribute to acquire required critical knowledge. The main contribution of physical modelling is in the understanding of process mechanism and determination of furnace layout and process parameters required for model generation. The aim of the mathematical modelling is rapid prototyping. For simulations at elementary and higher levels the generated mathematical models have been used.

The multistage combustion in the several chambers and the use of secondary air for combustion are specific for the microfluid furnace. The combustion medium in the next chamber is flue gases from the previous chamber. For the low-temperature processes, e.g. drying process, it is not possible to perform drying directly in the material chamber, but separately in the combustion chamber. In the high-temperature processes the combustion can be performed directly in the material section.

Conclusion:

The microfluid pilot furnace for fine-grained materials heat treatment has been designed and built based on the research. In the pilot furnace the magnesite caustification experiments were realized. The experiments results confirmed the functionality of the proposed equipment. Based on the experimental results the calibration of the mathematical model of semi-operational furnace was performed. Currently, the microfluid furnace research is focused on the fine-grained material thermal treatment in the magnesite extraction and processing. Hydro mechanical fluidization in microfluid furnace was proved as operationally and technically effective solution. The application possibilities of the hydraulic uplift are mainly in the field of materials heat treatment with a non-permeable compact layer which occurs in the fine-grained and dust materials. By fluidization the layer becomes permeable causing the heat exchange surface and the process intensity are multiple enlarged. Functionality of self-regulation was fully confirmed.

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