Association of Metallurgical Engineers of Serbia *Review paper*
AMES *UDC:669.782.6.015.8.001.26.17=861*

OPTIMIZATION OF NON-TRANSPARENT NON-CRYSTAL SILICA PRODUCTION PROCESS

SANJA MARTINOVIC, MILICA VLAHOVIC,
VELISLAV VIDOJKOVIC, TAMARA BOLJANAC, PREDRAG JOVANIC

Institute for Technology of Nuclear and Other Mineral Raw Materials, 86 Franchet d'Esperey St., Belgrade, Serbia, E-mail: s.martinovic@itnms.ac.yu

ABSTRACT

The aim of this research is complex analysis of non-transparent non-crystal silica obtaining and process optimization by determining of process control algorithm. Experiments were realized using electro resistance furnace. Raw material was floated quartz sand. ThV camera was used for observing the melting. On the basis of these measurements, temperature profiles in the system were obtained. Working models of the process were also defined. Models were the basis for determination of control-optimization algorithm. The "black box" method making connection between temperature and time was applied. Namely, on the basis of the virtual process defined by different models, sets of parameters used for the process control are determined.

Key words: ThV camera, working model, optimization

INTRODUCTION

Optimization of technology process includes optimization of mixture composition and optimization of technology processing parameters. In case of powder mixtures, "functional additives" are introduced into the matrix powder. The additives are particular powders that have some specific role, for example to decrease melting temperature and/or viscosity. In case of standard single-component raw materials, with clearly defined compositions and properties, focus of analysis is transferred to the process parameters. In such cases, the properties of raw materials could be considered as the constants of technological process. According to this approach, the research is not focused on material but on the control of processing factors and their relation to the products quality. That approach is called model of "black box", where the optimization is occupied with definition of control processing algorithm presenting feedback of the system. Selection of method for quantification of material properties and level of technological factors is made on basis of optimization object definition (material or process).

EXPERIMENTAL

Methods and Materials. Electro-thermal melting procedure to obtain non-crystal SiO_2 was performed in a electro-resistance furnace with horizontally placed movable graphite heater. Numerous experiments with the same raw material were realized while the heights of electrode elevating and total time of melting durations (velocities of electrode elevating) were variable. Voltage and amperage were increased to the maximal power for each melting. The step of electrode elevating was 2cm. Existence of caught gaseous bubbles into the viscous melt during the process causes non-stationary process inside of reactive volume, so the process itself was analyzed as a non-stationary [1,3].

In the processes where the temperature is changed in the time, the toughest problem is successful temperature measuring in all spots of processing reactor space. Classic method of temperature measuring by the application of thermocouple is very complex, since selection of the spots for temperature measuring that would appropriately represent all temperature changes into the processing reactor space is quite difficult. Also, the main assumption of the experiment was non-stationary of the process with numerous accompanying effects, so the usage of thermocouples would not show reliable results. Because of that, thermo visual method (ThV) was selected for recording of temperature fields and dissipations. The method gave information about surface temperature distribution. On the basis of these visual and thermal images, isotherms and temperature distribution in relation to time were obtained. Modified camera AGEMA, type 9000, was used during the research. Non-contact temperature measurements are enabled in the range from – 40 to 2000^{o}C, with average measurement accuracy of ±2^{o}C. Analysis of obtained thermograms is processed by the program package of “Explorer” type [2].

RESULTS AND DISCUSSION

Analysis of isothermal lines and thermograms. Besides the analysis of thermograms, time changes of temperature at the distance of 1, 3 and 5 cm from the heater were analyzed. With the aim to design control algorithm i.e. optimize the process, working model of time-temperature profile during the process was made. Since the process was completely non-stationary and dynamical, definition of mathematical model regarding the processing parameters was almost impossible. It was the main reason for applying “black box” method (connection between temperature and time) instead of model processing definition, Fig. 1.

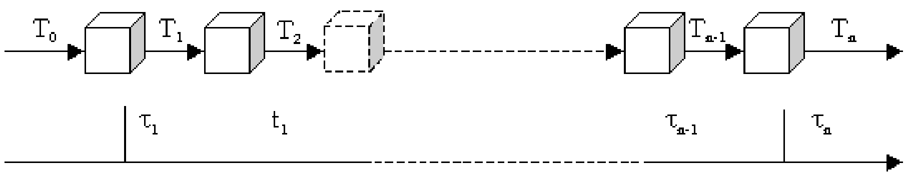

Fig. 1. Discretional model of ”black box"

Changing of temperature (ΔT) at the distances from the heater of 1, 3, 5 cm was tracking during the research. Mathematical equation can be obtained by correlation between obtained information that is temperature changes and time in a model. There are numerous mathematical equations and the most appropriate one should be defined.

The term “degree of correlation” is used in mathematical analyses. It shows level of confirming how well the model describes experimental data. However, since the measured values of analyzed properties present physical dimensions, the analyses should include simple models (equations). Linear model was applied in this analysis. Changes at the distance of 1, 3, 5 cm from the heater were observed, Fig. 2.

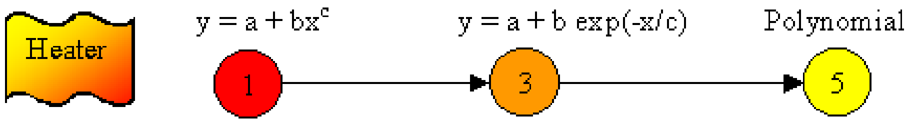

Fig. 2. Different aspects of powder reactions at the temperature impulse

Above analysis shows that “influence” of the heater on the process is reduced while the powder “takes the lead” in the process tendency at the distance between 3 and 5 cm. It indicates that it is not important to track the temperature changes at the distance from the electrode more than 5 cm according to aspect of process control. On the basis of these values, threshold values of the model parameters were calculated.

Optimization and control algorithm of process. Processing control implies series of experiments on virtual model (simulation) to get various sets of processing parameters with aim to obtain uniform quality of material. It means that model or set of models that describe the process should be defined as more accurately as possible. Real parts of the system are rector (furnace) and measuring and regulating devices. These parts are called executive parts of measuring and regulating system. On the basis of various information obtained from the virtual part of measuring and regulating system, they (real parts of the system) do control of the process. The essence of the control system is based on feedback principle with elements at very high level particularly system for data processing. Sofisticated control of non-stationary process and faster data processing is achieved in this manner. In this case, two aspects of process control are possible. The first one is static model of control with control elements placed in fixed spots in powder. Process control is performed by comparing of response on the control element and values obtained with modeling. If the values are inside the acceptable range, anyone action will not happen, but if the values are outside the acceptable range, corrective action will carry out. Another model of process control, dynamic model, implies moving of measurement system together with heater. This is technically easier and more efficient way for processing control.

Developed optimization algorithm presented in Fig. 3 shows that process has to be analyzed from the aspect of composition optimization as well as processing optimization of reactor. Since composition optimization and homogenization time were not taken account in this analysis, initial material was considered as a constant of the process.

Optimization of processing characteristics contains tracking and selecting of temperatures and velocity of heater lifting up.

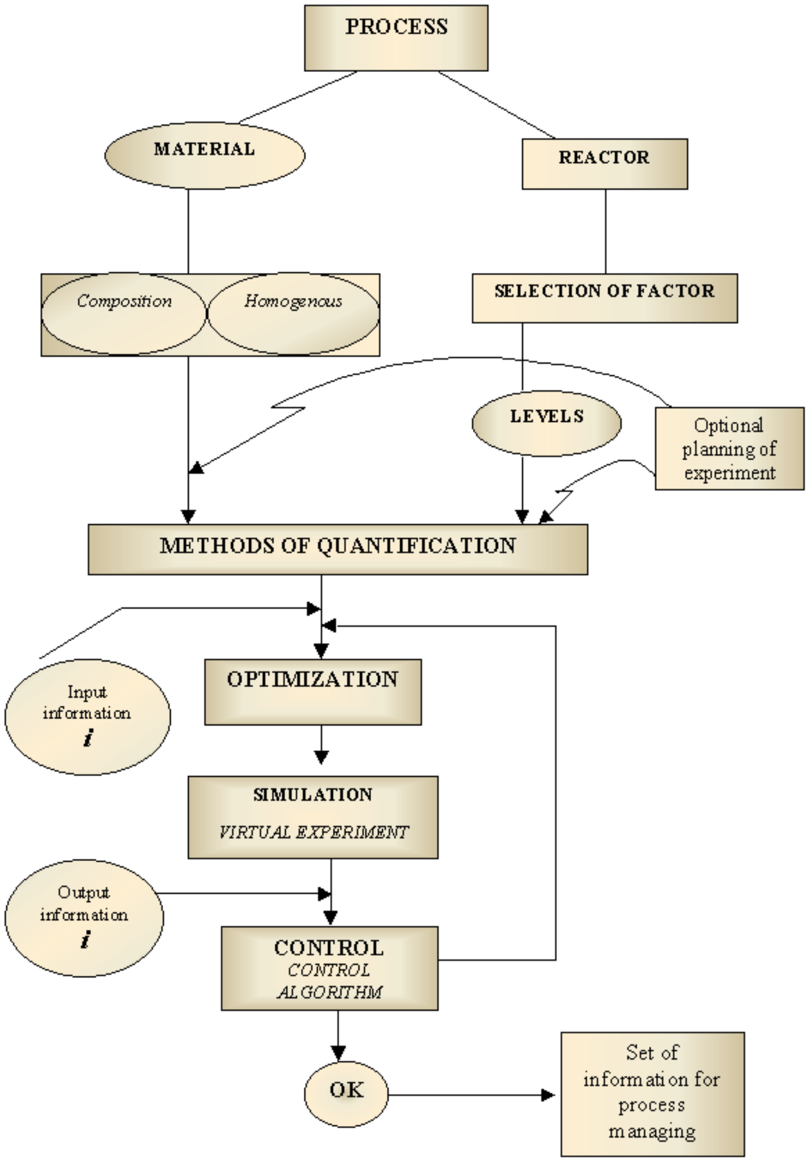

Fig. 3. Scheme of Optimization Algorithm

Besides of defining mass and energy transfer, developed algorithm also should define transfer of information. Namely, expert system can be determined in this manner and correctly designed virtual experiment continuously upgrade it, Fig. 4. According to flow of information transfer the information obtained by virtual experiment takes the role of feedback. This information is the only one that can be independently changeable without influence on real system and with precisely defining set of criteria in the system for support in decision making (SPO). SPO presents the database or filter for information toward control system. Scheme of algorithm is shown on Fig. 4.

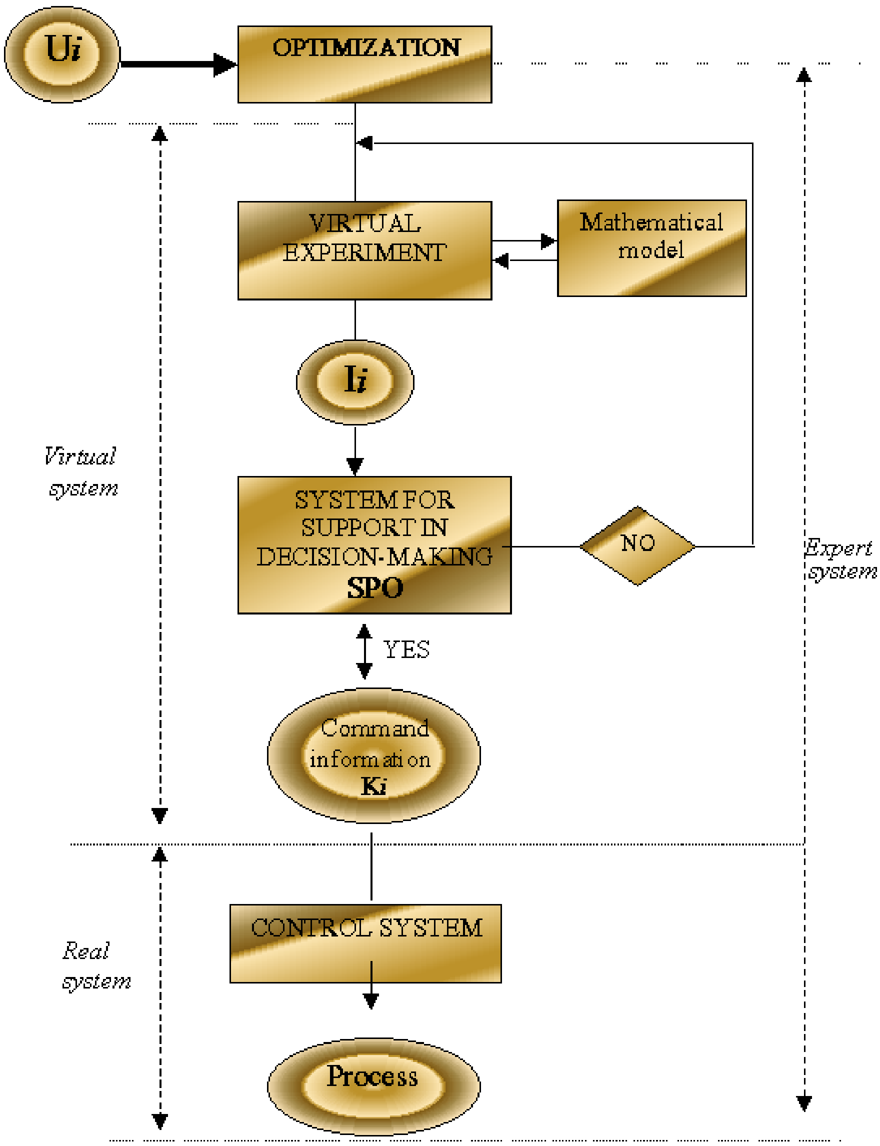

Fig. 4. Control algorithm of process

SUMMARY

Different levels of the process simulation are possible by definition of working mathematical models (virtual process). On the basis of virtual experiments (VE), a number of information in conjunction with the process was obtained with the aim to define every subsequent experiment. Collection of information from experiments and virtual experiments was database of process that was the base for system for support and decision making (SPO) and source of execute information for system of process control and regulation. On the basis of performed research further detailed process analysis can be possible. Namely, adaptation of control-measuring algorithm on the scale-up system can be determined, too.

REFERENCES

[1] Sanja Martinovic, MSc Thesis, Faculty of Technology and Metallurgy, University of Belgrade, 2003.

[2] Predrag Jovanic, PhD Thesis, Faculty of Technology and Metallurgy, University of Belgrade, 1993.

[3] *"New Approach of the Non-Stationary Process Analysis of SiO_2 Melting"*, Sanja Martinovic, Predrag Jovanic, Dimitrije Kristic, Milica Vlahovic, Journal of Metallurgy, No.2, Vol. 10, (2004).