INNOVATION OF ROTARY FURNACES FOR GRANULAR MATERIALS HEAT TREATMENT

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Abstract:

The current rotary furnaces have very good application possibilities in materials processing of various granularities. Their main disadvantages are negative economic and ecological indexes. The rotary furnaces research was focused on the furnace operation improvement so as to obtain improved operating parameters. Based on the results of the simulation and operations in pilot conditions, the following six optimization measures were tested: charge preheater, self-regulating charge feeder, radial seal, controlled cooling of furnace shell, diffusion burner and sinter cooler. As the result of evaluation of individual measures, the fuel savings can be achieved. Applying the measures, the rotary furnace indexes will approach to other thermal apparatus while preserving or increasing their most significant index which is high furnace output.

Keywords: Granular materials thermal treatment, rotary furnace, innovations

Introduction:

For today's rotary furnaces situation is characteristics that their optimization potential was already used. A low added value of production, an increase of production costs and an insufficient quality of the product are results of these factors. Furthermore, a decline of economic efficiency of production leads to reduction of funds needed to increase the innovation potential of the company. Therefore, a good solution is to use innovative tools for technological processes problems solving. Using innovative tools means the transformation of a new product, service or process into practice. The new processes are implemented since then they are used in the business operations. A great emphasis is placed on technical innovation of rotary furnaces, as the basis of innovation activities in the connection with research and development activities.

Innovation of rotary furnaces is an essential, radical transformation of the processes via the application of a new technology to achieve improvements in process efficiency, quality and productivity. Optimization and innovation complement each other and synergistically affect the technological processes efficiency in rotary furnace. The optimization measures can achieve real cost savings of approximately 1-8 % with innovative measures 10 % and more. A technical innovation presents a set of measures which lead to the setting parameters of the production facilities to a level that they can be regarded as an optimal device. This technical innovation shifts technical limitations of the equipment or is focused on move of the limits close to the optimal technical conditions. The aim of technical innovation is to find the optimal operating conditions corresponding to minimum objective functions with a change of structural parameters of the device.

1. Rotary furnaces:

Rotary furnaces (Fig. 1) are among the continuous operating furnaces. They are widely used in many industries. Their advantages include a high performance and demands for lower quality of a charge which don't require a charge with limited granulometric composition. Their main disadvantages are large heat losses from the furnace walls and outgoing gases, large investment and operating costs.

Fig. 1 Rotary furnaces

Extensive use of rotary furnaces is given by possibility of high adaptation to different technologies and outputs. The furnaces producing a magnesia sinter and cement are among the largest and energy-demanding rotary furnaces. From technological point of view, the provision of the basic technological requirements (process duration, maximum temperature, high output) is critical. The rotary furnaces are used for the treatment of the solid granular charge with a grain composition up to 80 mm, usually 5-30 mm with different granulometric distribution. The charge is mixed in the furnace unevenly. However, the furnaces consider their charge as homogeneous. Heat in the furnace is obtained primarily by fuel combustion and partly also under favorable conditions as a result of exothermic reactions in the charge (especially for roasting of sulphide of metallurgical ores and concentrates).

2. Results:

Within research and development a number of measures enabled a decrease in specific fuel consumption while maintaining or improvement of product quality has been designed and implemented. Technical measures focused on a reduction of losses of the outgoing flue gas are affected by development and application of charge preheater, continuous charge feeder with adjustable height of the layer and seal of cold and hot rotary furnace head.

2.1 Technical optimization

Impacts of technical optimization of rotary furnace were calculated by mathematical simulations. The technical solution was validated and performed on the laboratory, pilot plant or operationally.

Charge feeder and an increase of its layer at the furnace input

The solution lies in self-charging while maintaining constant height of the charge layer. An increased thickness of the layer is achieved as well. The technical solution of feeder ensures self-regulating maintaining of the level of charge in the furnace at a constant (adjustable) level and thus prevents material loss from the furnace by appropriately placed partitions and spirals (Fig. 2). This will include the following benefits: improvement of the thermal operation of the furnace, reduction of specific fuel consumption, increase of performance and sinter quality and decrease in flue gas. Dosage of charge is carried out by internal feedback.

Fig. 2 Rotary furnace charge feeder

After installation of the feeder an average layer has been increased at the first 10 m from the furnace entry from 0,4 m to 1,2 m. High level was evident along the entire working length of the furnace and was also reduced depending on the level of decarbonisation and charge sintering. Thickness of layer particularly affects the length of stay of the material in the furnace. The charge is being stayed in the individual zones of the furnace longer by 30–50 %. There is a theory that the degree of magnesia sinter compaction is a function of time and temperature and porosity magnesia sinter is decreasing by extending the stay at sintering temperatures. Due to the enlarged surface area of the material and the enlarged surface of contact material with furnace linings the heat transfer to the material has been improved.

With layer thickness and degree of furnace filling above 30 %, the character of the material motion is being changed from sliding to tumbling even at low furnace revolutions.

Radial seal

Designed radial seal (Fig. 3) is based on rolling friction. Sealing system consists in replacing sliding friction with rolling friction. Using this solution is achieved high-effective seal with very low energy consumption to overcome the resistance by friction and long service life. Radial seal was verified on an experimental high-revolution furnace.

The seal is applied to the following parts of the thermal apparatus:

- cold rotary furnace head,
- hot rotary furnace head,
- cooler hot head.

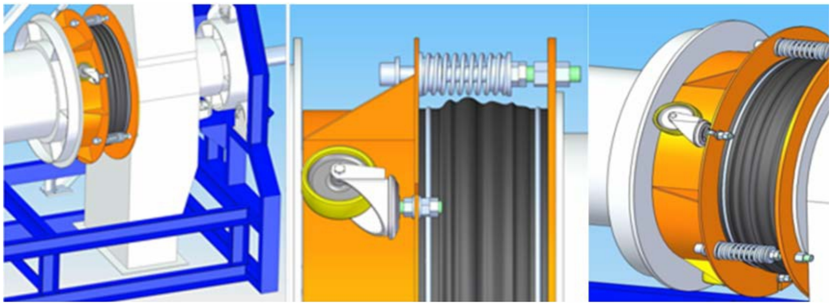

Fig. 3 Technical solution scheme of the furnace radial seal

The results have confirmed the high operational parameters of seal that exceed the expected goals. Annual benefits should reach 2-3 % of the total production cost of the apparatus. The benefits are mainly in the removal of inlet air conveyed to waste flue gases thereby the energy consumption for the flue gas exhausting, load filters, flue consumption, the amount of flue dust will be reduced and control of the furnace will be improved.

Layer increase – hot rotary furnace head

Increase of the layer thickness in the rotary furnace leads to reduction of flue gas temperature by 196°C. Thereby an average temperature of the material from the preheater is reduced from 507°C to 414°C. Maximum temperature of the material in the preheater is reduced from 667°C to 489°C thereby a decomposition of $FeCO_3$ and production of CO in the flue gas is reduced from 1,66 % to 0,06 %.

Thus, length of stay of sinter on the side of hot rotary furnace head will be increased proportionally to volume of sinter. As a result will be a reduction of fuel consumption, higher performance and higher sinter quality.

Intelligent diffusion burner

Diffusion burner provides heat generation and heat transfer to the material by a new method. Use of diffusion burner enables significantly intensive rotary furnace operation and thus increasing the use of heat for the product processing. The solution purpose was to propose and verify the diffusion burner, whose application in the carbonization process would bring substantial fuel savings. This solution is unique on a worldwide scale. Diffusion burner has two basic functions (Fig. 4):

- enables to generate an optimal shape and temperature of the flame,
- and efficient use of secondary air.

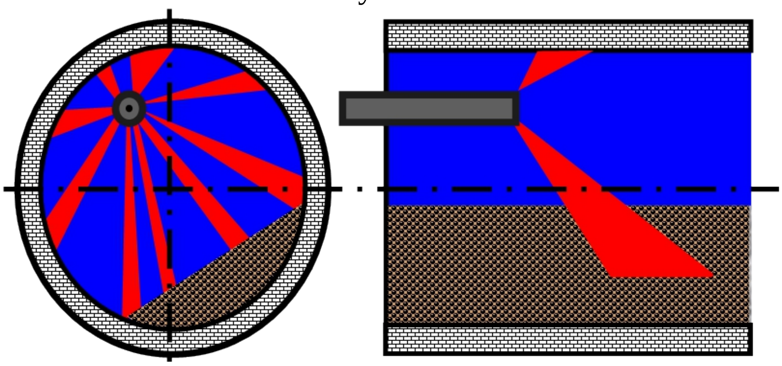

Fig. 4 Operation principle scheme of diffusion burner

System of shell regulated cooling

The system of controlled cooling of furnace shell was designed in order to reduce heat loss through furnace shell. Essence of rotary furnace controlled cooling is a creation of an air gap between the furnace shell and the length of the furnace environment. The controlled amount of cooling air is running through length of the furnace and is taking such quantity of heat so that the temperature of the shell surface does not exceed the permissible limit by design (up to approximately 350°C).

Reduction of heat loss through furnace shell and using the heat taken through shell for combustion air heating is achieved by controlled shell cooling of rotary furnace (Fig. 5). Reduction of heat loss through the shell rotary furnace is achieved by increasing the surface temperature to value near the maximum temperature (approximately 350°C), thus reducing the temperature gradient and consequently the heat flow. The solution has been tested in pilot conditions.

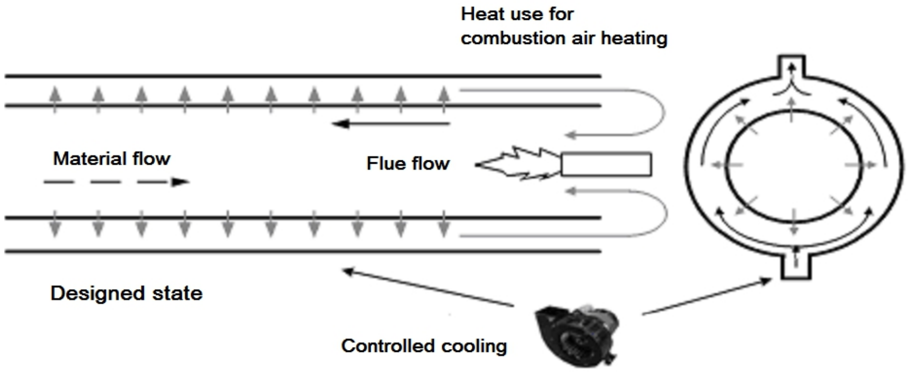

Fig. 5 Rotary furnace scheme with a system of shell controlled cooling

Cooler optimization

The current system of product cooling in the rotary drum cooler with external water cooling of furnace shell doesn't enable an effective use of product heat. It is the quantity of heat which corresponds to approximately 1/3 of the total heat losses in the process. In addition, a final quality of the carbonized anthracite is also influenced by cooling process and atmosphere in the cooler during cooling. Design of a new two-stage cooler (Fig. 6) is based on the principle of a compact thin layer of material and cross flow of cooling medium through the charge. Waste flue gas from a preheater can be used as a cooling medium due to minimize the contact of carbonized anthracite with air. For after cooling of the product and also removal of dust fractions from the product the second stage of low-temperature cooling will be used.

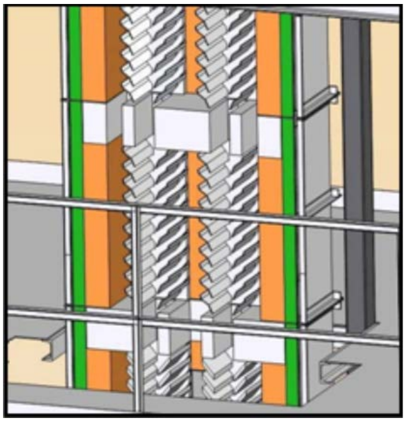

Fig. 6 Concept of cooler on the principle of a compact thin layer

Charge preheater - ITA

Charge preheater installation will significantly contribute to improve an energy side of the carbonization process. This is completely new type of thermal apparatus for the granular materials thermal treatment in a thin dynamic layer. Its main contribution is the use of heat from waste flue gas for charge preheating into the rotary furnace and thereby significant increase of its performance. The preheater operates on the same principle as the proposed product cooler, i.e. on the principle of cross flow of flue gas through a compact dynamic thin layer.

Alternative fuels

Reduced fuel consumption will be achieved by using biomass or waste as an alternative fuel.

Charge optimization in rotary furnace

The rotary furnace uses the charge of size from 0 to 60 mm. A fine-grained charge creates a lot of flue dust and a coarse-grained charge has large specific heat consumption. The object of the research is to process the charge in the rotary furnaces which is inappropriate for other apparatus thereby achieving a reduction of specific fuel consumption.

2.2 Operational optimization

The task of the operational optimization is to find the optimal operating conditions of the technical equipment corresponding to minimum purpose-built functions. Optimization parameters are the furnace performance, fuel input, the amount of air (primary and secondary), layer thickness and influence of revolutions. An example of rotary furnace operational innovation is the use of control system based on the future states prediction.

Rotary furnace predictive control system

The predictive control system is based on the interaction of the operator with the direct control system (Fig. 7), in which the operator directly interferes with the process or the direct control system through entering desired values and quantities. The primary task of the control system is to ensure the required quality of sinter during fluctuations of input parameters and operating conditions. The system consists of a supervisory level of the processes control and the level of direct control. The quality control at boundary conditions changes is carried out on the supervisory level. The individual regulators are located on the level of direct control providing the regulatory loops, large amounts of gas, combustion and cooling air and material flow. The main part of the supervisory level is the furnace model by which the operator sets the range of desired quantities on the process level according to state of production planning process and experiences. The mathematical mode will be set based on the obtained data whereby the optimal operating parameters will be calculated. While the material composition is unknown, a mathematical model will be used to set upper and lower limits.

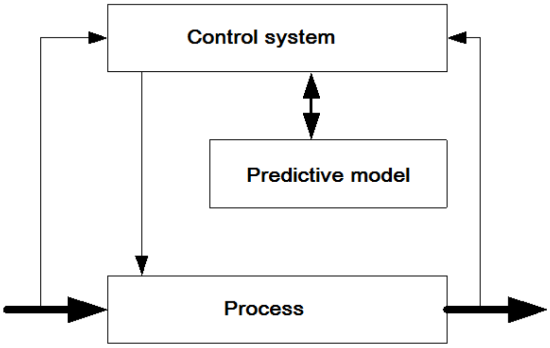

Fig. 7 Scheme of the predictive system

3. Discussion:

An energy intensity of the rotating apparatus is partly reduced by alternative fuels, which change demands on the furnace lining. Rotary furnace lining is composed of various refractory materials according to temperature conditions in the individual zones. In the section from the entrance to the transition zone of the furnace are used hard chamotte or refractory concretes. A critical area defying time use of the furnace is the sintering zone with the highest temperatures and related physical and chemical effects.

For its bricking up are used a number of basic elements: magnesia - spinel, magnesia-hercynite, magnesia-zirconium (Fig. 8). These bricks can not be considered as substantially improved materials but as alternative materials.

Successive categories are magnesia-spinel products containing magnesia-spinel from 6 to 20 % in the various forms. The products are mainly applied in those zones where the creation of stickers is insufficient.

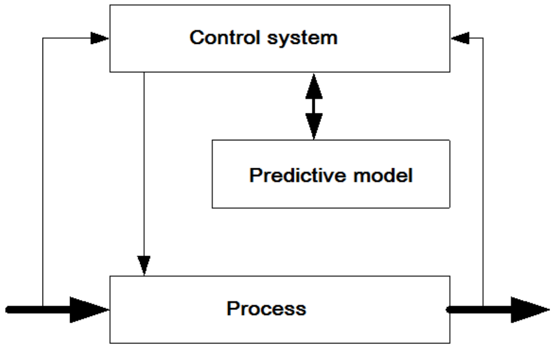

Fig. 8 Rotary furnace a) Lining cross–section b) placement of furnace lining bricks

Use of shell furnace waste heat for water heating

Heat losses from rotary furnaces represent a significant proportion of the total input energy, especially in energy-intensive industries (production of sinter, cement 10 – 15 % of the total heat input). The proposal of the waste heat use lies in the installation of pressure tubes arranged longitudinally on the surface of the furnace shell which are used for transfer and heat of water - Fig. 9. This system enables to handle higher flow rate of fluid transfer.

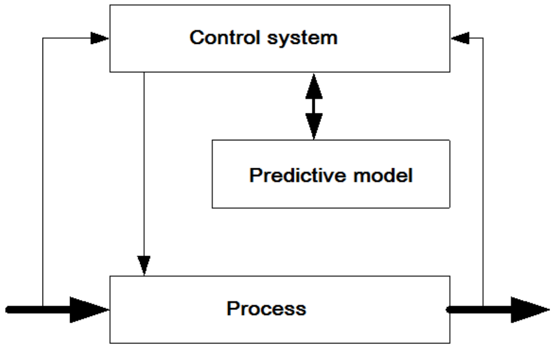

Fig. 9 Double furnace shell a) with axial arrangement of tubes, b) with radial arrangement of tubes

Conclusion:

For the rotary furnaces innovation twelve innovative measures have been proposed. The individual measures have been verified in the laboratory, at the pilot or industrial scale. For the evaluation of their work the indexes and criteria have been proposed. The simulation and experimental results confirmed the possibility of achieving the expected parameters. A significant improvement in rotary furnaces can be achieved by individual measures. For instance, applying the self-regulating continuous charge feeder leads to increase the charge layer thickness, which is presented in the following savings:

- decrease in furnace revolutions by approx. 30–50 %,
- extend of charge duration in the furnace individual zone by 30–50 %
- increase of output by approximately 6 % and reduction of specific fuel consumption by approx. 6 %,
- reduction of dust in the flue gas by approx. 25 % due to reduced revolutions,
- reduction of CaO in raw sinter in fraction 0 – 0,5 mm,
- increase and balancing of the achieved values OH in the magnesite sinter,
- reduction of sticks creation on the furnace lining and its lower wear.

Total application of the measures will enable an inclusion of these rotary furnaces in the BAT category which will exceed other types of thermal apparatus by its parameters.

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