european cement research academy

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Cement Manufacturing Training using the SIMULEX® Simulator

Plant operators gain experience from virtual cement production under realistic conditions

The Simulex® cement plant simulator is an effective tool which has proven to be of high benefit for training plant operators and plant supervisors. The simulation programme fosters the trainees' understanding of the process technology of cement manufacture and teaches them how to economically operate a cement plant. The simulation is based on a state-of-the-art process control system and ensures cement production training under almost real-life conditions.

The Simulex® cement plant simulator was developed by KHD Humboldt Wedag AG in co-operation with the Research Institute of the Cement Industry for training plant supervisors and production controllers. This training tool realistically simulates the operation of a cement plant. It reacts to the control actions taken and sets the process parameters like in real plant operation. Furthermore, the trainer can initiate malfunctions which the trainee must recognize and react accordingly.

The simulator models all the subsystems of the plant, such as raw mill, coal mill, rotary kiln including preheater, calciner, bypass system, clinker cooler and cement grinding plant. Silos and material handling equipment are also included and guarantee consistent material flows throughout the production process.

The trainees can practice to produce raw meal, clinker and cement on the screen, like they would be doing via the process control system in the control room of a cement plant . They learn how to operate their plants economically, how to recognize critical process conditions reliably and in good time, and how to implement appropriate countermeasures quickly.

Technical design of Simulex®

Simulex® is based upon a complex mathematical process model, which simulates the dynamic behaviour of the production plant. A combustion calculation gives detailed information about the gas composition at different places within the kiln. Also the model encompasses a complete balance of the material and gas flows as well as a calculation of the pressure conditions in the various plant subsystems.

Simulex® takes into account that the substems influence each other. For example, changes of the raw mill operation can influence the pressure distribution in the kiln and consequently the exhaust gas composition.

In addition, Simulex® contains the standard controllers (e.g. the kiln hood pressure control) that are nowadays realized in programmable control systems and the interlock systems for the simulated plant drives. This means, for instance, that the kiln main burner can only be started up if the preheater fans are operating properly. Also, the kiln line will shut down to protect the electrostatic precipitator in the event of an excessive concentration of CO in the exhaust gas.

An additional component of the simulator is a high-grade process control system. It operates with the same range of process control functions as real-life cement plants. The control technology encompasses high-resolution process graphics, an alarm system and alarm-activation function, data archiving and graphs of data against time.

Simulex® has in the meantime proved its value in various courses for plant supervisors and production controllers. Thanks to Simulex®, the Research Institute now has at its disposal a finely tuned simulation program with a modern user interface.

Although Simulex® models a five-stage preheater kiln with precalciner the trainees get a in-depth inside into the production process, even if they are used to other kiln types. Up to date training courses have been held for young plant operators to get a first experience of cement production. However, also many experienced operators have taken the opportunity to improve their understanding for new equipment that was going to be installed in their plants.

Fig. 1: Plant operators at work with the simulator Simulex®

ecra Workshop

Training with the simulator can be structured in different ways depending on the target group or the task that has been set. For the ERCA-Workshop the following procedure has been scheduled: The trainees are presented with a “cold” plant that has to be started up. On the first day of the training course their task is to heat up the kiln system. In so doing, a certain heating gradient must not be exceeded so as to protect the refractory materials. The heat-up time can be decreased by using a time-compression function. During the heating phase cement can already be ground, and here the trainer stipulates the quality parameters. On the second day of the course the kiln system has already heated up sufficiently for meal feed to take place and for the first clinker to be produced. After a certain time, the filling levels in the silos will make it necessary to activate the raw meal grinding plant and the coal grinding plant. No later than the third day of the course all subsystems should be increased to full throughput and the specific energy consumption optimized. Finally, from day four of the course onwards, training is given on the individual training computers on how to proceed in the event of plant malfunctions.

The simulator is an excellent tool for teaching trainees cement production. All material flows have characteristic material properties. As in a real cement plant, if the raw meal is not fine enough when it is burnt in the kiln this will increase the free lime content of the clinker. An increase in the levels of chlorine and sulfur in the hot meal leads to the formation of deposits, which becomes apparent through a change in the pressure conditions at the kiln inlet. If certain limit values in the levels of chlorine and sulfur are exceeded, a cyclone blockage function will be activated automatically. The production controller can limit the recirculating systems effectively by operating the bypass system.

Simulex® can be employed not only to provide training in the operation of a plant but also to allow trainees to recognize operational malfunctions and to counteract properly. Both plant malfunctions and process malfunctions can be brought into play. In the case of plant malfunctions, individual plant drives, for instance, will stop functioning. Process malfunctions include, for instance, besides cyclone blockage functions, coating in the kiln, clogged tertiary air ducts or smouldering fires in the coal grinding plant.

Trace Elements in Clinker Production and Cement

Measurement of mercury emissions and abatement techniques

Mercury – like all trace elements- is introduced into the clinker burning process via the raw materials and fuels. Mercury has a very high vapour pressure. Therefore it belongs to the high volatile trace elements. According to the current understanding mercury contained in the fuels is under kiln atmosphere conditions initially present in the high temperature range in elementary form (Hg^0).

When the flue gases cool down to temperatures below about 550 °C the elementary mercury is oxidized, and tends to form gaseous components like $HgCl_2$. While passing the raw mill and electrostatic precipitator these gaseous mercury components are partly bound to dust particles from cement. The simultaneous existence of gaseous and particulate mercury compounds demands a specific emission measurement technique.

Measuring technology

Individual measurements for determining mercury mass concentrations in exhaust gases are for instance carried out in accordance with the European standard EN 13211. The experimental set-up normally used is illustrated in fig. 1. A part of the specific volume flow is isokinetically extracted from the exhaust gas stream. The dust particles are separated in a retainer system. A plane filter is used for collecting the particle-bound mercury. The filter-passing substances are sucked through a heated sampling probe and subsequently fed into an absorption system. In this place the gaseous mercury and its compounds are absorbed in a sulphuric acid potassium permanganate solution.

According to this, the percentage of mercury combined with particles and passing the filter are measured simultaneously in a fraction of the gas flow. After appropriate pretreatment of the samples the mercury is then analyzed in the laboratory using the AAS cold-vapour technique.

Particle-bound mercury does not significantly contribute to the total mercury emissions because the exhaust gas cleaning devices used at cement kilns always have a high collecting efficiency. Emission measurements by the Research Institute of the Cement Industry confirm that mercury emissions are attributable essentially to mercury and its compounds in the vapour state.

Continuous monitoring of mercury emissions

For the continuous measurement of mercury emissions there are different measuring devices available on the European market. As the particle-bound mercury emissions are not significant all, the available measuring devices only analyse the gaseous mercury compounds.

For one of the commercially available devices the test principle is confined exclusively to the detection of elementary mercury. Determination gaseous mercury compounds (i.e. $HgCl_2$) is not possible with this in-situ measuring device.

As the mercury emissions from rotary kiln plants in the cement industry normally consist of both elementary and ionic fractions, the use of such an in-situ analyzer does not appear appropriate in cement works.

The other measuring devices operate extractively. All the gaseous mercury compounds in the small fraction of the gas flow taken from the exhaust gas must first be completely reduced to elementary mercury before the analysis. The manufacturers use different methods for this purpose, a wet-chemical reduction stage or a solid catalyst.

After the reduction and gas preparation all the extractive devices use cold-vapour photometers for determining the mercury concentrations.

First experiences with the use of mercury emission monitors have been gained in the USA in 1996, where a comparative test with three devices was carried out on a wet kiln. None of the devices investigated proved to be suitable. Based on the experience gained at a few cement works since 1999 it has to be pointed out that up to now it is not possible to rely on the devices without further testing. The continuous monitoring device have to be checked in each individual case at the respective kiln. In some cases the monitors seem to be applicable but there are still cases where a continuous monitoring of mercury is not possible.

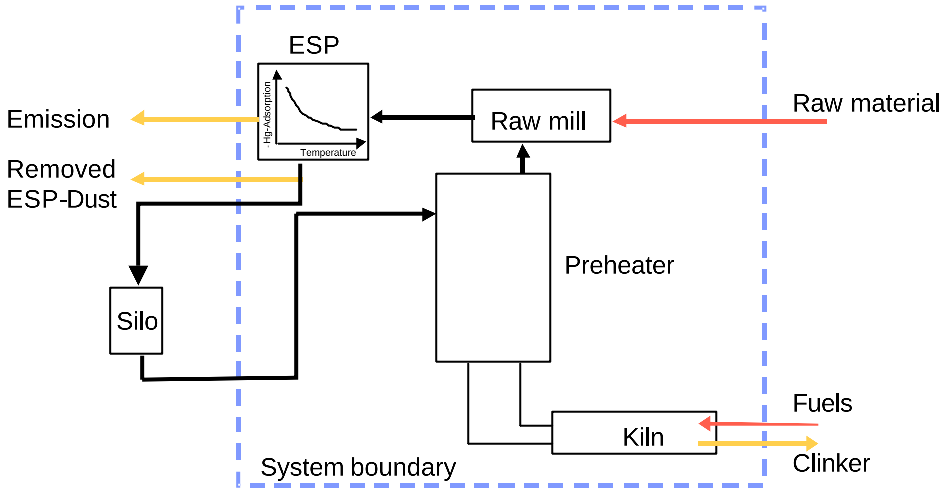


Fig. 2: Principle of the mercury recirculating system

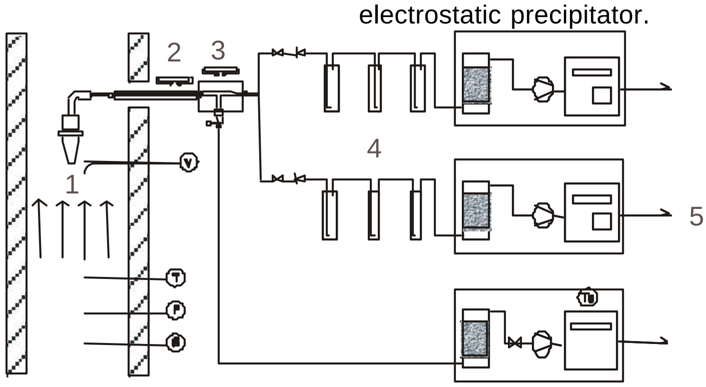
Recirculating behaviour of Hg

In the clinker burning process mercury reacts to form compounds which are not deposited in the kiln or preheater. Practically no fixation of the mercury in the clinker takes place. Part of the mercury carried out of the preheater with the raw gas is collected in the gas cleaning systems with the raw gas dust or the dust from the drying and grinding plant.

The extent to which mercury is bound to dust particles at the exhaust gas cleaning equipment is dependent on the temperature level and the dust loading of the gas stream. Lowering the exhaust gas temperature has the effect that the mercury compounds present in vapour form in the raw gas are deposited to a greater extent on the dust particles and can be collected in the electrostatic precipitator.

Returning the raw material to the raw meal silo can therefore result in an external recirculating system for mercury. Stabilization of these cycles can be achieved in some cases by removing a small fraction of raw meal from the system. Fig. 2 shows these aspects schematically.

The temperature- and surface-depending adsorption effect of mercury can be used as a process-integrated measure to reduce mercury emissions only within certain limits. By the partial removal of the precipitated dust it is possible to reduce the load of the outer mercury material cycle as well as the associated mercury emissions. To use this reduction potential most effectively it is necessary to optimize the process behaviour of the kiln regarding different technical aspects. Besides the exhaust gas temperature the change and duration of the mode of operation (mill-on/mill-off operation) has an important influence on the mercury cycles and emissions.



1 particle-retaining system
2 sampling probe, heated
3 insulated adapter, treated
4 absortion system
5 gastight pumps with condensate separator and gas meter

Fig. 1: Scheme of the measuring device for the simultaneous detection of particulate and filter-passing matter