ecra

european cement research academy

2 / 2009

NEWSLETTER

Contents

Next ECRA events to come:

- Kiln Examinations – Energy/Material Balances and Efficiency
  2–3 September 2009
- Production of Blended Cements and their Performance in Concrete
  13–14 October 2009

Using kiln performance tests to optimise plant units and operation

Kiln examinations and measurement techniques are standardised methods for kiln performance tests

The optimisation of cement kiln plant operation with respect to economy, efficiency and environmental impact can be achieved by performing energy and material balances and by determining material cycles. To obtain useful and comparable results, standardised methods have to be used and trials have to be prepared, carried out and evaluated very thoroughly. In cement plants, kiln examination tests not only serve to gather data with regard to the performance of the kiln system such as clinker output, fuel energy consumption or the kiln feed/clinker ratio, but are also carried out to verify for instance warranty performance data, for example on cooler efficiency.

Objectives of performance tests and kiln balances

Kiln trials create a reliable basis for the optimisation of individual system components, operation and cement quality, as well as for the reduction of emission levels. The objective of balances of volatile, e. g. alkali, chlorine and sulphur, and non-volatile compounds is the assessment of material cycles and coating formation. The utilisation of alternative fuels, for instance, usually entails higher chlorine input into the kiln system, which in some cases results in malfunctions due to increased coating formation in the kiln inlet section and in the lower cyclone stages. A kiln trial, aiming at the investigation of material cycles, provides reliable data for the design or the upgrading of a bypass system. Balance investigations for trace elements can be carried out in order to obtain more knowledge about the behaviour of heavy metals in the kiln plant. Heat recuperation of clinker coolers is influenced by cooler operation, cooler exit air and secondary air, and at precalciner kilns by tertiary air. The degree of heat recuperation affects the fuel energy consumption and energy balance of the complete kiln line. Therefore, the determination of cooler efficiency may result in optimising the operational mode or in modifying the cooler technology.

Planning, organisation and realisation of plant trials

The reliability of the values measured depends on the successful realisation of the performance test. In the planning phase of a kiln trial, many details have to be considered. Balance boundaries have to be defined and suitable measurement techniques have to be chosen. In **Fig. 1** the red line shows the balance and system boundary which includes the whole kiln line, the blue line encloses the system for determining the cooling area efficiency and the green line indicates the system for determining the cooler efficiency. Besides taking the necessary measurements for the energy and mass balances, it is highly recommendable to carry out additional measurements and samplings in order to evaluate the kiln operation and the level of material cycles. The essential operational mode should already be determined during the planning phase. All circumstances relating to the performance test and all samplings and measurements which have to be carried out should be outlined in a measuring plan. Ideally, the measuring plan should include detailed working plans for all participating persons as well as an analysis plan for all samples. The inspection of the measuring sites prior to a kiln trial is also necessary to ensure the success of the examination. Generally, measuring and sampling points have to be prepared for the examination beforehand. Often, measuring sockets and openings have to be cleared, crusts removed and grips of worm rethreaded. If necessary, a platform has to be erected in order to reach the measuring points. Some measurement devices need operating resources, so electric power, compressed air or water have to be provided close to the measuring points.

Sampling and measurement techniques

Representative sampling and sample preparation are of decisive importance for the chemical analyses. Besides samples of solids, taken from belts or at the discharge end of conveyers, dust samples from gas streams also often have to be taken. Volume flow measurements (**Fig. 2**) including gas concentration (**Fig. 3**) and humidity analyses are integral parts of kiln trials. If energy balances are carried out, the measuring of wall heat losses also has to be part of the kiln trials. At all measuring points the requirements of health and safety at work must be fulfilled.

Evaluation of energy balances

The individual system configuration has to be taken into account regarding energy balances. Trials for energy balances can be executed for both grate and preheater cyclone plants without or with precalciner technology including tertiary air ducts. Assays of subsystems such as cyclone stages, the precalciner stage, the cooling area and the clinker cooler are also possible. There are no constraints with regard to grate, planetary or rotary coolers.

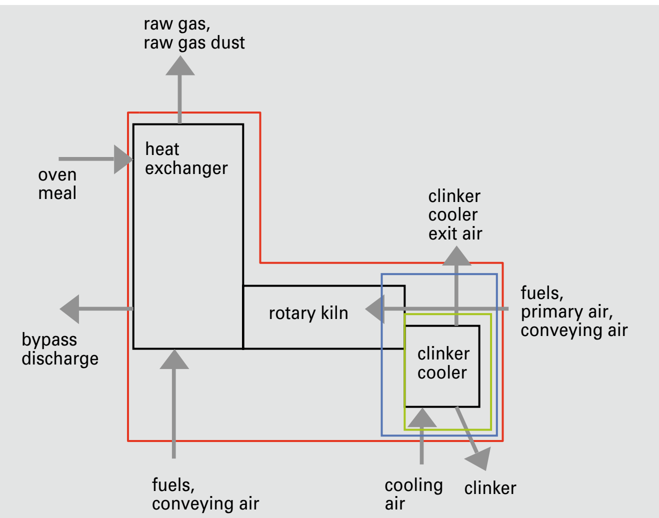

Fig. 1: System and balance boundaries – Red: Kiln line; Blue: Cooling area; Green: Clinker cooler

Fig. 2: Instruction on volume flow measurements

Fig. 3: Sampling of volatile chlorine, sulphur or heavy metal compounds

Energy balances are carried out in order to gather data on the kiln performance and to verify warranty performance data such as fuel energy consumption, process efficiency and cooler efficiency. Gas and material streams carry thermal and chemical energy across the balance boundaries. Methods and techniques are standardised in the VDZ code of practice "VT 10: Executing and Evaluation of Kiln Performance Tests", which is used by cement producers worldwide. It includes the calculation of the main parts of energy streams considering sensible and latent energy, humidity, clinker reactions and fuel energy. The description of heat losses by radiation and convection beyond kiln walls as well as the electric power consumption complete the list. All energy streams are summed up in an energy balance.

Evaluation of material balances

Balances of non-volatile compounds are necessary either to determine the kiln feed/clinker ratio or to finalise the balance. Non-volatile compound balances help to adjust the kiln feed composition with regard to the input of fuel ashes or the discharge of dust in preheater exit and bypass gas. Trace elements build up inner cycles between the preheater and the rotary kiln or outer cycles between mill systems and the kiln line. Balance investigations point out the most effective way of discharging trace elements and diminishing cycles.

In order to assess alkali, chlorine and sulphur cycles, the measurements have to be supplemented with samplings of hot meal in the preheater. The evaluation of volatile compounds identifies spots of coating formation. Based on volatile compound balances as well as estimates of the cycles, the risk of cyclone blockings can be assessed.

ECRA's research activities on carbon capture and storage (CCS)

At the moment CCS seems far from realisation due to technical and economical reasons

Climate protection is a priority issue on the political agenda, and the European Community's objective is to limit the atmospheric temperature increase to 2 °C. According to different scenarios from the International Energy Agency, this can only be achieved if global CO_2 emissions can be reduced by 50 % by 2050. CO_2 capture and storage technologies (CCS) are being discussed as a potential means to reduce the CO_2 emissions from industrial sources, including cement kilns. However, to date there is no existing experience with CCS technologies. The European Cement Research Academy (ECRA) therefore took the initiative and started a long-term research project on the applicability of carbon capture technologies at the clinker burning process. Initial results are available and give an indication of the technical feasibility, but underline at the same time that CCS is not available at viable costs.

The current research project is divided into five phases. Phase I was completed in summer 2007 with the release of a report which is available on the ECRA website. It was concluded that all capture technologies are far from being applicable to the cement industry due to technical and cost reasons. However, some capture technologies seemed to be more appropriate for application at cement kilns than others. This applies to oxyfuel and post-combustion technologies (chemical absorption). The main advantage of chemical absorption technologies is that they are available and that there is existing experience from pilot projects in the power sector. Furthermore, existing cement kilns could be retrofitted with these technologies.

Next, the research agenda determined more detailed investigations about oxyfuel and chemical absorption technologies. The subsequent phases III, IV and V would include

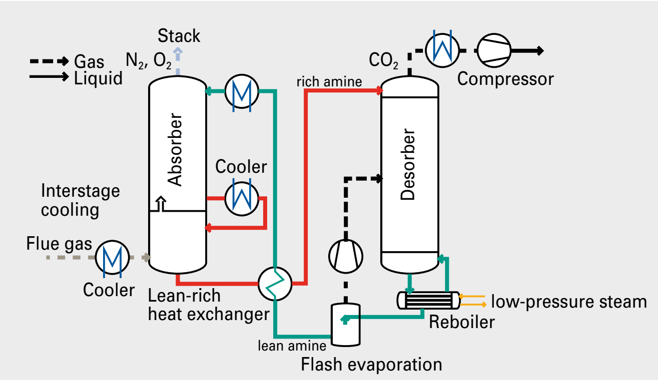

Fig. 1: Amine-based CO_2 absorption with state-of-the-art process

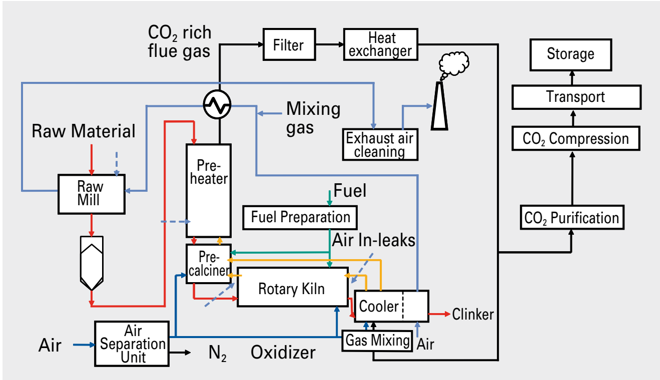

Fig. 2: Investigated configuration of an oxyfuel cement plant

laboratory-scale (phase III) and pilot trials (phase IV) respectively and should lead into a demonstration project (phase V). The end of every phase is a milestone in the overall project, associated with a decision on how to proceed further.

Research results of phase II

The research work within the framework of phase II will be completed in summer 2009. For the application of chemical absorption processes, the flue gas composition is of special importance. Gas components like SO_2, NO_2 and O_2 can lead to a degradation of the solvent. The cement-specific flue gas characteristics were therefore identified, and tolerable SO_2 and NO_2 concentrations were estimated. Furthermore a plant layout was designed for the implementation of a chemical absorption process at a rotary cement kiln (**Fig. 1**). Investigations regarding solvent regeneration showed that an auxiliary power block would be necessary to provide the energy for the regeneration of the absorbent (i.e. low-pressurised steam). A compilation of cost figures was given which were mainly determined within two external studies. According to this, the calculated investment costs showed a great range – from about 100 M EUR to almost 300 M EUR. Today the specific costs are estimated to range between around 30–100 EUR/t CO_2. However, the objective of several research projects in the power sector is to reduce the costs significantly to 20–30 EUR/t CO_2 or even lower. In view of the mentioned figures and a significant increase in energy demand, it can be questioned if the application of chemical absorption technologies would be a sustainable way to reduce the CO_2 emissions.

In contrast to post-combustion CO_2 capture, oxyfuel combustion would significantly influence the clinker burning process. More basic investigations about the clinker burning process were therefore carried out. A possible configuration of an oxyfuel cement plant was designed (**Fig. 2**), using an established process model. The oxygen demand was calculated and also the required oxygen purity. Moreover, the subsequent steps of CO_2 purification and compression were included in the overall assessment of the oxyfuel process. The interdependency between these chemical plant components was then pointed out. For the energetic dimensioning, aspects such as the raw material drying and heat recovery posed problems. Simulations via the process model showed an energy shifting in the kiln plant. This effect was induced by a higher CO_2 concentration in the kiln atmosphere due to the different gas properties compared to N_2. By adjusting the oxygen concentration it is possible to compensate for this effect of the CO_2. As a result of insufficient sealings, the flue gas – still also containing moisture – would contain less than 80 vol.-% CO_2 from today's perspective.

Apart from the modelling process, laboratory trials were also conducted to find out the impact of the oxyfuel combustion on the burning process. In particular, the influence of an increasing CO_2 partial pressure on the limestone decarbonation reaction was investigated. It turned out that the reaction enthalpy increased due to a temperature shift of the decarbonation reaction. As a result of this, a higher temperature in the calciner would be required, which could have a negative impact on the refractory. Otherwise the degree of calcination in the precalciner would have to be reduced. The specific costs for avoided CO_2 emissions via oxyfuel combustion were calculated to be about 30–35 EUR/t CO_2 (excluding transport and storage). The operating costs of an oxyfuel plant are the main factor of the overall costs, due to the energy-intensive air separation and CO_2 compression.

Further activity

The research project will be continued with investigations on chemical absorption technologies and on oxyfuel combustion also. The main advantage of chemical absorption is that the technology is in principal available and could be installed end-of-the-pipe at industrial sources. Compared with this, oxyfuel is still in an earlier stage of technical development. However, in the medium and long term, oxyfuel might be a less expensive option for CO_2 reduction – at least for newly built kilns.

According to the schedule, the work packages for phase III will include initial laboratory and small-scale investigations, extended simulation studies and further development and optimisation of burner design, sealings and refractories. The estimated expenditure for the next phases of the research project will increase step by step so that an appropriate funding scheme has to be developed.

ecra
european cement research academy

European Cement Research Academy

Tannenstr. 2 · 40476 Düsseldorf
P.O. Box 30 03 32 · 40403 Düsseldorf
Germany

Phone: +49 (0)211 2 39 83 8-0
Fax: +49 (0)211 2 39 83 8-500

info@ecra-online.org
www.ecra-online.org