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Process technology for efficient and sustainable cement production

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ABSTRACT

Over the years technology in the cement industry has been further developed with a growing focus on sustainable, cost- and energy-efficient production. While significant steps may not seem visible on a year to year basis, the medium-term view shows notable progress. The trend of increasing the capacity of cement kilns has slowed down in recent years — maximum clinker output still lies between 12,000 and 13,000 tpd. Burning and cooling technologies have progressed, especially with respect to burners specifically designed for the co-incineration of high levels of alternative fuels. Taking into account all process-integrated measures, thermal process efficiency reaches values above 80% of the theoretical maximum. The grinding of raw materials and cement has been in the focus of better energy utilisation, but product quality is also of the highest importance. In terms of sustainable production, NO_x abatement and CO_2 capture and its reuse remain in the focus of extensive research.

1. Introduction

Over the years technology in the cement industry has developed with a growing focus on sustainable and also cost and energy efficient production. While significant steps may not seem visible on a year to year basis, the medium-term view shows notable progress. The drivers for progress are certainly cost-based, but at the same time the cement industry, together with its equipment suppliers, has always strived to improve the overall efficiency and sustainability of the cement production process. Substantial energy savings have been achieved in recent years, and product-related emissions of CO_2 and other parameters have also been significantly reduced.

The trend of increasing the capacity of cement kilns has slowed down in recent years — maximum clinker output now lies between 12,000 and 13,000 tpd. There are good technical and economic reasons for this. The slowdown of the economy in many regions of the world may also have contributed to this trend. While notable growth for the BRIC countries (Brazil, Russia, China, India) is expected up to 2020, this growth is expected to level out in the years 2020 to 2030. However, major growth until 2030 can be expected from the “SETIVIM-countries” (Saudi Arabia, Egypt, Turkey, Iran, Vietnam, Indonesia and Mexico), as well as the “Next 7” (Algeria, Morocco, Nigeria, Pakistan, Malaysia, Thailand and the Philippines) as main drivers [1].

No breakthrough technologies are currently in sight with respect to clinker burning. Fourth generation clinker coolers are available from several suppliers and can be seen as state of the art. Cooler efficiencies of about 75% of the theoretical maximum can usually be achieved. Some developments have been made in burner technology, especially with respect to burners specifically designed for the co-incineration of high levels of alternative fuels. Taking into account the process-integrated drying of raw materials, other main constituents and fuels, the efficiency of the thermal process reaches values above 80% of the theoretical maximum [2]. The grinding of raw materials and cement has been in the focus of better energy utilisation, but product quality is also of highest importance. Therefore, new research approaches have been initiated focusing on the questions of how to comminute more efficiently and how to fully control particle size distribution. NO_x abatement on the basis of high efficiency selective non-catalytic reduction (SNCR) as well as selective catalytic reduction (SCR) has been tested in pilot and demonstration plants; CO_2 capture is the subject of intensive research with a strong focus on the potential reuse of CO_2. With respect to further increase materials and fuel efficiency, the substitution of natural fuels and raw materials by alternative ones is under on-going positive development. Many other examples can be given. Nevertheless, challenges remain and the cement industry will certainly continue to develop its technology, always in cooperation with the various equipment suppliers.

2. Thermal process technology

Energy utilisation in the cement industry has always been optimised for economic reasons; therefore, the potential for further optimisation is comparatively low. In 2010, the “Cement Technology Roadmap” of the International Energy Agency (IEA) [3] showed that at a global level, energy efficiency can only contribute a maximum of a further 10% towards the reduction of the CO_2 emissions of the global cement industry. A VDZ case study on Germany [4] revealed a maximum savings potential of 14%, even if all kilns and cement mills in Germany were rebuilt as completely new on “greenfield sites”, which is certainly

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an unrealistic scenario just for economic reasons. However, alternative fuels can contribute considerably to the energy requirement, saving fossil fuels and at the same time in many cases lowering the CO_2 emissions of the respective kiln.

The reason for the very limited additional potential savings of thermal energy is the necessary heat for the clinker production process. Fig. 1 shows the heat flows, the thermal input, the use for clinkering and drying, and the remaining waste heat flows that might be utilised. However, the remaining waste heat is already used to a high degree, indicated by the already low temperatures of these flows, which does not allow a further efficient recovery of energy at this temperature level. Taking into account all the thermal energy supplied to the process, all energy utilised as well as the energy that cannot be utilised due to the low temperature level, the overall thermal efficiency of the process exceeds 80% of the theoretical maximum, which is among the highest of all industrial processes [4].

Fig. 2 depicts the overall cement-related energy demand including electrical and thermal energy, as derived in the case study for Germany [4]. While the overall demand seems to have been nearly constant over recent years due to the above mentioned effects, the figure clearly shows that the use of alternative fuels can significantly contribute to reduce thermal energy from fossil sources.

Electrical energy only comprises between 10 and 15% of the overall energy demand for cement production but is a notable cost driver [4,5]. Over the last decades the average specific electrical energy consumption has decreased (Fig. 3) [6]. However, there are counteracting effects: CO_2-emissions can be significantly reduced by the increased use of blast furnace slag as a cement constituent but this is more difficult to grind and consequently requires more energy for grinding. Also customer requirements for higher product fineness in some markets, and finally growing requirements for exhaust gas cleaning, be it for dust abatement or NOx reduction, cause an additional electrical and also thermal energy demand and have contributed to an increase in the product specific electrical energy consumption [4].

2.1. Alternative fuels

In recent years, the worldwide use of alternative fuels has increased significantly in many markets because their use may reduce the demand for fossil fuels and can – depending on the type of alternative fuel – increase the overall cost efficiency of the respective plant. Moderate substitution rates may be reached by the use of widely available bulky materials (e.g. entire tyres) combusted in the kiln inlet. Further substitution requires high-quality or even tailor-made alternative fuels with guaranteed constant moisture contents, particle sizes and heating values to avoid possible issues regarding process conditions and clinker quality.

The fluctuation in the moisture content of a given alternative fuel derived from selected industrial wastes is shown as an example in Fig. 4. The cement industry has developed techniques and burning strategies to homogenise such varying properties through specialised on-site pre-treatment [7]. In the case of moisture content, dedicated drying strategies such as drum driers or mill driers can substantially lower the moisture [8] and can also improve the burning characteristics of the waste [9], utilising in many cases waste heat that cannot be used otherwise. Again, these measures go along with increased treatment costs and also in most cases with an increase in electrical energy consumption. Computational fluid dynamics (CFD) simulation may help to optimise the combustion including optimal injection points [2]. In any case, the simulation requires a comprehensive specification of the fuels used in order to representatively illustrate the particle trajectory and combustion (Fig. 5).

To increase energy efficiency by ensuring a complete combustion of alternative fuels, fuels can be gasified in fluidised or fixed bed chambers or suspension flow processes. Different concepts for combustion chambers for calciner systems have been developed and installed in the past years [10–12]. Enabling longer retention times and the handling of coarse materials with more heterogeneous properties, they add a new level of flexibility regarding the choice of fuel.

Separate combustion chambers using a burner design similar to rotary kiln burners provide longer retention times than conventional calciner combustion systems without the need of further combustion points [10]. Also pyrolysis systems can provide a sufficiently long retention time and cope with coarse materials by drying and pyrolising alternative fuels in a rotational system before fully combusting in the calciner and kiln inlet [11]. A different approach is the use of a blower system in a step combustor to transport burnt out fuel fractions within the gas stream into the calciner while heavy fractions remain within the chamber until fully combusted [12]. In all three systems, hot tertiary air and preheated raw meal are used to adjust optimal conditions in the combustion chamber.

Moreover, a moderate oxygen enrichment in the combustion air can support the complete fuel particle burnout, which allows an increased substitution rate or the utilisation of slow-burning alternative fuels [13].

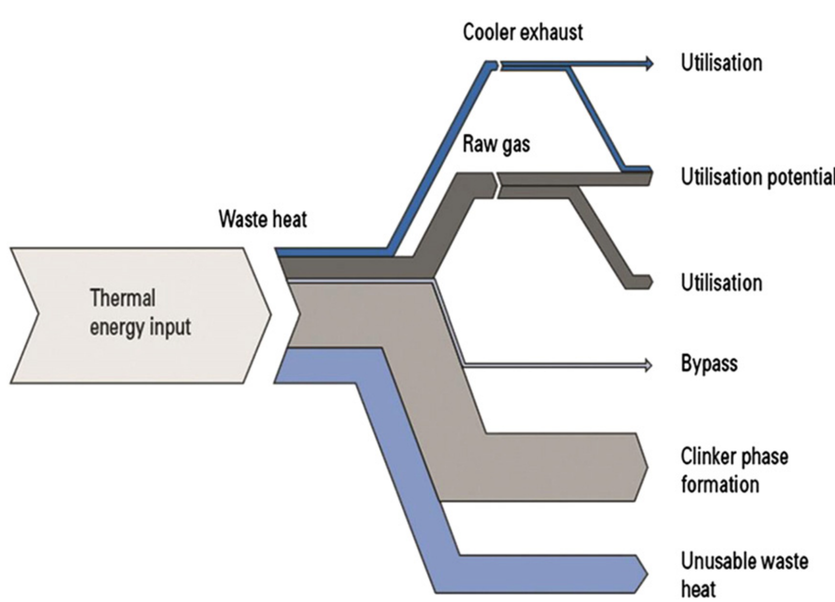

Fig. 1. Thermal energy and waste heat flows for the clinker production process. The relative sizes of the energy flows correspond to the respective thermal energies in the process.