ORC: direct exchange

Cement producers are increasingly installing waste heat recovery (WHR) systems in their plants to reduce power costs and CO_2 emissions. Organic Rankine cycle (ORC) systems and direct heat exchange are some of the key technologies particularly suited to the cement production process.

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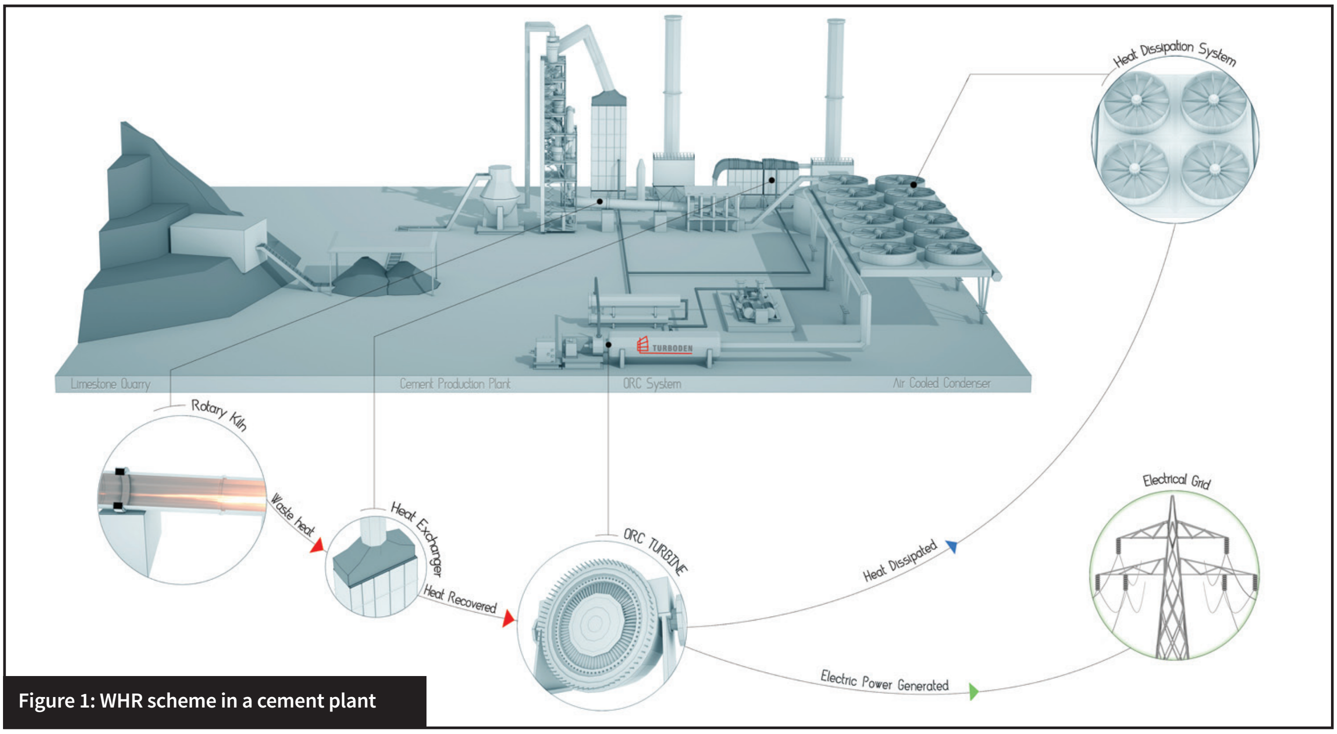

Figure 1: WHR scheme in a cement plant

The last two decades have seen the successful application of waste heat recovery (WHR) systems in cement plants. For cement producers this technology provides several benefits, including:

- lower power costs
- increased competitiveness
- no additional fuel consumption
- CO_2-free power generation.

WHR technology in cement production

In the cement production process there are two main hot gas streams where the heat can be recovered and transformed into electricity to be used in the cement plant. The two streams are the preheater gas (with a temperature of about 300-380˚C) and the clinker cooler exhaust air (at a temperature of about 250-400˚C).

As an indication, the power that can be produced by a heat recovery system in a typical cement making process ranges between 0.5-1kW/t of daily clinker production capacity (assuming heat recovery from both kiln and cooler waste flows). On this basis a WHR plant can produce 10-20 per cent of a cement plant's total power requirement.

The heat contained in the hot gas is typically transferred through heat exchangers directly or indirectly to the organic fluid inside the organic Rankine cycle (ORC) plant.

ORC technology, as used in cement plant WHR installations, employs an intermediate loop (thermal oil, pressurised water or saturated steam) that transfers the heat from the primary heat sources to the organic fluid. The use of intermediate loops has the advantage of increasing the flexibility of the heat recovery plant and stabilising set operating conditions.

Disadvantages are related to the higher captive consumption (heat carrier loop pump consumption) as well as higher maintenance and investment costs due to the heat carrier loop.

In general, a dedicated heat exchanger for each heat source is installed. Technical features of the two heat recovery exchangers are different due to the different characteristics of the exhaust gas. While the dust in the preheater gas is sticky (and requires a cleaning system), the dust contained in the clinker cooler air is abrasive. Therefore, the thickness of the tubes of the heat exchanger is typically increased, as well as the installation of a dedusting chamber, before the heat exchanger to eliminate the largest dust particles from the stream. The heat recovery exchangers are installed in a bypass to the main gas duct line to prevent any impact of the heat recovery plant on the main production process.

The design of such heat recovery exchangers takes into account the following characteristics:

- amount and type of dust (typically 20 -80g/Nm^3)
- gas temperature and flow for raw and/


ORC room in CRH's Rohožník cement plant, Slovakia

"ORC is a mature technology, which has been commercially available since the 1970s, originally for geothermal energy exploitation and, since the 1980s and 1990s, for power generation from biomass combustion, solar sources and heat recovery from industrial processes."

or coal mill (or other thermal user)
- maximum gas pressure drops allowable to prevent the substitution of the ID fan
- space availability.

ORC in cement heat recovery

Until recently the most-common WHR technology used in cement plants was based on steam (large-scale steam plants, less efficient cement plant, low cost of personnel, availability of water, etc). However, in the last decade ORC technology has emerged, gaining acceptance in new WHR projects.

ORC is a mature technology, which has been commercially available since the 1970s, originally for geothermal energy exploitation and, since the 1980s and 1990s, for power generation from biomass combustion, solar sources and heat recovery from industrial processes.

Turboden has more than 35 years of experience in the ORC field and has carried out several improvements to the technology. There are currently about 300 Turboden ORC plants in operation and a further 40 plants are under construction. The average availability of the operating fleet exceeds 98 per cent and more than 10m operating hours have been reached. The company has completed several successful installations, including:

- Italcementi – Ait Baha plant, Morocco. A 2MWe Turboden ORC unit has been working since 2010. In 2014 this unit was hybridised with an integration of the thermal input given by solar power through a solar concentrating system
- Holcim – Aleşd plant, Romania. A 4MWe ORC started up in 2012.
- CRH (formerly Holcim) – Rohožník plant, Slovakia. A 5MWe ORC unit has been working since 2014.
- CarpatCement (HeidelbergCement) – a 4MWe ORC unit started up in 2015 in the Fieni plant, Romania.
- Switzerland (undisclosed customer). A 2MWe ORC unit started up at the end of 2016.
- Cementi Rossi – Piacenza plant, Italy. Innovative 2MW direct exchange ORC unit under construction.

ORC features and benefits

ORC has become a competitive alternative to steam technology, especially in units with sizes between 5-15MWe, thanks to several features and advantages.

Totally automatic system

The ORC module has a high level of automation. It is designed to automatically adjust itself to the actual operating conditions. Variations on exhaust gas temperatures and flows will not affect the functionality of the system, but just the power output.

No supervision personnel

ORC does not need supervision personnel in normal operating conditions nor during shutdown. A steam-based WHR plant requires 12-16 dedicated operators.

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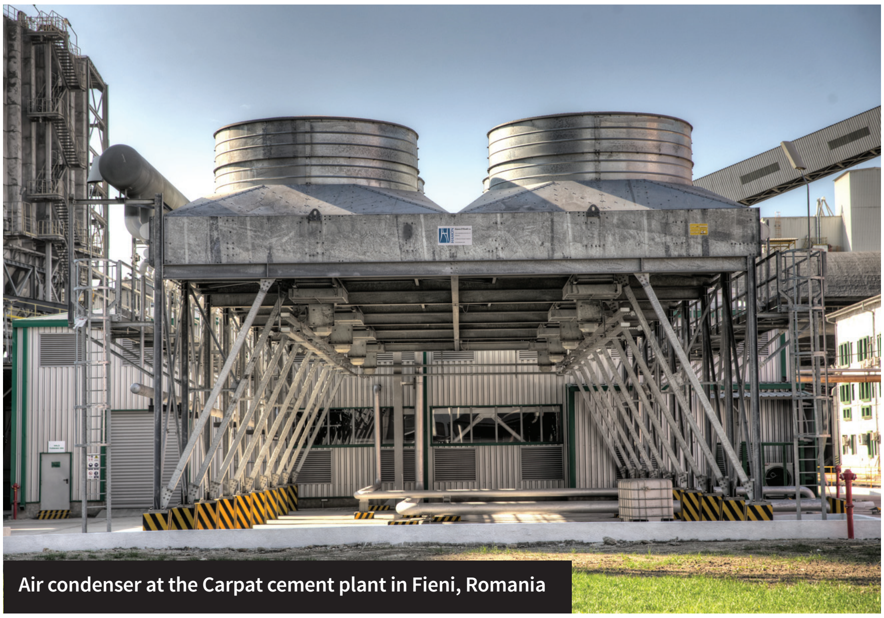

Air condenser at the Carpat cement plant in Fieni, Romania

ORCs are remotely monitored and require minimal annual maintenance. Therefore, cement plant operators are able to focus on their core activity, producing cement.

Flexible, highly-efficient operation for a wide range of thermal power loads

ORC plants can work down to 10 per cent of the designed thermal load. Electric efficiency remains high down to 50 per cent of the thermal load.

In the case of multiple kilns or a variable heat source load, ORC can maximise the energy produced per year.

Minimum maintenance requirements

Maintenance activities and costs are minimised compared to steam turbine thanks to several characteristics of the ORC technology, including organic fluid dry expansion in the turbine (no erosion of blades), non-aggressive and non-corrosive organic fluid and low turbine speeds.

Zero water consumption

The main advantage of ORC technology compared to steam is the possible configuration without the use of water and, therefore, zero water consumption. Consequently, at locations where water demand is an issue, ORC provides a suitable alternative to steam-based technology.

High availability

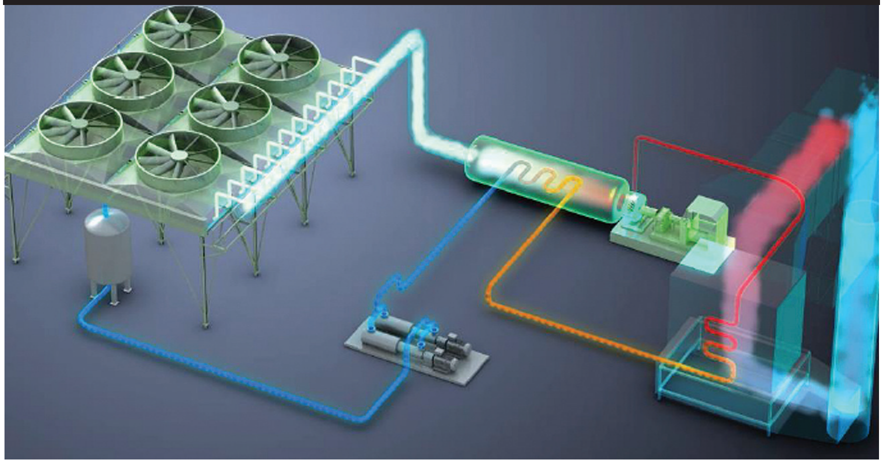
Based on a statistical average of the Turboden ORC units in operation, the availability is higher than 98 per cent.

Flexibility

The flexibility of ORC allows WHR suppliers to design a suitable and optimised solution for the specific cement plant by selecting the type of heat carriers, the most-appropriate organic fluid and cooling technology.

"Typical sizes of ORC facilities are between 15-18MWe following recent improvements such as an 8MWe ORC system in a biomass plant, a 10MWe ORC in a steel factory and a 16MWe ORC in a geothermal project."

Figure 2: direct heat exchange technology: the organic fluid is preheated and evaporated in a heat exchanger thanks to hot gas



Future cement processes will be more and more efficient, thus leaving low-temperature exhaust gas available for WHR plants that can be easily exploited with ORC technology. Typical sizes of ORC facilities are between 15-18MWe following recent improvements such as an 8MWe ORC system in a biomass plant, a 10MWe ORC in a steel factory and a 16MWe ORC in a geothermal project.

Direct heat exchange

Direct heat exchange between exhaust gas and organic fluid is the next step in the development of WHR for cement plants. In this technology, no heat transfer loop is needed: the liquid organic fluid is pre-heated and evaporated in a heat exchanger where the hot gas passes through. The organic vapour is then sent to the turbine where it expands generating mechanical power that drives the electric generator. Downstream of the turbine, the expanded fluid firstly releases its sensible condensing heat in the regenerator and then condenses, getting back to the liquid form and closing the loop.

Avoiding the delta T introduced by the intermediate loop, the organic fluid evaporates at a higher temperature leading to greater electrical efficiency. Besides higher gross efficiency, captive consumptions of the heat recovery plant are lower because there is no intermediate fluid pump.

Overall, a direct exchange plant is a simpler solution with a more compact layout and less components, resulting in lower capital and operating expenditure.

Barriers for the installation of such solutions can be layout constraints.

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Since December 2014 Turboden has participated in the EU-funded TASIO project. The project aims to develop new solutions to recover waste heat produced in energy-intensive manufacturing processes such as cement, glass, steelmaking and petrochemicals, and to transform it into useful energy.

It seeks to implement a full demonstration project of a direct exchange heat recovery system to generate electrical energy at Cementi Rossi's cement plant in Italy. Installation of the ORC is expected in 2017 with commissioning due in 4Q17.

Conclusion

As demonstrated by about 300 Turboden working installations, ORC can be adapted for any industrial environment. The ORC technology – due to its ability to recover heat at low temperatures, together with good electrical efficiency, high flexibility and minimum operation and maintenance cost – has the potential to be the ideal technological solution for effective and profitable implementation of WHR systems from cement processes.

Finally, there is a continuous commitment to finding new technical solutions, like direct exchange, with the aim of improving the economical results of heat recovery plants. ■