Supplying cost-effective power

Recent energy market price volatility has been impacting cement producers as power prices having increased considerably. By installing waste heat recovery (WHR) systems based on organic Rankine cycle technology, cement companies can reduce their exposure to price fluctuations as well as lower their carbon footprint - making WHR an increasingly attractive option.

■ *by **Turboden**, Italy*

A 5MWe ORC turbogenerator installed at a cement plant in Slovakia

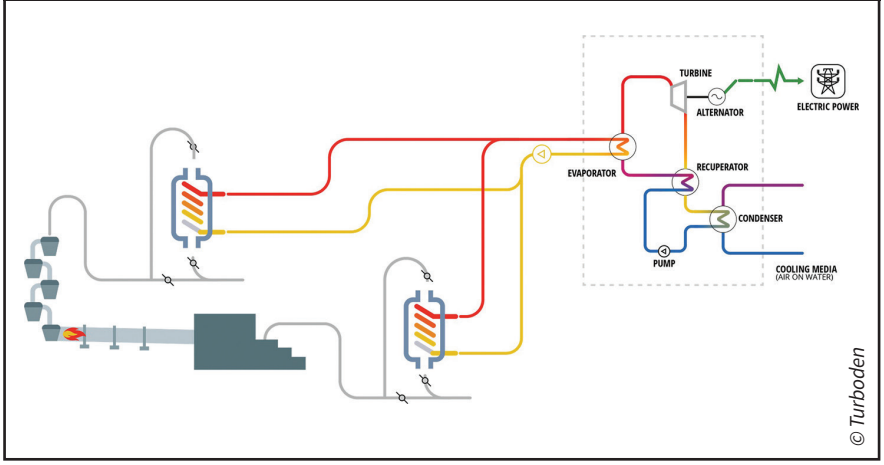
Over the past decade, organic Rankine cycle (ORC) technology has emerged as a viable and safe alternative to the classic steam Rankine cycle as a waste heat recovery (WHR) technology for the cement industry. Technological improvements, increased competitiveness, and the general tendency towards a greener and more sustainable environment supported by governments across the world have made ORC systems for WHR an increasingly attractive option. In addition, recent price volatility in the international electricity market have added to the attractiveness of generating power in-house.

Net zero targets with WHR

According to the International Energy Agency (IEA), during the 2015-21 period, the direct CO_2 intensity of cement production (tCO_2/t of cement) increased by ~1.5 per cent per year. This is in contrast to the three per cent annual declines to 2030 that are necessary to reach the IEA's Net Zero Emissions by 2050 Scenario.

Among the strategies that could be implemented to cut carbon emissions from a cement plant (eg, carbon capture or the use of lower-carbon fuels) WHR from the cement production process is one of the most effective and efficient ways to start the journey towards a more sustainable and remunerative plant immediately. A WHR plant can produce up to 30 per cent of the electric energy required by a cement plant. In combination with other technologies, WHR will be essential in the cement plant of the future.

Figure 1: waste heat recovery system in a cement plant



ORC – working principle

In cement plants, there are typically two sources of recoverable thermal power that can be exploited by means of an ORC unit:

- exhaust gas from the preheater
- hot air from the clinker cooler.

Turboden has installed several ORC units in cement plants that recover energy

Turboden turbogenerator

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from one or both of these two sources. The electrical power output of these specific units ranges from 1-11MWe, depending on the conditions of the thermal source being exploited. However, Turboden offers units with a mechanical power of up to 20MW from a single turbine. Table 1 lists some of Turboden's references projects at cement plants worldwide. In addition, the company is currently installing ORC systems for four customers in the UAE, Portugal and Turkey at cement plants with kiln capacities of between 3000-10,500tpd, supplying gross electric power ranging 6000-11,000kW via thermal oil-based systems.

In these WHR systems, the exhaust gas or the hot air from the process enters a heat exchanger that transfers the thermal power contained in the gas stream to a thermal vector – typically a thermal oil. The heat exchanger is designed to operate in the conditions of the gas stream as well as manage the pollutants and dust that are often entrained in the gas.

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The thermal vector then transfers the thermal power to the ORC working fluid (in such applications this is likely to be cyclopentane). The cyclopentane is evaporated and enters the turbine producing the required mechanical power, which is subsequently converted to electrical power by a generator connected to the turbine.

The expanded vapour leaves the turbine and enters an internal heat exchanger (ie, a regenerator), in which it releases heat to its liquid phase entering this exchanger from the other side. After the regenerator, the vapour enters the

Table 1: Turboden references in the cement industry

Cement producer	Country	Start-up date	Kiln capacity (tpd)	Heat source	Heat carrier	ORC gross electric power (kW)
Ciments du Maroc (HeidelbergCement)	Morocco	2010	5000	Preheater	Thermal oil	2000
Holcim Romania	Romania	2012	4000	Preheater + clinker cooler	Thermal oil + superheated water	4000
CRH Slovakia	Slovakia	2014	3600	Preheater + clinker cooler	Thermal oil	5000
Carpatcement (HeidelbergCement)	Romania	2015	3500	Preheater + clinker cooler	Thermal oil	3800
Jura-Cement-Fabriken (CRH)	Switzerland	2016	3000	Preheater	Superheated water	2300
Cementi Rossi	Italy	2018	3500	Preheater + clinker cooler	None – direct exchange	1500
Çimko (Sanko Group)	Turkey	2019	9500	Clinker cooler	Thermal oil	7000
Holcim Suisse	Switzerland	2020	2300	Preheater + clinker cooler	Superheated water	1300
Sönmez Çimento	Turkey	2020	6000	Preheater + clinker cooler	Thermal oil	8100
Secil	Portugal	Under construction	3800	Preheater + clinker cooler	Thermal oil	7000

condenser, in which it is further cooled and brought back to its liquid phase. This condensation occurs either by means of a cooling water circuit, or through the direct use of ambient air. In this second case, water consumption is not required to operate the ORC plant. This is a considerable advantage, particularly in countries where water is a scarce and precious resource. The ORC working fluid is then pumped back through the regenerator, up to the evaporator, in its continuous cycle toward decarbonisation.

Benefits

The significant amounts of energy required during the cement production process are primarily used to heat and grind raw materials. These generate a large amount of waste heat as a byproduct. Capturing this waste heat and utilising it to generate electricity, or even to co-generate electrical power and thermal power in the form of hot water (up to 110˚C), can offer several benefits to cement plants, as discussed below.

Reducing fossil fuel usage

The electricity produced by an ORC unit can be used to feed the internal loads of a cement plant, therefore reducing the amount of energy generated in less sustainable ways. This results in lower energy costs and reduced carbon emissions.

Increasing energy efficiency

"Turboden has installed several ORC units in cement plants that recover energy from one or both of these two sources. The electrical power output of these specific units ranges from 1-11MWe, depending on the conditions of the thermal source being exploited. However, Turboden offers units with a mechanical power of up to 20MW from a single turbine."

By adopting an ORC solution, cement plants can improve their overall energy efficiency by utilising the thermal power that is generated during the production process and would otherwise be dissipated into the environment.

Lowering costs

Implementing an ORC system can also result in cost savings as it reduces the amount of energy that has to be purchased from the national grid to run a plant.

In addition, by installing an ORC unit, the plant can ideally fix the price of the electricity that it will pay throughout the entire lifetime of the ORC system. This can avoid, at least partially, the risks of sudden peaks and fluctuations in energy markets, such as those seen over the last year.

Furthermore, the WHR levelised cost of energy (LCOE) is typically lower compared to other renewable energy sources such as photovoltaic systems or wind-based power as ORC-based WHR systems can generate power during the entire operating time of a cement plant.

Installing an ORC unit also allows plants to cool down the gas producing electrical power, instead of consuming electricity to run air-to-air heat exchangers or consume water in conditioning towers.

Increasing competitiveness

Due to society's increased focus on sustainability and energy efficiency, the installation of an ORC unit enables cement producers to demonstrate their commitment to reducing their carbon footprint, and thereby potentially, improving their market position.

Environmental benefits

By reducing energy consumption and carbon emissions through the implementation of ORC units, cement plants can also lower their environmental impact and contribute towards global efforts to mitigate climate change.

Operational flexibility

Compared to other heat recovery solutions, ORC systems have a higher operational flexibility. They are able to perform when receiving 10-110 per cent of the design inlet thermal power, maintaining actual efficiency close to their design parameters.

Moreover, automatic operation eliminates the need for the continuous presence of personnel, who can then be deployed to oversee core activities.

"Following the rapid increase of electricity prices in several countries, combined with the growth of greener but more expensive electricity generation technologies and the trend towards higher carbon taxes, cement plants are seeking alternative ways to improve their power supply. WHR technology, and particularly ORC-based systems, can provide a better, more cost-effective way of supplying cement plants with their electricity requirements."

Furthermore, as the system is installed in the bypass to the existing gas treatment line, the clinker production process is not affected by WHR stoppages.

Clean energy ahead

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With more than 40 years' experience in the design of ORC units and over a decade of being active in the cement industry, Turboden is ready to take up the challenge and lead this sector towards a greener future.

Part of the Mitsubishi Heavy Industries group since 2013, Turboden can count on the technical prowess of its parent company to provide strong guarantees to cement producers. ■