Stepping up ORC

by Exergy SpA, Italy

Driven by the cement industry's need to reduce energy consumption for a variety of reasons, demand for waste heat recovery (WHR) is steadily increasing. Recent technology developments have seen investment requirements fall considerably, bringing WHR within the reach of an increasing share of the cement sector.

The average embodied energy (thermal and electrical) consumed to produce 1kg of cement is 4MJ, although this value can vary depending on the age and configuration of a kiln. A large amount of this energy is lost due to inefficiencies. With power accounting for nearly a third of cement production costs as well as impacting the environment, cheaper and more sustainable alternative ways of electricity generation are increasingly attractive in today's competitive cement sector.

The waste gases and exhaust air produced in the preheater and in the clinker cooler contain valuable thermal energy that can be converted into power by waste heat recovery (WHR) systems and, as such, meet up to 30 per cent of a plant's total electricity needs.

Organic Rankine benefits

WHR systems commonly used in the cement industry are based on the steam Rankine cycle and organic Rankine cycle (ORC). Compared to the traditional Rankine cycles, ORCs are ideally suited for lower-temperature heat sources and small- to medium-sized power outputs, realising higher turbine efficiency as well as eliminating the requirement for water treatment and make-up, or extensive maintenance.

Other benefits of the ORC for WHR over the traditional Rankine cycle include:

- compact and automated, without the need for an operator
- ideal for cycling environments and where fast start/stops are required
- modular configuration for ease of transportation and installation
- design adaptability with the option to use the most efficient working fluid available
- operational flexibility for superior off-design performances
- high market availability of chemicals/ fluids with refilling rarely required
- low associated costs for foundation work and assembly
- simple and reliable system maintenance makes for long product life.

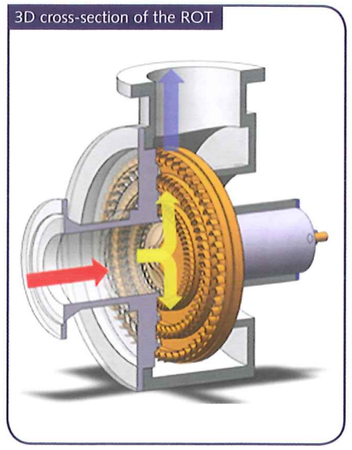
The Radial Outflow Turbine rotor

Latest ORC advances

Recent efforts in ORC WHR technology have provided a major opportunity for cement producers to minimise investment in a WHR system while increasing efficiency and profitability. The latest R&D innovation is Exergy's Radial Outflow Turbine (ROT) technology. This ORC energy recovery system mainly consists of heat exchangers that transfer the thermal power contained in the heat source to a thermal oil. In the second stage the thermal oil transfers the thermal power to the organic working fluid in the ORC evaporator, where the organic fluid vaporises. The vaporised fluid then passes to the ROT. Here it expands causing the turbine to spin and creating electricity into the generator.

The ROT has several benefits when compared with existing ORC technologies using axial or radial inflow turbines. ROT technology leads to better efficiency (up to 20 per cent more power) as well as lower operational and maintenance costs. This is attributed to:

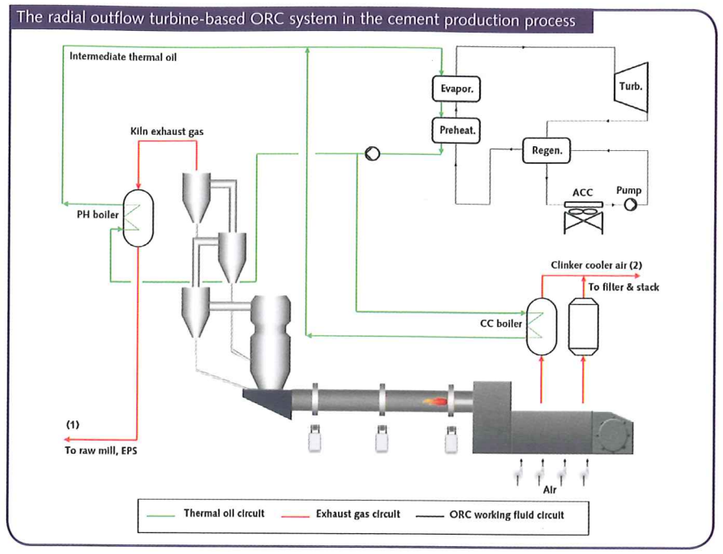
- The turbine disk incorporates up to seven stages in comparison to the maximum three stages allowed by the axial turbine.
- The turbine disk rotates at a lower speed than a radial inflow turbine. Therefore, there is no gearbox and hence, higher reliability is observed.
- There is no need for partial admission, less tip leakage and disk friction losses lead to lower vibration, resulting in maximum efficiency and longer life on the bearing.
- Noise is minimised.



3D cross-section of the ROT

In addition to the efficiency advantages, this ORC solution also offers the option to includes air-cooled condensers with direct exchange. This is particularly important when cooling water is not available at the production plant.

ORC technology is applied to cement mills recovering heat from the kiln exhaust gas and clinker cooler air. As the streams have to enter into the filters at a certain temperature, or since their dew point is quite high, there is generally a minimum cooling temperature below which it is not recommended to go. In this particular configuration the best choice is to harvest thermal power with two boilers in parallel and then mix the oil at the maximum temperature to feed the evaporator system of ORC. The total mass flow of the oil is split into the two boilers so as to maintain an approach point temperature. The suspended particles and the risk of erosion do not allow performance to be pushed further without loss of reliability of the system. The specific thermal cycle is designed at the optimum point and with the more appropriate fluid to ensure the best conversion efficiency from thermal to electricity.



The radial outflow turbine-based ORC system in the cement production process

In addition, air condensers reduce the condensing pressure of the cycle, leading to higher power production.

Furthermore, using direct air-cooled condensers results in less equipment (no intermediate water circuit), considerably reducing plant costs.

Exergy's ORC system can be customised and the ORC working fluid can be chosen to best fit the heat release curve of the source.

Gains

These major technical and operational advantages offered by the new WHR ORC plant design result in competitive capital costs, leading to faster payback and thus increasing the profitability of the plant. Project payback and financial return vary depending on the required investment and prevailing electricity prices, but simple paybacks for WHR systems typically range between 3-7 years depending on the cement plant configuration, size of the power project and many other minor project features.

In addition, the WHR ORC system can help to improve the cement industry's green credentials by contributing to lower carbon emission.

Exergy's EPS Radial Outflow Turbine enables the customer to use the electricity produced to supply the plant's raw material and cement grinding equipment, kiln and cooler sections, thus decreasing the plant's total variable annual costs and increasing its competitiveness.

Exergy WHR ORC plant application

Cement plant capacity (tpd)	5000
Type of production process	dry
Fuel used	coal
Application	heat recovery (cement mill)
Model	EPS 730
Flue gas outlet temperature – 1.2 (°C)	170
Kiln exhaust gas flow – 1 (Nm³/h)	330,000
Kiln exhaust gas temperature – 1 (°C)	335
Clinker cooler air flow – 2 (Nm³/h)	300,000
Temperature clinker cooler air – 2 (°C)	300
Cooling agent	air-cooled condenser
Electrical power (KWe)	7000

ROT turbine