INNOVATIONS

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ENVIRONMENT

Turboden's Sabrina Santarossa discusses EAF waste heat recovery

HISTORY

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HYDROGEN STEELMAKING – AN INDIAN PERSPECTIVE

Low emission steelmaking

Sabrina Santarossa* argues that the steel industry can play a huge part in helping to reach the European Commission's net zero target by way of recovering heat lost in the atmosphere. In this article she discusses EAF waste heat recovery

HISTORY books will mark 2020 for the Coronavirus pandemic hitting the entire world, causing over half a million deaths and other countless problems.

Covid-19 changed our day-to-day lives and affected the global economy in a way that will be felt for many years to come.

One must hope that the lessons of 2020 will teach us how to be more proactive in order to create a more just and sustainable world for our children.

In this context, European citizens, institutions and governments have very clear tasks outlined in the European Green Deal, launched by the European Commission (EC) in December 2019 .

In the words of the EC, the Green Deal aims to transform the European Union into a fair and prosperous society, with a modern, resource-efficient and competitive economy where there are no net emissions of greenhouse gases by 2050 and where economic growth is decoupled from resource use.

Within the Green Deal roadmap, the steel industry at large is seeking to put forward innovative technologies, mostly focusing on hydrogen, in order to reach zero-carbon iron ore-based steelmaking processes by 2030. This effort, which runs in parallel with research and development on cost effective renewable hydrogen, relies on strong EU financial support through the old European Coal and Steel Community fund and the Emissions Trading System Innovation Fund.

Pilot installations at several steel plants are showing how, in the coming years, the emissions of large integrated steel plants can be drastically reduced. At the same time, a small but significant group of family- owned minimills have already demonstrated how to reduce the intrinsically low emissions of steelmaking based on recycled scrap, even further.

The feasibility of steelmaking with extremely low carbon emissions is the result of continuous EAF process improvements particularly with continuous scrap feeding and preheating combined with off gas waste heat recovery (WHR).

This best available technology to decarbonise steelmaking is largely a European achievement, thanks to the development work of dedicated technology and equipment suppliers and the forward-looking attitude of steelmakers willing to invest in innovative applications.

The most important metal technology specialists like Danieli, Primetals Technologies, SMS, and Tenova supply advanced WHR systems to steel plants in Europe and Asia and put to good use thermal energy that would otherwise be wasted.

In instances where steel melting shops are within large integrated facilities, these WHR systems utilise existing steam networks to feed the thermal users (i.e. pickling lines).

In case large thermal users are not available within the complex or in the nearby area, the most logical solution is to convert the recovered energy from the WHR system to mechanical/electrical energy. This conversion could be done with steam turbines or more commonly with Organic Rankine Cycle (ORC) systems guaranteeing safety, reliability, and flexibility with minimum O&M.

*Chemical engineer, industrial heat recovery specialist, Turboden

The main advantages of ORC compared to traditional steam technology are both technical and operational. On the technical side, the organic fluid does not need to be superheated before expanding into the turbine due to the shape of the liquid vapour equilibrium curve. In fact, the expansion of an organic fluid in the turbine is always in dry condition, with no liquid formation.

Additionally, ORC modules have a high level of automation and do not need personnel supervision in normal operating conditions or in shut down procedures. This allows the steel plant technicians to focus on their core activity, steel production. ORC modules are designed to automatically adjust to the actual operating conditions: variations on exhaust gas temperatures and flows will not affect the functionality of the system, only the power output will. In fact, ORC plants can operate in a wide range of thermal power loads (from 10% to 110% of nominal load) with high efficiency, even at partial load.

Finally, ORCs are remote-monitored and require minimal yearly maintenance activities compared to steam turbines, due to several characteristics of the ORC technology such as: organic fluid dry expansion in the turbine (no erosion of blades), non-aggressive and non-corrosive organic fluid, low rpm of the turbine, etc. ORC life is longer than 25 years without the necessity of a major overhaul. Looking at all Turboden ORC units in operation, the availability is higher than 98%.

The following table (**Fig.1**) summarises the advanced WHR systems for electricity

production installed in the last year by two companies particularly active in this field: Tenova, whose heat recovery system is called iRecovery® and Turboden, that developed the ORC system.

The technical solution – ORC (Organic Rankine Cycle)

Thanks to over 30 years' experience and almost 400 ORC units that are mostly used in distributed generation systems fed by renewable heat sources, ORC is now the preferred choice for demanding WHR applications in energy-intensive industries like cement, glass and electric steel melting shops.

With power ranges up to 15 MW, ease of operation, dependability and minimum personnel are mandatory; traditional steam turbines cannot compete with ORC. In EAF heat recovery, where the thermal power available in the exhaust gas is not constant, the flexibility of ORC technology together with high reliability and self-adjusting automatic operations are defining characteristics of this solution. Because the temperature and flow-rate of the furnace

CUSTOMER	PLANT TYPE	FURNACE HEAT SIZE	AVG. DESIGN STEAM PRODUCTION	USE OF STEAM	ORC POWER	START UP
GMH Germany	ECS	EAF, 100 t	22 t/h	Thermal only		2007
Feralpi Germany	ECS, WHB, ORC	EAF, 100 t	30 t/h	Thermal & Electric	2,700 kW	2014
Hyundai Steel Korea	ECS, WHB	EAF, 90 t	27 t/h	Thermal only		2014
Hyundai Steel Korea	ECS, WHB	EAF, 80 t	26 t/h	Thermal only		2015
ORI Martin Italy	WHB, ORC	EAF Consteel, 100 t	16 t/h	Thermal & Electric	2,200 kW	2015
TPCO China	ECS, WHB	EAF, 100 t	33 t/h	Thermal only		2015
Aichi Steel Japan	ECS, WHB, ORC	EAF, 150 t	25 t/h	Thermal & Electric	2,500 kW	2019
Arvedi Italy	WHB, ORC	EAF Consteel, 260 t	52 t/h	Electric only	7-10,000 kW	2018

Fig 1.

fumes change continuously during the furnace tapping cycle, the design of the heat recovery system is optimised to store part of the steam produced during power on so that during power off, the steam accumulated is sent to the ORC allowing it to work continuously and automatically.

An example of the variable working load of a working EAF WHR plant is detailed in the charts below. The steel shop is located in Italy at Acciaieria Arvedi in Cremona and the actual EAF is a Consteel® of 250 ton. Arvedi has a large iRecovery® system coupled with an ORC unit converting the off-gas waste heat generated steam to 7 MW power. The ORC will soon reach 10 MW once the present Consteel® EAF is finally upgraded at the end of summer 2020 to increase production and maximise waste energy recovery.

The data shown in the chart was collected over 10 EAF heat cycles. In **Fig.2** it is shown in green the furnace power On and Off, in violet the thermal power

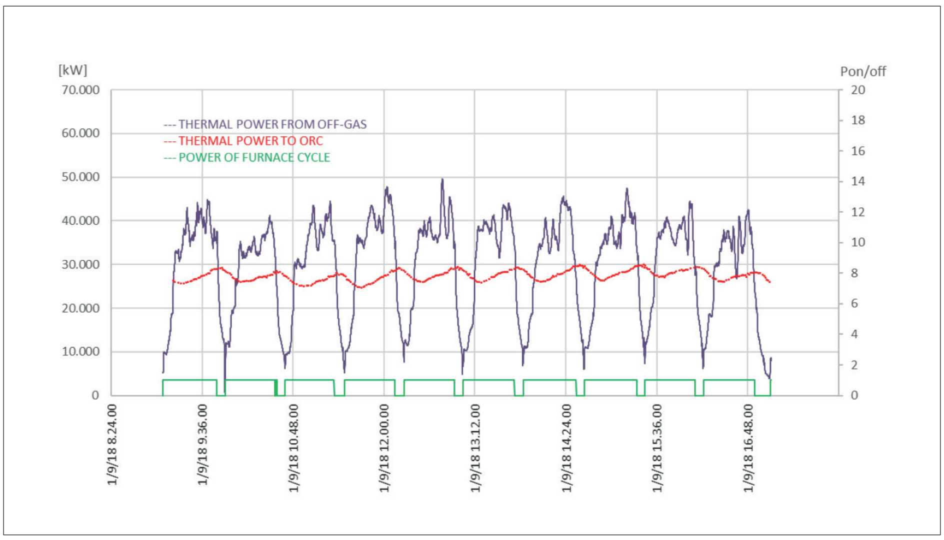

Fig 2.

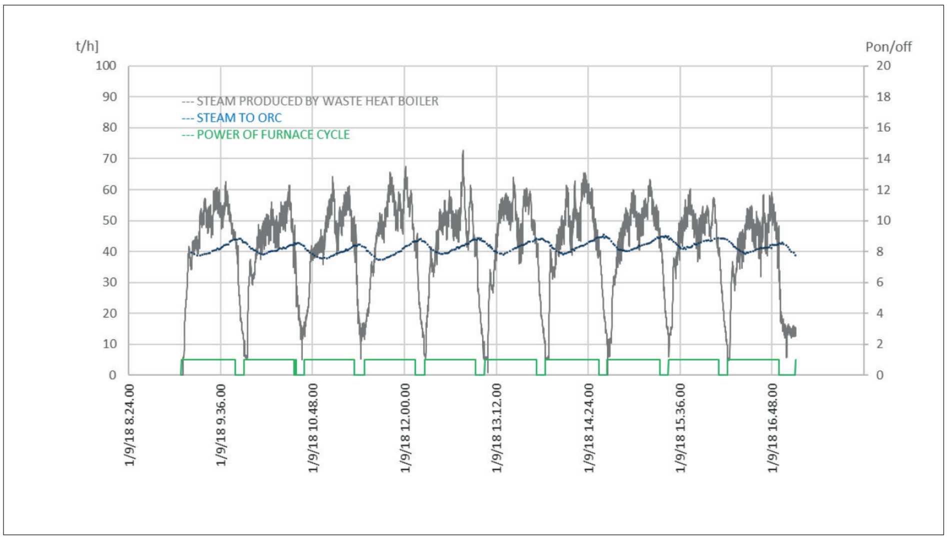

Fig 3.

available from the off gas and in red the thermal power sent to the ORC. In the second chart, (**Fig.3**) the steam produced by the heat recovery exchanger in grey and the steam input to the ORC is in red. In both charts, the highly variable steam/ thermal power available during power on and off is made clear. Additionally, the almost constant steam/thermal power sent to the ORC thanks to the buffer tank that smooths the picks and allows the maximum energy recovered and produced by the system, is evident.

The relation between steam input (in blue) to the ORC and electric power production (in white) is shown in **Fig.4**. Steam sent to the ORC is in the range of 40-55 ton/hr and is continuously converted into 6-7 MWe even when EAF furnace power is off. As expected, the WHR system was designed to produce up to 70 ton/hr of steam and 10 MWe; soon it will reach this capability after a Consteel® upgrade.

Economic feasibility

Both the heat recovery exchanger that generates steam and the ORC unit guarantee minimum overall O&M costs thanks to inbuilt technology and improvements resulting from operating experience.

Additionally, the specific capital costs of WHR systems have been decreasing from the first to the most recent plant with increasing size (scale factor) and improved simplified design. It is expected that this trend will continue into future projects with further lower cost per kW of produced energy.

Still, the investment cost and the resulting payback time, often-exceeding five years, are restraining the growth of EAF WHR plants unless capital grants or other incentives on actual energy saved in industrial operation become available. The further growth of new and improved EAF WHR installations will depend on the future of EU policies and country-specific policies. Right now, there are few incentive schemes. There needs to be increasing implementation across multiple geographies in order to support the use of waste heat actually present in ambient air.

Another opportunity for steel producers is the use of cooling heat generated from a melt shop to power the heating of nearby towns. When melt shops are located next to cities or even industrial parks that require hot water for heating, very often the temperature from the EAF cooling system is lower than what is required. In this case, it is possible to increase the water temperature to optimal levels by using a heat pump; the first large heat pump will be installed in Ori Martin thanks to a Life 2020 project financed by the European Commission.

Conclusion

The steel industry can play a huge part in helping to reach the European Commission's net zero target by way of recovering heat lost in the atmosphere. Heat recovery in the steel industry is possible and there are already some great examples of WHR plants in the world. The Green Deal should aim to incentivise the steel industry to improve and implement this solution. ■

Fig 4.