Steel degassing goes 'green'

Simon Bruce, Vic Cheetham, Graham Legge and Alessandro Villa* assess how via lower energy consumption and a smaller carbon footprint, steel degassing technology is going 'green'. The latest high capacity, dry mechanical vacuum pump modules enable an integrated and optimised approach to vacuum steel degassing, precisely specified for the actual metallurgical needs of the process and completely free from any requirement to consume steam as a utility.

Steel production remains an energy-intensive industry, in a world where there is an ever-increasing emphasis on dramatically lowering energy costs, reducing greenhouse gas emissions, ensuring environmental compliance and improving production rates. In particular, the drive towards low carbon technologies – those technologies which can significantly reduce energy consumption and therefore, save considerable amounts of greenhouse gas carbon dioxide (CO_2) emissions – is gathering momentum.

This drive is founded on the scientific data on global warming (Fig 1) and on the pressing international commitments to reduce greenhouse gas (GHG) emissions, through the UNFCCC (United Nations Framework Convention on Climate Change) and the Kyoto Protocol agreement. Indeed, this year's major international UNFCCC meeting in Copenhagen in December 2009 promises "an ambitious and effective international response to climate change", signalling further strenuous commitments in many countries to reduce GHG emissions.

In the UK particularly, these efforts have included the Government's ambitious White Paper 'The UK Low Carbon Transition Plan', released in July 2009. This seeks to deliver an 18% cut in the nation's CO_2 emissions from 2008 levels by 2020 and includes commitments to provide 40% of electricity from low carbon sources by 2020 and to help "make the UK a centre of green industry". These aspirations are backed by practical resourcing, such as the £405 million government support promised for low carbon investment in the parallel document 'UK Low Carbon Industrial Strategy'.

However, there are additional factors to be considered, especially the increasing cost of energy and the prevailing uncertainties of energy availability in some regions. Energy security itself has become a major concern and in the UK again, the recent Wicks Report highlights the inevitable future rise in the cost of energy and the pressing need to be "far smarter with the energy we use".

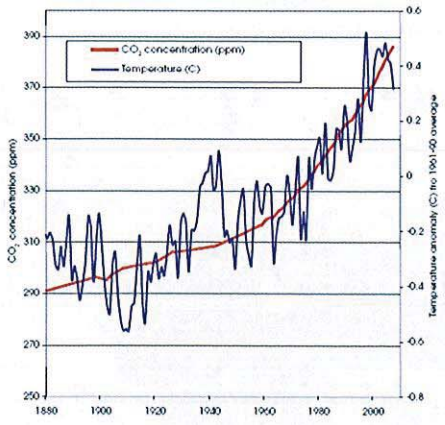

Fig 1. The link between mean global temperature and atmospheric carbon dioxide concentration.

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Fig 2. Standard dry mechanical vacuum pump module for steel degassing.

While the steel industry can comfort itself to some degree in that steel is a highly recyclable (and arguably 'green') material, against the backdrop of such concerns, the following issues are becoming increasingly important:

Energy consumption should be reduced: The ever-increasing cost of fuel means that energy costs are a significant operating expense and this is forcing a closer evaluation of energy consumption. As a particular consequence, the need for steam generation systems is coming into question, especially on steel degassing plants which historically have relied on large steam ejector systems, fed by large steam boilers to provide the necessary process vacuum.

Greenhouse gas emissions should be minimised: Combustion plant, including steam raising boilers, are a major source of CO_2 emissions and the reduction of such emissions is a key national target through various emissions reduction initiatives and carbon trading fiscal mechanisms (eg the trade in emission reduction units) now in place. This should provide a significant incentive to minimise CO_2 emissions from steel plants.

Environmental compliance must be assured: Air pollution regulations continue to put pressure on combustion processes such as steam raising and any opportunity to minimise or avoid steam raising can be a benefit.

Safety can be improved: The traditional use of high pressure stream to power steam vacuum ejectors always carries risks associated with high pressure piping and pressure vessels, high temperature steam, hot fuel distribution systems and burner installations. Eliminating such systems can represent significant safety improvements for the user.

Better production consistency can be achieved: Steel degassing is a batch process and the increasing value of the secondary steel products, coupled with the need to increase plant efficiency and maximise revenues, means that accurate scheduling of degassing cycles is required, with little time allowable for maintenance and unplanned outages. Operational variability and limitations on the availability of process steam to run steam ejector vacuum systems can lead to upset schedules and variable end product quality. The provision of instantaneous 'vacuum on demand' at the push of a button is a desirable alternative to this situation.

Modular dry mechanical vacuum systems

To address these issues on vacuum degassing (VD) and vacuum oxygen decarburisation (VOD) vacuum stations, the latest high capacity, dry mechanical vacuum pump modules are recognised as a significant 'green' technology. These dry pumping systems enable an integrated and optimised approach to vacuum steel degassing, precisely specified for the actual metallurgical needs of the process and completely free from any requirement to consume steam as a utility.

These systems are based on a standard, modular pumping package, optimised for steel degassing processes and designed for minimised power consumption, low utility consumption and significantly improved ease and speed of installation and commissioning. This results in a fully integrated three-stage vacuum pump system on a transportable skid, with each standard module providing a net pumping speed of 28,300m³/h (equivalent to 22.6kg/h dry air mass flow) at 0.67 mbar (hPa), suitable to degas around 23 tonnes of liquid steel. Higher performance versions are also available. The modules are installed singly or in multiples, according to the size of the heat mass to be

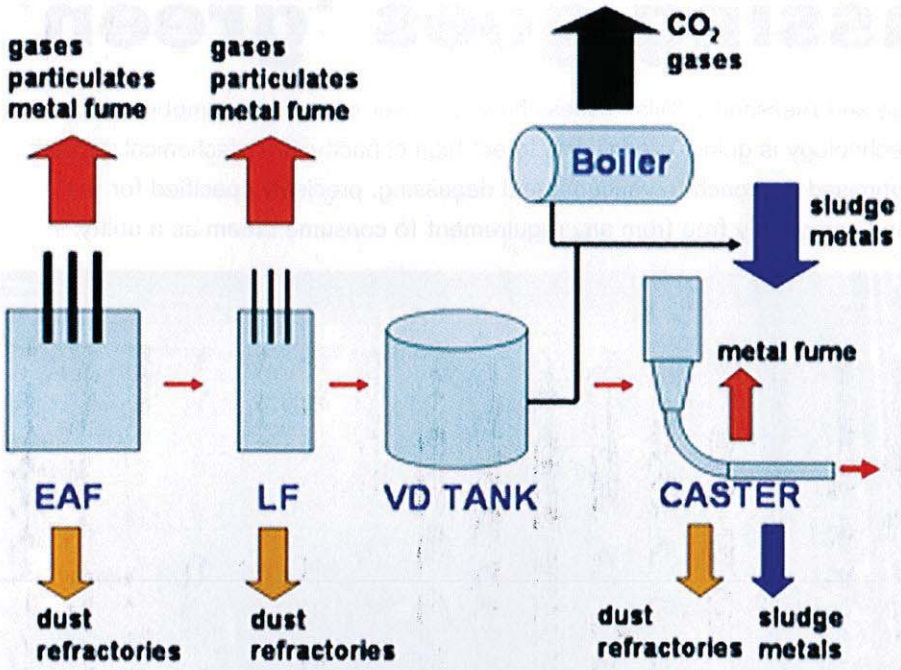

Fig 3. Simplified environmental emissions inventory diagram for a typical EAF mini mill with VD by steam ejectors.

degassed and are suitable for degassing systems of 230 tonnes and more. The standard module is illustrated in Fig 2.

The modular dry pump approach also provides good operational flexibility and enables the integration of pump control directly into the plant control system to provide a true pushbutton, 'vacuum on demand' plant. The excellent controllability is especially beneficial in dealing with slag foaming and enables consistent performance and proven, high quality metallurgical results. Field experience also shows rapid commissioning and start-ups are achievable and the rapidly growing numbers of operating steel degassing plants around the world using such dry vacuum pumping systems demonstrates the effectiveness of this technology.

Lowering energy consumption

Significant reduction in energy use and good operational cost savings are a key feature of the modular vacuum pump systems compared to conventional steam ejector vacuum systems and these savings arise from two key considerations.

First is simply the cost comparison. The cost of raising steam to power steam ejectors for process vacuum has become a major factor in the operation of many steel degassing plants. On a typical VD plant, the cost of the steam consumed may account for over 50% of the total pump system running costs, to which are then added the costs of feed water, condenser water and the waste water disposal charges. Compared to the cost of steam, electricity costs for running an equivalent mechanical vacuum pump system can be as little as 5% of the steam cost. Secondly, there is a question of required pumping capacity. A typical specification for an efficient steam ejector system may provide for a pumping capacity of around 2.4kg/h (dry air at 20°C equivalent) at 0.67 mbar (hPa) per tonne of steel degassed. This appears to include a historical capacity excess to allow for variation in steam quality and for routine degradation of the ejector performance, due to fouling with process dust deposition between ejector cleaning operations.

In contrast, the true metallurgical off-gas, argon purge gas and air leakage flow rates from the degassing process would imply an actual suction capacity requirement much closer to 1.0kg/h per tonne. This required capacity figure is certainly borne out in recent experience with modular dry mechanical pump systems. This means that steam ejector systems are not only typically more costly to operate in energy terms but also appear to be frequently oversized for the duty. This means that the higher cost of energy involved in steam generation, the routine maintenance requirements for ejector cleaning and the higher demand for water with ejector systems (plus the disposal costs of contaminated waste water) all contribute to an increase net operating cost, compared to modular dry mechanical pump systems.

Reducing carbon footprint

In environmental terms, a typical 'mini mill' EAF plant with associated VD installation can represent a complex emissions inventory in terms of solid, liquid and gaseous waste. This may be usefully represented in a simple diagram such as Fig 3. Clearly, the key concern for reducing carbon footprint here is the combustion of fuel in the steam boiler, which leads directly to a CO_2 emissions burden from the plant. The immediate environmental advantage of completely eliminating the use of steam and replacing the ejector system with dry vacuum pump modules will be obvious. As a general approximation based on typical values, a steam ejector vacuum system used for VD processing may be expected to consume around 1MWh of steam energy per tonne of steel degassed and emit around 2.5 tonnes of CO_2 per tonne of steel degassed from the supplying boiler. In stark contrast, an equivalent dry module pumping system consuming electrical power only would consume less than 2kWh of electrical energy per tonne of steel degassed and have no direct CO_2 emissions. By any definition, this equates to a significant low carbon technology and enables the concept of 'green' steel degassing to be fully realised.

Carbon emissions case study

Many dry pumping degassing systems have now been installed around the world, as typified by the system illustrated in Fig 4. One of the recent 100 tonne VD installations using dry pumping modules in place of steam ejector systems has been the subject of a UNFCCC Joint implementation Project, in which the overall improvement in energy efficiency of a steel plant by the implementation of various plant upgrades has been assessed in terms of achieved CO_2 emissions reductions.

Installation of the VD system was one of seven subprojects within this overall scheme but accounted for the largest single reduction in CO_2 emissions. In the assessment, it was determined that the original steam ejector degassing system used 1.16 MWh of energy per tonne of steel degassed, compared to just 1.92kWh per tonne of electrical energy with the dry pump modules. For the normal annual production of degassed steel (around 100,000 tonnes/year for this plant) this converts to a reduction in direct emissions of around 280,000 tonnes of CO_2/year.

In today's regulatory and fiscal regimes, such emission reductions can have significant value in helping achieve national emission reduction targets, or indeed as saleable emissions reduction units on the international emissions reduction market.

Fig 4. Typical modular dry mechanical vacuum installation for 90 tonnes VD.