

SECONDARY STEEL PROCESSING UNDER VACUUM – THE END OF THE LINE FOR STEAM EJECTORS?

As energy costs rise around the world, Simon Bruce and Vic Cheetham examine the increasing opportunities to save both money and the environment by replacing steam ejectors with modular dry vacuum pump systems on vacuum degassing plant.

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The current high level of demand for steel around the world, much of which results from the growing economies of China, India, Russia and Eastern Europe, is driving continuing investment in steel production in many locations. With the renewal and expansion of oil and gas distribution networks, and increased investment in rail transport and in other areas that require high performance steels, the market for special degassed steels is also experiencing strong growth.

To meet this demand for premium steel products, attention is being focused on secondary steel processing, and particularly on vacuum degassing (VD) and vacuum oxygen decarburisation (VOD) processes.

The VD process is usually associated with long products requiring a very low hydrogen content. VOD is mainly used to reduce the carbon content of stainless steels. These processes are suited to the small to medium heat sizes (typically up to around 200 tonnes) often provided by electric arc furnace (EAF) plants processing recycled scrap.

Such plants can be a very flexible way of enabling the melt shop to make a variety of different steels for different clients or market opportunities in relatively short timescales. However, the historical method for providing vacuum pumping for these VD and VOD processes - the traditional large multi-stage steam ejector pump system - is now proving to be less than ideal.

Greenhouse gas emissions and the cost of energy

There is an increasing focus on reducing energy usage and environmental impact in the steel industries around the world, especially given the rising cost of fuel and the commitments of many nations to reduce their emissions to atmosphere of carbon dioxide (CO₂), the most important greenhouse gas resulting from combustion processes.

Concerns are demonstrated by the forthcoming first international conference on energy efficiency and CO₂ reduction in the steel industry (EECR Steel 2009) to be held next March 2009 in Budapest, Hungary¹. While greenhouse gas emissions are an urgent consideration, steam boilers can also generate emissions of hazardous air pollutants, adding to the complexity of the regulatory regime under which the melt shop must operate.

Faced with escalating operating costs for raising steam to power the steam ejector pump systems, and environmental concerns, many melt shop owners are now investigating alternative technologies. Dry mechanical vacuum pumping systems can offer very significant savings in running costs, and have become the obvious choice for vacuum pumping systems for VD and VOD installations.

Dry vacuum pumping technology

The basic requirement for degassing steel under vacuum in the standard VD process is to hold the liquid steel at, or below, 1 mbar (1 hPa) for a period of around 15 to 20 minutes while at the same time purging (or “stirring”) the liquid steel with argon to carry away the impurities, especially hydrogen.

This means that the vacuum pumping system must be able to evacuate the ladle tank from atmospheric pressure down to around 1 mbar in a short time (typically around 6 – 8 minutes) to avoid unnecessary cooling of the steel. It should also be able to control the rate of pressure descent carefully across the 100 – 20 mbar region, if required, to avoid slag foaming, and so the applied suction capacity must be controllable at any pressure.

The ideal configuration of the simplest dry vacuum pumping system to comply with these requirements is a three-stage configuration, comprising two stages of Roots-type mechanical vacuum boosters backed by a high capacity, dry screw vacuum pump.

This concept has now been further developed into the skid-mounted modular pumping system, fully optimised for steel degassing processes, in which a number of parallel modules can be installed together to provide a vacuum pumping capacity appropriate to the heat size of the process. Each module is capable of degassing around 23 tonnes of steel.

An example of such a modular system for a 90 tonne VD plant is shown in Figure 1. It provides excellent flexibility, as modules can be added if the heat size increases later, or removed to another location if old plant is to be replaced with new.

Modularisation of the dry pumping system also offers a number of other benefits, including compact size, the ability to refine system operating characteristics to meet the exact needs of the process, minimised utility consumption and significantly easier transport, installation and commissioning.

Figure 1 Typical modular dry pump installation for a 90 tonne VD process



The electric motor of each pump in the module is operated by an electronic variable frequency drive (an “inverter”) which is integrated into the degasser control system and to which the installed module instrumentation is also connected. This results in a vacuum pumping system which is both energy-efficient and fully integrated with the process control system. It can either be operated fully automatically or with operator intervention to control pumping speed when required.

Successful implementation of many such pumping modules on steel degassing plant around the world has been achieved over the last few years, as shown in Table 1. An example of the latest version of a steel degassing pump module, which is supplied fully pre-piped and pre-wired, is illustrated in Figure 2.

Table 1 Some recent installations of modular dry vacuum pump installations for steel degassing

Year commissioned	Country	Heat size (tonne)	Peak suction capacity (m ³ /h)	Primary pump type
2006	USA	41	87,000	dry screw
2006	Spain	42	35,000	dry screw
2006	Ukraine	100	145,000	dry screw
2007	Turkey	90	116,000	dry screw
2007	Germany	60	87,000	dry screw
2007	Ukraine	60	87,000	dry screw
2008	Italy	100	87,000	dry screw
2008	Belgium	90	120,000	dry screw
2008	Romania	100	116,000	dry screw
2008	Romania	60	87,000	dry screw
2008	Italy	20	29,000	dry screw
2008	Brazil	30	58,000	dry screw

Significant savings in operating costs

A key feature of the modular three stage steel degassing system is the potential for significant operational cost savings compared to conventional steam ejectors.

Figure 2 Edwards steel degassing pumping module



The specification consumption for a typical new and efficient steam ejector system is generally around 20-30 kg of steam per tonne of steel processed. However, experience indicates that older steam ejector systems may actually require up to double this amount.

The suction capacity required for vacuum degassing is usually standardised in terms of an air mass flow in kg per hour (expressed at 0.67 mbar pressure and 20°C temperature). A typical steam ejector design capacity allows around 2.4 kg/h suction capacity per tonne of steel for the VD process. This appears to include a historical capacity excess to allow for a high leak rate plus routine degradation of ejector performance due to fouling with dust deposition between ejector cleaning operations.

In contrast, the sum of the true metallurgical off-gas, purging argon and tank air leakage flow rates from a modern VD tank degasser with a low leak rate would imply an actual suction capacity requirement much closer to 1.0 kg/h per tonne. This lower required capacity figure is borne out in the success of recent dry mechanical pump systems, clearly demonstrating that steam ejector systems are not only much more costly to operate in energy terms, but also appear to be frequently oversized for their theoretical duty.

In overall terms, the much higher cost of energy involved in steam generation, the routine maintenance requirements for ejector cleaning and the high demand for utility water with steam ejector systems, plus the disposal costs of contaminated waste water, all contribute to a significantly lower operating efficiency and a much higher net operating cost of steam ejectors compared to modular dry mechanical pump systems. The dry pumping systems, in contrast, require only modest amounts of electrical power, purge gas and cooling water.

Furthermore, the potential for eliminating a major item of combustion plant – the steam boiler – offers the melt shop an immediate and significant reduction in emissions of pollutants and CO₂, while removing the additional risks associated with high pressure steam pipes and high temperature fuel distribution lines. It also eliminates the need for boiler insurance, thus reducing costs, and ensures the availability, day and night, of full vacuum capacity at the push of a button.

A typical operating cost comparison is shown in Figure 3. This shows the potential annual cost saving projections when steam ejectors are replaced by modular dry vacuum pumps on a 60 tonne VD plant. Depending on individual plant configuration and utility costs, the operating costs of a dry modular system can be less than 10 per cent of the steam ejector system costs, representing potential savings of over €1 per tonne of steel processed and offering a comfortably short payback time for the investment.

Major orders

The market demand for dry pumping systems for VD and VOD processes continues to rise around the world, driven by the expansion of secondary steel processing, the need to reduce energy costs and concerns about greenhouse gas emissions from the steel industry. Particularly strong activity has been seen this year in recent major orders for dry modular pumping systems for steel degassing plants going into Russia, Ukraine and Germany. Interest in Italy and Brazil also remains strong, and this year has also seen interest developing in India and China.

We remain confident that this developing trend away from traditional steam ejectors toward dry modular pumping systems for steel degassing will continue for the foreseeable future.

1. EECR Steel 2009, 25-28 March 2009, Budapest, Hungary.

Further details available at <http://eecrsteelcom.web.maxer.hu/>

