PFEIFFER VACUUM

STEEL – MATERIAL FOR INDUSTRY

Energy efficient pumping stations for steel degassing

Hardly any material has influenced world economic development to such an extent as steel. It not only plays an important role in industry but also in our everyday life. Steel is used in the manufacture of machinery, plants, bridges, buildings, ships, cars and household appliances. The economic growth of emerging markets makes it the most important metallic material of the 21st century.

Steelmaking under vacuum

Steel is defined as iron-carbon alloys containing less than 2% of carbon, which may additionally contain other alloying elements. The result is a wide range of different steel variants: construction steels, tempering steels, stainless, heat-resistant and cold-resistant steels are just a few examples.

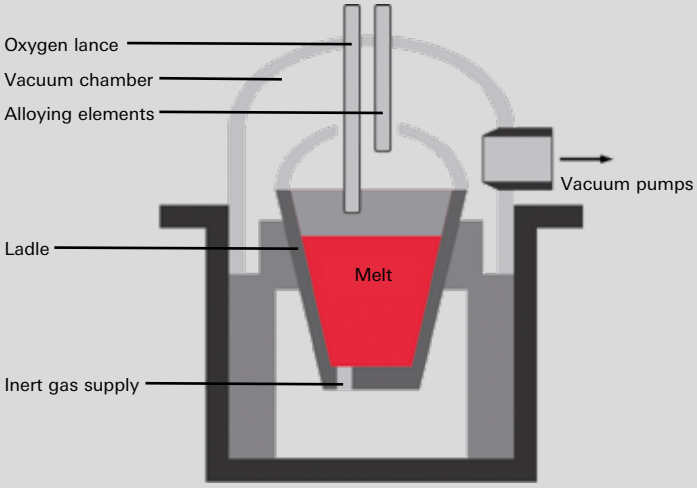


Figure 1: VOD (Vacuum-Oxygen-Decarburisation) Process

Although they differ in application and properties, all steels contain iron and varying amounts of other elements. The proportions of these elements generally determine the steel's physical properties, particularly those elements that are not desirable:

- Sulfur
- Nitrogen
- Hydrogen

The basic requirement for any high-quality steel is the removal of these elements from the steel in order to improve the material properties such as:

- Impact resistance
- Aging resistance
- Impact strength
- Elongation
- Weldability and malleability

The processes used to refine liquid steel are referred to by the term "secondary metallurgy".

A removal of these elements from steel can be achieved by various vacuum processes. Pfeiffer Vacuum focuses on the Vacuum Degassing (VD) and the Vacuum Oxygen Decarburisation (VOD) processes.

In both processes, a ladle of liquid steel is placed inside a vacuum chamber, which is evacuated by a corresponding vacuum system. By the aid of appropriate feeding systems, other alloying elements can be added to obtain the desired steel composition.

In vacuum processes, substances will outgas or evaporate from the liquid steel (depending on their vapour pressure). This leads to additional gas loads for the vacuum system. During the evacuation process, the following substances/ fumes, which place high demands on the robustness of the pumps in use, may be present:

- Metallic and metallic oxide dust/fume
- CO, CO_2 (VOD process)
- Hydrogen (H_2), Nitrogen (N_2)

The VD process uses pressures below 1 hPa (0.75 Torr) and stirring with Argon to remove these non desired elements. The VOD process applies a lance to blow oxygen onto the melt and starts at a pressure of 100 to 200 hPa.

In the production of high alloyed stainless steel, raw material costs represent roughly 80 % of the manufacturing costs. To control the raw material cost, high carbon ferroalloys and stainless scrap have to be used, yet stainless steel must also have a very low carbon content to inhibit corrosion. The VOD process can be employed to remove carbon from the liquid steel.

In the VOD process, there are two competing reactions; carbon oxidation and chrome oxidation. The second reaction is not desirable. Fortunately, the products of these two reactions differ significantly: Carbon monoxide (CO) is a gas and chrome oxide (Cr_2O_3) is a solid chemical compound. This difference makes it possible to favor carbon oxidation by lowering the partial pressure of CO. In a VOD, this is achieved by vacuum. Consequently, the carbon content in the liquid steel can be reduced to the desired low level.

Figure 2: SKID solution

Figure 3: STAGE solution

Energy-efficient alternative to steam ejector pump systems
In recent years, low energy consumption and environmentally friendly products have become increasingly important. This trend can also be observed where vacuum systems are concerned.

Previously, mainly steam ejector pumps were used for steel degassing. While purchasing costs for the ejector pumps are low, operating costs for steam production and cooling water are very high, as the created dust contaminates the cooling water.

For this reason, mechanical vacuum pumps are increasingly used today. They are cost effective and have a high pumping capacity at low pressures. Equipped with a dust filter, they offer reliable and stable performance under various conditions.

Mechanical vacuum systems compared to steam ejector pump systems can achieve substancial operating and maintenance cost savings.

Pfeiffer Vacuum solutions
Pfeiffer Vacuum has developed two concepts for steel degassing systems based on mechanical vacuum pumps. These can be individually tailored to the customer's specific requirements. Three or more stages can be integrated into an application-specific pumping system.

These pump system stages consist of gas-circulation-cooled Roots pumps (OktaLine G), Roots pumps (OktaLine) and screw pumps (HeptaDry).

The core element of both variants of the system are OktaLine G type pumps, which allow a reduction in the number of screw pumps and fast evacuation from atmospheric pressure downwards due to their enormous pumping speed even with high differential pressures.

In the so-called "SKID" solution, an Okta 25000, an Okta 4000 G with an integrated gas cooler and a Hepta 600 are assembled on a common frame. The skid includes interconnecting piping and convenient connections for utilities and automation systems. The required pumping speed is obtained by the parallel connection of identical modules ("Skids", fig. 2), which are specifically designed for the particular application.

In the so-called "STAGE" solution, the optimal number of parallel pumps is determined. The single stages are then connected to the next by a manifold (fig. 3). If necessary, the system can optionally be switched from a three to a four stage operation.

By optimizing existing systems, Pfeiffer Vacuum was able to reduce the number of pumps needed so that the energy consumption and the system costs are comparatively low. Only eleven pumps were needed for a previously successfully developed pumping station for the VD/VOD treatment of 45 tons of steel. The three stages were therefore limited to five OktaLine pumps, three OktaLine G pumps and three HeptaDry pumps.

Advantages of this system:
- Low energy costs compared with steam ejector pump systems
- Low number of pumps
- Compact size of the system
- Significant cost savings

For additional cost savings, customers can replace the large Roots pumps (produced in small quantities) by smaller more inexpensive pumps due to their lower cost of production.

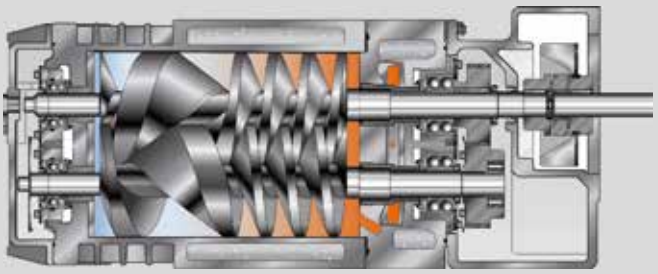


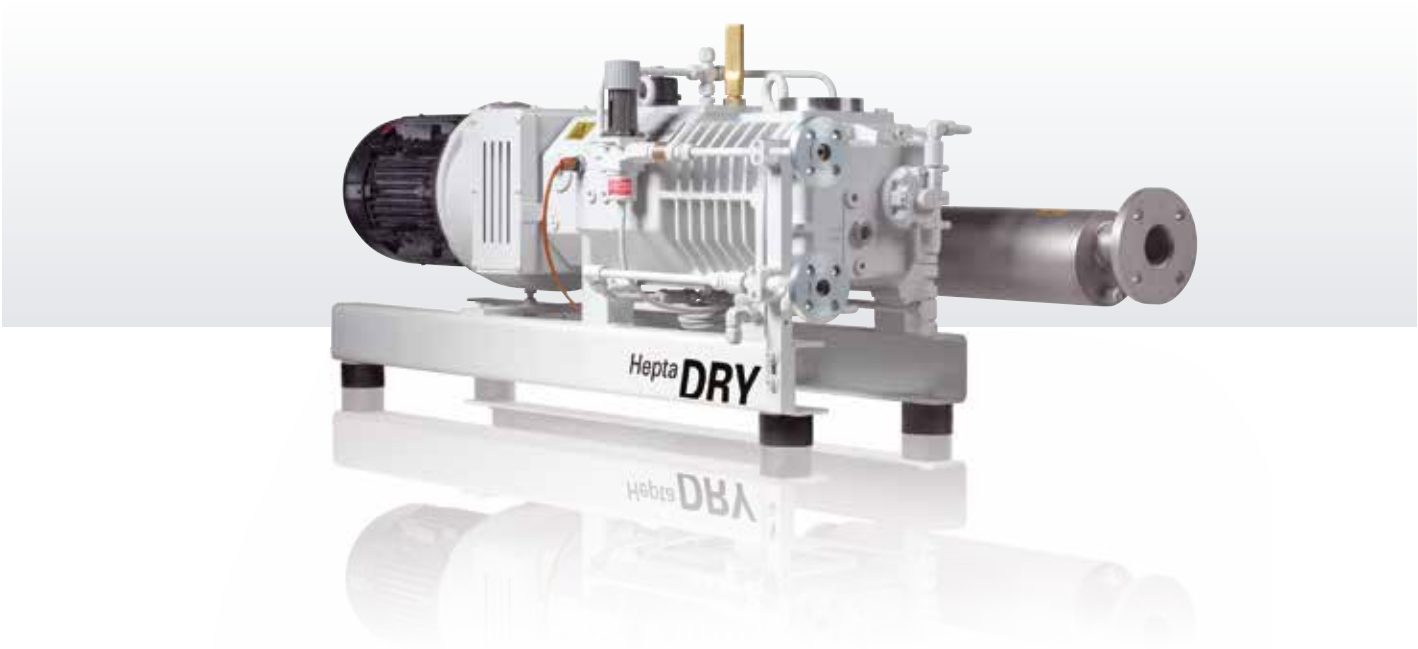
Figure 4: Cross section HeptaDry

The individual components of the vacuum system at a glance

Screw pumps
Screw pumps transport gas by counter-rotating, intermeshing screw rotors. Internal compression is achieved by reducing the thread pitch in the direction of the outlet. This results in lower power consumption, quiet operation and low cooling water consumption. This makes these pumps extremely cost-effective, in spite of their robust design.

Screw pumps are ideally suited for applications in low and medium vacuum (10^3 – 10^{-3} hPa) and have pumping speeds of 100 to 600 m^3/h. Thanks to the low operating speed, the bearings and seals are less stressed. Therefore, they are very reliable and are ideal for a combination with Roots pumps.

Advantages of Pfeiffer Vacuum screw pumps:
- Optimal final pressure
- Low energy costs
- Low noise level
- No risk of overheating by reducing thread pitch and water cooling
- Direct gas flow minimizes dust deposits
- Absolutely dry and oil free
- Robust and reliable



Roots pumps
In a Roots pump, two rotors rotate synchronously and frictionlessly in the opposite direction. The rotors have a figure-eight configuration and are seperated from one another as well as from the housing by a narrow gap. They have no internal compression and no outlet valve. An overflow valve prevents overheating due to limiting the pressure difference between the inlet and outlet side. Roots pumps can therefore not eject against atmosphere, they need a backing pump (e.g. screw pumps) instead.

Due to the different pumping speeds and versions, Roots pumps can be perfectly tailored to customer-specific requirements. The pumping capacities in the low and medium vacuum range are between 250 and 25,000 m^3/h. Vertical flow through the pump renders this pump largely insensitive to dust and liquids.

In addition to traditional Roots pumps, there are also gas-circulation-cooled pumps (OktaLine G). Instead of an overflow valve, the pump has gas-circulation cooling. The gas flows from the outlet flange, is cooled in a heat exchanger and is partially recirculated into the suction chamber. The pump can therefore operate at atmospheric pressure without the risk of thermal overload.

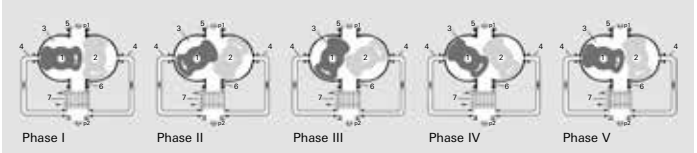


Figure 5: Operating principle of a gas-cooled Roots pump

This makes Roots pumps ideally suited for applications with high pressure differences and maximum compression ratios and they can be operated without a backing pump.

Advantages of Pfeiffer Vacuum Roots pumps:
- Short pump-down times due to the high compression ratio
- Protection against thermal overload
- Components according to guideline 94/9 EC (ATEX) available
- Robust, minimal maintenance
- Low operating costs due to air cooling and magnetic coupling
- Reliable and stable

Expert partner in the steel industry
Pfeiffer Vacuum's custom solutions for the steel industry have been tested in long-term cooperation with renowned steel manufacturers. In addition to complete vacuum systems, Pfeiffer Vacuum also offers the expansion and modernization of existing systems (e.g. replacing steam ejector vacuum systems). From their conception right up to servicing existing systems, the company stands for outstanding quality and a strong customer focus.

VACUUM SOLUTIONS FROM A SINGLE SOURCE

Pfeiffer Vacuum stands for innovative and custom vacuum solutions worldwide, technological perfection, competent advice and reliable service.

COMPLETE RANGE OF PRODUCTS

From a single component to complex systems:
We are the only supplier of vacuum technology that provides a complete product portfolio.

COMPETENCE IN THEORY AND PRACTICE

Benefit from our know-how and our portfolio of training opportunities!
We support you with your plant layout and provide first-class on-site service worldwide.

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