New-Technology, Dry-Compression Screw-Type Vacuum Pumps Reduce Operating Costs

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More and more in modern heat-treatment applications, furnace users are striving to increase productivity and reduce operating costs for their furnace investment. Through use of a new-technology, dry-compressing screw-type vacuum pump, this target can now be achieved. This article will review the traditional oil-sealed vacuum pumps used in furnace applications and introduce the modern design of dry-compression vacuum pumps with a cantilevered screw rotor. Also, we'll point out the advantages of this new innovative screw design and contrast it to other dry vacuum pumps.

With hundreds of years of history, heat treatment of workpieces is a known and well-proven technology. The purpose of heat treatment is to modify or influence the properties of a material in a controlled manner.

Generally speaking, heat treatment needs a higher quality base material. In times of diminishing raw-material resources and increasing pressure on costs, this technology has a growing worldwide demand.

Many furnace applications require the use of vacuum pumps. Vacuum ensures that the material surface will stay free from oxidization. No color changes or decarburization will occur under vacuum. Typical applications utilizing vacuum are hardening, annealing, sintering, tempering, nitriding, brazing and carburizing.

Typical vacuum-pump systems for furnace applications have historically been combinations of a booster stage and an oil-sealed vacuum pump. For most applications the use of these combinations is still sufficient. The trend in modern industrial vacuum-furnace design, which requires higher productivity and more simplified, reduced maintenance steps, can only be met by the advantages of using dry-compressing vacuum pumps.

Oil-Sealed Vacuum Pumps

Oil-sealed vacuum pumps are widely used in the field of heat-treatment applications as a single pump in combination with mechanical boosters or backing a high-vacuum system such as an oil-diffusion pump. While in Europe mainly rotary-vane pumps are popular, in the U.S. rotary-piston pumps and, to a lesser extent, rotary-vane pumps are used for furnace applications. Rotary-piston pumps consist of a housing (pumping ring) in which a piston rotates in a plunging movement. Gas entering through the intake is pushed along by the rotor and is finally ejected from the pump by the oil-sealed exhaust valve.

Inside a rotary-piston pump (Fig.1), piston 1 divides the chamber into two sections that change in size. During the first rotation, volume A increases and causes the gas aspiration. During the second rotation of the piston, the aspired gases (now volume B) are compressed against the exhaust

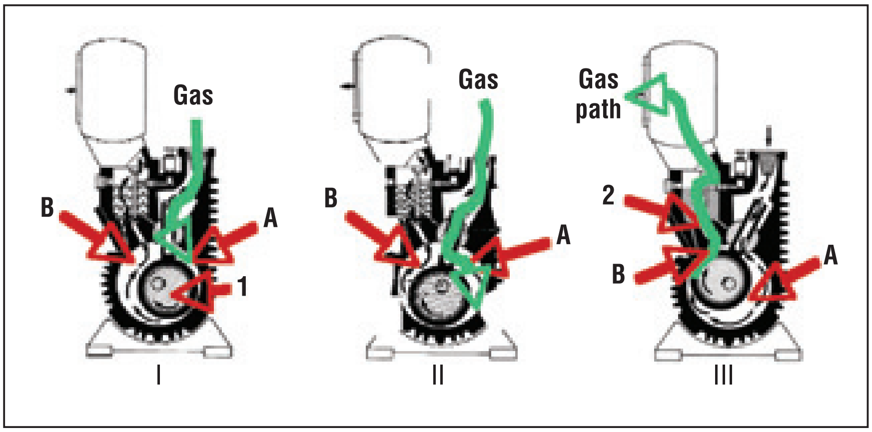

Fig. 1. Function of a rotary-piston pump

valve 2 until the pressure is high enough to open this valve and exhaust the gases.

Why Dry-Compression Pumps in Furnace Applications?

Environmental protection is certainly an issue. Less production of contaminated waste oil, no oil loss into the exhaust system and a cleaner working area due to no oil leaks are all advantages. However, companies may find it difficult to justify the capital cost on these alone.

Other reasons could depend on the process that may involve dealing with condensable vapors of binders, fluxing agents, solvents or cooling liquids, which enter the vacuum pump, often combined with metal particles, soot or tar. To reach a sufficient vacuum stability, some applications make us exchange the oil of an oil-sealed pump frequently. Some users need to exchange their pump oil monthly, weekly or even daily. In addition, exhaust filters, oil filters, dust filters and shaft seals need to be cleaned or exchanged regularly. At least one major service per year plus a complete overhaul of the oil-sealed vacuum pump every few years is typical. All of these involve costly consumables, spare parts, maintenance hours, downtime of the equipment and disposal costs. In harsh applications where oil-sealed vacuum pumps are employed, pro-active vacuum-pump maintenance is required. In these days of increased equipment responsibility and reduced maintenance staffs, failures without any prewarning resulting in a loss of the production are more likely.

Dry-Compressing Vacuum Pumps

Claw Vacuum Pumps

Like Roots mechanical boosters, claw pumps belong to the group of dry-compressing vacuum pumps. These pumps may have several stages (Fig. 2), and their rotors have the shape of claws (Fig. 3).

The cross section inside the pump casing has the shape of two partly overlapping cylinders. Within these cylinders there are two freely rotating rotors in each pump stage with their claws and the matching recesses rotating in opposing directions about their vertical axis. The rotors are synchronized by a gear just like a booster pump. In order to attain an optimum seal, the clearances are in the range of 0.01 mm (0.0004 in). The rotors periodically open and close the intake and discharge slots.

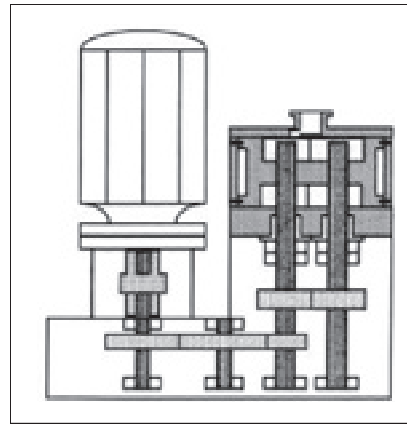

Fig. 2. Two-stage claw pump

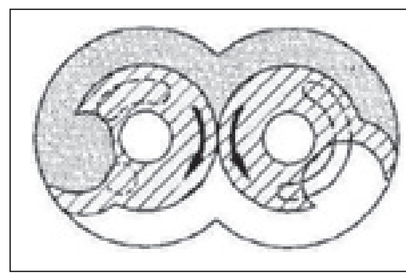

Fig. 3. Cross section of a claw pump

Working Principle of a Claw Pump

At the beginning of the work cycle (Fig. 4), the right rotor just opens the intake slot (5). Gas now flows into the continually increas-

Application Example: Sintering Processes

Sintering processes for the production of metal-carbide parts – drills, cutting inserts and tools, semi-finished products, etc. – involve process steps in a vacuum in which large quantities of binder evaporate and enter the vacuum pump. Such binders are usually paraffin or polymers such as polyethylenglycol (PEG), polypropylene (PP) or polyethylene (PE). The polymers decompose during the evaporation.

In oil-sealed vacuum pumps, the cracked hydrocarbons of the binder result in a thickening of the oil, and as a result the oil channels can become clogged. This effect can cause an unexpected pump failure, which ultimately can only be prevented through very frequent oil changes and maintenance.

In dry-compressing pumps, the cracked polymer residues will result in increasing deposits over time. When using the ScrewLine pumps, however, unscheduled downtimes due to excessive formation of deposits can be reliably prevented. For this, the pump is equipped with the SP-Guard monitoring system, which constantly assesses the level of any increase of vibration, thereby informing the operator early enough about the formation of deposits. After a certain warning threshold has been exceeded, cleaning of the pump can be scheduled. Cleaning of ScrewLine pumps can be completed on-site with little effort.

For an application in which PEG is used as the binding agent and where the system is operated in three shifts, a cleaning interval of between six to eight weeks has been successfully implemented.

The internal cleaning, using a flushing process, is performed on the running ScrewLine vacuum pump with only a few liters of tap water with noticeable results being attained (Fig. 9). After the flushing process, the pump is left running to thoroughly dry out, which takes approximately 20-30 minutes. It is possible to fully automate this process using a suitable valve control setup.

Using the ScrewLine in such an application brings the following main advantages to the user:

- Trouble-free operation without unplanned stops. Maintenance can be scheduled and is mostly reduced to a simple regular flushing process.
- Nearly wear-free operation reduces service costs dramatically.
- Environmental protection - no mass production of contaminated waste oil or emissions.

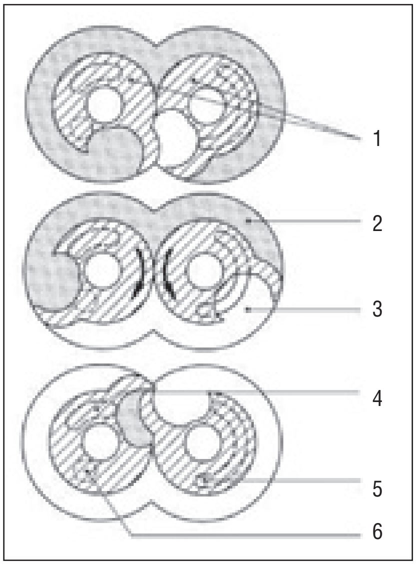

Fig. 4. Working principle of a claw pump

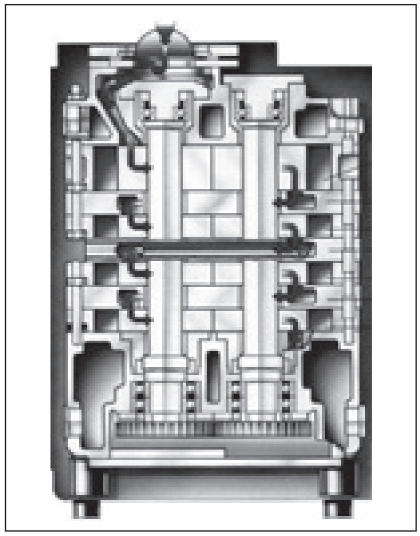

Fig. 5. Guiding of the gas flow inside a four-stage claw pump

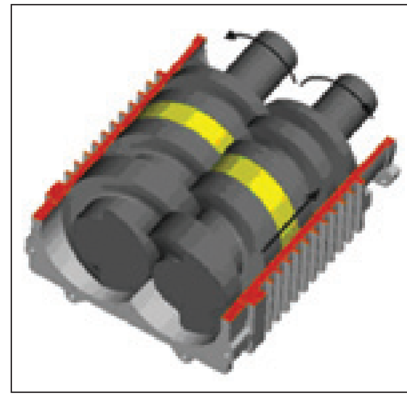

Fig. 6. Screw rotors with pumping chamber

ing intake space (3) until the right rotor seals off the intake slot (5). After both claws have passed through the center position, the gas that has entered is then compressed in the compression chamber (2) until the left rotor releases the discharge slot (4), thereby discharging the gas. Immediately after the compression process has started, the intake slot (5) is opened simultaneously and gas again flows into the forming intake space (3). Influx and discharge of the gas is performed during two half periods. Each rotor turns twice during a full work cycle.

Disadvantage of Claw Pumps

Typically, the multistage design has a complex gas flow path (Fig. 5) that results in particles settling inside the pump. Also, a water-cooled housing coupled with claw rotors that are not cooled can seize up the pump during starting and stopping. Therefore, the pump must cool down completely before restarting. Other typical disadvantages:

- Bearing can get easily contaminated and wear down quickly
- No simple disassembly for cleaning on-site is possible
- Higher noise level and motor power consumption

Screw Pumps

Modern-designed, dry-compressing screw-type vacuum pumps open new horizons for furnace applications. For benign applications, they offer enough robustness and process stability to reduce the required maintenance to a simple gearbox oil exchange once per year, which can be done by the user. But they also offer the possibility to be adapted to even the harshest applications so that maintenance and service costs are dramatically decreased compared with traditional oil-sealed vacuum-pump solutions.

Since 2003, Oerlikon Leybold Vacuum has been manufacturing and selling the latest-generation, dry-compressing screw-type vacuum pumps designed specifically to the requirements of the vacuum-furnace industry. The rich application experience and knowledge collected with oil-sealed piston and vane vacuum pumps, as well as other dry-compressing pumps, have been utilized in the design of the ScrewLine product family, resulting in a highly innovative product.

Concept of the ScrewLine

A screw is capable of pumping a gas flow without deflection – this being of great advantage if significant quantities of dust are involved. Moreover, the pump chamber is formed by only three components – two rotors and rotor housing – so that disassembly and cleaning is very simple (Fig. 6).

In the case of the ScrewLine pumps, the two screw rotors are cantilevered (Fig. 7a). Thus, bearings and shaft seals on the vacuum side of the pump – a notorious weak point of vacuum pumps – are avoided (Fig. 7b). The bearings for the rotors are located in the gear housing and

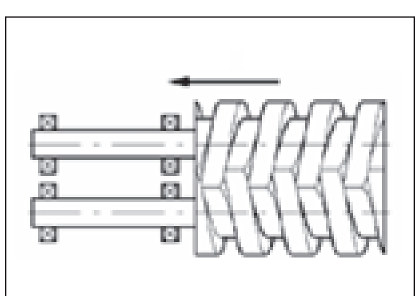

Fig. 7a. Cantilevered rotor design

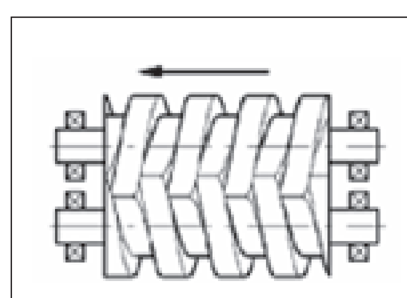

Fig. 7b. Conventional rotor design

Fig. 8. ScrewLine SP630 with directly coupled booster pump

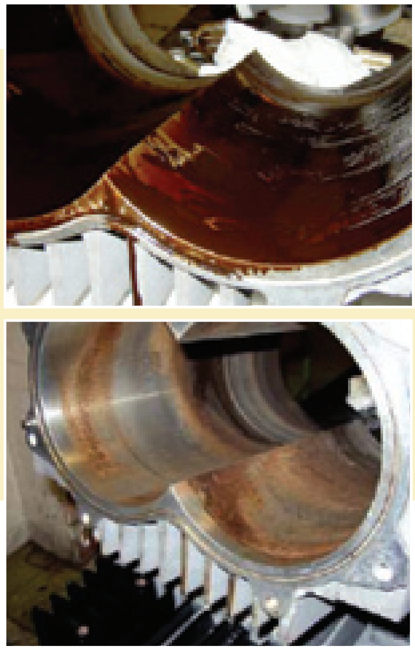

Fig. 9. Pumping chamber before and after flushing procedure

are lubricated directly by the gear oil. This arrangement allows for rapid on-site disassembly of the rotor housing, thereby permitting cleaning of all surfaces within the pumps' compression stage that have come in contact with the medium.

In addition to the basic concept, many details of the ScrewLine have also been optimized in view of the aforementioned requirements.

- Through the decreasing pitch of the screw profile from the intake to the delivery side ("internal compression"), very low power consumption is ensured.
- The shaft seal on the delivery side of the rotors allows for effective use of a combined piston ring and labyrinth seal due to a low-pressure differential with respect to the gearbox. By means of a purge gas, that seal may also be further enhanced, providing protection against any process media if required. By not using traditional lip seals, the shaft seals of the ScrewLine are virtually wear free.
- A monitoring system, the SP-Guard, has been developed for the ScrewLine range of pumps. This system allows for continuous real-time monitoring of internal gear oil level and temperature, exhaust pressure and pump run-time. The SP-Guard also monitors the vibration level of the pump. In this way, the formation of deposits on the screw rotors or bearing wear can be detected at an early stage to avoid unscheduled downtimes.
- Further accessories are available such as an adapter for directly fitting a booster to the ScrewLine pump (as shown in Fig. 8 for the RUVAC WAU 2001). In addition, a matching exhaust silencer and a flushing kit facility allows the cleaning of the screw rotors while the pump is running. Even when using only water for flushing, cleaning performance is excellent due to the high rotor speeds – "a steam jet effect."

Summary

Modern dry vacuum pumps such as the ScrewLine are clearly a step ahead for the furnace industry. They offer cost of ownership reductions, not only in the aforementioned harsh-application example but also in benign applications where the low maintenance and trouble-free operation is easily achieved.

Optimized monitoring systems now enable the user to gain an internal view of critical vacuum-pump parameters. This allows the user enhanced control of the vacuum process, whereby maintenance may be scheduled in accord with planned factory maintenance.

Dry vacuum pumps have evolved over the last decade, and the ScrewLine technology represents the latest technology in this field. Even with a higher initial capital cost, the benefits of this new technology benchmark will start to pay off quickly. **IH**

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