PFEIFFER VACUUM

TIPS AND TRICKS FROM THE EXPERTS

Common errors when using turbopumps and how to avoid them

The ideal vacuum solution at the best price is very often the main decision criterion. But this fact poses the danger that a less optimal pump solution is selected for cost reasons – a decision which could eventually cause less uptime and higher maintenance costs. Selecting reliable vacuum pumps and the corresponding accessories as well as sensible monitoring and operating modes will pay off in the long run.

When selecting and operating a turbopump, it is not rare that considerable errors are being made. They can easily be avoided by considering the specific parameters valid for the individual pump type. In the following, a summary of the most important information and insights for the operation, equipment selection, and maintenance of commonly used turbopumps is presented.

Turbopumps – powerful and reliable

The turbopump is a high- to ultra-high vacuum pump and essentially consists of a rotor and a stator. A rotating rotor disc and a stationary stator disc create a pump stage, which generates a specific compression ratio.

By consecutively turning on multiple pumping stages that multiply themselves in the compression effect, high compression ratios of up to 10^{13} can be reached. Modern pumps use Holweck stages on the backing side, for example, which reduce the number of turbo stages without affecting the compression. At the same time, the permitted foreline pressure increases to over 30 hPa. Therewith, the size of the backing pump decreases drastically so that diaphragm pumps can be used as backing pumps for the first time.

Figure 1: The correct installation of the turbopump ensures its safe operation

Turbopumps without additional compression stages should be used for processes that are prone to condensation, sublimation, and particle formation as the narrow gaps can lead to deposits, mechanical damage, and clogging.

Fore-vacuum pressure – monitoring for safe pump operation

The fore-vacuum pressure can rise to over 30 hPa for pumps with additional compression stages. For pumps with pure turbo stages, the maximum fore-vacuum pressure is 2 – 3 hPa and moreover depends on the pumped gas, e.g. 2 hPa for nitrogen and 0.5 hPa for hydrogen.

Exceeding the maximum pressures specified by the manufacturer can lead to bearing damage and, in extreme cases, to total failure due to the pump's overheating. In these cases, the gas friction rises too high and the resulting additional compression heat cannot be dissipated. For pumps whose bearing and rotor temperature is not monitored, this is particularly critical and - in many cases - unavoidable. When using diaphragm pumps with final pressures between 2 – 5 hPa, the equipment is operated in the vicinity of this border area.

Except for diaphragm pumps, dry pumps do not have any outlet valves. Should the backing pump fail, the process chamber will be vented from the backing side. Abrupt venting of large chambers can cause the turbo rotor to tarnish due to the so-called helicopter effect in the housing. To protect the turbopump, Pfeiffer Vacuum offers safety valves that shut off the exhaust line against the chamber immediately should the backing pump or fore-vacuum pressure fail.

The closing time must be correspondingly short. If fore pressure measuring is available, the valve can be controlled and operated using the pressure rise or the backing pump's failure signal.

Dimensioning the exhaust line

It is recommended to install the exhaust line and valves at least in the pump's nominal size as significant pumping speed losses could occur due to adverse conducting values.

Below is a slightly exaggerated example to illustrate the influence of the conductance value losses in an inlet line with a 25 mm diameter and a length of 100 mm.

Effective pumping speed of a turbopump with a nominal pumping speed of:
60 l/s: 10 l/s
5000 l/s: 14 l/s

As can be seen, a turbopump larger by a factor of 80 produces only 40 % more pumping speed.

High and fore-vacuum connections

If the pump's high-vacuum flange is connected to the recipient, it is necessary to make the foreline flexible If the foreline is rigidly connected, the pump casing cannot expand when it warms up. This leads to improper material stresses. In this rigid connection, the rotor cannot move freely and the remaining minimal imbalance can - over time - lead to bearing failures or rotor damage.

Turbopumps are balanced to ensure low-vibration operation and optimal bearing durability. During a normal startup, depending on the rotor dynamics, they run through certain resonance frequencies.

Should these frequencies stimulate the natural frequency of the vacuum chamber, the frame or the entire system, they can lead to a considerable increase in the frequency amplitudes. At these frequencies, the pump begins to vibrate strongly and becomes very loud. Running through these frequency areas holds the danger of rotor damage and possible damage to the equipment or built-in, vibration-sensitive components. Turbopumps with magnetic bearings are no exception.

Therefore, it is advisable to determine the natural frequency of the system and to consult the pump manufacturer with these values. The vibrations can be prevented with reinforcements, additional weights, and design changes.

Securely connecting the high-vacuum flange and the vacuum chamber

Turbopumps, especially larger ones with magnetic bearings and bell-rotor designs larger than 1000 l/s, have high torques at their nominal speed. They are degraded in milliseconds when the rotor crashes. If the chamber is laid out improperly and the turbopump is mounted directly on it, deformation of the chamber can occur. In the worst case, the turbopump could twist or even detach from the chamber flange.
In recent years, the moments and forces on the pump housings and inlet flanges have been identified and tested by crash tests and containment analyses. It was found out that the flange connection to the chamber should ideally be carried out in ISO-F or CF-F. A turning of the pump with an ISO-F flange is prevented by the slotted holes and with ISO-CF by the mounting screws.

Pfeiffer Vacuum provides so-called mounting kits, which contain a sufficient number of clamps or mounting screws in the required material grade as well as the appropriate centering rings. Only by this it can be ensured that the connection remains intact and sealed in case of a crash. The manufacturer's instructions in the operating manuals must strictly be followed.

Splinter Protection

It is advisable to insert a protective guard into the high-vacuum flange of the turbopump to avoid rotor damages due to falling debris. Because of conductance losses, the pumping speed is reduced by up to 30%, depending on the gas type.
If possible, the turbopump should be placed upside down on the chamber as foreign objects will fall out because of gravity. Thereby, it needs to be ensured that the pump can be used for overhead operation.

Baking out the pump

When baking out the pump, the manufacturer's specified maximum high-vacuum flange temperatures of 120 °C must be observed. Exceeding the permitted temperature leads to overheating of the pump and to bearing or rotor damage. When baking out, water cooling of the pump is required. The bake-out process should take at least 6 hours.

Venting the pump

Without venting, the turbopump will be contaminated with hydrocarbons after coming to a standstill when the pressure is balanced from the fore-vacuum to the high-vacuum side and if rotary vane pumps are used as backing pumps. If no valve has been installed at the high-vacuum side, the contamination will spread into the recipient or appliance.

Venting the pump with dry gas, nitrogen, or oil-free air prevents contamination and properly aerates the backing pump. The pump can be safely vented using a venting valve at a certain speed when the turbopump drive electronics are applied.

As the compression ratio of a turbopump also depends on the speed, the optimum initial vent should occur at about 50 % of the nominal speed and should begin at 20 % latest. In addition to their factory settings, modern electronics allow for a certain flexibility in the venting speed. With proper venting, the recipient is also protected safely from contamination.

There are processes during which pump-independent venting is preferred over the control system. This leads to a loss of the important link to the pumping speed. Additional monitoring of the pumping speed is not necessary when the venting process is carried out via the pump's drive electronics. When venting, the pump's inner surface is covered with dry nitrogen. It significantly shortens the evacuation time, as no difficult-to-remove gases or water can accumulate on the surface. The venting gas is not to be let in from the backing side, as condensates, particles, and even oil might reach the high-vacuum side.

In unstable grids with frequent power failures, especially when overloaded by the use of air conditioners in the summer, it is advisable to use a so-called power failure venting valve that can automatically vent the pump and properly shut it down during a power failure. Frequent venting, especially over the high vacuum side, leads to excessive heating of the pump, mechanical stress, and shortened bearing durability due to massive amounts of gas friction.

Magnetic fields and radiation

Magnetic fields generate eddy currents in the rotor of a running turbopump, which warm and quickly overheat the rotor. The energy required is taken from the electronics and leads to a significant increase in the motor current. This represents a direct value for the heating of the rotor.

The maximum permitted magnetic fields specified in mT (Milli Tesla) are provided in the pump manufacturer's operating instructions. If these values are exceeded, the pump must be shielded or - if the distribution of the magnetic field is known - must be rearranged.

Neutron and gamma radiation of varying intensity and duration occurs around particle accelerators. This radiation destroys drive electronics and frequency converters mounted on the pump, both of which have sensitive power transistors and diodes. In this case, the drive electronics must be installed a safe distance away from the radiation, using connecting cables. The same applies to measuring equipment. Active sensors must be avoided, as their electronics are also destroyed by the radiation.

Process Suitability

It is very important to ensure that the turbopump is suitable for the particular process. Detailed advice from our experts as well as accurate information about the process and its characteristics guarantee an optimal solution. For corrosive processes, especially in the semiconductor industry, it is necessary to operate the pumps with sealing gas, to use synthetic PFPE oil for ball-bearing pumps, and to use corrosion resistant materials on the rotors, such as nickel or ceramic coatings.

The sealing gas, such as dry nitrogen, forms an outstanding corrosion and dust protection for the ballbearings in connection with a labyrinth seal. When sizing the backing pump, this additional gas load must be considered. Offered sealing gas valves regulate the optimal sealing gas flow. The sealing gas pressure specified in the operating instructions must be observed.

When pumping oxygen in concentrations higher than atmospheric oxygen levels, it is important to ensure that the mineral oil is not oxidized and loses its lubricating properties. This can be prevented by using nitrogen as a sealing gas and/or PFPE oil.

For processes with a tendency to form deposits, for example in Chemical Vapor Deposition (CVD), the coating process will continue on the rotor and the casing parts, which face the process chamber. This leads to imbalance and vibrations that could cause a rotor crash. In such processes, it is important to include precautions and additional supervision even while designing the process chamber. If possible, the turbopump should be installed upside down so that gravity can pull the dust down and make it harder for it to accumulate in the pump. It would make sense to install a baffle plate to prevent dust from falling directly into the running pump. If an overhead installation is not possible, the pump can be installed sideways on a T-frame at a 90 degree angle. The backing port should point downwards.

We would be happy to assist you in optimizing your vacuum solutions for specific applications – go ahead and ask us: http://www.pfeiffer-vacuum.com/contact

Figure 2: Cross section of a HiPace turbopump with hybrid bearing by Pfeiffer Vacuum

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.

Are you looking for a perfect vacuum solution? Please contact us:

Pfeiffer Vacuum GmbH
Headquarters · Germany
T +49 6441 802-0
info@pfeiffer-vacuum.de

www.pfeiffer-vacuum.com

PFEIFFER VACUUM