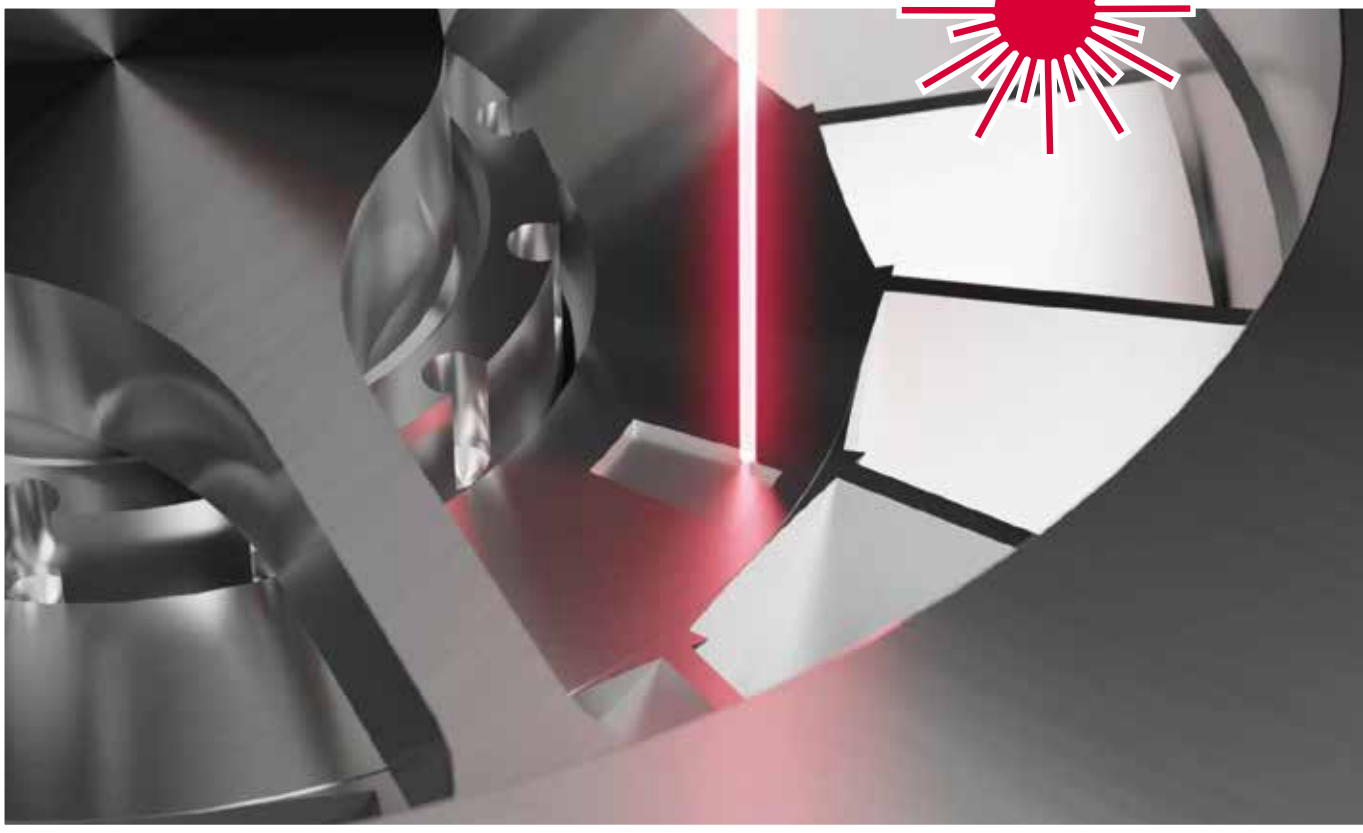
Innovative Patent for Turbopumps:

The New Laser Balancing™ Technology from Pfeiffer Vacuum

Turbopumps play an important role in vacuum technology for generating clean high and ultra-high vacuum. Inside the hybrid-bearing turbopump, a rotor is supported by a combination of permanent magnet bearings and roller bearings and driven at very high speeds.



PFEIFFER VACUUM

The balancing of these hybrid-bearing rotors has been a core competence of Pfeiffer Vacuum for many years, enabling the supply of technologically advanced turbopumps with a very low vibration level. With the launch of the new advanced HiPace 80 Neo, the Laser Balancing developed by Pfeiffer Vacuum is introduced - an innovation that provides improved durability and lower vibration as well as noise emissions.

But from the beginning: Why do rotors need to be balanced at all? What is the difference between conventional practice and balancing with the Laser Balancing method?
And what advantages does it offer?

HiPace 80 Neo – the world's first laser-balanced turbopump in its class

Why are rotors balanced?

The process of balancing is most likely familiar from the automotive sector. There, new car tires must also be balanced. Even bodies that appear symmetrical on the outside actually have slight inequalities in their mass distribution. This can be due, for example, to the manufacturing process of the component or an inhomogeneity in the density of the raw material. This uneven mass distribution is described by the term unbalance. When an unbalanced body is set in rotation, vibrations occur. In the case of a car tire, these can be felt in the steering wheel. The resulting forces depend on the rotational speed as well as the amount of unbalance. They can quickly increase sharply and cause damage to other components of the vehicle. For this reason, the unbalance of rotating objects is reduced by balancing.

While the speed of automotive tires is optimally 1500 to 2500 rpm, rotors of turbopumps reach speeds of up to 90,000 rpm, or 1,500 rpm/sec. The demands on the balance quality are therefore extremely high. The slightest unbalance in the range of a few milligrams can already have a strong influence on the operation of the pump. A high balance quality is therefore relevant both for the smooth running of the rotor and for years of damage-free operation of the turbopump. It also ensures minimization of vibrations that are transmitted to the vacuum chamber and the customer application.

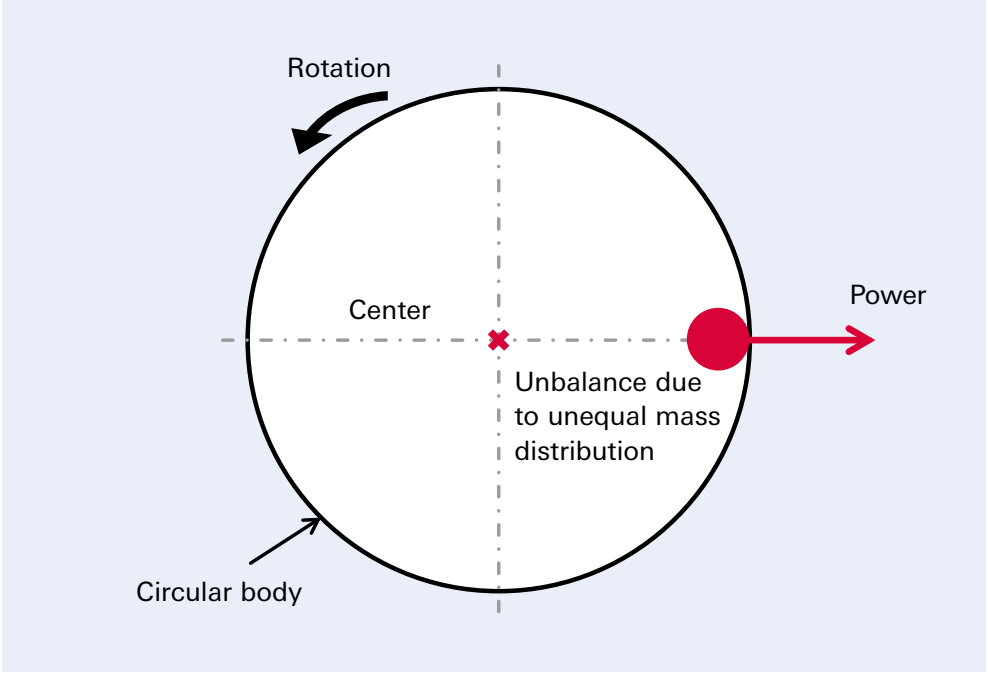


Figure 1: An outwardly symmetrical circular body exhibits unbalance due to unequal mass distribution. The rotation of the body around its center point generates a circulating force, which leads to vibrations.

Conventional balancing

The conventional balancing technology has been one of Pfeiffer Vacuum's core competencies for many years. It enables vibration-reduced operation of hybrid-bearing turbopumps. By adding additional mass, for example through balancing weights, uneven mass distribution is reduced. Mass balancing is widely used with the aid of machining processes. This includes, for example, grinding and the removal of material by drilling holes.

In conventional balancing, balancing weights are manually screwed in along the circumference of each balancing level.

In conventional balancing, the radial deflection of the rotor is measured in two measuring levels near the bearing. With the aid of a special algorithm, the unbalance of the rotor is determined from this. To reduce the total unbalance, the rotor is divided along the axis of rotation into several balancing levels with corresponding holes. Balancing weights are manually screwed in along the circumference of the individual balancing levels. This reduces the uneven mass distribution and the remaining unbalance of the rotor is reduced below the necessary limit value. The unbalance is determined here at several speeds and gradually compensated for to enable a vibration-reduced run-up of the rotor to nominal speed.

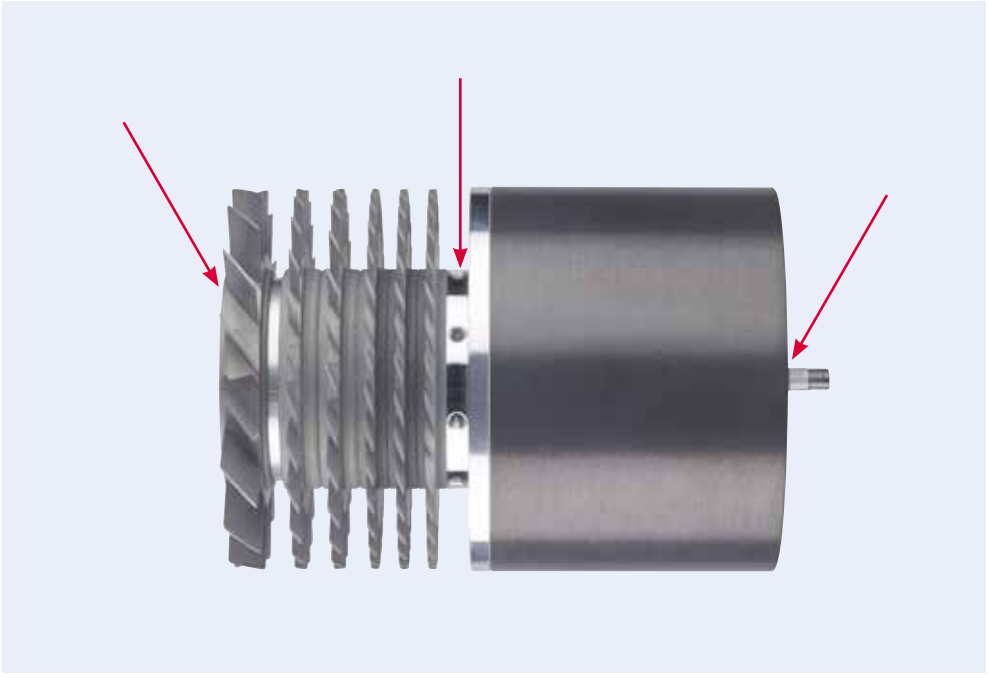


Figure 2: Illustration of a turbopump rotor showing the position of the balancing levels.

Balancing with the Laser Balancing™ method

Especially in the area of secondary properties, the application requirements for turbopumps have increased over the last decade. The high-speed rotors are therefore subject to permanent further development, including the service life of the ball bearing, vibroacoustic emissions, i.e. emitted sound and vibrations on the pump housing, as well as cleanliness in terms of the outgassing behavior of the components and surfaces.

Pfeiffer Vacuum has now created a further innovation in the field of vacuum technology: In recent years, the company has developed and patented the novel Laser Balancing. It balances turbopump rotors even more efficiently and ensures technological progress.

Laser Balancing revolutionizes the conventional process of balancing by eliminating the need for balancing holes and balancing weights. Mass balancing is reversed by removing material using laser ablation, minimizing uneven mass distribution. The material removal by a laser is much more precise, so that an even lower residual unbalance can be achieved. Material properties are not affected in the process.

By dispensing of geometrically defined balancing holes and graduated balancing weights, defined laser ablation segments can be removed. With the help of the laser, the uneven mass distribution of the rotor is thus corrected exactly at the necessary point in the individual balancing levels.

Figure 3: Comparison of a balancing level of conventional balancing (left) with balancing holes and of laser balancing (right) with laser ablation segments

What are the advantages of the Laser Balancing™ method?

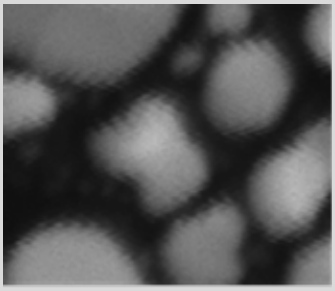
Through the use of Laser Balancing and many years of expertise in the underlying calculation algorithms, Pfeiffer Vacuum was able to improve the balancing quality of turbopump rotors by 20% in a modern, automated balancing system. Pfeiffer Vacuum thus offers significantly improved ball bearing life as well as lower vibration and noise emissions from the pump during operation. The particles generated during laser ablation are already extracted and filtered during the process. The subsequent cleaning of the laser-balanced rotor and the elimination of manual handling of the screw balancing process guarantee the highest level of surface cleanliness. In addition, virtual leakages caused by air pockets in the balancing holes are avoided.

By employing laser balancing, Pfeiffer Vacuum was able to improve the balancing quality of turbopump rotors by 20%.

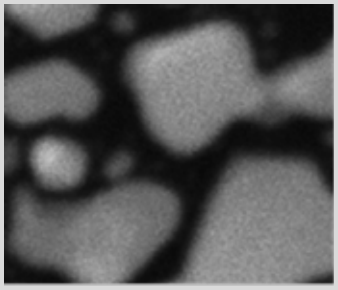
In applications where low vibrations and quiet turbopumps are required, the new rotors can now be used even more efficiently. For example, the low vibroacoustic emissions enable high-resolution images of electron microscopes with integrated turbopumps.

The advantages of the innovative Laser Balancing highlight the unique selling point of Pfeiffer Vacuum's turbopump in vacuum technology and provide a technological outlook for the company's upcoming developments.

Comparison of two images from an electron microscope with integrated turbopump:



Stronger vibrations (~20 nm) at the high-vacuum flange result in a blurred image at high magnifications.



Lower vibrations (~5 nm) achieve a sharper image.

Images courtesy of TESCAN, Czech Republic

Are you looking for your optimized vacuum solution? Please contact us:

Pfeiffer Vacuum GmbH
Germany
T +49 6441 802-0

Follow us on social media
#pfeiffervacuum

www.pfeiffer-vacuum.com

PFEIFFER VACUUM