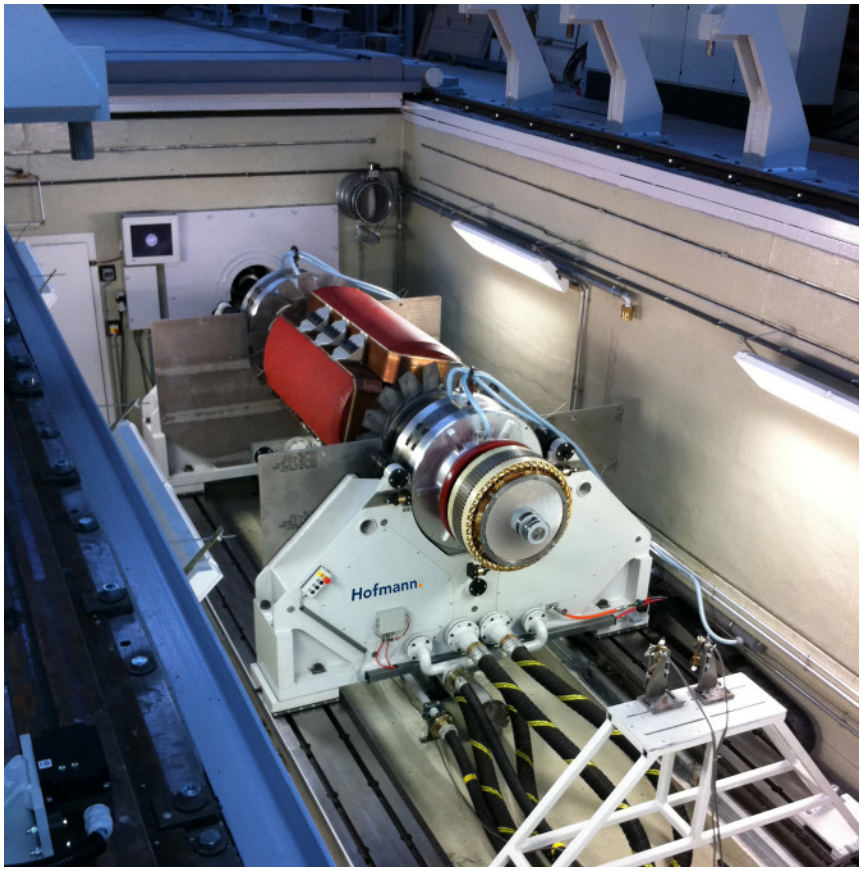
Balancing and over-speed testing of flexible rotors

Installations for low- and high-speed balancing and for over-speed testing HS 16 - HS 34



HS 28 for generators, constructed as pit with movable cover.

Application

- Balancing of flexible rotors from turbo-machinery
  - Steam and gas turbines
  - Turbogenerators
  - Axial- and centrifugal-com-pressors
- Balancing of flexible rotors at low- and high-speed
- Balancing of flexible rotors in their own bearings
- Spin-testing of the rotors at over-speed

Description

Many shafts from rotating machinery are being balanced applying the methods of rigid rotor balancing. Rigid rotors have the property that their unbalance state does not vary significantly with speed. However this is no longer valid with flexible rotors (rotors from turbo-machinery, for example steam- and gasturbines, turbogenerators and turbocompres-sors).

The operation of flexible rotors is being affected at least by one critical speed. Many (shaft-) flexible rotors pass even several critical speeds on their way to operational speed..

In the vicinity of a critical speed the rotors bend in a typical mode (eigen-mode). As a result new unbalances are being generated, which are depending on speed.

Because the unbalance state of flexi-ble rotors is depending on speed, they require balancing up to maximum operational speed apply-ing special methodes.

Among the unbalances due to the shaft flexibility unbalances may result from settings of rotor parts.

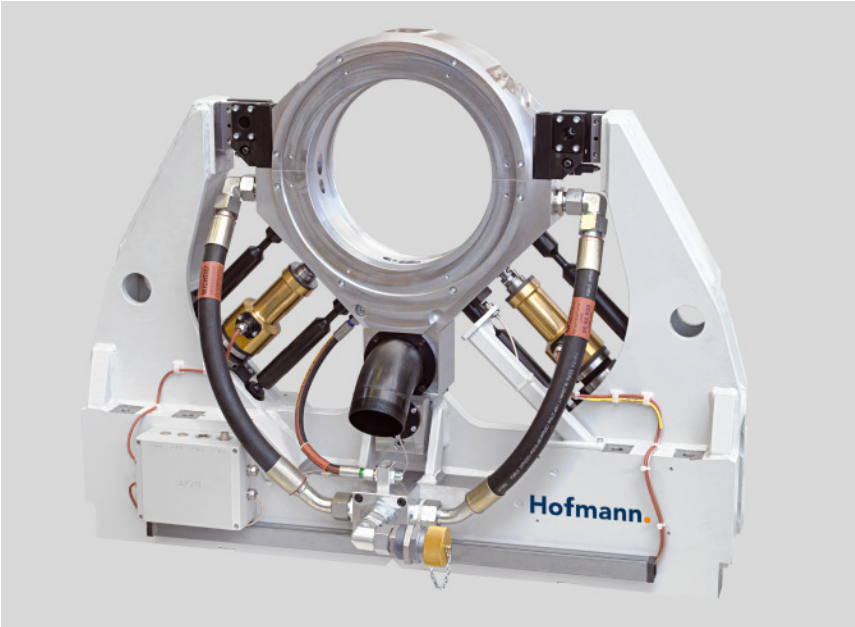
In addition it is many times of inte-rest, whether a rotor can withstand the exposure at over-speed. In order to initiate settings or to check the strength flexible rotors must be acce-lerated to speeds substantially above the maximum operational speed.

To perform all those task the Hof-mann installations for low- and high-speed balancing and for testing at over-speed of flexible rotors HS 16 to HS 34 are being applied. Those ins-tallations cover rotor weights from just a few kg up to 100 tons.

System Components

Bearing Pedestals

When balancing flexible rotors it is important, that the stiftnesses of the operational bearings and of the mounting into the bearing pedestals of the HS balancing installation are of similar size. Then the critical speeds and mainly the corresponding bending modes well match for the different bearing conditions. Thus in the bearings of the balancing installations those modal unbalances exactly are being identified and corrected, which would excite rotor vibrations during operation.



Bearing pedestal HS 22

High vibrations and high dynamic forces occur when passing critical speeds. Some rotors may set and thereby get high unbalance again. Therefore the bearing pedestals of a HS balancing installation have to be designed in a way, that such critical conditions are being well controlled.

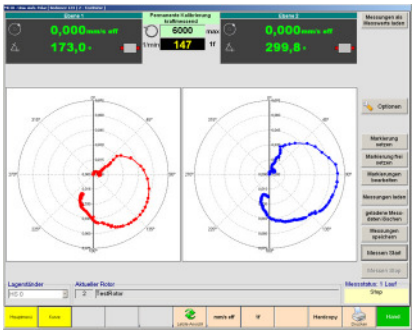
The necessary high stiffness of the HS bearing pedestals is being achieved by application of the Hofmann force measuring principle. The force sensor, integrated into the force flow, is highly sensitive and has a high mechanical load capacity and is contributing to the stiffness of the bearing pedestal. The support of the bearing head under 45° results in an isotropic stiffness. This avoids a splitting of the critical speeds and - as a consequence - an unnecessary increase of the complexity of the balancing proccedure.

The inclination of the bearing heads can be adapted to the static deflection curve of a rotor to be balanced. Natural frequencies, based on the principle design of the HS bearing pedestals are being specifically damped. Thus they do not interfere balancing.

The bore of the bearing head has got sufficient size to adapt also tilting-pad journal bearings with increased outer diameter. The same applies also for the oil drain which can receive the increased high oil flow of tilting pad journal bearings in comparison to journal bearings with fixed lobes.

Measuring and Monitoring

Special balancing methods have to be applied, so that flexible rotors show a low vibration level over their entire speed range. Thereby the Hofmann unbalance measuring systems support modal balancing as well as the application of the influence coefficient method.



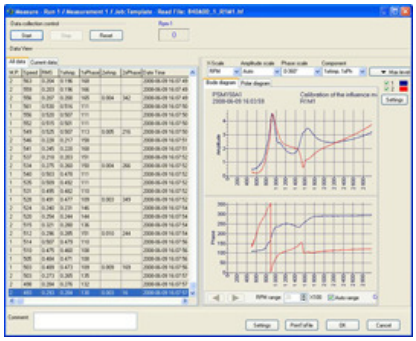
MC 10 HS for balancing flexible rotors applying modal methods

Among others the systems provide these functions:

- Evaluation of the unbalance induced vibrations,
- evaluation of the vibrations at twice the rotor speed,
- presentation of the measuring values in terms of unbalance or vibration units,
- presentation of the measuring values in polar or x-y diagramm,
- pre-diction of the effect of an unbalance correction,
- Processing of additional measuring values captured outside the bearing pedestals (for example relative journal vibration or shaft vibration at a rotor position of special interest).

Control room of a high-speed balancing and over-speed testing installation

The operators of a HS installation shall fully concentrate on balancing and must not be surprised by un-expected events. Therefore the Hofmann HS installations are equipped with extensive safety and monitoring technique.



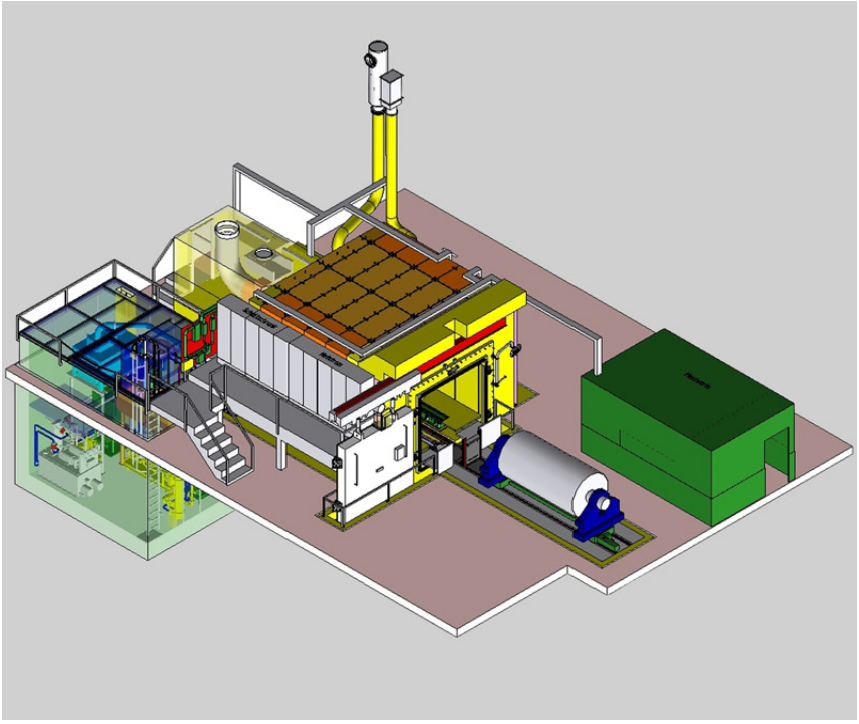
Balancing applying influence coefficient method

Spinning Chamber

While balancing and over-speed testing parts may get loose from the rotors or even the rotors may burst. Therefore the space around the rotor must be designed as a safety containment.

For small rotors the spinning chamber is being constructed with a movable steel enclosure. In closed position that enclosure is being moved against a stationary frontwall. For rotors from 6 to 8 tons on, the spinning chamber is being constructed as a bunker with rectangular or circular cross-section. Those bunkers are accessible and have thick reinforced concrete walls.

A special transport system will be used to move a rotor into a bunker erected on floor level having a movable door at one face end. Therefore the rotors will be installed into the pedestals already outside the bunker. The construction as a pit having a movable cover makes it possible to load the rotor into the pedestals using a crane.



High-speed balancing and over-speed testing installation HS 25 with accessible bunker made from reinforced concrete

Drive system with motor, gear box, intermediate shaft and moving device

Bladed rotors or rotors with impellers create high ventilation losses when revolving in normal air. Therefore the spinning chambers will be constructed as vacuum containers for balancing and over-speed testing of turbines and compressors. Special vacuum pumping stations achieve an absolute pressure of appr. 1 mbar. The size of such vacuum pumping stations is being determined by the volume of the spinning chamber to be evacuated and the required evacuation time.

Drive System

The drive system of a HS installation must be capable to quick and safely accelerate the rotors up to the required speeds. Given measurement speeds then must be held constant and critical speed ranges have to be rapidly passed.

Depending on the existing rotor range a gearbox will be used to best adapt the power of the electric drive motor to a rotor's moment of inertia, its friction losses and its max. speed.

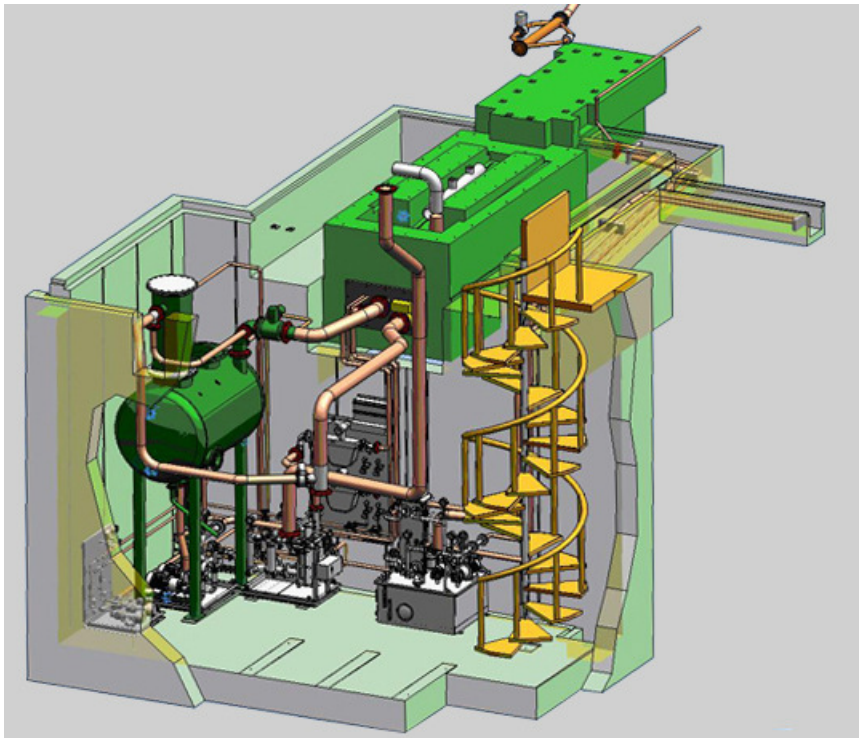
If necessary, an intermediate shaft will be required. That shaft had to bear high axial loads caused by the rotor and allows the integration of a vacuum seal.

A well constructed, high-precision drive shaft forms the connection to the rotor. In case of high speeds special high-speed Hofmann membrane joint shafts are being used.

Oil System

High-reliable oil stations are being provided for the supply of the rotor's journal bearings and of the bearings and gears of the drive system (drive motor, gearbox, intermediate shaft) with lubricating and cooling oil. In case of larger rotor weights the journals are being lifted by use of a jacking oil station. Then the rotors can be brought up to speed more or less without friction or wear.

In case rotors are being balanced under vacuum condition, the supply of a rotor's journal bearings will be provided by a special vacuum oil station. Then also the jacking oil station will be included in that vacuum oil circulation.



Design of oil supply system installed in oil pit

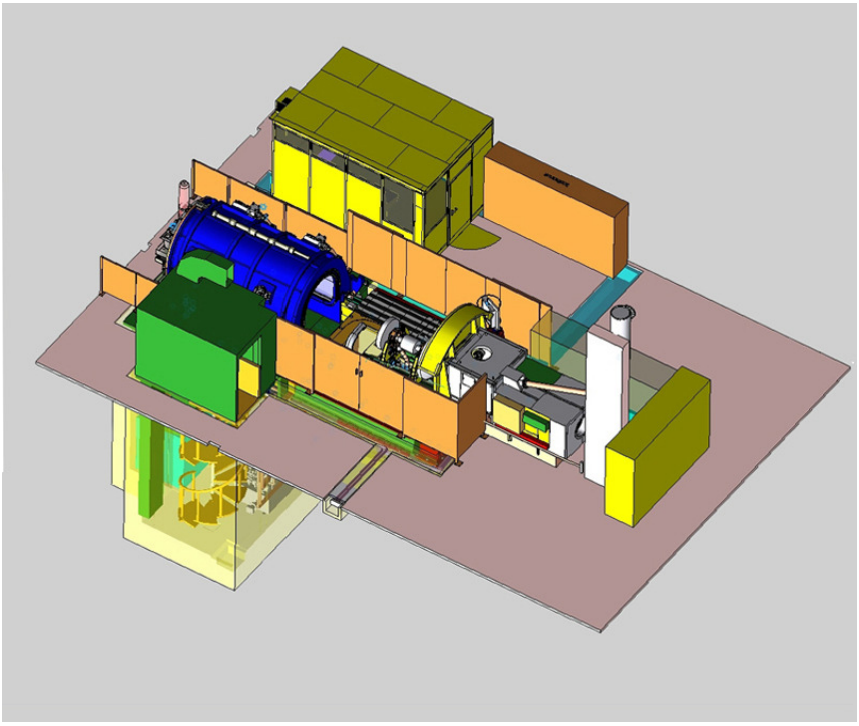
Emergency Supply

The rotors which are balanced and/or tested at over-speed in a HS installation are quite valuable. Under any circumstances they must not be damaged. This is also valid in case of power failure.

Therefore the Hofmann HS installations are designed to safely bring back a rotor to zero speed even in case of electrical power outage. For that purpose it is necessary to keep up the supply of the rotor bearings and specific drive components with lubricating oil.

With small HS installations this is being realized by the application of uninterrupted power supplies (UPS), which provide sufficiant battery capacity. With larger installations the UPS overtakes the supply instantly after the power failure. Then an emergency power unit will start, which can supply also pumps with high power request.

Vacuum oil station, installed underneath vacuum oil tank, and vacuum oil distribution with filtering, flow monitors and pressure control



High-speed balancing and over-speed testing installation HS 22 with movable, vacuum tight steel enclosure

Realisation

The Hofmann scope of supply depends on the strategy of our customers. It may range from the core balancing components of a HS installation to the responsibility for the delivery and construction of the complete installation.

Part of the Hofmann scope of supply is engineering work. That covers the design of the installation area, the evaluation and design of the spinning chamber including foundation, the evaluation and design of the necessary oil and vacuum pumping stations and of the electric control as well as the adaption to the existing infrastructure.

Technical Data

Type of installation	HS 16	HS 18	HS 19	HS 22	HS 23	HS 24
Max. rotor weight [kg]	150	300	700	1,500	3,000	5,500
Max. rotor diameter [mm]	1,260	1,260	1,260	1,260	1,260	1,600
Max. speed [1/min]	> 50,000	32,000	30,000	22,500	20,000	18,000
Typical driving power [kW]	160	200	250	250	315	315

Type of installation	HS 25	HS 26	HS 27	HS 28	HS 29	HS 34
Max. rotor weight [kg]	8,000	12,500	20,000	32,000	50,000	100,000
Max. rotor diameter [mm]	2,000	2,250	2,500	3,000	3,200	4,000
Max. speed [1/min]	15,000	12,000	10,000	8,000	6,000	4,500
Typical driving power [kW]	500	500	500	1,000	2,000	4,000

Modifications are possible. To cover a wider weight- and/or speed-range within one installation two or more pairs of pedestals with different sizes are being applied.

All information without obligation, subject to change without notice!

HS 16 - 34 / en / © 08.11 / 372-0067

Hofmann Mess- und Auswuchttechnik GmbH & Co. KG, Werner-von-Siemens-Straße 21, D-64319 Pfungstadt, Germany,
Phone: +49 (0) 6157 / 949-0, Fax: +49 (0) 6157 / 949-100, E-Mail: germany@hofmann-global.com, Web: www.hofmann-global.com