



Innovative Power Transmission



RENK-MAAG

Turbo Gearboxes and its applications

For every need the right gearbox!

Parallel Shaft Gearbox – your reliable work horse

Parallel shaft gearboxes of RENK-MAAG are designed and manufactured in accordance with the latest technical standards (AGMA, DIN, API, ISO – other standards or special designs upon request) and are based on proven MAAG technology. As a result of our continuous research and development RENK-MAAG is able to offer highly efficient and reliable turbo gearboxes for both high speed and high power. This type is available in the range of 1 to 180 MW.

The perfect basis for translation of movement, energy and/or forces!

Applications

- Oil and gas
- Power generation
- Petrochemical industry
- Steel production
- Paper industry
- Energy recovery
- Testbeds

Free standing design

- G... type with steel casing for an extreme rigid construction.
- GB, GN and GS type with cast iron casing, high rigidity with standardized centre distance (only for older repeats).
- Separate inspection covers for easy inspection and service access.
- Gear ratio for all G types:
single stage $i \leq 10$
double stage $i \leq 50$
- Single or double helical gearing calculated in acc. to API, AGMA and ISO standards.
- RENK-MAAG cylindrical sleeve bearings or tilting pad bearings.

Design Details

Tooth Modifications

Gears and pinions under load exhibit elastic deflections and their temperatures are raised unevenly. Deformations and thermal expansion impair tooth engagement. The tooth flanks are therefore modified during grinding to optimize load distribution at all loads and speeds, especially at rated load and speed. Compensation for thermal effects is absolutely vital for high speed applications and especially for single helical gears essential. This is one of the strengths of RENK-MAAG.

Journal Bearings

Pressure-lubricated two, three or four-lobe bearings provide excellent load capacity and journal stability. Gears which operate at extreme velocities are equipped with direct lubricated tilting pad bearings. The MAAG 3-pad principle is designed to reduce power losses, while providing excellent stability at

high circumferential speeds (up to 140 m/s). Additional features help to reduce babbitt temperature (if requested).

Thrust Bearings

Standard tilting pad thrust bearings with direct lubrication can be provided if required.

Thrust Cones/Thrust Collars

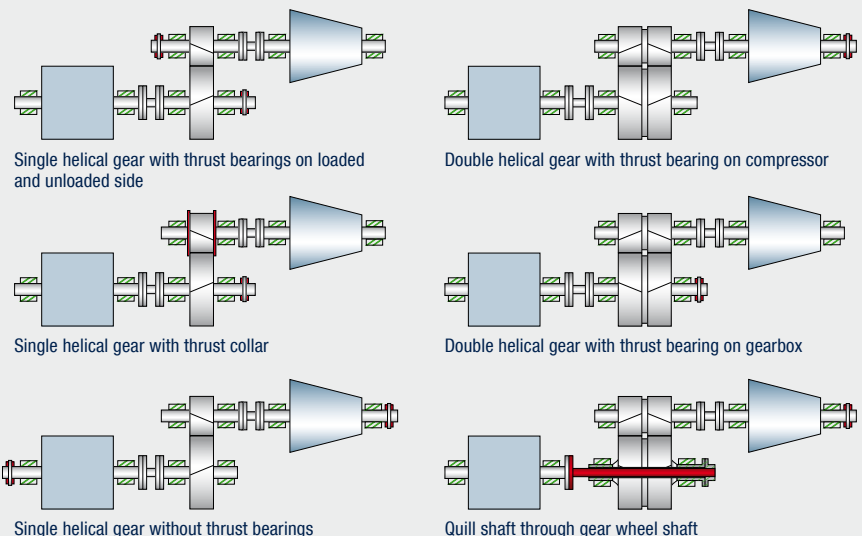
The thrust faces are slightly cone-shaped, surface-hardened and ground. They are lubricated with oil from the meshing teeth.

Geared Systems

The choice of the basic gear design is governed by the disposition of the entire train and the types of couplings and clutches used. Careful selection of gears and couplings can reduce the number of thrust bearings and hence the overall losses.

Examples

(Thrust bearings concept depending on type of coupling and design of driver as well as driven machine.)





Flexible Couplings

Gear couplings or diaphragm couplings are used to absorb shaft misalignments and axial heat expansion.

Quill Shafts/Torsional Shafts

Quill shafts are axially rigid and able to transmit thrust loads. They can compensate small shaft misalignments. Where short lengths are important the quill shafts are

placed in the center bores through the gear shafts. This principle reduces the length of the system.

Clutches

Synchronous clutch couplings (type MS) are used for automatic engagement and disengagement. When engaged, these form-fitted geared clutches have identical characteristics as a gear type coupling.

These clutches can also be quill-shaft-mounted to reduce length.

Rigid Flanges

Only recommended when satisfactory shaft alignment can be maintained or with special layouts such as where machinery rotors are supported in the gearbox.

Instrumentation

Standard instrumentation includes:

- Thermocouples or RTD's on each radial bearing (2 each)
- Thermocouples or RTD's on each thrust bearing, loaded and unloaded side (active/inactive side)
- Provisions for mounting two shaft-vibration probes (90° apart) on each shaft (input/output side)
- Provisions on casing for mounting two accelerometers if requested
- Other provisions according to customer requirements
- Keyphaser if requested





Turbo gearbox types		Older MAAG designs (on request)			
"G" series (incl. GD and GX)		SG*	GB	GN	GS
Transmission range "i"		Transmission range "i"			
up to 10		up to 10	up to 2.5	up to 2.5–6.5	up to 6.5–10
Types Description	variable centre distance from to in cm (in 1 cm increments) and variable span	Fixed centre distance and fixed span			
G- 13	12 – 14			GN- 13	
G- 16	15 – 17		GB-16	GN- 16	
G- 19	18 – 20		GB-18	GN- 19	
G- 22	21 – 23		GB-22	GN- 22	GS- 22
G- 25	24 – 26		GB-25	GN- 25	GS- 25
G- 28	27 – 29		GB-28	GN- 28	GS- 28
G- 32	30 – 33	SG-320	GB-32	GN- 32	GS- 32
G- 36	34 – 37	SG-360	GB-36	GN- 36	GS- 36
G- 40	38 – 42	SG-410	GB-40	GN- 40	GS- 40
		SG-430			
G- 45	43 – 47	SG-470	GB-45		
G- 50	48 – 52	SG-500	GB-50	GN- 50	GS- 50
G- 56	53 – 59	SG-560	GB-55		
			GB-60	GN- 60	GS- 60
G- 63	60 – 66	SG-610			
G- 71	67 – 75	SG-710		GN- 70	GS- 70
G- 80	76 – 84	SG-800		GN- 80	GS- 80
G- 90	85 – 94			GN- 90	GS- 90
G-100	95 – 104			GN-100	GS-100

Design in compliance with API or AGMA or DIN/ISO, special designs on request.

* Center distance in mm for type "SG"

Types of RENK-MAAG "G" gearboxes

RENK-MAAG's range of parallel shaft gearboxes features a wide variability. Based on experiences and customer specification a design to accommodate the latest findings is made.

The wheel and pinion can be offset horizontally or vertically and are housed in ridged welded or casted housings with two halves and a number of inspection covers for easy maintenance. The gears are usually carburized, hardened and ground – spur gear, single helical or double helical is possible. External and internal axial forces will be taken over by thrust collars or axial bearings depending on the design and train layout. The sizing will be carried out in accordance with RENK-MAAG design criteria, or to AGMA, ISO or API standards to insure the most compact design and legendary longevity. In today's world reduction of noise and vibrations is key. RENK-MAAG's design incorporates lead modification accounting

for bending, torsional and thermal deflection – thus insuring perfect tooth contact pattern in any load situation.

The bearings ensure a high rotor dynamic stability with the least possible oil consumption and losses making the gearbox a high performance product working like SWISS clockwork.

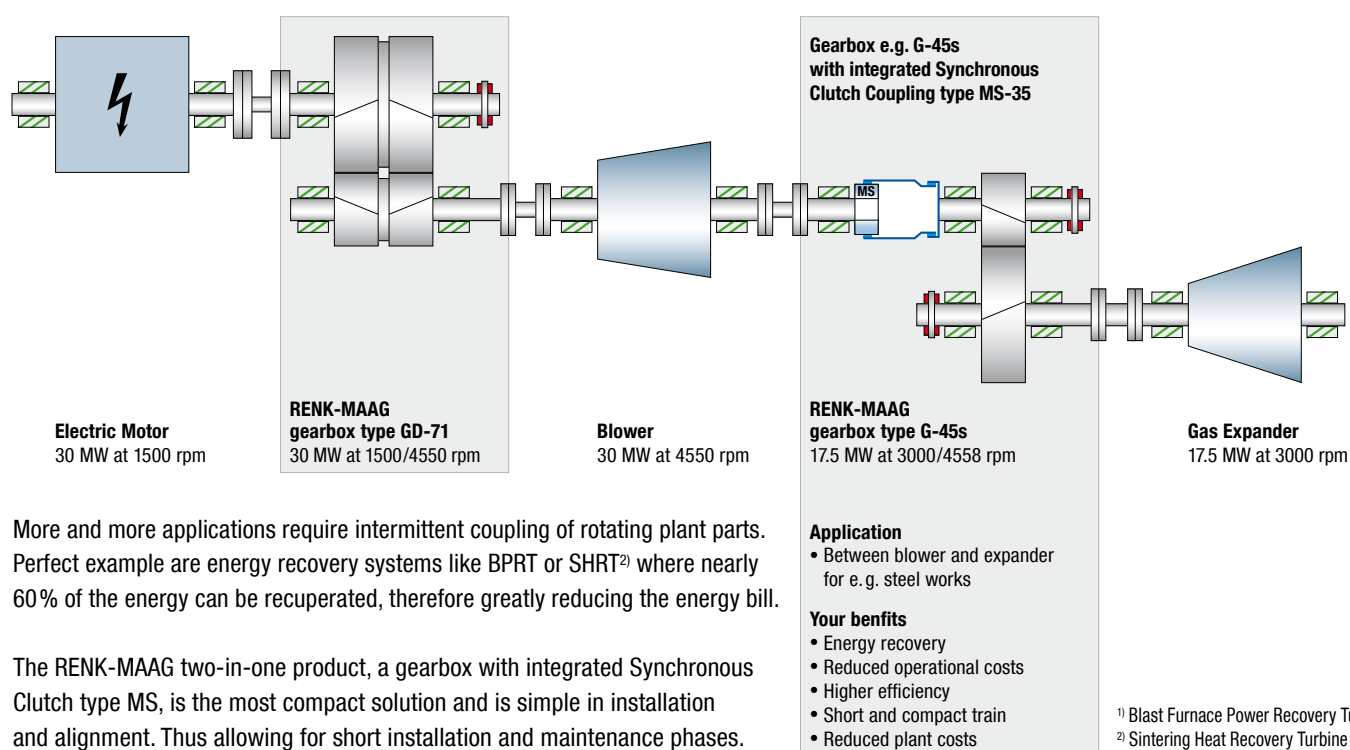
More than 100 years of design, manufacturing, gear cutting, measuring and testing experience are built into our products. Our customers vouch for us. See our homepage for the latest references.

- Optimum centre distance and optimum tooth width
- Toothing is ground in longitudinal direction and in the direction of the profile in the MAAG grinding process to compensate for pre-calculated distortion that can occur in operation: Resulting in optimum tooth contact pattern under full load
- RENK-MAAG bearing program for radial and axial bearings for dynamically balanced running behaviour

- Welded steel casing – extremely rigid design
- 4-point support casing for ease of alignment
- If necessary adjustable radial bearing for perfect tooth contact pattern
- Single-helical or double-helical toothing (D)
- Gearbox with thrust collar (X)
- HET Gear® High Efficiency Turbogear (reduced power dissipation)
- Parallel shaft gearbox with pinion and wheel arranged vertically (**Ro** model with pinion at the top, **Ru** model with pinion at the bottom)

- G** = Slide bearing, single-helical toothing
- GD** = Slide bearing, double-helical toothing
- GX** = Slide bearing, single-helical gear with thrust collar
- SG** = Standard slide bearing:
External pipes, standard size casing
- GB** = Slide bearing width toothing
- GN** = Normal face width (cast casing)
- GS** = Narrow face width (cast casing)

Train arrangement e.g. with gearbox type GD-71 and G-45s (clutch gearbox BPRT¹⁾)



More and more applications require intermittent coupling of rotating plant parts. Perfect example are energy recovery systems like BPRT or SHRT²⁾ where nearly 60% of the energy can be recuperated, therefore greatly reducing the energy bill.

The RENK-MAAG two-in-one product, a gearbox with integrated Synchronous Clutch type MS, is the most compact solution and is simple in installation and alignment. Thus allowing for short installation and maintenance phases.

Accessoires

Rotor Turning Gear

A turning gear, also known as jacking gear, is needed to slowly turn steam or gas turbine trains during the heating or cooling phase, as well as for slow shutdown and in the event of maintenance work. Various sizes are available. These are comprised of an electrically driven right-angle gearbox and an overrunning clutch.

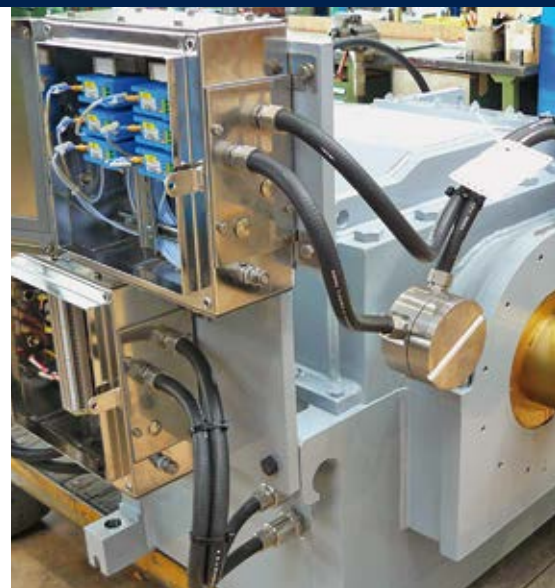
- Tailor-made sizing in collaboration with specialised suppliers
- Design developed by RENK-MAAG in line with specific requirements
- Integrated in gearbox assembly
- ATEX standard possible

Monitoring equipment

A full range of monitoring equipment is available to complement the gearboxes. Items include integrated resistance thermometer assemblies, rev counters, oil pressure or temperature switches and other sensors. Conforming to the requirements of API 670 or other standards, radial and axial vibration sensors can be installed at all bearings.

Shaft driven oil pump

Most commonly gearboxes operate with lube oil from a common system. Alternatively shaft driven oil pumps can be integrated into the gearbox.



Summary

Customized to meet specifications – individual requirements are addressed for functionality, efficiency, safety and reliability.

- Rigid casing in welded or casted design
- Tailor made to match specifications
- Low loss and high stability bearing
- API, AGMA or ISO compliant
- Integrated turning gear or oil pump possible
- Integrated Synchronous Clutch type MS possible
- Adjustable bearing for perfect tooth contact
- Profile and lead correction

High-Speed Epicyclic Gears – full power in minimum space

High-speed epicyclic gears (planetary gears) can be built relatively small as the power is distributed over several meshes. This results in a high “power to weight ratio” and, together with lower pitch line velocity to a smaller gearbox.

A simple, efficient principle when space and weight is at a premium, therefore plant construction costs can be reduced by the coaxial design. Epicyclic gears are available in the range of 1 to 45 MW.

Expanding of skills and abilities based on decades of growing experience.

Applications

- Compressor drive
- Power generation
- Pump drives

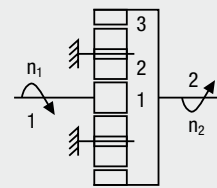
Epicyclic gearboxes are used wherever train arrangements require that the input and output shaft are arranged coaxially. An epicyclic gearbox is more compact and weighs less than a comparable parallel shaft gearbox. At transmission ratios above 1 : 6, an epicyclic gearbox is usually a more cost-effective option.

RENK-MAAG epicyclic gearboxes are characterized by their simple and straightforward structure, which is made possible by the use of straight teeth with hardened and precision-ground tooth flanks. The effect of the torque forces evens load distribution from the sun gear to the planet gears. The straightforward design and the precise manufacturing ensure high operational reliability.

PF = Planetary gear with fixed planets

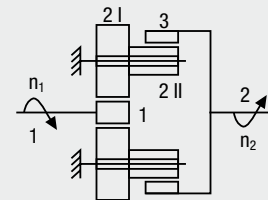
PU = Planetary gear with revolving planets (PF3-27 e.g. means 3 planets, size 27)

Epicyclic gear unit type PF



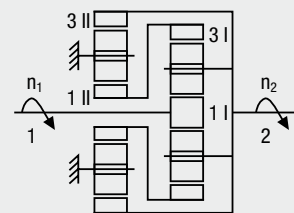
$$i = \frac{n_1}{n_2} = \frac{z_3}{z_1} = 1.7-12$$

Epicyclic gear unit with double planets type PD



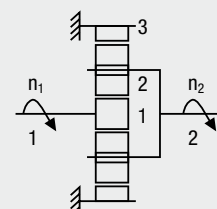
$$i = \frac{n_1}{n_2} = \frac{z_{2I}}{z_1} \cdot \frac{z_3}{z_{2II}} = 12-40$$

Power splitting gear unit type PV



$$i = \frac{n_1}{n_2} = 1 + \frac{z_{3II}}{z_{1I}} \cdot \left(1 + \frac{z_{3II}}{z_{1II}}\right) = 8-80$$

Epicyclic gear unit type PU



$$i = \frac{n_1}{n_2} = 1 + \frac{z_3}{z_1} = 2.7-13$$





The RENK-MAAG concept has other advantages too. The reduction in overall length combined with the rigid coupling of the sun pinion and turbine rotor, which is possible on RENK-MAAG epicyclic gearboxes, reduces overall system costs.

The special design of the RENK-MAAG epicyclic gearbox enables standard gear clutches to be used at both shaft ends. Auxiliary equipment such as one or more oil pumps, turning gear, etc. can be

mounted onto RENK-MAAG epicyclic gears very easily.

The PU epicyclic type is designed with a rotating planet carrier and fixed ring gears: the input and output shafts rotate in the same direction. On epicyclic gears of the PF type, the planet carrier is permanently attached to the casing and the ring gear with internal teeth rotates so that the input shaft and the output shaft rotate in opposite directions.

As a result of continuous research and development RENK-MAAG is in a position to offer highly efficient and reliable epicyclic gears that cover a large power and gear ratio range.

Summary

A simple, efficient principle when space is at a premium – plant construction costs can be reduced by the coaxial design!

- Compact design
- Coaxial arrangement of turbine and generator or compressor
- Directly coupled to generator or turbine
- High gear ratio
- Single or multiple stage
- High “power to weight ratio”
- Generator mounted possible
- Integrated lubeoil pump

Of raw material, tooth lead modification and other specialties



Metallurgy – materials and heat treatment

Rotors made from case-hardened steel

Today, the gear teeth in most high performance gearboxes are hardened and ground. This process gives the teeth the necessary surface hardness, the required core hardness and the requisite precision in the contact pitch (on separation). Along with the tooth shape maximum gear life is achieved. The graph below shows that surface hardening can increase the long-term endurance of the tooth flank to flank pressure by 100% compared to using steel which has simply been heat-treated.

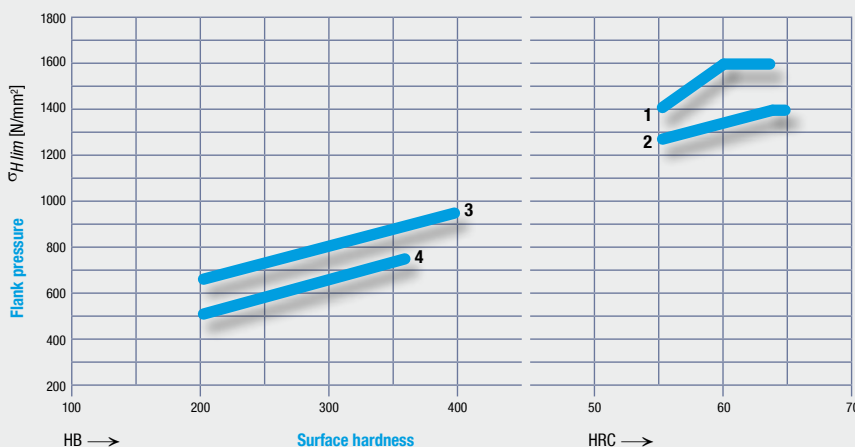
The graph also shows that case-hardened steel maximizes potential strength as well. The austenitic part of the steel is carburized (i.e. carbon is introduced into the surface layer of the toothed zones) before being case-hardened by means of special heat treatment.

18CrNiMo7-6 has proven to be a particularly advantageous material in this process and is now used by many gearbox manufacturers. Case hardening has two major advantages over nitrogen hardening, which produces similar surface hardnesses. Hard layer thicknesses of significantly more than 1 millimetre can be achieved (they are less than 1 mm with nitrogen hardening). The use of case hardening generates residual compressive stresses in the tooth root, which go some way towards compensating the load in the root caused by tooth force (tensile stresses).

Tooth lead modification

The charts on following page depict the separate and combined bending, torsional deflections and thermal distortions of the rotors, as well as the lead modification of the pinion for typical single helical and double helical high-speed gears. The shape and the considerable amount of bending deflections (slope of the toothed parts) strongly influence the lead modification of the double helical gear. Working flanks with such lead modifications cannot be used to align a gear because the contact bearing pattern (Prussian blue) is much too short. Therefore, the non-working flanks of the pinion and gear are ground absolutely parallel and used as the basis for the correct alignment of the gear (contact checking in the gear casing). This is also valid for single helical gears.

Reference values for long-term endurance

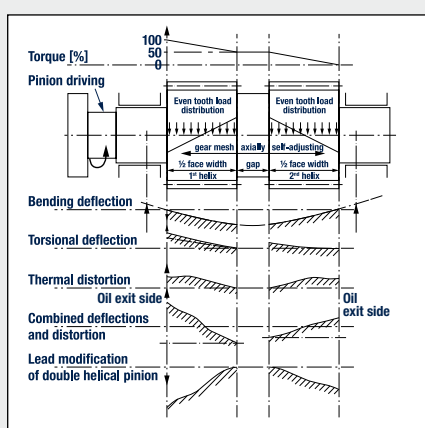
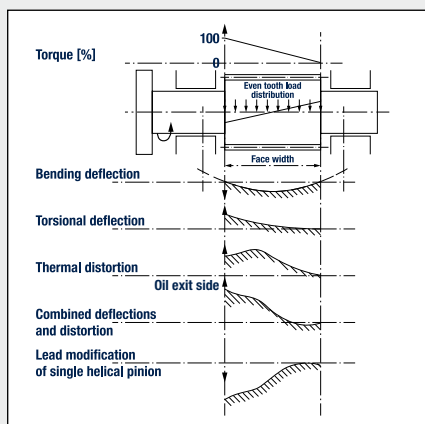


$\sigma_{H/lim}$ for flank pressure dependent upon surface hardness HB, HRC for:
 1 = alloyed case-hardened steel 3 = alloyed heat-treated steel
 2 = alloyed nitriding steel 4 = alloyed cast steel

Bearing Technology

Hydrodynamic slide bearings are normally used in RENK-MAAG turbo gearboxes. This is

**Single and double helical gear:
Deflection, thermal distortion and lead modification**



the only type of bearing which can be used at the high loads and velocities required. The radial bearings in a gearbox differ from those of a turbo machine with regard to operational loads. The bearings in a turbo machine are dimensioned for a single load, namely the weight of the turbine rotor. This does not change regardless of the operating conditions; nor is it dependent upon the power output by the turbine. This is in contrast to a gearbox. The torque output by the driving machine and transmit-

ted by the gearbox to the driven machine primarily generates tangential and axial forces in the gear teeth which are known as tooth forces. The tangential forces are taken up by the gearbox's radial bearings, with the axial forces being absorbed by the axial bearings or by the double-helical toothing itself. This means that when a turbo generator train ramps up, for example, and during subsequent synchronization with the main grid, the gearbox bearings are constantly exposed to loads which vary

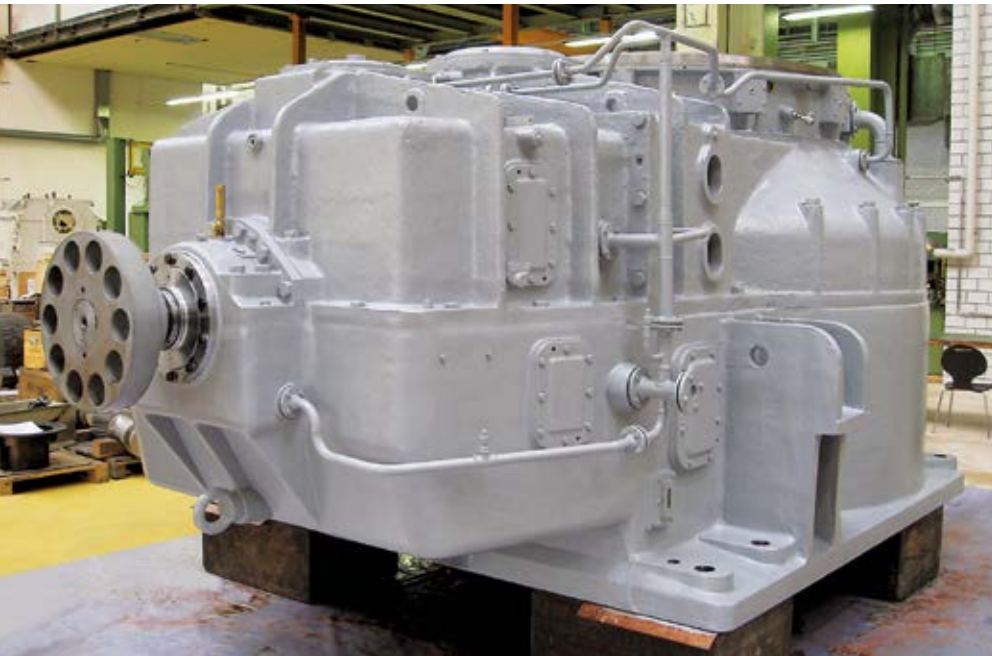
according to the torque to be transmitted at any given time. The radial bearing at the gear pinion, for example, is dimensioned according to the maximum tooth forces prevailing at full load. These tooth forces are up to 50 times greater than the weight of the pinion; this explains why a gear pinion "floats" at very low load in bearings which are actually too large. In many cases, this also explains why gear rotors sometimes respond sensitively to shock and malfunctions in the system – measured as a rotor vibration.

Summary

Lowest vibrations and noise based on a gearset of highest quality and adequate tolerances – according to ISO 1328/ AGMA 2015 accuracy grade 3 or better.

- Profile modification for smooth meshing
- Lead modification for perfect tooth contact
- Bearing optimized for high efficiency
- Customized according specifications
- Precision ground for low vibrations
- Case hardened for long service live
- Legendary longevity
- Lower OPEX

Buy new? – Or may have been repaired or modified?



The same applies to all MAAG turbo and marine gearboxes, couplings and GP pumps for which spare parts are manufactured according to original drawings. RENK-MAAG also maintains individual components such as bearings, rotors, turning gears, etc. and also conducts repairs of third party products.

Repair procedure

A detailed inspection is initially made of the affected parts. This results in an objective report regarding the condition of the parts and any deviations from the norm, as well as a repair proposal. The second step is the repair itself. A test run of each complete gearbox or coupling can be conducted on our efficient testbed for certification purposes.

Repair goals

- Quick turnaround time
- Original dimensions are maintained where possible
- Reusable as new parts

Damage assessments

RENK-MAAG conducts non-destructive, and if necessary, destructive damage assessments together with external independent experts.

Modifications

RENK-MAAG undertakes modifications of gearboxes after clarification of the technical feasibility. This includes:

- Speed alterations
- Performance modifications
e.g. power upgrades
- Additional instrumentation
- Turning gear
- Mounted pumps
- Custom modifications



Although defects in RENK-MAAG gearboxes are rare, incorrect storage, improper care, changing operating conditions or poor maintenance can occasionally result in damage. New parts do not always have to be procured in such circumstances.

A repair is possible in the majority of cases.

Why preventive control?

Even if no damage is apparent we still recommend that specific periodic inspections of major components are conducted by RENK-MAAG. Such preventive measures do not necessarily result in repairs. On the contrary, inspections safeguard long-term, trouble-free operation, and extend service life.

RENK-MAAG repairs or overhauls all RENK-MAAG products where necessary.



Field service – Regular maintenance means long operating life



Maintenance schedule

Depending on the number of years of operation or operating hours since commissioning or the last maintenance work, we recommend the following RENK-MAAG standard inspections:

1000 operating hours check

This check is undertaken on gearboxes when taken into service.

8000 operating hours check/annual check

A brief check through the inspection cover provides an overview of the gearbox condition.

20000 operating hours check

The gearbox is opened – but not dismantled – to gauge the condition of its

interior. This is ideal if you have only a brief shutdown or a limited budget.

40 000 operating hours check

This large-scale check involves dismantling, cleaning and re-assembling the gearbox. If necessary, individual components or worn parts are replaced.

After each inspection or overhaul, our service technicians will provide you on the spot with a system report containing the following points of importance to safety and optimum availability:

- General condition of the gearbox
- Possible and detected defects
- Recommended spare parts
- Due date and scope of next inspection

Insurance spare parts on-site



RENK-MAAG recommends holding the following key components in stock:

- 1 spare set of rotors
- 1 spare set of bearings
- 1 spare set of oil scrapers
- 1 spare set of instrumentation

The defective parts can then be replaced immediately, limiting any production downtime to a minimum. Keep in mind that even under the best conditions, it will take several months for spare bearings or rotors to be delivered.

Contact us all over the world

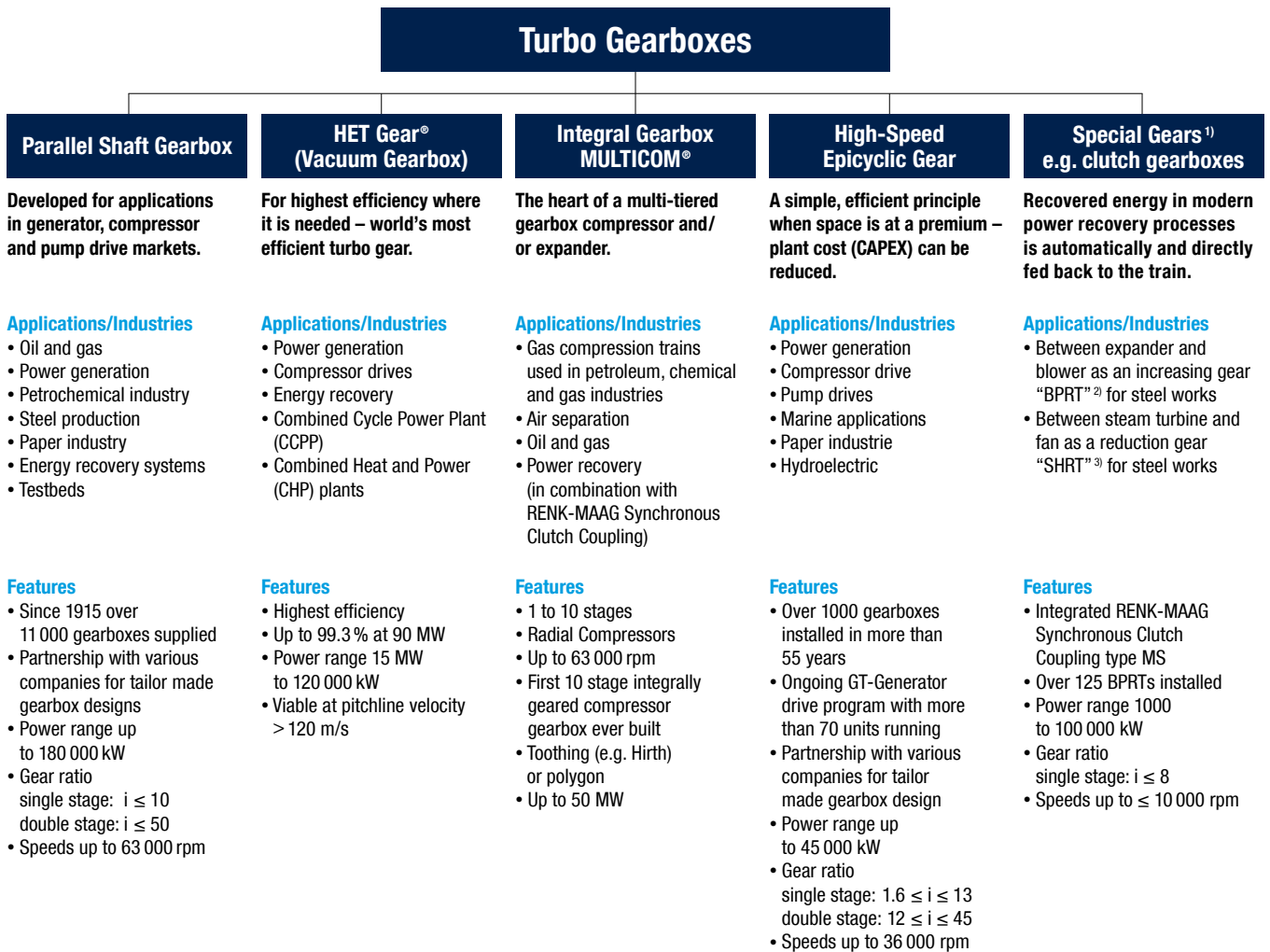
RENK-MAAG is represented by designated agents in over 35 countries around the world. So we can advise and support our customers on all continents directly – whether on new gearboxes or couplings, modifications, replacements, spare parts, repairs or field service.

The current contact details are readily available on our website:
www.renk-maag.ch



Product portfolio

RENK-MAAG provides new products, services, inspections, repairs and spare parts (incl. complete gearboxes) for all types of MAAG/RENK-MAAG gearboxes.



All RENK-MAAG gearboxes are according to DIN/ISO, AGMA or API (other norms or special design upon request).

Ask also for RENK-MAAG gear couplings (such as automatically synchronizing, engaging on demand or completely disengageable).

¹⁾ RENK-MAAG develops and manufactures special gears for an enormously wide range of applications. The clear strength lies in the close technical cooperation with customers. A detailed specification and required gearbox design for optimum solutions are discussed and developed in person with the customer.

²⁾ BPRT = Blast Furnace Power Recovery Turbine

³⁾ SHRT = Sintering Heat Recovery Turbine



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Our manufacturing and other operational activities are implemented in accordance with our internal quality assurance system and in strict compliance with ISO 9001:2008, ISO 14001:2004 and OHSAS 18001:2007.