Reliable and Application specific

Slewing Drives for Wind Turbines

LIEBHERR

Slewing Drives for Wind Turbines

Powerful and versatile

Yaw and pitch gearboxes based on proven technology: For almost 20 years Liebherr has been supplying highly reliable components to the wind industry. Based on a variety of intelligently designed solutions, such as special sealing concepts, corrosion protection systems, as well as optimised anti-friction bearings and gearing.

Reliability and compact design are the essential factors for the rotor blade and yaw adjustment drives. For both applications, Liebherr offers multi-stage planetary gearboxes. Depending on the requirement, up to twelve yaw gearboxes per plant are installed to transmit the high torques encountered in wind turbines in the multi-megawatt class.

Product Portfolio

Yaw gearboxes

The yaw gearboxes are offered with a short output shaft (design 1) or long output shaft (design 2) or alternatively as a bevel gear.

Yaw gearboxes, also called wind tracking mechanisms, are used to align the nacelle to the wind direction. Ideally several of these drives are used to transmit the high adjustment forces required. The typical output speed of these drives is around 1 min^{-1}.

In order to realise the high transmission ratios, Liebherr recommends planetary gearboxes with three or four planetary stages for this application. Designs with five or more transmission stages are also possible. The portfolio includes five sizes, which can reach a maximum transmissible torque of up to 230 kNm.

The gearboxes can also be supplied with preassembled electric motors manufactured in-house or from external suppliers. In-house development of electric motors in sizes of up to 3 MW guarantee the necessary know-how and expertise when handling electric machines.

The drives are designed using the very latest development and calculation methods. Extensive testing facilities and an in-house materials laboratory form the basis for ongoing development and even better performance.

Pitch gearboxes

Pitch gearboxes are also available in the following versions:
With short output shaft (design 1), with long output shaft (design 2) or alternatively as a bevel gear.

To adapt to the wind speed the blades are pitched to adjust the angle of attack. The rotation around the rotor blade axis is realised with pitch gearboxes. For turbines with high pitch activity, the drives have to regualry perform small adjustments. This increases the stress levels which the drives need to withstand.

Typical output speeds here are around 10 min^{-1}. In order to be able to realise the appropriate transmission ratios for the pitch gearbox, Liebherr generally recommends three transmission stages. The portfolio includes four sizes, which can achieve a maximum transmissible torque of 96 kNm.

Highest manufacturing quality and sturdy gearbox components ensure reliable performance of the function throughout the entire service life of the plant. Optimised manufacturing tolerances and high-quality lubricants see to quiet and efficient power transmission.

Pitch gearboxes can be supplied with reduced play, which has a positive effect on the positioning accuracy of the rotor blades. Besides the rotor blade adjustment via slewing drives, the rotor blade can be adjusted by means of hydraulic cylinders, also available from Liebherr.

Selection of the appropriate Slewing Drive

Starting with establishing the technical conditions, such as the number of drives to be used, the following process chart shows one possible approach to using the catalogue for selecting the drive.

1. Number of drives		• According to customer requirements
2. Determining number of teeth of output pinion		• Liebherr recommendation: t ≤ 13 or according to specific requirements
3. Determining the output speed		• According to transmission ratio and desired yaw speed
4. Determining the defining loads		• Equivalent output torque • Max. static output torque
5. Selection depending on application and certification guideline		• Yaw gearbox or pitch gearbox • E.g. GL 2010, IEC 61400
6a. Selection suitable size of yaw gearbox	6b. Selection suitable size of pitch gearbox	• According to tables
7a. Selection of transmission ratio for yaw gearbox	7b. Selection of transmission ratio for pitch gearbox	• Depending on motor speed and desired output speed • Choice of motor according to customer specifications or Liebherr choice
8. Design selection		• Long output shaft • Short output shaft • Bevel gear (on request)
9. Additional options		• Integrated lubrication system • Tooth root safety geometry • Certification (3.1/3.2) • Measuring technology • Endurance test • Service • Motor • Painting

1.
Number of drives

The number of drives to be used is determined by the (desired) performance requirements, nacelle dimensions and spatial conditions or other specific requirements.

2.
Determining number of teeth of output pinion

With the data already known from the slewing bearing or gear ring design, the gearbox selection can be started. The number of teeth and module as well as the number of drives to be used permit a preselection of the number of teeth of the output pinion. Liebherr recommendation: $t \leq 13$, resulting in the selection of the smallest possible drive with the lowest required constant output torque.

3.
Determining the output speed

The required output speed of the drive pinion is defined based on the ratio between the slewing bearing or gear ring and the drive pinion $i_{pinion/ring}$ taking the specified pitch or yaw speed into account.

4.
Determining the defining loads

To make a proper assessment of the drive required, a calculation of the equivalent torque of the load collective acc. to ISO 6336-6 is useful. This torque is determined from the number of load cycles per load stage and the SN-curve. The standard stipulates the following formula:

$$T_{eq} = \left(\frac{N_1 T_1^p + N_2 T_2^p + \ldots}{N_1 + N_2 + \ldots} \right)^{\frac{1}{p}}$$

T_{eq} the equivalent torque in [Nm]
N_i the number of load changes per load stage i
p the gradient of the Wöhler curve

The gradient of the Wöhler curve must be measured in this simplifying interpretation with $p = 8.7$. The number of load changes is dependent on the output speed of the drive and the dwell time at this stage. For the pitch and yaw gearboxes from Liebherr a size-dependent factor must also be allowed for, which includes the specific conditions and the increase of the load change figures by multiple gear meshing in the gearbox. The following formula must be applied:

$$N_i = t_i \times n_{ab} \times f_{DAT}$$

t_i the dwell period at load stage i
n_{ab} the output speed of the drive
f_{DAT} the size-dependent conversion factor acc. to the following table

DAT	DAT 250	DAT 300	DAT 350	DAT 400	DAT 450	DAT 500
f_{DAT}	960	1012,5	950	950	950	950

5.
Selection depending on application and certification guideline

In order to be able to choose the correct size, the application and certification guidelines to be applied must be defined first due to different requirements.

Selection of the appropriate Slewing Drive

Yaw gearboxes

6a.
Selection suitable size of yaw gearbox

The indicated value (on the right) for maximum dynamic torque must be greater than the calculated equivalent torque.

Output data point 4:
Calculated T_{eq} T_{stat}
Guideline selected:
General notes:

Size	Maximum dynamic output torque				Maximum static output torque			
Certification guideline	Germanischer Lloyd 2003 Wind tracking*	Germanischer Lloyd 2012 Yaw system**	IEC61400-4 / DIN EN61400-1 Component class 1	IEC61400-4 / DIN EN61400-1 Component class 2	Germanischer Lloyd 2003 Wind tracking*	Germanischer Lloyd 2012 Yaw system**	IEC61400-4 / DIN EN61400-1 Component class 1	IEC61400-4 / DIN EN61400-1 Component class 2
DAT 300	20,900	18,100	18,100	14,900	34,800	34,800	34,800	34,800
DAT 350	26,500	21,000	21,000	17,300	68,400	64,100	68,400	68,400
DAT 400	52,200	43,200	43,200	35,700	96,300	96,300	96,300	96,300
DAT 450	73,400	63,800	66,700	55,800	187,600	146,000	187,600	187,600
DAT 500	114,600	82,900	82,900	68,500	231,600	207,200	231,600	231,600

* Guideline for the certification of wind turbines, 2003 edition, with supplement in 2004
** Guideline for the certification of wind turbines, 2010 edition. Guideline for the certification of offshore wind turbines, 2012 edition

These permissible torque levels refer to the toothed components of the gearbox at a rated speed of 1 min^{-1} and are also based on carefully weighed representative assumptions. The bearings of the output shaft are not considered as an element of the customer-specific output shaft.

It is recommended to check the load documents with load collective and extreme loads by Liebherr when compiling a detailed proposal. The technical data of the output tooth system are also required for interpreting the bearing load.

7a.
Selection of transmission ratio for yaw gearbox

Several iterations may be required here with different numbers of teeth at the output pinion. Then a preselection can be made from existing transmission ratios and dimensions or a specific inquiry can be made to Liebherr. The transmission ratios listed correspond to the preferred series for yaw systems. The drive must be adapted to the installation situation.

Gear transmission ratios for yaw*

DAT 300	975.0	1,140.0	1,230.0	1,330.0	**1,422.7**	**1,537.8**
DAT 350	960.0	1,004.3	1,090.2	1,162.5	1,237.5	1,443.8
DAT 400	**960.0**	**1,004.3**	**1,090.2**	**1,162.5**	**1,237.5**	**1,443.8**
DAT 450	**712.5**	**1,140.0**	**1,260.0**	**1,628.9**	**1,954.2**	**2,143.8**
DAT 500	**915.0**	**1,140.0**	1,260.0	1,628.9	1,954.2	2,143.8

* The gear transmission ratios already realised are **marked in bold**

Pitch gearboxes

6b.
Selection suitable size of pitch gearbox

The indicated value (on the right) for maximum dynamic torque must be greater than the calculated equivalent torque.

Output data point 4:
Calculated T_{eq} T_{stat}
Guideline selected:
General notes:

Size	Maximum dynamic output torque				Maximum static output torque			
Certification guideline	Germanischer Lloyd 2003 Pitch adjust-ment system *	Germanischer Lloyd 2012 Pitch**	IEC61400-4 / DIN EN61400-1 Component class 1	IEC61400-4 / DIN EN61400-1 Component class 2	Germanischer Lloyd 2003 Pitch adjust-ment system *	Germanischer Lloyd 2012 Pitch**	IEC61400-4 / DIN EN61400-1 Component class 1	IEC61400-4 / DIN EN61400-1 Component class 2
DAT 250	13,600	8,500	8,500	7,000	26,500	26,500	26,500	26,500
DAT 300	21,300	15,900	15,900	13,100	34,800	34,800	34,800	34,800
DAT 350	26,000	19,000	19,000	15,700	68,400	64,100	68,400	68,400
DAT 400	52,100	31,800	31,800	26,300	96,300	96,300	96,300	96,300

* Guideline for the certification of wind turbines, 2003 edition, with supplement in 2004
** Guideline for the certification of wind turbines, 2010 edition. Guideline for the certification of offshore wind turbines, 2012 edition

These permissible torque levels refer to the toothed components of the gearbox at a rated speed of 10 min^{-1} and are also based on carefully weighed representative assumptions. The bearings of the output shaft are not considered as an element of the customer-specific output shaft.

It is recommended to check the load documents with load collective and extreme loads by Liebherr when compiling a detailed proposal. The technical data of the output tooth system are also required for interpreting the bearing load.

7b.
Selection of transmission ratio for pitch gearbox

Several loops may be required here with different numbers of teeth at the output pinion. Then a preselection can be made from existing transmission ratios and dimensions or a specific inquiry can be made to Liebherr. The transmission ratios listed correspond to the preferred series for pitch gearboxes. The drive must be adapted to the installation situation.

Gear transmission ratios for pitch*

DAT 250	**105.5**	**120.9**	**127.4**	**132.6**	**150.3**	**164.9**	188.7	194.8
DAT 300	**121.1**	**137.1**	**138.8**	**163.6**	**181.0**	**183.8**	187.2	208.0
DAT 350	116.4	**132.1**	**154.2**	165.6	175.0	185.7	198.0	212.5
DAT 400	116.4	132.1	154.2	165.6	175.0	185.7	198.0	212.5

* The gear transmission ratios already realised are **marked in bold**

8.
Design selection

See table on page 10

9.
Additional options

- Tooth root safety geometry
- Integrated lubrication system
- Certification (3.1/3.2)
- Measuring technolgoy
- Endurance test
- Service
- Motor
- Painting

Dimensions of the Slewing Drives

The dimensions of the listed slewing drives correspond to the preferred series.
The drive must be adapted to the installation position in relation to the requirements.
Each size is available in two designs – design 1 and 2.

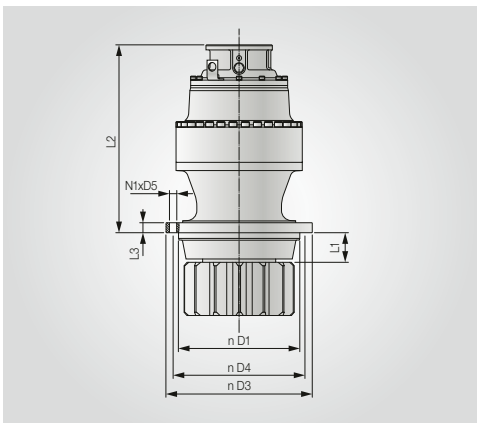
	DAT 250		DAT 300		DAT 350		DAT
	Design 1	**Design 2**	**Design 1**	**Design 2**	**Design 1**	**Design 2**	**Design 1**
D_1* (mm)	220	190	310	250	340	268	365
D_2* (mm)	-	210	-	290	-	270	-
D_3 (mm)	280	270	415	363	405	450	440
D_4* (mm)	250	245	380	325	375	410	400
$N_1 \times D_5$ (mm)	12 x 17.5	12 x 14	12 x 20	18 x 17.5	24 x 17.5	18 x 17.5	24 x 22
L_1 (mm)	68	185	130	233	90	160	90
L_2** (mm)	Approx. 400	Approx. 325	Approx. 375	Approx. 275	Approx. 500	Approx. 420	Approx. 560
L_3 (mm)	25	113	30	49	25	30	131
Z (mm)	15	14	16	13	11	14	14
M (mm)	12	10	14	12	16	13	20
L_R (mm)	110	105	130	110	115	135	160
D_R (mm)	215	170	260	190	220	225	340

D_1 Diameter of centering seat
D_2 Diameter of centering seat
D_3 External diameter
D_4 Pitch circle diameter
N_1 Number of bolts
D_5 Diameter of bolts
L_1 Installation depth
L_2 Gearbox height
L_3 Flange height
Z Number of teeth of output pinion
M Gear module of output pinion
L_R Height of output pinion
D_R Diameter of output pinion

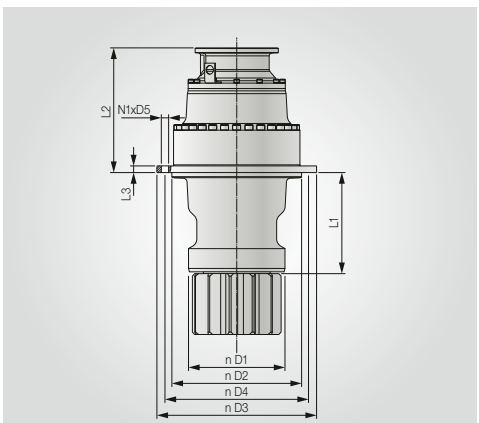
400	DAT 450		DAT 500	
Design 2	**Design 1**	**Design 2**	**Design 1**	**Design 2**
290	395	360	420	370
390	-	440	-	475
480	483	540	510	565
440	435	500	460	520
32 x 22	24 x 26	30 x 22	28 x 26	24 x 26
305	115	337	115	432
Approx. 375	Approx. 620	Approx. 465	Approx. 585	Approx. 485
20	50	30	70	70
12	13	12	13	12
18	22	22	22	24
183	165	210	135	245
270	350	330	350	360

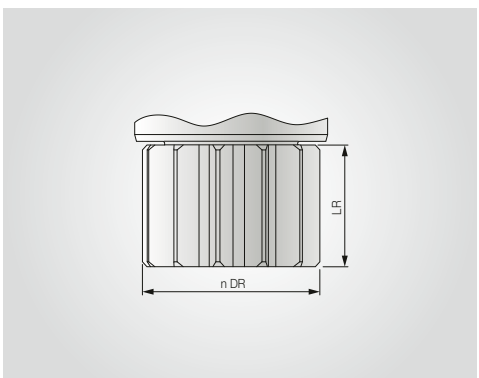
* eccentric version on request
** exact design depending on number of transmission stags and motor type

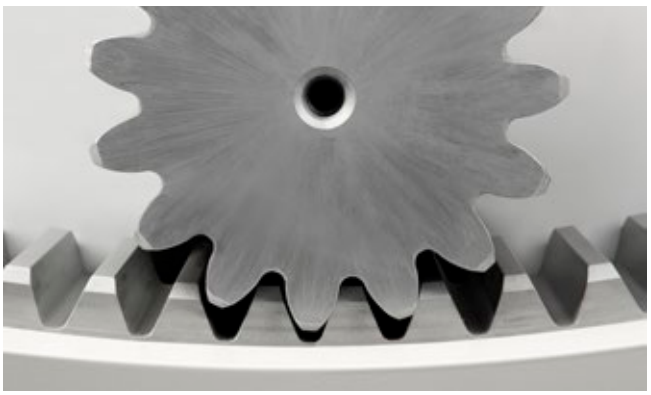
Design 1



Design 2







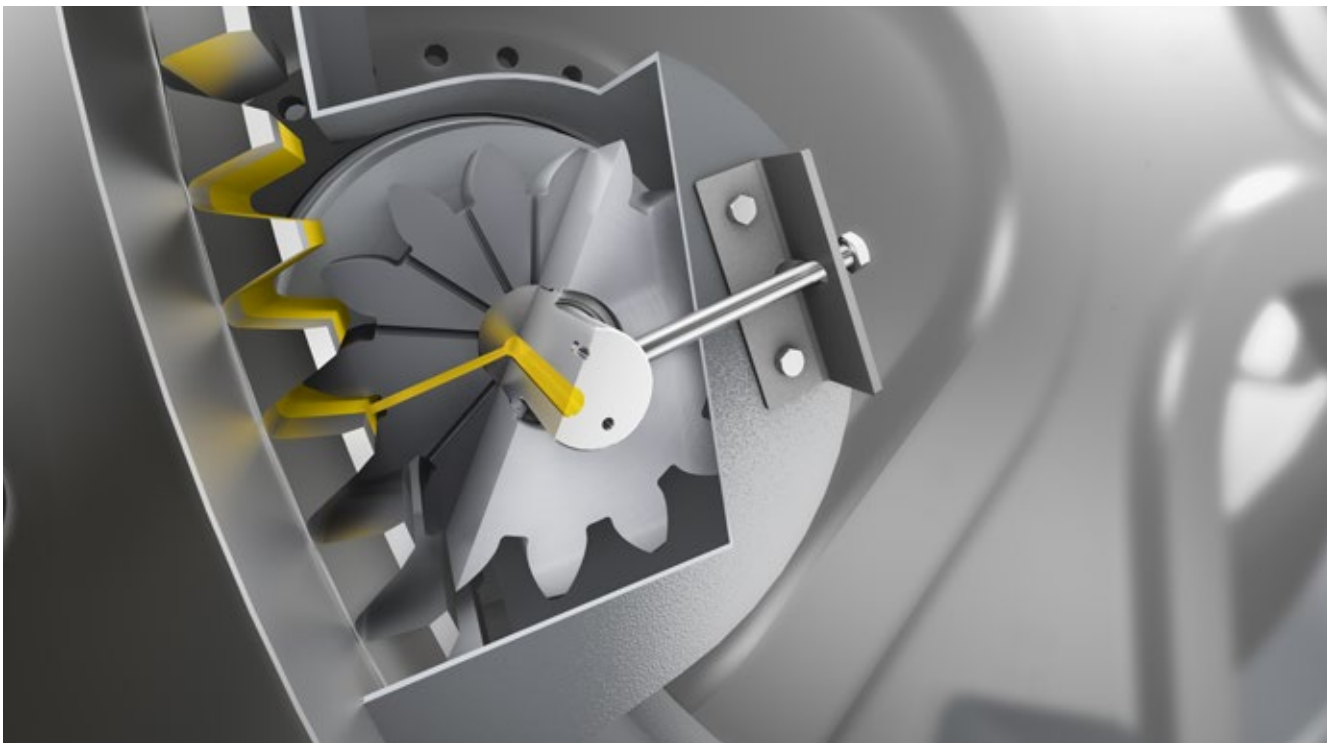
Tooth trace correction
The pinion has a correction in order to offset strains of the hub, slewing bearing and drive with the output shaft under load and to guarantee optimal load distribution across the tooth width. High load peaks and also the frequently occurring operating loads are included in the calculation.

Measuring technology
The output shafts of the gearbox can be equipped with strain gauges and corresponding evaluation and signal transmission devices to verify the sets of loads within the framework of the plant's type approval. It is also possible to use sensors to monitor the temperature and air humidity, oscillations and vibrations, noises, run times and the lubricant level.

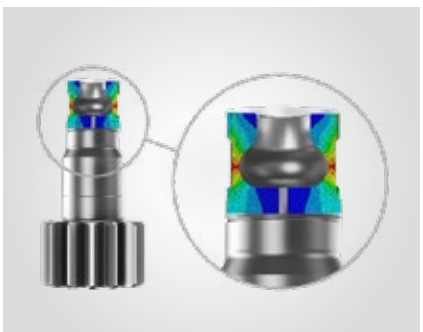
Endurance test
Various highly specialised measuring stations and test benches are available to the development engineers with which, for example, the behaviour of gearboxes is measured under defined load specifications. The Highly Accelerated Life Test (HALT) makes it possible to reproduce individual torque and speed cycles at the test bench in order to be able to ensure the service life of the gearbox in realistic conditions.

Service
Original spare parts are available for all components from Liebherr. Customised kits can be provided so that elaborate or time-consuming part upgrades can be avoided and entire assemblies can be replaced. Quick availability can be guaranteed with a service agreement. The extensive internal quality assurance system checks assure, along with our components themselves, that these meet the highest demands in terms of perfection and performance.

Innovations from Liebherr



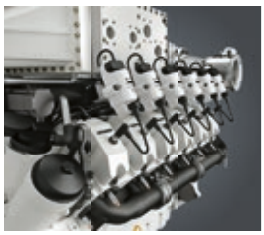
Integrated lubrication system
With this innovative component, which is embedded into the front of the output shaft, the grease lubrication is performed directly at the gear mesh. As a result, the otherwise standard external lubrication pinion can be dispensed with. The lubricant is supplied via the lubricant distributor in the centre of the output shaft, which guides the grease directly into the gear mesh via a duct that ends in the tooth root.



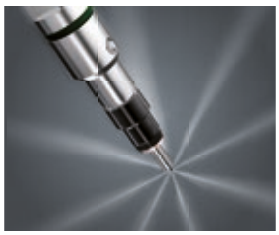
Tooth root safety geometry
Consequential damage to the gear ring or geared slewing bearing from a gearbox failure can be avoided with the use of an output shaft with tooth root safety geometry. With this option the output shaft has a precisely dimensioned predetermined breaking point, which in a situation where the brake, motor or transmission stage is blocked ensures that the lower part of the output shaft rotates freely with the rotating slewing bearing at the nacelle. In this way the risk of a tooth break at the gear ring and thus a complicated replacement of the slewing bearing is avoided.

Certifications
For the certifications required in the industry we can look back on a long-standing collaboration with classification companies such as DNV-GL or TÜV.

Liebherr Components


Gas engines


Diesel engines

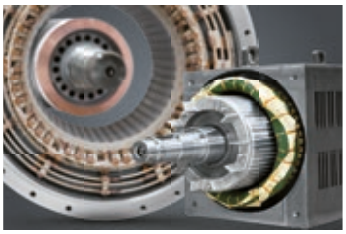

Fuel injection systems


Axial piston hydraulics


Hydraulic cylinders

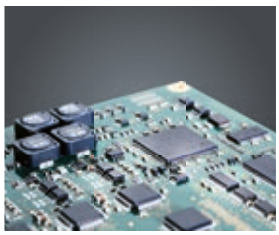

Slewing bearings


Gearboxes and winches


Electric machines


Remanufacturing


Human-machine interfaces and gateways


Control electronics and sensor technology


Power electronics


Control cabinets


Software

From A to Z – the components division of the Liebherr Group offers a broad range of solutions in the area of mechanical, hydraulic, electric and electronic drive system and control technology. The efficient components and systems are produced at a total of ten production sites around the world to the highest standards of quality. Central contact persons for all product lines are available to our customers at Liebherr-Components AG and the regional sales and distribution branches.

Liebherr is your partner for joint success: from the product idea to development, manufacture and commissioning right through to customer service solutions like remanufacturing.

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