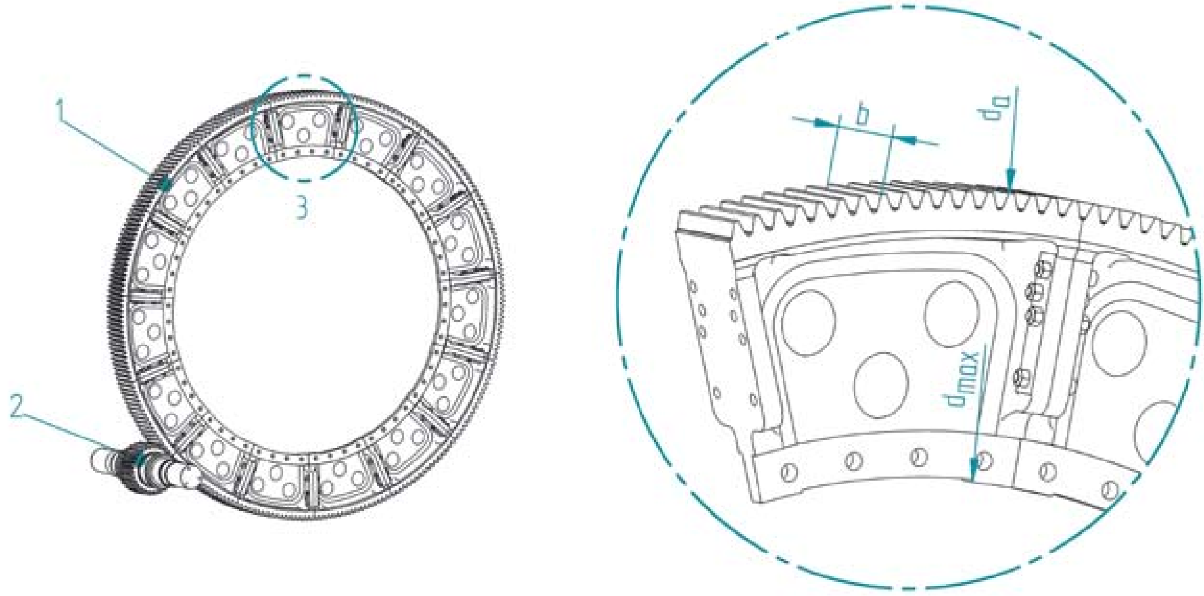
Girth Gear Technical Manual

KUMERA

Girth gears are manufactured from segments. A girth gear is divided into 8–16 segments, which are joined by bolts. The segment length typically varies between 0.8–1.6 m. Short segments enable the use of small versatile and accurate machines. Due to this, optimal and precise tooth reliefs can be produced. Casting of short segments is easy, securing high and even material strength properties. Segments are interchangeable, which reduces spare part costs. Short segments also enable easy and cost-efficient transportation.



1	girth gear
2	pinion
3	segment
b	face width
d_a	tip diameter
d_{max}	max. drum diameter

Picture 1. *Terms and definitions of an open gear*

A girth gear can be single or double pinion driven. A pinion is manufactured as a single part with an integrated shaft. The pinion can also be separate and mounted on a separate shaft, supported by bearings, or on the output shaft of the main gear unit.

The rotation speed of a drum normally varies between 0.5–20 rpm corresponding to the peripheral velocity from 0.3 to 10 m/s of the girth gear. The nominal power of a standard Kumera girth gear is up to 8 MW per mesh, i.e., 16 MW when double pinion driven.

The manufacturing method of girth gears enables wide possibilities for geometry modifications. Typically, the tooth geometry is according to Table 1.

Pinion flanks are modified by tip, root and end reliefs. The modifications compensate the deflection of the drive system, thus high contact pressure on the tooth edges can be avoided.

Table 1. *Typical geometry of a girth gear*

	Min.	**Max.**	**Standard**
Module	20	40	27
Pressure angle, [°]			24
Helix angle, [°]	0	45	0
Number of teeth:			
– Girth gear	100	300	
– Pinion	18	30	
Face width, [mm]	100	500	
Reference diameter [mm]	2000	no limitation	
Quality	**ISO**	**AGMA**	
Girth Gear	8–10	9–7	
Pinion	7	10	

The tooth load carrying capacity can be calculated according to the following standards:

– ANSI/AGMA 6004-F88 Gear Power Rating for Cylindrical Grinding Mills, Kilns, Coolers and Dryers

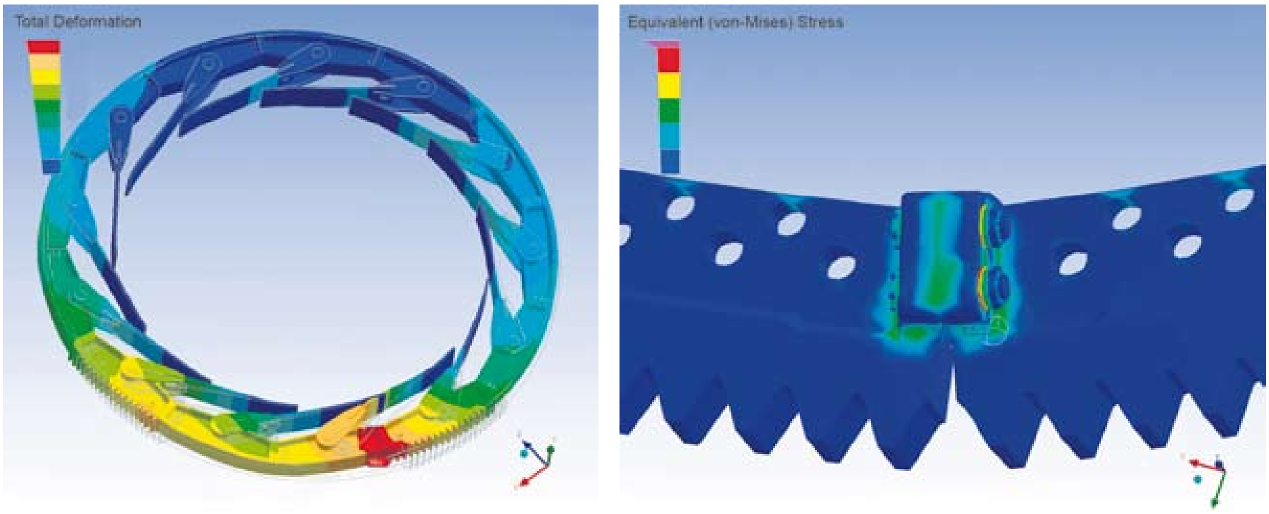
– ISO 6336 Calculation of load capacity of spur and helical gears

– DIN 3990 Calculation of load capacity of cylindrical gears

Table 2. *Minimum service factors according to AGMA 6004 (* < 1.5 rpm)*

Application	Durability, C_{SF}	Strength, K_{SF}
Coolers	1.00 *	1.5 *
Dryers	1.00 *	1.5 *
Kilns	1.00 *	1.75*
Grinding Mills:		
Ball	1.5	2.25
Autogenous	1.5	2.4
Rod	1.5	2.5

A girth gear can be assembled to a drum with a flanged connection or with spring elements.



Picture 2. *The FE-method is utilized for deformation and stress calculation of a whole girth gear including the strength calculation of the fixing structure*

A common material for girth gears has been spheroidal graphite cast iron EN 1563 – GJS 800-2. Nowadays, austempered ductile iron, ADI, EN 1564 – GJS1000-5 is more and more used. Its principal attribute is its high strength-to-weight ratio.

In the past, pinions were often made from through-hardened steel. At present, the standard material for Kumera pinions is case-hardened 17CrNiMo7-6. Teeth are ground after heat treatment. The pinions have a substantially improved load-carrying capacity, better quality of teeth, and good surface quality of tooth flanks, resulting in better operational reliability. Pinions are also less wide with the same nominal output torque, which improves the load distribution across the face width.

Table 3. *Material properties*

Material	**Hardness**	**Tensile strength [N/mm²]**	**Allowable contact stress [N/mm²]**	**Allowable bending stress [N/mm²]**	**Young's modulus [kN/mm²]**
Girth gear					
EN 1563 – GJS 800-2	280–320 HB	800	700	248	185
EN 1564 – GJS 1000-5 (ADI)	300–360 HB	1000	1200	320	159
Pinion					
EN 10084 – 17CrNiMo7-6	58–62 HRC	1200	1500	500	206

The standardization of the ADI material has proceeded in recent years, which facilitates its use. The standards ASTM A897/A897M-06, EN 1564:1997, and ISO 17804:2005 outline the ADI grades varying in mechanical properties. The information sheet AGMA 939-A07 Austempered Ductile Iron for Gears covers the areas of designing, purchasing specifying and verifying the ADI material, in particular for applications in gears and power train components.

ADI is produced by heat treating ductile iron, using the austempering process. Austempering is a specialized, isothermal heat treatment. When compared to conventional ductile iron, ADI can have over twice the strength for a given level of ductility. ADI can have a fatigue strength comparable to that of cast and forged steels. ADI's strength can be greatly enhanced by subsequent grinding, fillet rolling or shot peening.

The ausferrite matrix in ADI undergoes a strain transformation hardening when exposed to a high normal force. This same strain transformation hardening is what gives ADI a better wear resistance than the bulk hardness would indicate. Other attributes of ADI material include good noise dampening, fracture toughness, low temperature properties, and reasonable stiffness. ADI has a 20 % lower Young's Modulus than steel. In gears, this results in a larger contact area for a given input load. In some cases, this has been shown to reduce contact stress and noise.

Table 4. *Properties of different ADI-grades*

ADI	750	900	1050	1200	1400	1600
Herzian resistance	Modest	Moderate	Fair	Good	Good	Very good
Bending resistance	Very good	Good	Good	Fair	Modest	Poor
Machinability	Very good		Good			Poor
Shot peening		Good	Good			
Load capacity	Moderate				High	Very high
	Exceeds ductile iron	Competes with through-hardening	Exceeds through-hardening	Competes with nitrided steel	Exceeds flame hardening	Competes with case hardening

The most common type of operational lubrication is automatic interval spray lubrication, where the applied lubrication volume is controlled by the spray as well as pause times.

If a drum is rotated by a girth gear before the lubrication system is taken into operation, priming lubrication is recommended. A priming lubricant prevents damage during initial operation. The priming lubricant is applied once to all tooth flanks by a brush or spatula.

Based on experience, it can be stated that a girth gear's rolling strength and scuffing load capacity are improved by reducing flank roughness and increasing the effective contact ratio. During the running-in period, limited wear is intentionally produced at the tooth flanks, which improves the tooth surface roughness and further increases the load contact area.

During the running-in, increased lubricant throughput is necessary to flush out the initial metal wear generated through the removal of the surface peaks and high spots during the first stages of the process. An average running-in time is 300 hours.

Table 5. *Lubricant consumption for running-in and operational lubrication*

Application	Consumption (g/cm/op. hour.)	
	Running-in	Operational
Rotary drum drives (coolers)	4	1.0 – 1.5
Single pinion kiln drives	5	1.5 – 2.0
Single pinion mill or kiln drives	6	2.0 – 2.5
Single pinion mill drives and double pinion kiln drives of large dimensions	7	2.5 – 3.0
Double pinion mill drives	8	3.0 – 3.5

Selection

Determine the minimum diameter of the girth gear (table 9)
$d_{drum} < d_{max}$

Determine the required girth gear selection torque
$T_{drum} * K_A = T_{2D}$

If the required drum torque is not known, it can be calculated from motor power
$T_{drum} = 9{,}550 * P_1 * \eta / n_2$

Select ratio, face width, and material in accordance with the equation below
$T_{2D} < T_2 * f_w * f_d$

Selection example

Application:	Kiln
Outer diameter of drum:	d_{drum} = 4500 mm
Input power of drum:	P_1 = 2 * 200 kW (double pinion)
Rotation speed of drum:	n_2 = 1.4 rpm,
Main gear unit:	three-stage
Smallest possible girth gear:	$d_{drum} < d_{max}$, d_{max} = 4600 mm
Application factor:	K_A = 1.75
Drive number factor:	f_d = 1.95
Efficiency of drive:	η = 0.96
Drum torque: kNm	T_{drum} = 9,550 * (2 * 200) * 0.96 / 1.4 = 2619
Selection torque of drum:	T_{2D} = 2619 * 1.75 = 4583 kNm
Select girth gear from table 7:	$T_{2D} < T_2 * f_w * f_{d,}$ 4583 < 2050 * 1.95 * 1.19
Selected girth gear:	
Material:	GJS-1000-5 (ADI)
Tip diameter of drum, d_a:	5346 mm
Number of teeth of girth gear, z_2:	196
Number of teeth of pinion, z_1:	18
Girth gear ratio, i:	10.89:1
Face width of girth gear, b:	380 mm

Symbols

d_{drum}	outer diameter of drum, [mm]
d_{max}	max. diameter of drum, [mm]
T_{drum}	drum torque, [kNm]
K_A	selection factor, (table 6)
T_{2D}	girth gear selection torque, [kNm]
T_2	nominal torque of girth gear, [kNm] (table 10)
P_1	input power of drum drive, [kW]
n_2	drum speed, [rpm]
z_1	number of teeth of pinion
z_2	number of teeth of girth gear
i	open gear ratio
f_w	face width factor, (table 7)
f_d	drive number factor, (8)
η	efficiency, (table 9)

Table 6. *Selection factor, K_A*

Application	Selection factor, K_A
Coolers	1.5
Dryers	1.5
Kilns	1.75
Grinding Mills:	
Ball	2.25
Autogenous	2.4
Rod	2.5

Table 7. *Face width factor, f_w*

B, [mm]	100	140	180	220	260	300	340	380	420	460	500
Factor	0.38	0.52	0.65	0.78	0.89	1.00	1.10	1.19	1.27	1.34	1.40

Table 8. *Drive number factor, f_d*

Single drive	1
Double drive	1.95

Table 9. *Approximated efficiency, η*

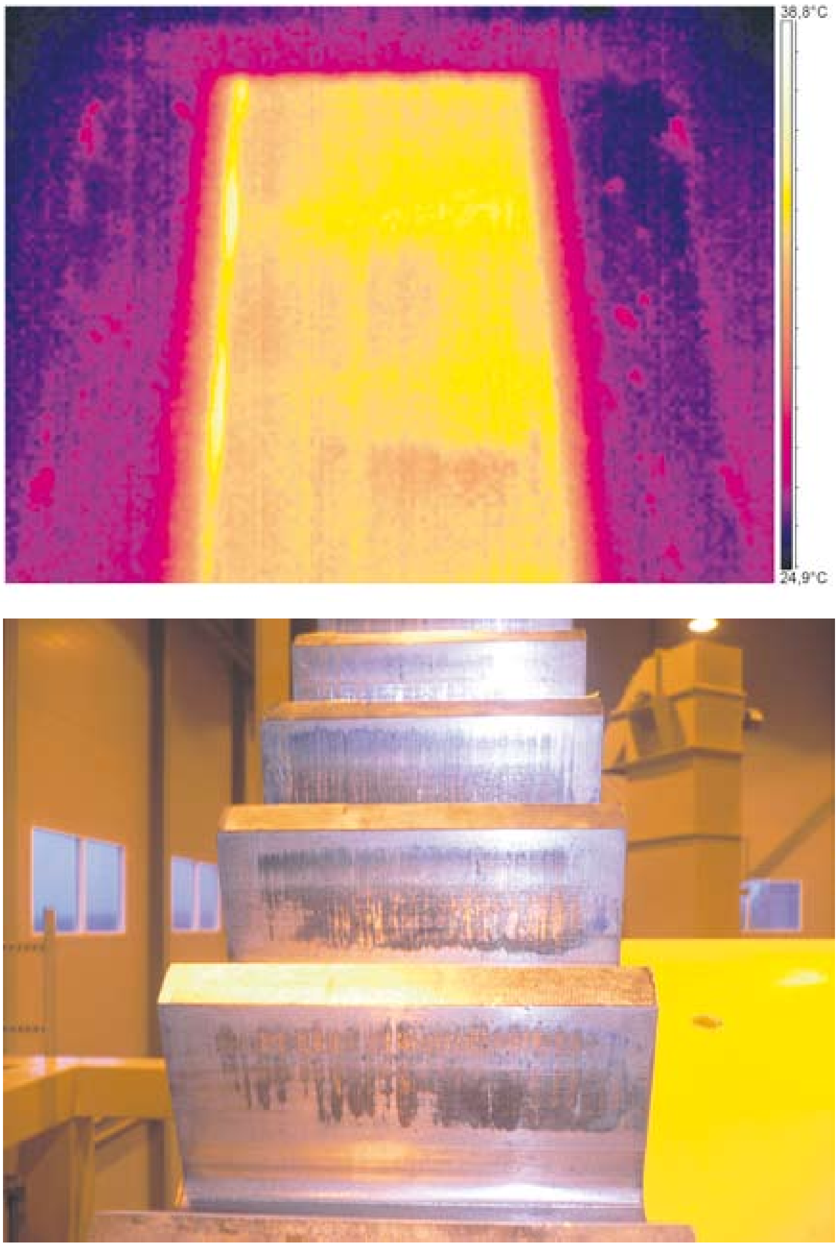
Number of stages including girth gear	1	2	3	4	5
efficiency	0.99	0.98	0.97	0.96	0.95

Table 10. *Selection table for girth gear*

Geometrical data					GJS-800-2					GJS-1000-5 (ADI)				
					n2 [rpm]					n2 [rpm]				
$d_{max,}$ [mm]	$d_{a,}$ [mm]	z_2	z_1	i	1	5	10	20	*10*	1	5	10	20	*10*
					P [kW]				*T2[kNm]*	P [kW]				*T2[kNm]*
2450	3078	112	18	6.22	34	180	370	765	355	125	635	1250	2450	1200
			24	4.67	47	255	535	1100	510	130	645	1250	2500	1200
			30	3.73	63	335	705	1450	675	130	650	1250	2500	1200
2850	3456	126	18	7.00	39	205	425	890	405	140	710	1400	2750	1300
			24	5.25	54	295	625	1300	600	145	720	1400	2800	1350
			30	4.20	73	395	830	1700	795	145	730	1400	2800	1350
3200	3834	140	18	7.78	44	235	480	1000	460	155	785	1550	3050	1450
			24	5.83	62	340	720	1500	690	160	800	1550	3050	1500
			30	4.67	84	455	955	1950	915	160	805	1550	3050	1500
3600	4212	154	18	8.56	50	260	535	1050	510	170	865	1700	3350	1600
			24	6.42	66	360	765	1600	730	175	875	1700	3350	1650
			30	5.13	90	490	1000	2150	985	175	885	1700	3350	1650
3850	4590	168	18	9.33	55	290	595	1200	565	185	940	1850	3600	1750
			24	7.00	73	405	855	1800	820	190	950	1850	3600	1750
			30	5.60	100	550	1150	2400	1100	195	960	1850	3600	1800
4250	4968	182	18	10.11	60	315	650	1300	620	205	1000	2000	3900	1900
			24	7.58	81	445	950	1900	905	205	1000	2000	3900	1900
			30	6.07	110	610	1250	2600	1200	210	1000	2000	3900	1900
4600	5346	196	18	10.89	65	345	705	1400	675	220	1050	2150	4150	2050
			24	8.17	89	490	1000	2100	995	220	1100	2150	4150	2050
			30	6.53	120	670	1400	2850	1300	225	1100	2150	4150	2050
5000	5724	210	18	11.67	71	370	765	1500	730	235	1150	2250	4450	2150
			24	8.75	96	535	1100	2300	1050	235	1150	2300	4450	2200
			30	7.00	130	730	1500	3100	1450	240	1150	2300	4400	2200
5400	6102	224	18	12.44	76	400	820	1600	780	250	1200	2400	4700	2300
			24	9.33	100	550	1150	2300	1100	255	1250	2450	4650	2300
			30	7.47	135	760	1600	3150	1500	255	1250	2450	4650	2350
5650	6480	238	18	13.22	81	425	875	1700	835	255	1250	2500	4800	2350
			24	9.92	105	590	1250	2500	1200	260	1250	2500	4800	2400
			30	7.93	145	820	1700	3150	1650	265	1300	2500	4750	2400
6100	6939	255	18	14.17	88	460	945	1850	900	275	1350	2650	5150	2550
			24	10.63	115	645	1350	2700	1300	280	1350	2650	5100	2550
			30	8.50	160	895	1850	3350	1750	280	1350	2650	5000	2550
6500	7344	270	18	15.00	93	490	1000	1950	960	290	1400	2800	5400	2700
			24	11.25	125	690	1450	2900	1400	295	1450	2800	5350	2700
			30	9.00	170	960	1950	3500	1900	300	1450	2800	5250	2700
6900	7749	285	18	15.83	99	520	1050	2100	1000	305	1500	2950	5650	2800
			24	11.88	130	740	1550	3100	1450	310	1500	2950	5600	2800
			30	9.50	185	1000	2050	3650	1950	315	1500	2950	5500	2800
7300	8127	299	18	16.61	100	550	1100	2150	1050	320	1550	3100	5900	2950
			24	12.46	140	745	1550	3050	1500	325	1600	3100	5800	2950
			30	9.97	185	1000	2050	3550	2000	330	1600	3050	5700	2950

The allowable radial and axial runout as well the required tooth clearance can be found in the installation instructions. If necessary, all necessary support and adjustment tools for installation can be delivered as an option.

The maintenance inspection typically covers assessment of the load carrying pattern, checking of the lubrication system, vibration measurement of the pinion bearings, measurement of the temperature profile across the tooth width, and documentation of the condition of the flanks. Written documentation includes photos of tooth flanks, which facilitate detection of changes in the girth gear condition by comparing and analyzing earlier inspection documents.



Picture 3. *Infrared photo of a running girth gear, load carrying pattern photo*

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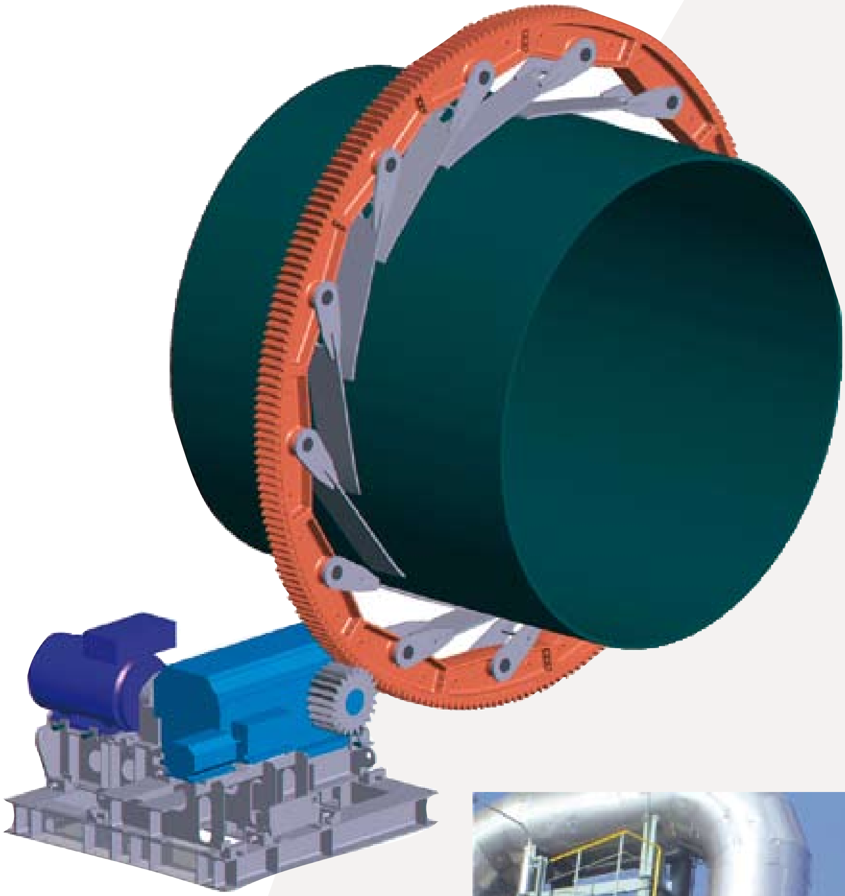
COMPLETE DRIVE PACKAGE



Girth gear is typically part of drum drive delivery which consist steel foundation, main drive, pinion, girth gear, fixing elements and girth gear cover. Depending on the application emergency drives, indexing drives, couplings, clutches and brakes can be also part of the delivery scope.

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