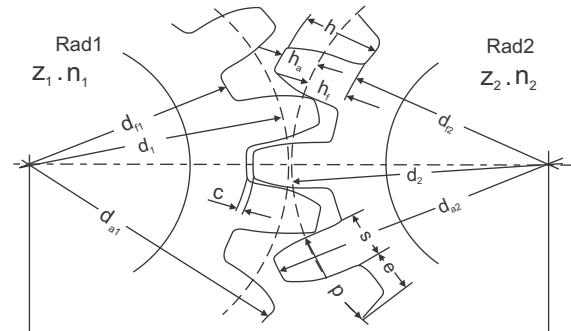


Gearwheels - Toothing Geometrie and Forces

reference data and formulae



Description	Symbol / Formula	Dimension
module	$m = \frac{p}{\pi} = \frac{d}{z}$	mm
number of teeth	$z = \frac{d}{m}$	
pitch diameter	$d = z \cdot m$	mm
outside diameter	$d_a = (z + 2) \cdot m$	mm
root diameter	$d_f = (z - 2,5) \cdot m$	mm
addendum	$h_a = m$	mm
dedendum	$h_f = m + c \approx 1,25 \cdot m = m + 0,25 \cdot m$	mm
tooth depth	$h = h_a + h_f = 2 \cdot m + c$	mm
centre distance	$a = \left(\frac{d_1 + d_2}{2}\right) = \frac{(z_1 + z_2) \cdot m}{2}$	mm
ratio	$i = \frac{z_2}{z_1} = \frac{d_2}{d_1} = \frac{n_2}{n_1}$	
peripheral force	$F_u = \frac{2 \cdot 10^3 \cdot T}{d}$	N
torque	$T = \frac{9550 \cdot P}{n}$	Nm
peripheral speed	$v = \frac{z_1 \cdot m \cdot n_1}{19100} = \frac{d_1 \cdot n_1}{19100}$	m/s
output	P	kW
r.p.m.	n	1/min



Selection and Load Tables for Straight Spur Gears, Ratio 1:1

Maximum permissible torques in Nm
with good grease lubrication, robust bearing, speed $v=2,5$ m/s,
loading and safety factor 1,0. The values of the table were
calculated in accordance with DIN 3990. A Safety factor for tooth
stress $S_F=1,4$ and for Herzian stress $S_H=1,0$ is taken in account.

module 1
b = 15 mm

Number of teeth	Pitch diameter	r.p.m.	C45 soft [Nm]	C45 induction hardened [Nm]
15	15	3183	0,6	1,9
20	20	2387	1,0	3,4
25	25	1910	1,6	4,7
30	30	1592	2,3	7,3
40	40	1194	4,4	12,9
50	50	955	6,9	19,5
60	60	796	9,2	32,4

module 1.5
b = 17 mm

Number of teeth	Pitch diameter	r.p.m.	C45 soft [Nm]	C45 induction hardened [Nm]
15	22,5	2122	1,6	4,7
20	30	1592	2,7	8,6
25	37,5	1273	4,1	13,2
30	45	1061	6,0	19,2
40	60	796	10,0	36,2
50	75	637	17,5	55,1
60	90	531	25,0	83,3

module 2
b = 20 mm

Number of teeth	Pitch diameter	r.p.m.	C45 soft [Nm]	C45 induction hardened [Nm]	16MnCr5 case hardened and ground [Nm]
15	30	1592	3,5	9,7	46,0
20	40	1194	5,6	18,4	73,9
25	50	955	8,5	29,2	106,8
30	60	796	12,6	41,9	163,6
40	80	597	23,1	73,7	326,3
50	100	477	37,8	115,4	489,5
60	120	398	47,6	174,4	750,0

module 2,5
b = 25 mm

Number of teeth	Pitch diameter	r.p.m.	C45 soft [Nm]	C45 induction hardened [Nm]	16MnCr5 case hardened and ground [Nm]
15	37,5	1273	5,9	18,2	70,5
20	50	955	10,0	35,0	106,8
25	62,5	764	15,9	47,7	163,6
30	75	637	23,1	75,6	252,4
40	100	477	42,0	135,9	463,2
50	125	382	65,2	206,0	795,5
60	150	318	90,1	338,0	1090,1



Selection and Load Tables for Straight Spur Gears, Ratio 1:1

Maximum permissible torques in Nm
with good grease lubrication, robust bearing, speed $v=2,5$ m/s,
loading and safety factor 1,0. The values of the table were
calculated in accordance with DIN 3990. A Safety factor for tooth
stress $S_F=1,4$ and for Herzian stress $S_H=1,0$ is taken in account.

module **3**
b = 30 mm

Number of teeth	Pitch diameter	r.p.m.	C45 soft [Nm]	C45 induction hardened [Nm]	16MnCr5 case hardened and ground [Nm]
15	45	1061	10,0	35,0	134,1
20	60	796	18,0	57,7	159,1
25	75	637	28,9	88,5	252,6
30	90	531	41,7	135,9	384,2
40	120	398	73,5	242,0	715,9
50	150	318	117,1	398,0	1477,3
60	180	265	162,9	565,8	1659,1

module **4**
b = 40 mm

Number of teeth	Pitch diameter	r.p.m.	C45 soft [Nm]	C45 induction hardened [Nm]	16MnCr5 case hardened and ground [Nm]
15	60	796	25,1	80,8	473,7
20	80	597	44,3	146,2	537,0
25	100	477	66,2	206,0	727,3
30	120	398	94,1	344,0	977,3
40	160	298	174,3	578,9	1840,9
50	200	239	300,0	921,1	3241,4
60	240	199	406,7	1400,0	

module **5**
b = 50 mm

Number of teeth	Pitch diameter	r.p.m.	C45 soft [Nm]	C45 induction hardened [Nm]	16MnCr5 case hardened and ground [Nm]
15	75	637	47,4	153,8	670,5
20	100	477	83,8	290,0	863,6
25	125	382	128,6	428,0	1318,2
30	150	318	182,9	631,6	1886,4
40	200	239	360,0	1089,5	2810,3
50	250	191	542,9	1769,2	
60	300	159	771,4	2538,5	

module **6**
b = 60 mm

Number of teeth	Pitch diameter	r.p.m.	C45 soft [Nm]	C45 induction hardened [Nm]	16MnCr5 case hardened and ground [Nm]
15	90	531	91,0	284,0	1181,8
20	120	398	163,3	476,0	1272,7
25	150	318	269,4	736,8	2413,8
30	180	265	402,7	1100,0	3655,2
40	240	199	768,7	1900,0	6704,5
50	300	159	1369,3		
60	360	133	2452,7		



Selection and Load Tables for Straight Spur Gears, Ratio 1:1

Maximum permissible torques in Nm
with good grease lubrication, robust bearing, speed $v=2,5$ m/s,
loading and safety factor 1,0. The values of the table were
calculated in accordance with DIN 3990. A Safety factor for tooth
stress $S_F=1,4$ and for Herzian stress $S_H=1,0$ is taken in account.

module 8
b = 64 mm

Number of teeth	Pitch diameter	r.p.m.	C45 soft [Nm]	C45 induction hardened [Nm]
15	120	398	157,1	789,5
20	160	298	293,3	1425,0
25	200	239	426,7	2000,0

module 1.591
b = 12 mm

Number of teeth	Pitch diameter	r.p.m.	C45 soft [Nm]	C45 induction hardened [Nm]
15	23,865	2001	1,7	5,4
20	31,82	1501	3,3	9,5
25	39,775	1200	4,5	15,0
30	47,73	1000	6,9	22,3
40	63,64	750	12,4	40,8
50	79,55	600	10,9	65,4
60	95,46	500	20,1	94,9

module 3,183
b = 25 mm

Number of teeth	Pitch diameter	r.p.m.	C45 soft [Nm]	C45 induction hardened [Nm]
15	47,745	1000	12,4	39,6
20	63,66	750	21,3	69,2
25	79,575	600	34,0	100,0
30	95,49	500	46,8	156,4
40	127,32	375	86,8	300,0
50	159,15	300	140,0	447,1
60	190,98	250	188,6	697,4



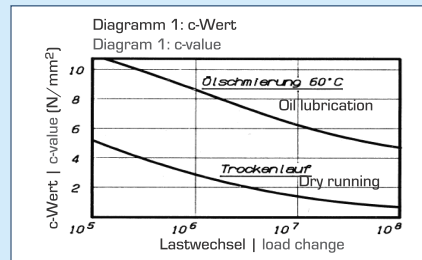
Calculation of Plastic Spur Gears

WMH-Bevel and Spur gears made of acetal resin (Hostaform C) are manufactured by injection moulding. Their relatively high hardness and low friction coefficient gives them particularly good wear properties. Their running characteristics are not effected by air humidity or lubricating oil. They operate satisfactorily in water and are resistant to many chemicals.

Under normal loads and working conditions they can operate at temperatures between -40° C and +100° C.

rough calculation of plastic spur gears with so-called c-value

Description	Symbol / Formula	Dimension
Transferable peripheral force	$F_u = c \cdot b \cdot p$	N
b: width of tooth		mm
p: pitch		mm
c: diagram 1		N/mm ²
Transferable output	$P = \frac{F_u \cdot d \cdot n}{19,1 \cdot 10^6}$	kW
d: pitch diameter		mm
n: r.p.m.		1/min



calculation strength at the root

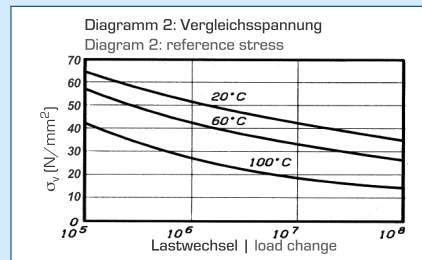
Description	Symbol / Formula	Dimension
Reference stress tooth root	$\sigma_v = \frac{F_u \cdot q_k \cdot q_r}{m \cdot b}$	N/mm ²
Score value diagram q_k	$q_r \approx 1,1-1,2$	

number of teeth

80 65 50 40 34 28 24 21 18 17 16 15 14 13 12 11 10

2,5 3,0 3,5 4,0 4,5 5,0

q_k

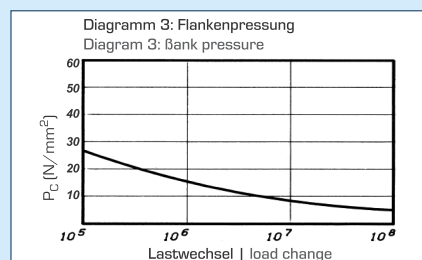


calculation flank pressure

Flank pressure

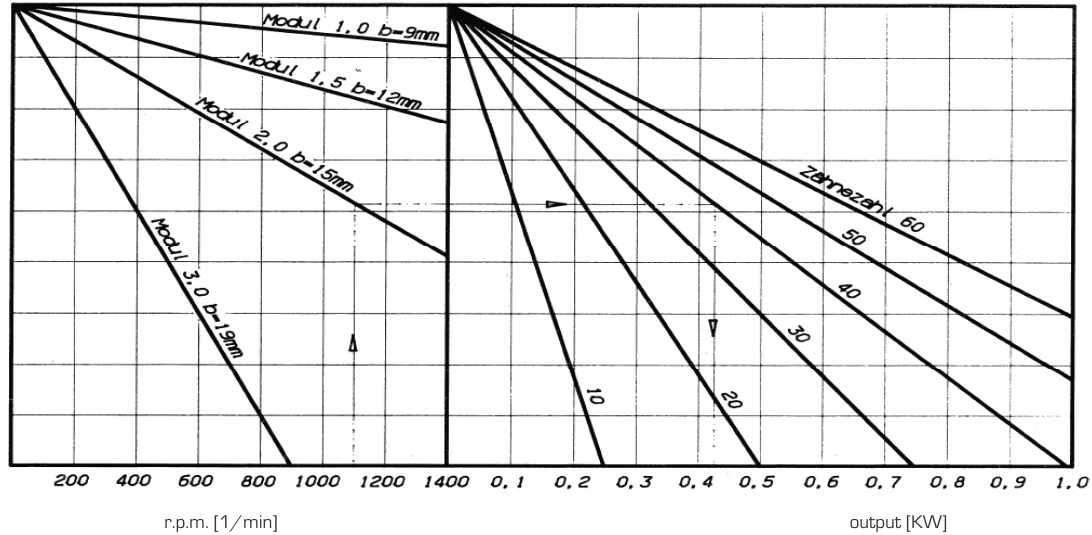
$$P_c = \sqrt{\frac{F_u}{b \cdot d} \cdot \frac{i+1}{i}} + \sqrt{\frac{0,8}{\frac{1}{E_1} \cdot \frac{1}{E_2} \cdot \sin \alpha \cdot \cos \alpha}} \quad \text{N/mm}_2$$

i: Übersetzungsverhältnis | gear ratio
 E_1, E_2 : E-Modul Zahnradwerkstoffe | E-module material spur gears
 E (Hostaform C): 1400 N/mm²
 α : Eingriffswinkel | pressure angle 20°



Calculation of Plastic Spur Gears

performance diagram applicable for plastic gears



calculation example

data

module $m = 2 \text{ mm}$
 number of teeth $z = 30$
 width of teeth $b = 15$
 RPM $n = 1500 \text{ 1/min}$
 ratio $i = 1$

c-Value choosen from diagram 1 1 N/mm^2

pitch	$p = m \cdot i$	$p = 2 \text{ mm} \cdot 1$	$p = 6,28 \text{ mm}$
peripheral force	$F_u = c \cdot b \cdot p$	$F_u = 1 \text{ N/mm}^2 \cdot 15 \text{ mm} \cdot 6,28 \text{ mm}$	$F_u = 94,2 \text{ N}$
pitch diameter	$d = m \cdot z$	$d = 2 \text{ mm} \cdot 30$	$d = 60 \text{ mm}$
transferable output	$P = \frac{F_u \cdot d \cdot n}{19,1 \cdot 10^6}$	$P = \frac{94,2 \cdot 60 \text{ mm} \cdot 1500 \frac{1}{\text{min}}}{19,1 \cdot 10^6}$	$P = 0,44 \text{ KW}$
reference stress tooth root	$\sigma_v = \frac{F_u \cdot q_k \cdot q_r}{m \cdot b}$	$\sigma_v = \frac{94,2 \text{ N} \cdot 3,1 \cdot 1,2}{2 \text{ mm} \cdot 15 \text{ mm}}$	$\sigma = 11,7 \text{ N/mm}^2$

According to Diagram 2 the allowed reference stress tooth root is 28 N/mm^2 , at operating temperature 60° C .

Bank pressure:

$$P_c = \sqrt{\frac{F_u}{b \cdot d} \cdot \frac{i+1}{i}} + \sqrt{\frac{0,8}{\frac{1}{E_1} \cdot \frac{1}{E_2} \cdot \sin \alpha \cdot \cos \alpha}}$$

$$P_c = \sqrt{\frac{94,2 \text{ N}}{15 \text{ mm} \cdot 60 \text{ mm}} \cdot \frac{1+1}{1}} + \sqrt{\frac{0,8}{\frac{1}{1400 \text{ N/mm}^2} \cdot \frac{1}{1400 \text{ N/mm}^2} \cdot \sin 20^\circ \cdot \cos 20^\circ}} \quad P_c = 19,1 \text{ N/mm}^2$$

According to Diagram 3 the limit for wearout of the plastic spur gears is at about 5 Million load changes.



Racks

Sonderanfertigungen

Custom Made Parts

Content

Due to our extensive manufacturing capabilities, we offer a wide range of custom made racks:

Racks with Ground Teeth

- Straight or helical teeth
- Max. length is 3 000 mm
- Gearing up to module 16
- Racks are ground on all faces
- Materials, hardening or surface coating according to customer requirements

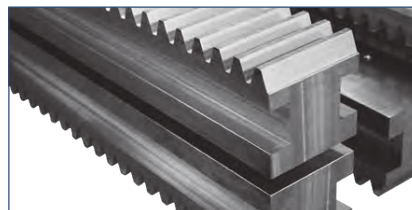
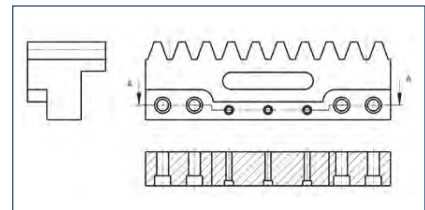
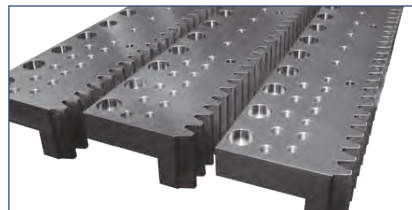
Racks in Milled Design

- Straight or helical teeth
- Max. length in one setting is 4 000 mm
- Modules 0,5 - 30
- Back and side surfaces either ground or milled
- Materials, hardening or surface coating according to customer requirements

Mounting Pieces

To ensure accurate pitch distance between two racks during assembly (for instructions see page B 35).

In addition to our standard range (page B 18) we offer mounting pieces with other modules and individually chosen dimensions.



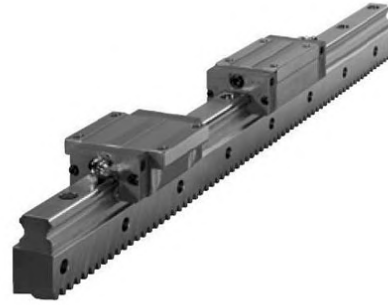
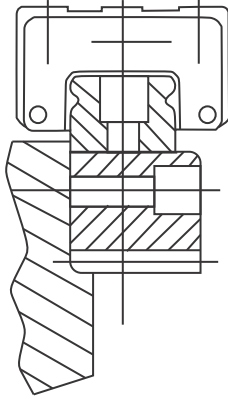
We offer more than competitive prices - contact our engineering department!



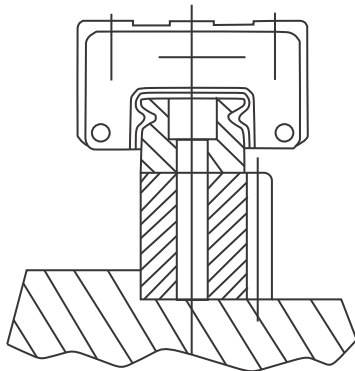
Racks for Guideways for Linear Guideways Z Series ⁽¹⁾



Design of the 180° rack guideway



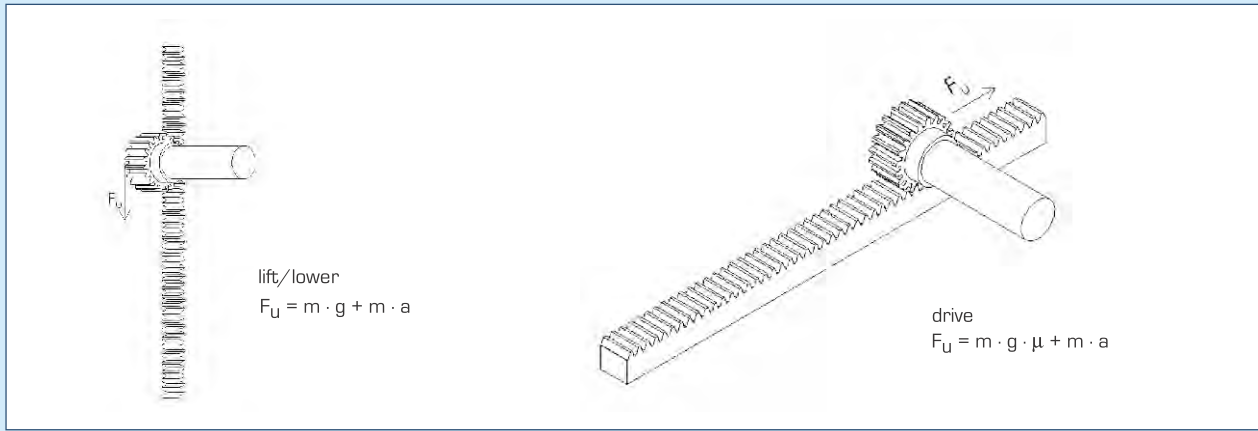
Design of the 90° rack guideway



[1] For more information about our Z series, please see catalogue chapter „Linear Drives“. General notes about our product range you'll find on the pages R 5 & R 6, for geometric dimensions please see the pages R 7 - R 10.



Racks - Selection Rack and Pinion Drive



general

Description	Symbol / Formula	Dimension
acceleration	$a = \frac{v}{t} = \frac{2 \cdot s}{t^2}$	m/s ²
speed	$v = \frac{s}{t} = \sqrt{2 \cdot a \cdot s}$	m/s
distance	s	m
time	t	s
revolutions per minute, rpm	$n = \frac{v \cdot 60.000}{\pi \cdot d_0}$	1/min
pitch diameter	d ₀	mm
torque	$M = \frac{F_u \cdot d_0}{2000}$	Nm
power	$P = \frac{M \cdot n}{9550} = \frac{F_u \cdot n \cdot d_0}{19100}$	kW

On pages B 33 and B 34 are listed some selection tables for rack/pinion drives for the maximum permissible power.

The dimensioning happened with
 application factor: 1.0
 safety for stress at single tooth contact: 1.0
 safety for Tooth root stress: 1.4
 service life in hours: 20,000 h

We calculate with following values for rolling load $\sigma_{F \text{ lim}}$
 and bending load $\sigma_{H \text{ lim}}$

Material	$\sigma_{F \text{ lim}} \text{ (N/mm}^2\text{)}$	$\sigma_{H \text{ lim}} \text{ (N/mm}^2\text{)}$
C45	440	550
C45 induction hardened	750	1250
16MnCr5 carburised and hardened	920	1500
42CrMo4V	600	730



Racks - Selection and Load Tables

Maximum permissible torques in Nm with adequate lubrication with safety- and application factor 1.0; and a speed of 1.5 m / s

module		1 mm b=10 mm				1,5 mm b=15 mm				2 mm b=20 mm				
number of teeth		15	20	25	40	15	20	25	40	15	20	25	30	40
rack	pinion													
material & tooth system														
C45 soft straight	C45 soft	0,3	0,9	1,1	10,7	1,0	2,8	8,8	35,3	4,4	14,1	26,9	44,2	98,2
	C45 ind.-hardened	1,2	2,5	4,5	14,7	2,0	5,7	17,7	60,0	13,8	28,1	48,0	74,1	134,7
C45 ind.- hardened straight	C45 ind.-hardened	2,0	8,7	14,7	25,3	7,0	28,2	52,9	95,3	29,8	75,0	128,2	151,7	200,2
C45 ind.- hardened ground teeth; straight	C45 ind.-hardened													
C45 ind.- hardened ground teeth; helical	C45 ind.-hardened													
16MnCr5 case-hardened ground teeth; straight	16MnCr5 case-hardened ground teeth										159,8	200,0	238,2	320,3
16MnCr5 case-hardened ground teeth; helical	16MnCr5 case-hardened ground teeth										180,9	227,8	270,2	365,2
42CrMo4V quenched & tempered; straight	16MnCr5 case-hardened ground teeth										42,8	68,2	100,2	186,7
42CrMo4V quenched & tempered; helical	16MnCr5 case-hardened ground teeth										45,9	73,0	104,8	195,1

module		2,5 mm b=25 mm				3 mm b=30 mm				
number of teeth		15	20	25	40	15	20	25	30	40
rack	pinion									
material & tooth system										
C45 soft straight	C45 soft	8,5	25,1	52,8	175,2	13,0	46,0	97,2	159,6	339,8
	C45 ind.-hardened	15,6	45,1	95,0	245,2	40,8	91,9	168,2	243,4	450,3
C45 ind.- hardened straight	C45 ind.-hardened	60,0	149,9	255,8	399,7	87,1	215,1	440,0	497,3	780,0
C45 ind.- hardened ground teeth; straight	C45 ind.-hardened									
C45 ind.- hardened ground teeth; helical	C45 ind.-hardened									
16MnCr5 case-hardened ground teeth; straight	16MnCr5 case-hardened ground teeth						420,1	530,2		880,0
16MnCr5 case-hardened ground teeth; helical	16MnCr5 case-hardened ground teeth						504,7	605,0		
42CrMo4V quenched & tempered; straight	16MnCr5 case-hardened ground teeth						138,0	234,8		620,2
42CrMo4V quenched & tempered; helical	16MnCr5 case-hardened ground teeth						145,0	245,1		



Racks - Selection and Load Tables

Maximum permissible torques in Nm with adequate lubrication with safety- and application factor 1.0; and a speed of 1.5 m / s

module		4 mm b=40 mm					5 mm b=50 mm				6 mm b=60 mm		
		15	20	25	30	40	15	20	25	40	15	20	25
number of teeth													
rack	pinion												
material & tooth system													
C45 soft straight	C45 soft	39,9	115,1	240,2	414,1	850,1	89,8	230,0	489,7	800,4	170,2	429,7	870,4
	C45 ind.-hardened	130,0	249,9	415,2	593,2	1100,4	259,7	499,7	800,4	1200,1	470,0	810,3	1400,5
C45 ind.- hardened straight	C45 ind.-hardened	220,2	640,1	1070,1	1306,9	1710,4	450,0	1150,0	1660,4	1999,5	794,6	2200,5	2950,0
C45 ind.- hardened ground teeth; straight	C45 ind.-hardened						1080,0		2060,0				3640,0
C45 ind.- hardened ground teeth; helical	C45 ind.-hardened						1330,0					3170,0	4180,0
16MnCr5 case-hardened ground teeth; straight	16MnCr5 case-hardened ground teeth		1070,1	1330,4		2000,3							
16MnCr5 case-hardened ground teeth; helical	16MnCr5 case-hardened ground teeth	770,1	1219,7	1530,2									
42CrMo4V quenched & tempered; straight	16MnCr5 case-hardened ground teeth		355,2	575,0		1550,4							
42CrMo4V quenched & tempered; helical	16MnCr5 case-hardened ground teeth	204,8	370,3	589,9									

module		8 mm b=80 mm			10 mm b=100 mm	
		15	20	25	20	
number of teeth						
rack	pinion					
material & tooth system						
C45 soft straight	C45 soft	420,1	1050,5	2101,0	4000,0	
	C45 ind.-hardened	1149,5	2101,0	3398,0		
C45 ind.- hardened straight	C45 ind.-hardened	1898,0	4502,0	7500,0	9900,0	
C45 ind.- hardened ground teeth; straight	C45 ind.-hardened		6870,0		12850,0	
C45 ind.- hardened ground teeth; helical	C45 ind.-hardened				14000,0	
16MnCr5 case-hardened ground teeth; straight	16MnCr5 case-hardened ground teeth					
16MnCr5 case-hardened ground teeth; helical	16MnCr5 case-hardened ground teeth					
42CrMo4V quenched & tempered; straight	16MnCr5 case-hardened ground teeth					
42CrMo4V quenched & tempered; helical	16MnCr5 case-hardened ground teeth					



Racks - Assembly Instruction



- Positioning and fixing the rack (for example with clamps).
- Mount the rack with screws accordant to the defined torque.



- Connect another rack with the help of the mounting piece (mounting pieces see on page B 18).
- Mount the rack with screws accordant to the defined torque.



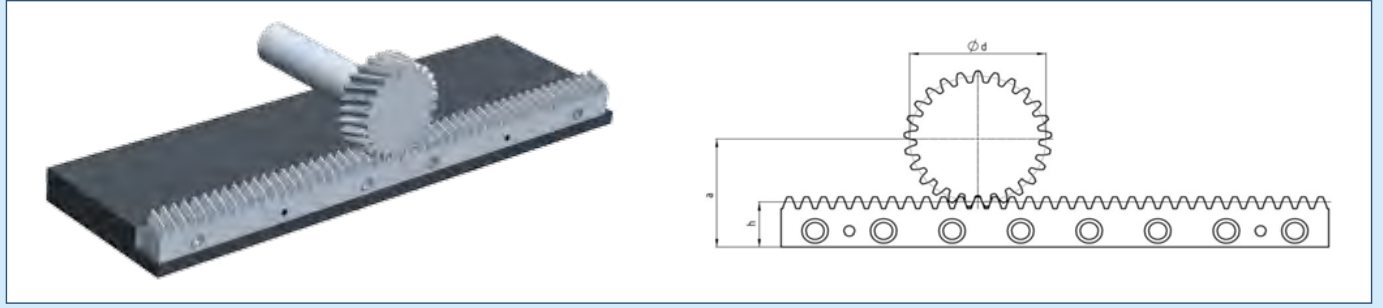
- After mounting these racks check the parallelism and the connection from one rack to the other.
- As well check the correct aligning of the racks.



- After the checkup the register pins reaming and pin the racks.



Racks - Center Distance

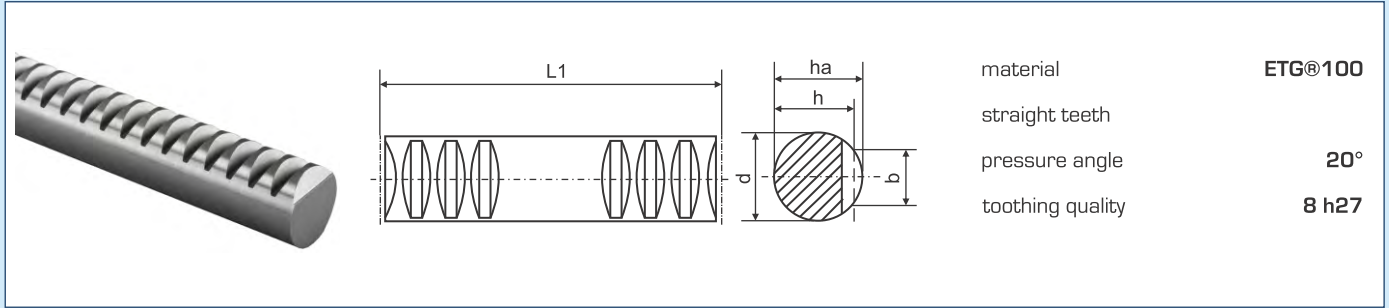


The center distance a resulting in the distance from the middle of the pinion to the back area of the rack to following formula:

$$a = h + \frac{d}{2}$$



Round Racks for Continuous Mounting



ground outside diameter h6

Modul Module	theor. L ₁	z**	d _{h6}	b	h _a	h	[kg]	Bestell Nr. Part No.
1,0	999,02	318	10	6,0	10	9,0	1,35	141-410-100
1,5	999,02	212	15	9,0	15	13,5	1,70	141-415-100
2,0	999,02	159	20	12,0	20	18,0	2,20	141-420-100

z**... number of teeth

ETG®100 is a high-quality alloy steel with a tensile strength of 960-1100 N/mm².
 The outside diameter is ground h6.

Please see also our bushes on page B 26.

Both ends of the rack are manufactured in such a way that they can be joint together in any length.
 For the mounting we propose the use of mounting pieces as described on page B 18.

