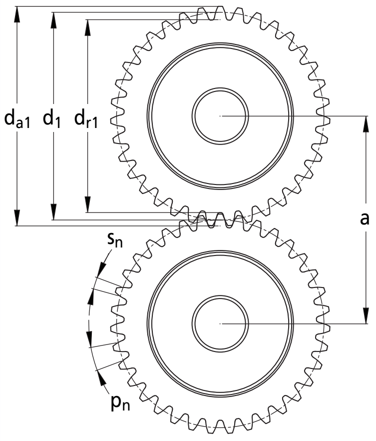
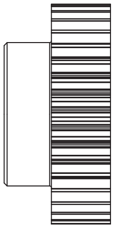
PRECISION GEARS

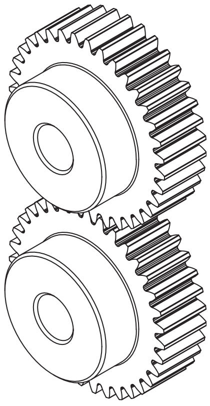
Spur Gears

Description	Symbol	Unit	Equation
Normal Module	m_n		
Transverse Module	m_t		$= m_n$
Normal Pressure Angle	α_n	degrees	$= 20°$
Transverse Pressure Angle	α_t	degrees	$= \alpha_n$
Number of Teeth	z		
Profile Shift Coefficient	x		= zero for Ondrives standard gears
Addendum	h_a	mm	$= 1.00 \cdot m_n$ (for Ondrives standard gears)
Dedendum	h_f	mm	$= 1.25 \cdot m_n$ (for Ondrives standard gears)
Tooth Depth	h	mm	$= 2.25 \cdot m_n$ (for Ondrives standard gears)
Gear Ratio	u		$= z_2 / z_1$
Centre Distance	a	mm	$= (d_1 + d_2) / 2$
Pitch Circle Diameter	d	mm	$= z \cdot m_n$
Tip Diameter	d_a	mm	$= d + (2m_n \cdot x) + (2 \cdot m_n)$
Root Diameter	d_r	mm	$= d_a - (2 \cdot h)$
Normal Pitch	p_n	mm	$= \pi \cdot m_n$
Normal Tooth Thickness in Pitch Circle	s_n	mm	$= (p_n / 2) + 2m_n \cdot x \cdot \tan \alpha_n$

When working with a pair of gears the subscript 1 & 2 denotes input (drive) and output (driven) gear.
Tip diameter is the theoretical diameter of the gear without tooth thickness tolerance applied.
For s_n at x = zero, this is the theoretical tooth thickness. Actual tooth thickness will be less.
The subscript e is for upper allowance values and i for lower allowance values.







PRECISION GEARS

Spur Gears

Gear Quality

Standard metal gears are supplied to quality Grade 7 DIN 3961 based on Pitch total deviation F_p, Pitch deviation f_p, Radial runout F_r and Pitch error f_u. Skive hobbed gears are supplied to quality Grade 6 DIN 3961.
GG25 Cast Iron, PEEK GF30® and Delrin (POM) are supplied to quality Grade 8 DIN 3961.
Ondrives can manufacture gears to higher grades on request. Ondrives can offer testing certification for a gear's individual parameters using the latest CMM machine with gear measuring software.
Double and single flank testing is available on request. Please contact our technical department for details.

Comparisons of Grade Standards

Example 3 mod, 50 teeth, 30mm face width spur gear

	Standard Grade	DIN 3961 6	DIN 3961 7	ISO 1328 7	AGMA 10
Pitch total deviation	F_p µm	32	44	50	51
Pitch deviation	f_p µm	8	12	13	13
Radial runout	F_r µm	22	31	40	41
Pitch error	f_u µm	10	15	-	-
Double flank composite transmission error	F_i'' µm	26	36	61	61
Double flank tooth-to-tooth transmission error	f_i'' µm	11	15	21	20

Torque

Stated value for metal spur gears is maximum torque (T_2) based on two identical gears with the same number of teeth running at standard centres. Value is minimum from surface stress or bending stress.
Other factors including duty cycle and temperature will affect maximum allowable torque and service life. Wear is dependant on lubrication. We recommend that each user compute their own values based on actual operating conditions and test in application.

Materials	**817M40**	**805M20**	**303 Stainless**	**316 Stainless**	**GG25 Cast Iron**
Input Speed	100 rpm Uniform, 12 hours running per day				
Bending Stress Factor S_b	32000	50000	20000	15800	7600
Surface Stress Factor S_c	3000	11000	1800	1400	1350

Stated value for plastic spur gears is maximum torque (T_2) based on two identical gears with the same number of teeth running at standard centres. Value is minimum from surface stress, bending stress or bulk/suface temperature using method from BS 6168:1987. The torque capacity of plastic gears is highly dependant on operating condition. All values are reference only. We recommend that each user test in application under specific operation conditions of application.

Materials	**Delrin POM (White)**	**PEEK GF30® (Light Brown)**
Input Speed / No. of Load Cycles	100 rpm / 10^8	100 rpm / 10^8
Limiting Bending Stress	22.0 N/mm^2	30 N/mm^2*
Limiting Surface Stress	13.5 N/mm^2	80 N/mm^2*
Initial Temperature	20°C	20°C
Max. Bulk or Surface Temperature	60°C	80°C
Coefficient of Friction	0.18 (Dry)	0.25**

* Reference Only ** Approximate value based on initial light greasing.

Maximum torque for titanium gears is approximatey 30% of 817M40 steel gears.
Due to lack of stress factors we are unable to offer specific values. Testing in application is required.

Torque for anti-backlash spur gears is limited by the spring rating. Please contact our Technical department for details.

When selecting gears application factors should be applied to required torque.

$T_2 > T_{\text{required}} \times K_a$

Application factor K_a

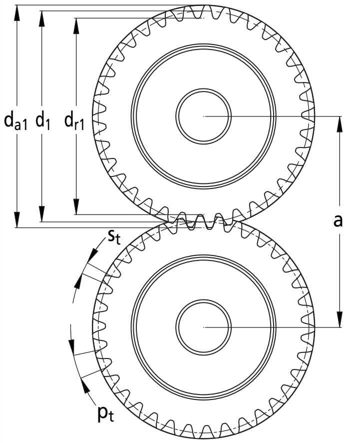
Working characteristics of driving machine	**Working characteristics of driven machine** **Uniform**	**Light Shocks**	**Moderate Shocks**	**Heavy Shocks**
Uniform	1.00	1.25	1.50	1.75
Light Shocks	1.10	1.35	1.60	1.85
Moderate Shocks	1.25	1.50	1.75	2.00
Heavy Shocks	1.50	1.75	2.00	2.25+

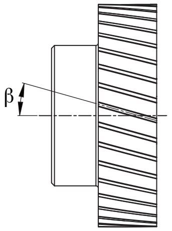
PRECISION GEARS

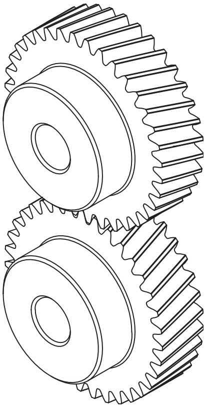
Parallel Helical Gears

Description	Symbol	Unit	Equation
Normal Module	m_n		
Transverse Module	m_t		$= m_n / \cos\beta$
Axial Module	m_x		$= m_n / \sin\beta$
Normal Pressure Angle	α_n	degrees	$= 20°$
Transverse Pressure Angle	α_t	degrees	$= \tan^{-1}(\tan\alpha_n / \cos\beta)$
Helix Angle	β	degrees	$= 15°$
Lead Angle	λ	degrees	$= 90 - \beta$
Number of Teeth	z		
Profile Shift Coefficient	x		= zero for Ondrives standard gears
Addendum	h_a	mm	$= 1.00 \cdot m_n$ (for Ondrives standard gears)
Dedendum	h_f	mm	$= 1.25 \cdot m_n$ (for Ondrives standard gears)
Tooth Depth	h	mm	$= 2.25 \cdot m_n$ (for Ondrives standard gears)
Gear Ratio	u		$= z_2 / z_1$
Centre Distance	a	mm	$= (d_1 + d_2) / 2$
Pitch Circle Diameter	d	mm	$= z \cdot m_t = (z \cdot m_n) / \cos\beta$
Tip Diameter	d_a	mm	$= d + (2m_n \cdot x) + (2 \cdot m_n)$
Root Diameter	d_r	mm	$= d_a - (2 \cdot h)$
Normal Pitch	p_n	mm	$= \pi \cdot m_n$
Transverse Pitch	p_t	mm	$= \pi \cdot m_t = (\pi \cdot m_n) / \cos\beta$
Axial Pitch	p_x	mm	$= \pi \cdot m_x = (\pi \cdot m_n) / \sin\beta$
Normal Tooth Thickness in Pitch Circle	s_n	mm	$= (p_n / 2) + 2m_n \cdot x \cdot \tan\alpha_n$
Transverse Tooth Thickness in Pitch Circle	s_t	mm	$= (p_t / 2) + 2m_n \cdot x \cdot \tan\alpha_t$

When working with a pair of gears the subscript 1 & 2 denotes input (drive) and output (driven) gear.
Tip diameter is the theoretical diameter of the gear without tooth thickness tolerance applied.
For s_n & s_t, when x = zero, this is the theoretical tooth thickness. Actual tooth thickness will be less.
The subscript e is for upper allowance values and i for lower allowance values.
For two helical gears to run together one must be left hand and the other right hand helix.







Parallel Helical Gears

Gear Quality

Standard gears are supplied to quality grade 7e25 DIN 3961 based on the following parameters

Radial Runout $F_r = \left(\left(1.68 + 2.18\sqrt{m_n} + \left(2.3 + 1.2\log m_n\right)\bullet d^{1/4}\right)\bullet 1.4\right)\bullet 1.4$

Pitch Deviation $f_p = \left(\left(4 + 0.315\left(m_n + 0.25\sqrt{d}\right)\right)\bullet 1.4\right)\bullet 1.4$

Total Pitch Deviation $F_p = \left(\left(7.25 \bullet \frac{d^{1/3}}{z^{1/7}}\right)\bullet 1.4\right)\bullet 1.4$

Pitch Error $f_u = \left(\left(5 + 0.4\left(m_n + 0.25\sqrt{d}\right)\right)\bullet 1.4\right)\bullet 1.4$

Ondrives manufacture gears to higher quality grades on request. Ondrives can offer testing certification of a gears individual parameters using the latest CMM machine with gear measuring software. Double and single flank testing is available on request. Please contact our technical department for details.

Comparisons of Grade Standards

Example 3 mod, 50 teeth, 30mm face width 15° helix parallel helical gear

	Standard Grade	**DIN 3961 7**	**ISO 7**	**AGMA 10**
Pitch total deviation	F_p µm	47	50	55
Pitch deviation	f_p µm	12	13	12
Radial runout	F_r µm	31	40	44
Pitch error	f_u µm	15	-	-
Double flank composite transmission error	F_i'' µm	36	61	65
Double flank tooth-to-tooth transmission error	f_i'' µm	15	21	20

Torque

Stated value is maximum torque (T_2) based on two identical gears with the same number of teeth running at standard centres. Value is minimum from surface stress or bending stress.
Other factors including duty cycle and temperature will affect maximum allowable torque and service life. Wear is dependant on lubrication. We recommend that each user compute their own values based on actual operating conditions and test in application.

Materials	**817M40**	**805M20**	**303 Stainless**	**316 Stainless**
Input Speed	100 rpm Uniform, 12 hours running per day			
Bending Stress Factor S_b	32000	50000	20000	15800
Surface Stress Factor S_c	3000	11000	1800	1400

When selecting gears application factors should be applied to required torque.

$T_2 > T_{required} \times K_a$

Application factor K_a

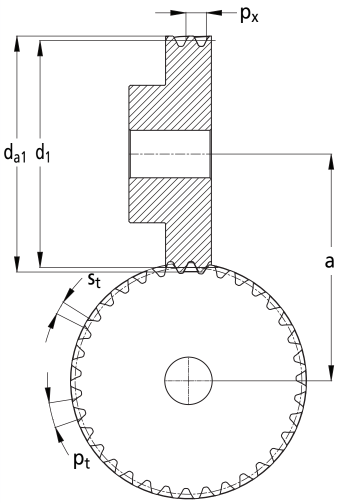
Working characteristics of driving machine	**Working characteristics of driven machine** **Uniform**	**Light Shocks**	**Moderate Shocks**	**Heavy Shocks**
Uniform	1.00	1.25	1.50	1.75
Light Shocks	1.10	1.35	1.60	1.85
Moderate Shocks	1.25	1.50	1.75	2.00
Heavy Shocks	1.50	1.75	2.00	2.25+

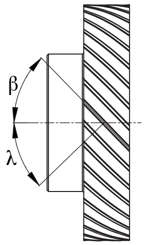
PRECISION GEARS

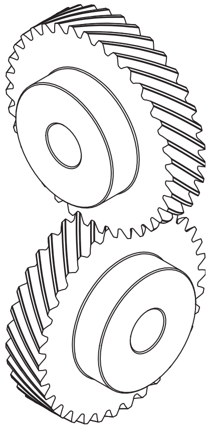
Crossed Axis Helical Gears

Description	Symbol	Unit	Equation
Normal Module	m_n		
Transverse Module	m_t		$= m_n / \cos\beta$
Axial Module	m_x		$= m_n / \sin\beta$
Normal Pressure Angle	α_n	degrees	$= 20°$
Transverse Pressure Angle	α_t	degrees	$= \tan^{-1}(\tan\alpha_n / \cos\beta)$
Helix Angle	β	degrees	$= 45°$
Lead Angle	λ	degrees	$= 90 - \beta$
Number of Teeth	z		
Profile Shift Coefficient	x		= zero for Ondrives standard gears
Addendum	h_a	mm	$= 1.00 \cdot m_n$ (for Ondrives standard gears)
Dedendum	h_f	mm	$= 1.25 \cdot m_n$ (for Ondrives standard gears)
Tooth Depth	h	mm	$= 2.25 \cdot m_n$ (for Ondrives standard gears)
Gear Ratio	u		$= z_2 / z_1$
Centre Distance	a	mm	$= (d_1 + d_2) / 2$
Pitch Circle Diameter	d	mm	$= z \cdot m_t = (z \cdot m_n) / \cos\beta$
Tip Diameter	d_a	mm	$= d + (2m_n \cdot x) + (2 \cdot m_n)$
Root Diameter	d_r	mm	$= d_a - (2 \cdot h)$
Normal Pitch	p_n	mm	$= \pi \cdot m_n$
Transverse Pitch	p_t	mm	$= \pi \cdot m_t = (\pi \cdot m_n) / \cos\beta$
Axial Pitch	p_x	mm	$= \pi \cdot m_x = (\pi \cdot m_n) / \sin\beta$
Normal Tooth Thickness in Pitch Circle	s_n	mm	$= (p_n / 2) + 2m_n \cdot x \cdot \tan\alpha_n$
Transverse Tooth Thickness in Pitch Circle	s_t	mm	$= (p_t / 2) + 2m_n \cdot x \cdot \tan\alpha_t$

When working with a pair of gears the subscript 1 & 2 denotes input (drive) and output (driven) gear.
Tip diameter is the theoretical diameter of the gear without tooth thickness tolerance applied.
For s_n & s_t, when x = zero, this is the theoretical tooth thickness. Actual tooth thickness will be less.
The subscript e is for upper allowance values and i for lower allowance values.
For two crossed axis helical gears to run together both must be right hand or left hand helix.

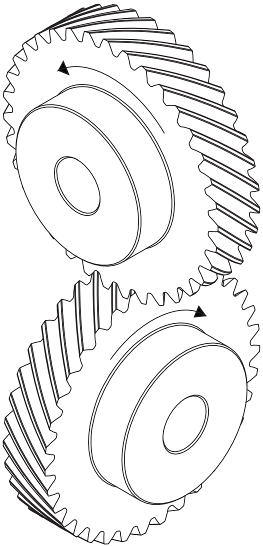




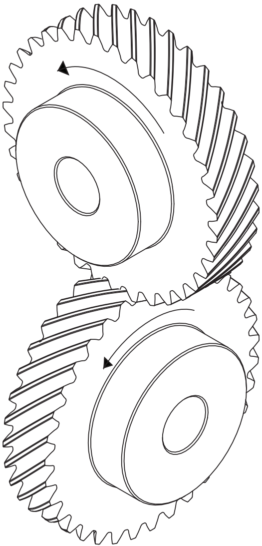


Crossed Axis Helical Gears

Direction of Rotation



Right Hand Helix



Left Hand Helix

Torque

Stated value is maximum torque (T_2) based on two identical gears with the same number of teeth running at standard centres.
Crossed axis helical gears transmit load by point contact. The limiting condition is typically surface stress.
Other factors including duty cycle and temperature will affect maximum allowable torque and service life.
Wear is dependant on lubrication.
We recommend that each user compute their own values based on actual operating conditions and test in application.

Materials	**817M40**	**805M20 (SAE 8620) Case Hd.**
Input Speed	100 rpm Uniform speed	
Bending Stress Factor S_b	32000	50000
Surface Stress Factor S_c	3000	11000
Lubrication	Mineral Oil	
Lubrication Viscosity	Between 60mm^2/s and 130mm^2/s at 60°C	

When selecting gears application factors should be applied to required torque.

$T_2 > T_{\text{required}} \times K_a$

Application factor K_a

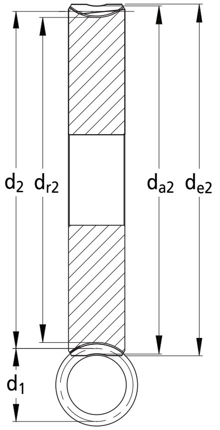
	Working characteristics of driven machine			
Working characteristics of driving machine	**Uniform**	**Light Shocks**	**Moderate Shocks**	**Heavy Shocks**
Uniform	1.00	1.25	1.50	1.75
Light Shocks	1.10	1.35	1.60	1.85
Moderate Shocks	1.25	1.50	1.75	2.00
Heavy Shocks	1.50	1.75	2.00	2.25+

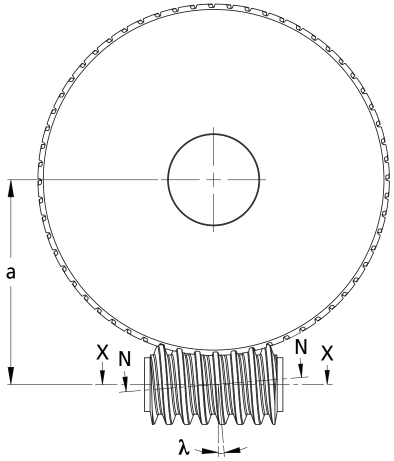
PRECISION GEARS

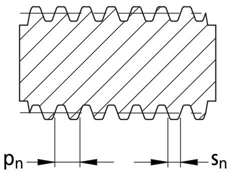
Worms & Wheels

Description	Symbol	Unit	Equation
Axial Module	m_x		
Normal Module	m_n		$= m_x \cdot \cos\lambda$
Normal Pressure Angle	α_n	degrees	$= 20°$
Transverse Pressure Angle	α_t	degrees	$= \tan^{-1}(\tan\alpha_n / \cos\lambda)$
Lead Angle	λ	degrees	$= \tan^{-1}((m_x \cdot z_1) / d_2)$
Helix Angle	β	degrees	$= 90 - \lambda$
Number of Starts on Worm	z_1		
Number of Teeth on Wheel	z_2		
Profile Shift Coefficient	x		= zero for Ondrives standard worms
Addendum	h_a	mm	$= 1.00 \cdot m_x$ (for Ondrives standard worms)
Dedendum	h_f	mm	$= 1.25 \cdot m_x$ (for Ondrives standard worms)
Tooth Depth	h	mm	$= 2.25 \cdot m_x$ (for Ondrives standard worms)
Gear Ratio	u		$= z_2 / z_1$
Centre Distance	a	mm	$= (d_1 + d_2) / 2$
Reference Diameter of Worm	d_1	mm	$= (m_x \cdot z_1) / \tan\lambda$
Reference Diameter of Wheel	d_2	mm	$= m_x \cdot z_2$
Tip Diameter of Worm	d_{a1}	mm	$= d_1 + (2 \cdot m_x)$
Root Diameter of Worm	d_{r1}	mm	$= d_{a1} - (2 \cdot h)$
Tip Diameter of Wheel	d_{a2}	mm	$= d_2 + (2 \cdot m_x)$
Root Diameter of Wheel	d_{r2}	mm	$= d_{a2} - (2 \cdot h)$
Outside Diameter of Wheel	d_{e2}	mm	$= d_{a2} + m_x$
Normal Pitch	p_n	mm	$= \pi \cdot m_n$
Axial Pitch	p_x	mm	$= \pi \cdot m_x$
Normal Tooth Thickness in Pitch Circle	s_n	mm	$= s_x \cdot \cos\lambda$
Transverse Tooth Thickness in Pitch Circle	s_x	mm	$= (p_x / 2)$

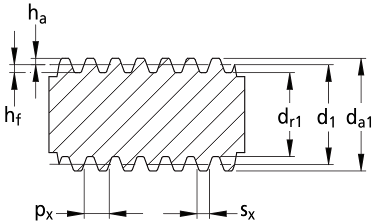
Gear Quality: Steel and Stainless Steel Worm = 6 DIN 3974, Bronze Wheel = 7 DIN 3974.
PEEK and Delrin Worms 7 DIN 3974, PEEK and Delrin Wheel = 8 DIN 3974.
When working with a gear set the subscript 1 denotes a worm and 2 a wheel.
Tip diameter is the theoretical diameter of the gear without tooth thickness tolerance applied.
For s_n & s_x, when x = zero, this is the theoretical tooth thickness.
Actual tooth thickness will be less.
The subscript e is for upper allowance values and i for lower allowance values.







Normal Section



Axial Section

Torque

Stated value is maximum torque based on lowest figure from surface durability, tooth root strength or wear.
Values for bronze and cast iron wheel are for matching with steel 817M40 worm.
Value is output torque T_2 at wheel.
Tooth root failure of teeth on wheel before teeth of worm is assumed.

Other factors including worm shaft deflection, duty cycle and temperature will affect maximum allowable torque and service life.
Wear is dependant on lubrication.
We recommend that each user compute their own values based on actual operating conditions and test in application.

	Surface Durability	**Tooth Root Strength**
Input Speed	100 rpm Uniform Speed	
Life	25,000 hours	
Limiting Stress N/mm² (CA104)	15.2	69
Limiting Stress N/mm² (GG25)	4.1	40
Lubrication	Mineral Oil	
Lubrication Viscosity	Between 60mm²/s and 130mm²/s at 60°C	
Application Factor	1.00	

	Delrin POM	**PEEK GF30®**
Maximum torque as % of CA104 Aluminium Bronze Wheel	50%*	55 - 65%*
Maximum Wheel Temperature	60°C	80°C

* Approximate value based on plastic wheel running with steel worm to allow initial selection. Testing in application will be required.

Torque for anti backlash wormwheel gears is limited by the spring rating. Please contact our Technical department for details.

When selecting worm application factors should be applied to required torque.

$T_2 > T_{\text{required}} \times K_a$

Application factor K_a

	Working characteristics of driven machine			
Working characteristics of driving machine	**Uniform**	**Light Shocks**	**Moderate Shocks**	**Heavy Shocks**
Uniform	1.00	1.25	1.50	1.75
Light Shocks	1.10	1.35	1.60	1.85
Moderate Shocks	1.25	1.50	1.75	2.00
Heavy Shocks	1.50	1.75	2.00	2.25+

Efficiency

The following allows an approximate value for the efficiency of the gears to be found allowing required input torque and gear forces to be calculated. Efficiency is dependant on lubrication and the figures below do not include bearing, seal and other losses.

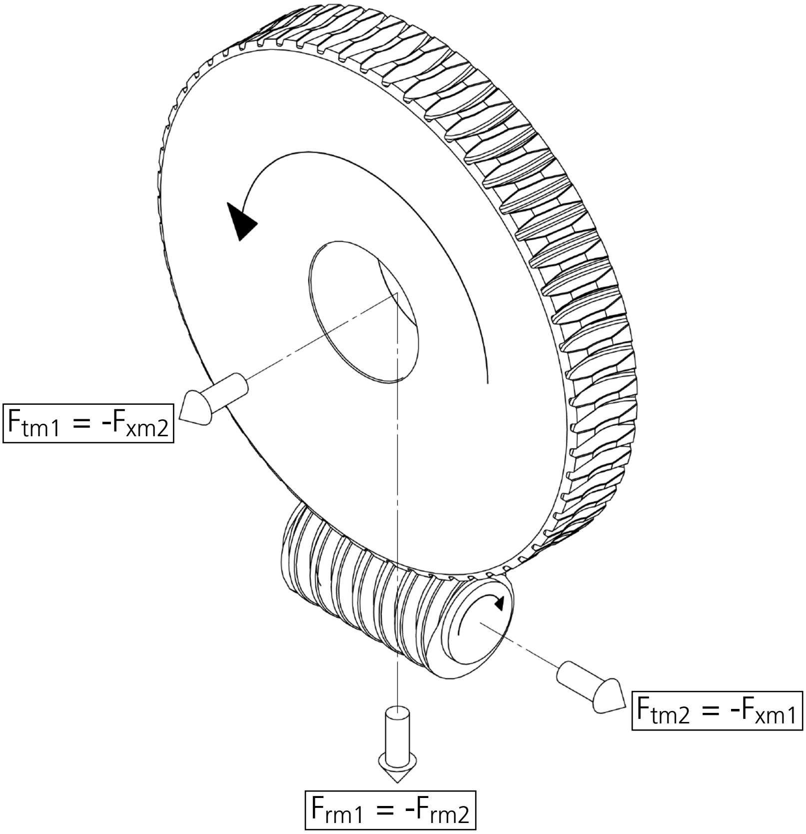
$\eta = \tan \lambda / \tan (\lambda + pz)$
$pz = \arctan (\mu)$
$v_g = (d_1 \cdot n_1) / (19098 . \tan \lambda)$
$T_1 = (T_2 / u) * \eta$

T_1 = Input Torque (Nm)
T_2 = Output Torque (Nm)
u = Ratio
η = Efficiency
λ = Lead Angle (degrees)
μ = Coefficient of Friction
pz = Angle of Friction
v_g = Sliding Speed (m/s)
n_1 = rpm of Worm
d_1 = Pitch Diameter of Worm (mm)

Coefficient of friction μ (Mineral Oil)

Velocity Range (m/s)	μ for Velocities 0-30m/s									
	0	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**
0.0-0.9	0.1500	0.0803	0.0694	0.0623	0.0583	0.0543	0.0521	0.0500	0.0480	0.0459
1.0-1.9	0.0438	0.0423	0.0410	0.0396	0.0382	0.0369	0.0359	0.0352	0.0344	0.0336
2.0-2.9	0.0329	0.0322	0.0316	0.0309	0.0304	0.0297	0.0293	0.0289	0.0286	0.0280
3.0-3.9	0.0276	0.0272	0.0268	0.0265	0.0261	0.0257	0.0254	0.0251	0.0248	0.0245
4.0-4.9	0.0242	0.0239	0.0236	0.0234	0.0232	0.0229	0.0226	0.0224	0.0223	0.0221
5.0-5.9	0.0219	0.0217	0.0215	0.0214	0.0212	0.0210	0.0209	0.0207	0.0205	0.0203
6.0-6.9	0.0202	0.0200	0.0199	0.0197	0.0196	0.0194	0.0193	0.0192	0.0190	0.0189
7.0-7.9	0.0187	0.0186	0.0185	0.0184	0.0183	0.0182	0.0181	0.0179	0.0178	0.0177
8.0-8.9	0.0176	0.0175	0.0174	0.0173	0.0173	0.0172	0.0172	0.0170	0.0169	0.0169
9.0-9.9	0.0169	0.0168	0.0166	0.0166	0.0164	0.0164	0.0164	0.0163	0.0162	0.0162
10.0-10.9	0.0161	0.0160	0.0159	0.0159	0.0159	0.0158	0.0157	0.0156	0.0156	0.0156
11.0-11.9	0.0155	0.0154	0.0154	0.0153	0.0153	0.0152	0.0151	0.0151	0.0150	0.0150
12.0-12.9	0.0149	0.0149	0.0149	0.0148	0.0148	0.0147	0.0147	0.0147	0.0146	0.0146
13.0-13.9	0.0146	0.0146	0.0146	0.0145	0.0145	0.0144	0.0144	0.0144	0.0144	0.0144
14.0-14.9	0.0143	0.0143	0.0143	0.0142	0.0142	0.0142	0.0142	0.0142	0.0141	0.0141
15.0-15.9	0.0141	0.0141	0.0141	0.0140	0.0140	0.0139	0.0139	0.0139	0.0139	0.0139
16.0-16.9	0.0139	0.0138	0.0138	0.0138	0.0138	0.0138	0.0137	0.0137	0.0137	0.0137
17.0-17.9	0.0137	0.0136	0.0136	0.0136	0.0136	0.0136	0.0135	0.0135	0.0135	0.0135
18.0-18.9	0.0135	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134	0.0134
19.0-19.9	0.0134	0.0133	0.0133	0.0133	0.0133	0.0133	0.0132	0.0132	0.0132	0.0132
20.0-20.9	0.0132	0.0131	0.0131	0.0131	0.0131	0.0131	0.0131	0.0131	0.0131	0.0131
21.0-21.9	0.0131	0.0130	0.0130	0.0130	0.0130	0.0130	0.0130	0.0130	0.0130	0.0130
22.0-22.9	0.0130	0.0129	0.0129	0.0129	0.0129	0.0129	0.0129	0.0129	0.0129	0.0129
23.0-23.9	0.0129	0.0129	0.0128	0.0128	0.0128	0.0128	0.0128	0.0128	0.0128	0.0128
24.0-24.9	0.0128	0.0128	0.0127	0.0127	0.0127	0.0127	0.0127	0.0127	0.0127	0.0127
25.0-25.9	0.0127	0.0127	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126	0.0126
26.0-26.9	0.0126	0.0126	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125	0.0125
27.0-27.9	0.0125	0.0125	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124
28.0-28.9	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0124	0.0123	0.0123
29.0-29.9	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123	0.0123
30.0	0.0123	-	-	-	-	-	-	-	-	-

Gear Forces and Direction of Rotation



$F_{tm1} = 2000*(T_1 / d_1) = - F_{xm2}$
$F_{tm2} = 2000*(T_2 / d_2) = - F_{xm1}$
$F_{rm1} = F_{tm1}*[\tan 20 / (\sin \lambda + p_z)] = - F_{rm2}$

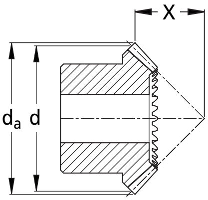
pz = arctan (μ)
F_{tm} = Tangential force (N)
F_{xm} = Axial force (N)
F_{rm} = Radial force (N)
The subscript 1 and 2 relate to the worm and wheel.

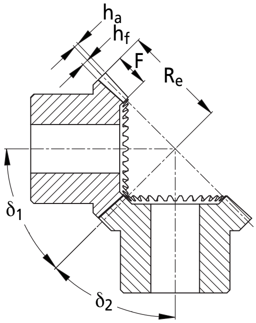
Ondrives worm and wheel gears are supplied right hand lead as standard.
The black arrows show the direction of rotation.

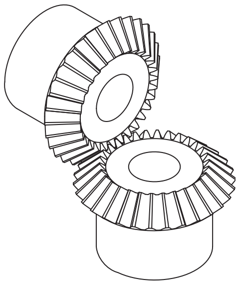
Bevel Gears

Description	Symbol	Unit	Equation
Normal Module	m_n		
Pressure Angle	α	degrees	= 20°
Shaft Angle	Σ	degrees	= (90° for Ondrives standard gears)
Number of Teeth	z_1, z_2		
Gear Ratio	u		$= z_2 / z_1$
Pitch Diameter of Worm	d_1, d_2	mm	$= z \cdot m_n$
Pitch Cone Angle	δ_1	degrees	$= \delta_1 = \tan^{-1} (\sin \Sigma / (u + \cos \Sigma))$
Pitch Cone Angle	δ_2	degrees	$= \delta_2 = \Sigma - \delta_1$
Cone Distance	R_e	mm	$= d_2 / 2 \sin \delta_2$
Addendum	h_a	mm	$= 1.00 \cdot m_n$ (for Ondrives standard gears)
Dedendum	h_f	mm	0.6 to $1.0m_n = 1.25 \cdot m_n$ (standard gears) 1.5 to $2.0m_n = 1.22 \cdot m_n$ (standard gears) $4.0m_n = 1.20 \cdot m_n$ (standard gears)
Outside Diameter	d_a	mm	$= d + 2\ ha \cdot \cos \delta$
Pitch Apex to Crown	X	mm	$= R_e \cos \delta - h_a \sin \delta$

Quality Grade 7 DIN 3965







Torque

Stated value is maximum torque (T_2) based on two identical gears with the same number of teeth running at standard centres.
Value is minimum from surface stress or bending stress.
Other factors including duty cycle and temperature will affect maximum allowable torque and service life.
Wear is dependant on lubrication.
We recommend that each user compute their own values based on actual operating conditions and test in application.

Materials	817M40	805M20	303 Stainless	316 Stainless
Input Speed	100 rpm Uniform, 12 hours running per day			
Bending Stress Factor S_b	32000	50000	20000	15800
Surface Stress Factor S_c	3000	11000	1800	1400

PRECISION GEARS

Materials

Ondrives can manufacture gears in a range of additional materials including bronzes, engineering plastics, special steels and stainless steels.
Gears can be heat treated by a range of methods to improve performance.
Please contact our Technical sales team who will be happy to discuss your specific requirements.

		Density (Kg/m^3)	Elongation after Fracture	Tensile Strength (N/mm^2)	0.2% Proof Stress (N/mm^2)
805M20	Case Hardened	7850	11%	980	785
817M40T		7850	5-13%	850-100	680
080M40		7850	7-17%	510-600	340
722M24T	Nitride Hardened	7850	13%	850-1000	650
303S21	Cold Drawn	8000	35-45%	480-510	180-200
316S16	Cold Drawn	8000	40%	515	205
17-4PH	Condition A	7780	10%	1103	100
CA104		7580	15%	750	430
PB2	Sand Cast	8600	5%	360-500	170-280
Brass CZ121		8470	20%	410	200
PEEK GF30		1490	2.70%	156	-
Delrin POM		1410	30%	67	-
Cast Iron GG25	Continuous Cast	7200	-	145-195	-
Titanium Ti-6AL-4V	Grade 5	4420	10-18%	895-1000	828-910

Material Equivalents

B.S. 970	En	DIN	Werkstoff	SAE/AISI
817M40T	24T	40NiCrMo8-4 / 34CrNiMo6	1.6562, 1.6582	4340, 4337
805M20	362	20NiCrMo2-2 / 20NiCrMo2	1.6523	8620
303S21	58	X10CrNiS189	1.4305	303
316S16	58J	X5CrNiMo17133	1.4436	316
080M40	8	C40	1.0511	1040
655M13	36	14NiCr14	1.5752	3415, 3310, 9314
722M24	40B	32CrMo12	1.7361	-

	ISO			
PB2	Cu89Sn11	CuSn12		SAE 64
CA104	GZ-CuAL10Ni	CuAL10Ni		ASTM B150 UNC C63200
Brass CZ121	CuZn39Pb3	-		UNC C38500

B.S. 1452	En	DIN
Cast Iron 250	EN-GJL-250	DIN 1691 GG25

	B.S.	UNS	Werkstoff	AMS
Titanium Ti-6AL-4V	2TA11	R56400	3.7165	4911/4928

PRECISION GEARS

Materials

Delrin POM (White)

DIN EN ISO 1043-1: POM C I polyacetal comopolymer.

Very good dimensional stability compared to Nylon & Hostaform.

Minimal absorption of moisture.

Good sliding properties.

High wear resistance.

High surface hardness.

High mechanical strength and stiffness compared to Nylon & Hostaform.

Can be in contact with food (FDA).

Delrin gears can be run dry or greased/oiled to improve wear.

PEEK GF30® (Light Brown)

DIN EN ISO 1043-1: PEEK I polyetheretherketone.

Excellent dimensional stability.

Outstanding high mechanical strength and hardness over a broad temperature range.

Shows only a slight distortion under the impact of mechanical load and high temperature.

Good electrical insulating properties.

Extremely high flame resistance.

Self-extinguishing.

Very low smoke emission in a case of a fire.

Can be run dry for slow speed hand operation.
Gears should be greased/oiled for all other operating conditions.

General Properties		**Delrin POM**	**PEEK GF30®**
Density	kg/m^3	1410	1490
Absorption of Moisture		0.20%	0.14%
Mechanical properties			
Yield Stress/ Tensile Strength	N/mm^2	67	156
Elongation at Break		30.0%	2.7%
Tensile Modulus of Elasticity	N/mm^2	2800	9700
Ball Indentation Hardness	N/mm^2	150	230
Shore - Hardness	Skala D	81	88
Coefficient of Friction against hardened and ground steel (dry)		0.10-0.30	0.38-0.46
Thermal Properties			
Melting Temperature	°C	165	343
Thermal Properties	W / (m · K)	0.31	0.43
Coefficient of Linear Thermal Expansion	10^{-6} K^{-1}	110	30
Service Temperature, long term (min.)	°C	-50	-20
Service Temperature, long term (max.)	°C	100	250
Service Temperature, short term	°C	140	310
Heat Deflection Temperature	°C	110	315
Electrical Properties			
Dielectric Constant		3.80	3.20
Dielectric Dissipation Factor		0.002	0.001
Specific Volume Resistivity	Ω · cm	1013	1014
Surface Resistivity	Ω	1013	1013
Comparative Tracking Index (test solution A)		600	175
Dielectric Strength	kV/mm	40	20

Backlash

The backlash figures given for spur, helical and crossed axis helical gears is the theoretical backlash for two identical gears at standard centre distance to the ISO 286 centre distance tolerance.
It is given as circumferential backlash in mm measured on pitch circle diameter. An upper and lower value is quoted.
Theoretical backlash is the difference between tooth thickness without and with tolerance applied.
Backlash is calculated according to DIN 3967
Ondrives can manufacture gears to a wide range of tolerances to suit customer application.
Please contact our Technical Sales team who will be happy to discuss your specific requirements.

Tooth Thickness Tolerances

Gear Type	Module 0.5 to 0.8	Module 1.0 to 3.0	Centre Distance Tolerance
Spur	7e/8e DIN 58405	e25 DIN 3967	Js7
Spur (Skive hobbed)	6e DIN 58405	e25 DIN 3967	Js7
Pinions	7e DIN 58405	e25 DIN 3967	-
Parallel Helical	7e DIN 58405	e25 DIN 3967	Js7
Crossed Axis Helical	7e DIN 58405	e25 DIN 3967	Js8
Worm & Wheel	7e/8e DIN 58405	e25 DIN 3967	Js8
		Module 0.6 to 4.0	
Bevel		7f24 DIN 3965/3967	

A_{sn} = Tooth thickness allowance which is the difference between measured gear tooth thickness and theoretical value measured in the normal section. When working with a pair of gears the subscript 1 & 2 denotes input (drive) and output (driven) gear. For worm and wheel, 1 relates to the worm and 2 to the wormwheel.
The subscript e is for upper allowance and i for lower allowance.

T_{sn} = Tooth thickness tolerance measured in the normal section. (mm)

$A_{sne} = S_n - S_{ne}$

$A_{sni} = A_{sne} - T_{sn} = S_n - S_{ni}$

Circumferential Backlash j_t

This is the length of arc on the pitch circle diameter through which each can be rotated whilst the other is held stationary.
It is measured in the transverse section.

$$j_t = \frac{A_{sn1} + A_{sn2}}{\cos\beta} + \Delta j_a$$

Units = mm & degrees

Normal Backlash j_n

This is the shortest distance between the flanks of the gears when the opposite flanks are in contact.
It is measured in the transverse section.

For spur, helical, crossed axis helical gear

$$j_n = j_t \bullet \cos\alpha_n \bullet \cos\beta$$

Units = mm & degrees

Change in Circumferential due to Centre Distance Tolerance $\triangle j_a$

$$\Delta j_a = 2 \bullet A_s \bullet \frac{\tan\alpha_n}{\cos\beta}$$

Units = mm & degrees

Spur Gear		Parallel Helical Gear		Crossed Axis Helical Gear	
Deviation from centre distance A_s (mm)	**Change in Backlash Δj_a (mm)**	**Deviation from centre distance A_s (mm)**	**Change in Backlash Δj_a (mm)**	**Deviation from centre distance A_s (mm)**	**Change in Backlash Δj_a (mm)**
0.001	0.001	0.001	0.001	0.001	0.001
0.010	0.007	0.010	0.008	0.010	0.010
0.015	0.011	0.015	0.011	0.015	0.015
0.020	0.015	0.020	0.015	0.020	0.021
0.025	0.018	0.025	0.019	0.025	0.026
0.030	0.022	0.030	0.023	0.030	0.031
0.035	0.025	0.035	0.026	0.035	0.036
0.040	0.029	0.040	0.030	0.040	0.041
0.045	0.033	0.045	0.034	0.045	0.046
0.050	0.036	0.050	0.038	0.050	0.051

Backlash

Angular Backlash j_θ

$$j_\theta = \frac{360 \times j_t}{\pi \times d_2}$$

Units = mm & degrees

d_2 = Reference diameter (mm)

A_s = centre distance tolerance (i.e. a = 30mm Js7, As = ±0.0105mm

α_n = Normal pressure angle ($\alpha_n = 20°$)

β = Helix angle (β = zero for spur gears)
Replace helix angle β with lead angle λ for worm and wheel.

1° = 60 arc minutes

e25 DIN 3967

Reference Diameter d (mm)		Upper Tooth Thickness Allowance	Tooth Thickness Tolerance
Over	Upto	A_{sne}	T_{sn}
-	10	-0.022mm	0.020mm
10	50	-0.030mm	0.030mm
50	125	-0.040mm	0.040mm
125	280	-0.056mm	0.050mm

7e DIN 58405

Reference Diameter d (mm)	Normal Module m_n	Upper Tooth Thickness Allowance A_{sne}	Tooth Thickness Tolerance T_{sn}
from 3 to 6	above 0.16 to 0.25	0.028	0.011
	above 0.25 to 0.6	0.030	0.012
	above 0.6 to 1.6	0.035	0.014
above 6 to 12	above 0.16 to 0.25	0.030	0.012
	above 0.25 to 0.6	0.035	0.014
	above 0.6 to 1.6	0.040	0.016
above 12 to 25	above 0.16 to 0.25	0.035	0.014
	above 0.25 to 0.6	0.040	0.016
	above 0.6 to 1.6	0.045	0.018
	above 1.6 to 3	0.050	0.020
above 25 to 50	above 0.16 to 0.25	0.040	0.016
	above 0.25 to 0.6	0.045	0.018
	above 0.6 to 1.6	0.050	0.020
	above 1.6 to 3	0.055	0.022
above 50 to 100	above 0.16 to 0.25	0.045	0.018
	above 0.25 to 0.6	0.050	0.020
	above 0.6 to 1.6	0.055	0.022
	above 1.6 to 3	0.063	0.024
above 100 to 200	above 0.6 to 1.6	0.063	0.024
	above 1.6 to 3	0.070	0.029
above 200 to 400	above 0.6 to 1.6	0.070	0.029
	above 1.6 to 3	0.080	0.032

*A_{sne} is converted from base tangent length allowance (A_W) according to $A_W = A_{sn} * \cos 20°$

Example for Calculating Backlash for Two Non-Identical Gears

Input Gear PSG0.5-20 7e
Ouput Gear PSG0.5-40 7e

1. Calculate the reference diameter d for each gear

PSG0.5-20 $d_1 = z * m_n = 10.00mm$
PSG0.5-40 $d_2 = 20.00mm$

2. Find A_{sne} and T_{sn} from the tables overleaf

PSG0.5-20 $A_{sne} = -0.035mm$ $T_{sn} = -0.014mm$
PSG0.5-40 $A_{sne} = -0.040mm$ $T_{sn} = -0.016mm$

3. Calculate A_{sni} for each gear

PSG0.5-20 $A_{sni} = A_{sne} - T_{sn} = -0.035-0.014 = -0.021mm$
PSG0.5-40 $A_{sni} = A_{sne} - T_{sn} = -0.040-0.016 = -0.024mm$

4. Calculate the centre distance of the two gears
and the centre distance tolerance

centre distance = (10 + 20) / 2 = 15mm
Js7 = ±0.009mm

5. Calculate the change in backlash due to centre distance

$$\Delta j_a = 2 \bullet A_s \bullet \frac{\tan \alpha_n}{\cos \beta} + 2 \bullet 0.009 \bullet \frac{\tan 20}{\cos 0} = 0.007mm$$

6. Calculate the maximum backlash
Remove the minus sign on A_{sn}

$$j_t = \frac{A_{sne1} + A_{sne2}}{\cos \beta} + \Delta j_a = \frac{0.035 + 0.040}{\cos 0} + 0.007 = 0.082mm$$

7. Calculate the minimum backlash
Remove the minus sign on A_{sn}

$$j_t = \frac{A_{sni1} + A_{sni2}}{\cos \beta} + \Delta j_a = \frac{0.021 + 0.024}{\cos 0} - 0.007 = 0.038mm$$

8. Convert to angular backlash

$$j_\theta = \frac{360 \text{ x } j_t}{\pi \text{ x } d_2}$$

1° = 60 arc minutes

$j_\theta =$ 28.208 to 13.072 arc minutes

PRECISION GEARS

Limits and Fits

Hole Sizes (mm)

Over	3	6	10	18	30	40	50	65	80	100	120	140	160	180	200	225
Inc.	6	10	18	30	40	50	65	80	100	120	140	160	180	200	225	250
Micrometres (10^{-3}m)																
F6	18	22	27	33	41		49		58		68			79		
	10	13	16	20	25		30		36		43			50		
F7	22	28	34	41	50		60		71		83			96		
	10	13	16	20	25		30		36		43			50		
G6	12	14	17	20	25		29		34		39			44		
	4	5	6	7	9		10		12		14			15		
G7	16	20	24	28	34		40		47		54			61		
	4	5	6	7	9		10		12		14			15		
H6	8	9	11	13	16		19		22		25			29		
	0	0	0	0	0		0		0		0			0		
H7	12	15	18	21	25		30		35		40			46		
	0	0	0	0	0		0		0		0			0		
H8	18	22	27	33	39		46		54		63			72		
	0	0	0	0	0		0		0		0			0		
H9	30	36	43	52	62		74		87		100			115		
	0	0	0	0	0		0		0		0			0		
H10	48	58	70	84	100		120		140		160			185		
	0	0	0	0	0		0		0		0			0		
H11	75	90	110	130	160		190		220		250			290		
	0	0	0	0	0		0		0		0			0		
J6	5	5	6	8	10		13		16		18			22		
	-3	-4	-5	-5	-6		-6		-6		-7			-7		
J7	6	8	10	12	14		18		22		26			30		
	-6	-7	-8	-9	-11		-12		-13		-14			-16		
J8	10	12	15	20	24		28		34		41			47		
	-8	-10	-12	-13	-15		-18		-20		-22			-25		
JS6	4	4.5	5.5	6.5	8		9.5		11		12.5			14.5		
	-4	-4.5	-5.5	-6.5	-8		-9.5		-11		-12.5			-14.5		
JS7	6	7.5	9	10.5	12.5		15		17.5		20			23		
	-6	-7.5	-9	-10.5	-12.5		-15		-17.5		-20			-23		
JS8	9	11	13.5	16.5	19.5		23		27		31.5			36		
	-9	-11	-13.5	-16.5	-19.5		-23		-27		-31.5			-36		
K6	2	2	2	2	3		4		4		4			5		
	-6	-7	-9	-11	-13		-15		-18		-21			-24		
M6	-1	-3	-4	-4	-4		-5		-6		-8			-8		
	-9	-12	-15	-17	-20		-24		-28		-33			-37		
M7	0	0	0	0	0		0		0		0			0		
	-12	-15	-18	-21	-25		-30		-35		-40			-46		

Limits and Fits

Hole Sizes (mm)

Over	3	6	10	18	30	40	50	65	80	100	120	140	160	180	200	225
Inc.	6	10	18	30	40	50	65	80	100	120	140	160	180	200	225	250
Micrometres (10^{-3}m)																
f6	-10	-13	-16	-20	-25		-30		-36		-43			-50		
	-18	-22	-27	-33	-41		-49		-58		-68			-79		
f7	-10	-13	-16	-20	-25		-30		-36		-43			-50		
	-22	-28	-34	-41	-50		-60		-71		-83			-96		
g5	-4	-5	-6	-7	-9		-10		-12		-14			-15		
	-9	-11	-14	-16	-20		-23		-27		-32			-35		
g6	-4	-5	-6	-7	-9		-10		-12		-14			-15		
	-12	-14	-17	-20	-25		-29		-34		-39			-44		
g7	-4	-5	-6	-7	-9		-10		-12		-14			-15		
	-16	-20	-24	-28	-34		-40		-47		-54			-61		
h6	0	0	0	0	0		0		0		0			0		
	-8	-9	-11	-13	-16		-19		-22		-25			-29		
h7	0	0	0	0	0		0		0		0			0		
	-12	-15	-18	-21	-25		-30		-35		-40			-46		
h8	0	0	0	0	0		0		0		0			0		
	-18	-22	-27	-33	-39		-46		-54		-63			-72		
h9	0	0	0	0	0		0		0		0			0		
	-30	-36	-43	-52	-62		-74		-87		-100			-115		
h10	0	0	0	0	0		0		0		0			0		
	-48	-58	-70	-84	-100		-120		-140		-160			-185		
h11	0	0	0	0	0		0		0		0			0		
	-75	-90	-110	-130	-160		-190		-220		-250			-290		
j6	6	7	8	9	11		12		13		14			16		
	-2	-2	-3	-4	-5		-7		-9		-11			-13		
j7	8	10	12	13	15		18		20		22			25		
	-4	-5	-6	-8	-10		-12		-15		-18			-21		
js5	2.5	3	4	4.5	5.5		6.5		7.5		9			10		
	-2.5	-3	-4	-4.5	-5.5		-6.5		-7.5		-9			-10		
js6	4	4.5	5.5	6.5	8		9.5		11		12.5			14.5		
	-4	-4.5	-5.5	-6.5	-8		-9.5		-11		-12.5			-14.5		
js7	6	7.5	9	10.5	12.5		15		17.5		20			23		
	-6	-7.5	-9	-10.5	-12.5		-15		-17.5		-20			-23		
k6	9	10	12	15	18		21		25		28			33		
	1	1	1	2	2		2		3		3			4		
m6	12	15	18	21	25		30		35		40			46		
	4	6	7	8	9		11		13		15			17		
m7	16	21	25	29	34		41		48		55			63		
	4	6	7	8	9		11		13		15			17		

Modifications

Bore Size d Over	Bore Size d Including	Keyway Size bxh	Pin Hole	Tapped Hole
-	6	-	1.50	M3x0.5
6	8	2x2	2.00	M3x0.5
8	10	3x3	3.00	M3x0.5
10	12	4x4	4.00	M4x0.7
12	17	5x5	5.00	M5x0.8
17	22	6x6	6.00	M6x1.00
22	30	8x7	8.00	M8x1.25
30	38	10x8	10.00	M10x1.5
38	44	12x8	10.00	M10x1.5
44	50	14x9	10.00	M12x1.75

Boring out available.
Keyways to DIN 6885 Js9 Sliding Fit. D10 free fit and P9 Tight fit available on request.
Woodruff keyways available on request.
Standard bore tolerance H7 ISO 286. Other tolerances available.
Special bore shapes available including square and hexagon.

Key	Width		Depth				Radius
bxh	Shaft b	Bore b	Shaft t_1		Bore t_2		r
mm	N9	Js9	Nom	Tolerance	Nom	Tolerance	Max – Min
2x2	-0.004/-0.029	+0.012/-0.012	1.2	+0.10/–0.00	1.0	+0.10/–0.00	0.16 – 0.08
3x3	-0.004/-0.029	+0.012/-0.012	1.8	+0.10/–0.00	1.4	+0.10/–0.00	0.16 - 0.08
4x4	+0.000/-0.030	+0.015/-0.015	2.5	+0.10/–0.00	1.8	+0.10/–0.00	0.16 – 0.08
5x5	+0.000/-0.030	+0.015/-0.015	3.0	+0.10/–0.00	2.3	+0.10/–0.00	0.25 – 0.16
6x6	+0.000/-0.030	+0.015/-0.015	3.5	+0.10/–0.00	2.8	+0.10/–0.00	0.25 – 0.16
8x7	+0.000/-0.036	+0.018/-0.018	4.0	+0.20/–0.00	3.3	+0.20/–0.00	0.25 – 0.16
10x8	+0.000/-0.036	+0.018/-0.018	5.0	+0.20/–0.00	3.3	+0.20/–0.00	0.40 – 0.25
12x8	+0.000/-0.043	+0.021/-0.021	5.0	+0.20/–0.00	3.3	+0.20/–0.00	0.40 – 0.25