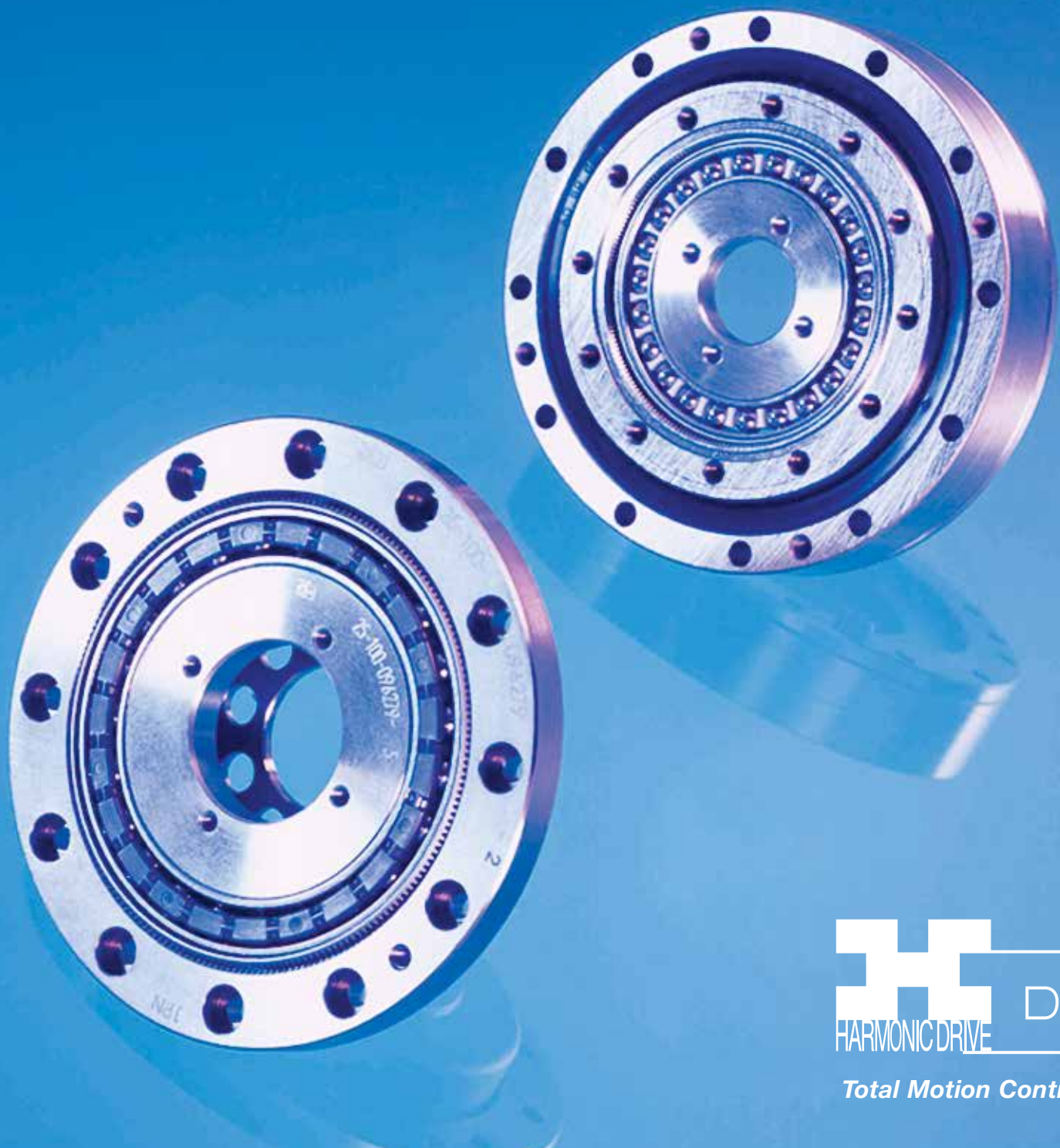# Cup Type Component Sets & Housed Units
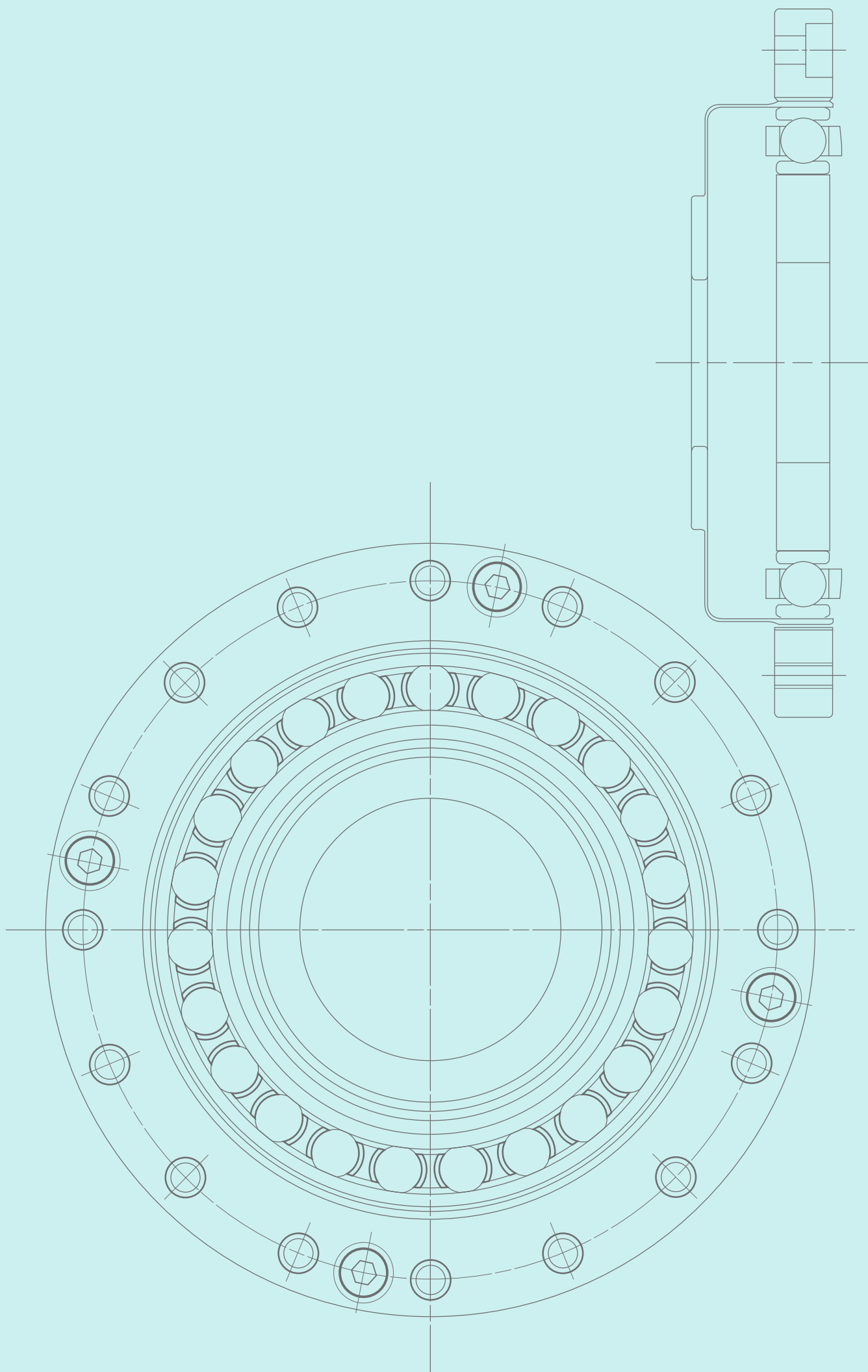
HD
HARMONIC DRIVE®

Total Motion Control

Harmonic Drive®gear

Precision Gearing and Motion Control
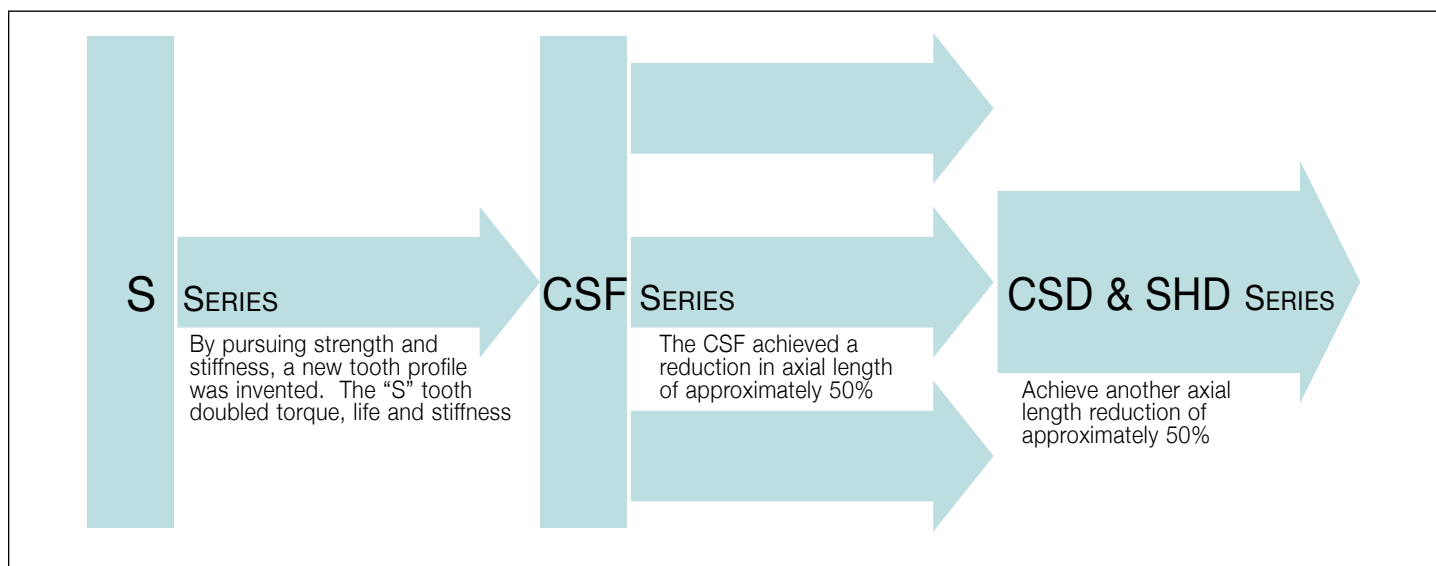
Contents

CSD - 20 - 100 - 2A - GR - SP

Name of Model	Size	Ratio	Model	
CSD	14	50, 100	2A-GR: Component Type (size 14 and 17 are 2A-R)	None: Standard
	17	50, 100		
	20	50, 100, 160		
	25	50, 100, 160		
	32	50, 100, 160		BB: Big Bore on Flexspline (CSD Series)
	40	50, 100, 160		
	50	50, 100, 160		
SHD	14	50, 100	2SH Simplicity Unit Type	
	17	50, 100		
	20	50, 100, 160		
	25	50, 100, 160		SP: Special
	32	50, 100, 160		
	40	50, 100, 160		

Evolution of Harmonic Drive® Gear Revolution

Harmonic Drive® precision gear continues to evolve by improving performance and functionality.

CSD

S SERIES

By pursuing strength and stiffness, a new tooth profile was invented. The "S" tooth doubled torque, life and stiffness

CSF SERIES

The CSF achieved a reduction in axial length of approximately 50%

CSD & SHD SERIES

Achieve another axial length reduction of approximately 50%

SHD

Outer Cross Roller Bearing (Output)

Circular Spline

Flexspline

Wave Generator

Bolt (temporary)

Cross Roller Bearing

CSD

Wave Generator

Flexspline

Circular Spline

CIRCULAR SPLINE

FLEXSPLINE

WAVE GENERATOR

System Components

The FLEXSPLINE is a non-rigid, steel cylindrical cup with external teeth on a slightly smaller pitch diameter than the Circular Spline. It fits over and is held in an elliptical shape by the Wave Generator.
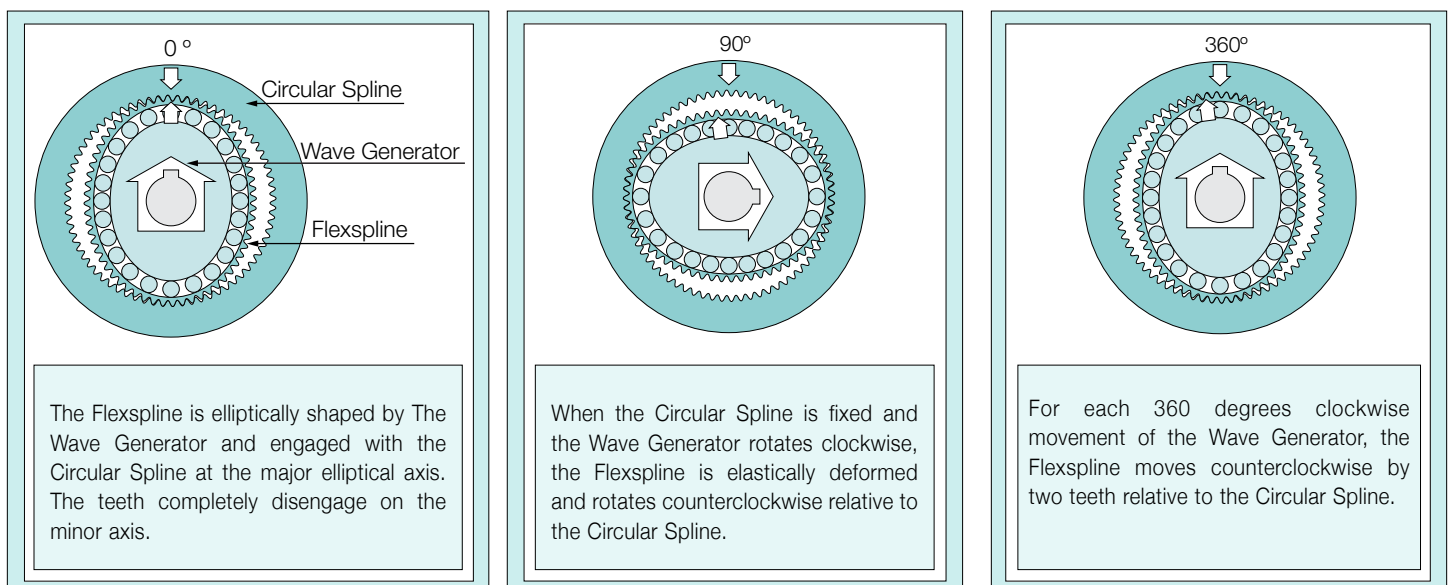
The WAVE GENERATOR is a thin raced ball bearing fitted onto an elliptical plug serving as a high efficiency torque converter.

The CIRCULAR SPLINE is a rigid ring with internal teeth, engaging the teeth of the Flexspline across the major axis of the Wave Generator.

0 °

Circular Spline

Wave Generator

Flexspline

The Flexspline is elliptically shaped by The Wave Generator and engaged with the Circular Spline at the major elliptical axis. The teeth completely disengage on the minor axis.

90°

When the Circular Spline is fixed and the Wave Generator rotates clockwise, the Flexspline is elastically deformed and rotates counterclockwise relative to the Circular Spline.

360°

For each 360 degrees clockwise movement of the Wave Generator, the Flexspline moves counterclockwise by two teeth relative to the Circular Spline.
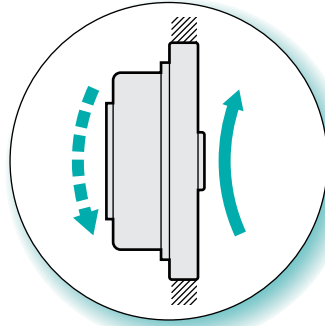
Driving Configurations

A variety of different driving configurations are possible, as shown below. The reduction ratio R, given in the tables on page 7 and 8, correspond to arrangement 1, in which the Wave Generator acts as the input element, the Circular Spline is fixed and the Flexspline acts as the output element.
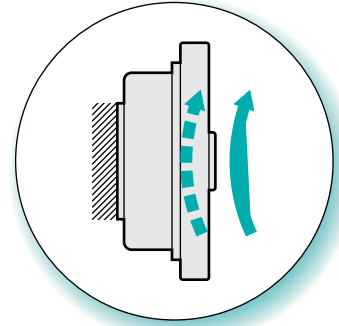
$$\text{Ratio} = \frac{\text{input speed}}{\text{output speed}}$$

1. Reduction Gearing
   CS   Fixed
   WG   Input
   FS   Output

$$\text{Ratio} = -\frac{R}{1} \qquad \text{[Equation 1]}$$
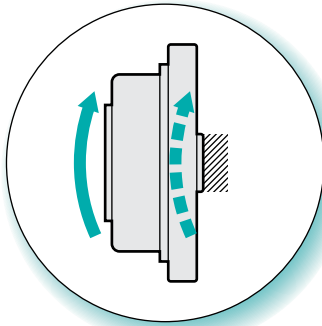
Input and output in opposite direction.

2. Reduction Gearing
   FS   Fixed
   WG   Input
   CS   Output

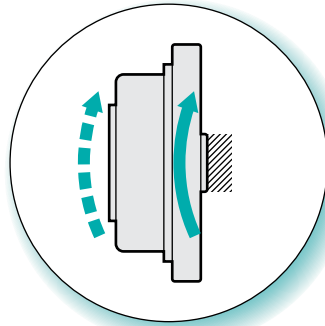$$\text{Ratio} = \frac{R+1}{1} \qquad \text{[Equation 2]}$$

Input and output in same direction.

3. Reduction Gearing
   WG   Fixed
   FS   Input
   CS   Output

$$\text{Ratio} = \frac{R+1}{R} \qquad \text{[Equation 3]}$$

Input and output in same direction.

4. Speed Increaser Gearing
   WG   Fixed
   CS   Input
   FS   Output

$$\text{Ratio} = \frac{R}{R+1} \qquad \text{[Equation 4]}$$

Input and output in same direction.
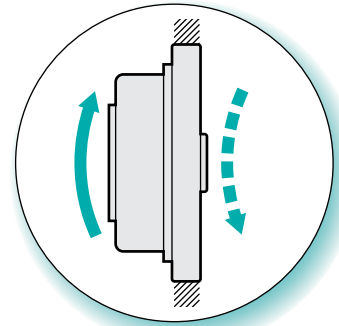
5. Speed Increaser Gearing
   CS   Fixed
   FS   Input
   WG   Output

$$\text{Ratio} = -\frac{1}{R} \qquad \text{[Equation 5]}$$

Input and output in opposite direction.
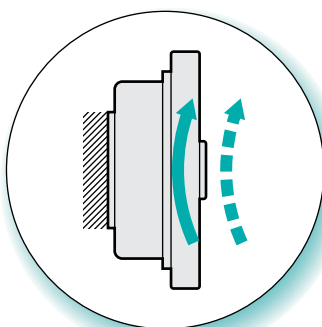
6. Speed Increaser Gearing
   FS   Fixed
   CS   Input
   WG   Output

$$\text{Ratio} = \frac{1}{R+1} \qquad \text{[Equation 6]}$$

Input and output in same direction.
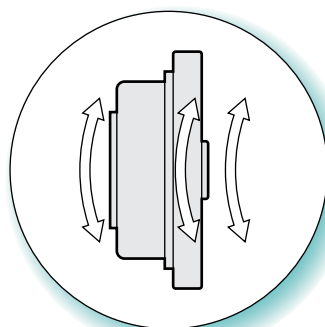
7. Differential Gearing
   WG   Control Input
   CS   Main Drive-Input
   FS   Main Drive-Output

Numerous differential functions can be obtained by combinations of the speed and rotational direction of the three basic elements.

CSD Series

Rotary Table for Machine Tool

Flexspline

Wave Generator

Circular Spline

SHD Series

SCARA

Simplicity Unit
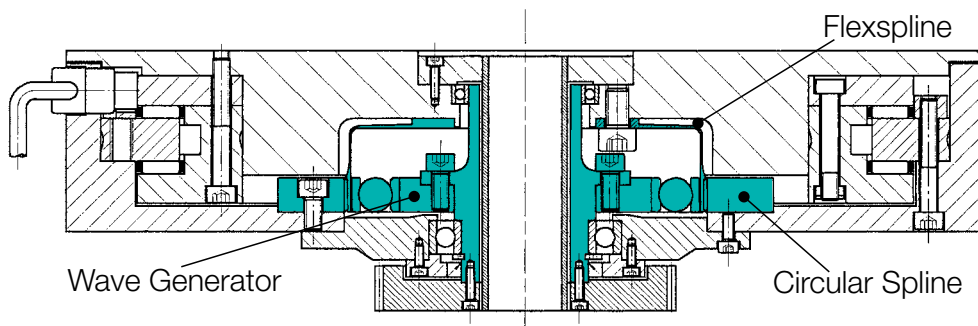
CSD · SHD Series

2 Axis - Output Unit

Circular Spline

Flexspline

Output 1

Output 2

Wave Generator

Flexspline (SHD)

CSD Rating Table

Table 1

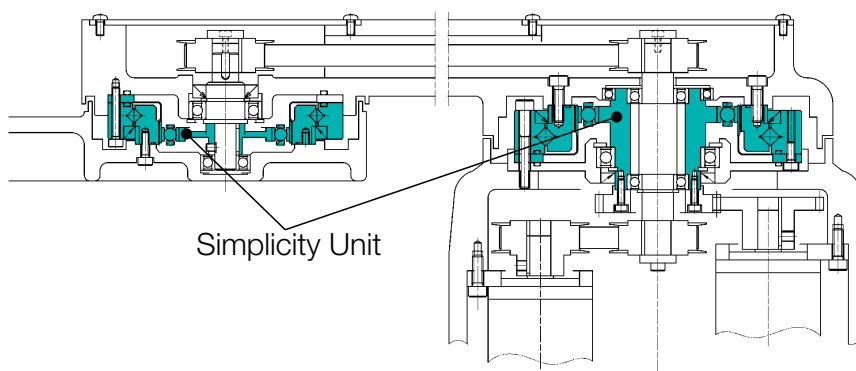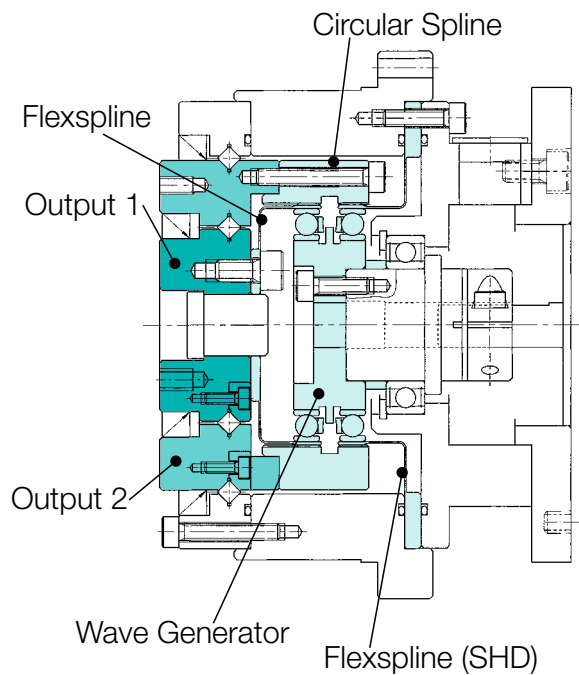| CSD Size	Gear Ratio R	Rated Torque at 2000 T_r rpm		Limit for Repeated Peak Torque		Limit for Average Torque		Limit for Momentary Peak Torque		Maximum Input Speed		Limit for Average Input Speed		Moment of Inertia	
		Nm	in-lb	Nm	in-lb	Nm	in-lb	Nm	in-lb	Oil rpm	Grease	Oil rpm	Grease	I x10⁻⁴kg·m²	J x10⁻⁵kgf·m·s²
14	50	3.7	33	12	106	4.8	42	24	212	14000	8500	6500	3500	0.021	0.021
	100	5.4	48	19	168	7.7	68	31	274						
17	50	11	97	23	204	18	159	48	425	10000	7300	6500	3500	0.054	0.055
	100	16	142	37	327	27	239	55	487						
20	50	17	150	39	345	24	212	69	611	10000	6500	6500	3500	0.090	0.092
	100	28	248	57	504	34	301	76* (65)	673* (575)						
	160	28	248	64	566	34	301	76* (65)	673* (575)						
25	50	27	239	69	611	38	336	127 (135)	1124 (1195)	7500	5600	5600	3500	0.282	0.288
	100	47	416	110	974	75	664	152* (135)	1345* (1195)						
	160	47	416	123	1089	75	664	152*	1345*						
32	50	53	469	151	1336	75	664	268 (331)	2372 (2929)	7000	4800	4600	3500	1.09	1.11
	100	96	850	233	2062	151	1336	359* (331)	3177* (2929)						
	160	96	850	261	2310	151	1336	359*	3177*						
40	50	96	850	281	2487	137	1212	480 (580)	4248 (5133)	5600	4000	3600	3000	2.85	2.91
	100	185	1637	398	3522	260	2301	694* (580)	6142* (5133)						
	160	206	1823	453	4009	316	2797	694*	6142*						
50	50	172	1522	500	4425	247	2186	1000 (1315)	8850 (11638)	4500	3500	3000	2500	8.61	8.78
	100	329	2912	686	6071	466	4124	1440 (1315)	12744 (11638)						
	160	370	3275	823	7284	590	5222	1577*	13956*						

Note: The moment of inertia : $I=1/4GD^2$, measured at the input

The momentary peak torque is limited by tightening torque on the flexspline.

The values in parenthesis are values in the case of the Big Bore option on the flexspline.

Table 2

SHD Size	Ratio R	Rated Torque at 2000 T, rpm		Limit for Repeated Peak Torque		Limit for Average Torque		Limit for Momentary Peak Torque		Maximum Input Speed	Limit for Average Input Speed	Moment of Inertia	
		Nm	in-lb	Nm	in-lb	Nm	in-lb	Nm	in-lb	rpm Grease	rpm Grease	I x10⁻⁴kg·m²	J x10⁻⁵kgf·m·s²
14	50	3.7	33	12	106	4.8	42	23	204	8500	3500	0.021	0.021
	100	5.4	48	19	168	7.7	68	35	310				
17	50	11	97	23	204	18	159	48	425	7300	3500	0.054	0.055
	100	16	142	37	327	27	239	71	628				
20	50	17	150	39	345	24	212	69	611	6500	3500	0.090	0.092
	100	28	248	57	504	34	301	95	841				
	160	28	248	64	566	34	301	95	841				
25	50	27	239	69	611	38	336	127	1124	5600	3500	0.282	0.288
	100	47	416	110	974	75	664	184	1628				
	160	47	416	123	1089	75	664	204	1805				
32	50	53	469	151	1336	75	664	268	2372	4800	3500	1.09	1.11
	100	96	850	233	2062	151	1336	420	3717				
	160	96	850	261	2310	151	1336	445	3938				
40	50	96	850	281	2487	137	1212	480	4248	4000	3000	2.85	2.91
	100	185	1637	398	3522	260	2301	700	6195				
	160	206	1823	453	4009	316	2797	765	6770				

Note: The moment of inertia : I=1/4GD², measured at the input.

Definition of Ratings

Rated Torque (Tr)

Rated torque indicates allowable continuous load torque at 2000 rpm input speed.

Limit for Repeated Peak Torque (refer to figure 1)

During acceleration a deceleration the Harmonic Drive® gear experiences a peak torque as a result of the moment of inertia of the output load. The table indicates the limit for repeated peak torque.
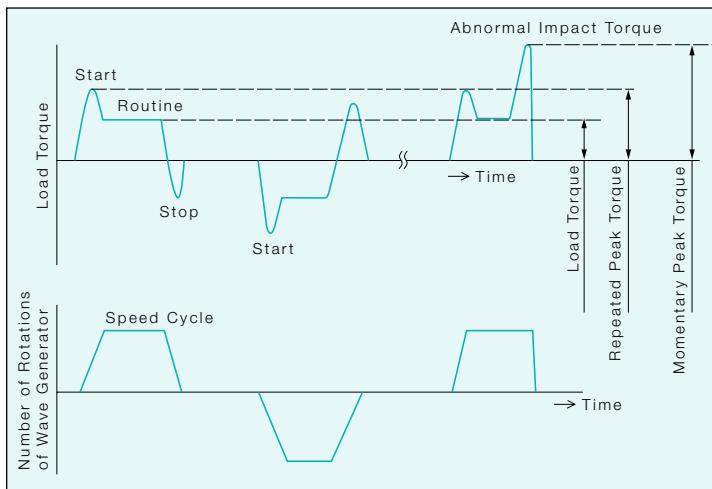
Limit for Average Torque

In cases where load torque and input speed vary, it is necessary to calculate an average value of load torque. The table indicates the limit for average torque. The average torque calculated must not exceed this limit.

Limit for Momentary Peak Torque (refer to figure 1)

The gear may be subjected to momentary peak torques in the event of a collision or emergency stop. The magnitude and frequency of occurrence of such peak torques must be kept to a minimum and they should, under no circumstance, occur during normal operating cycle. The allowable number of occurrences of the momentary peak torque may be calculated by using equation 1. Also see section "strength and life".

Strength and Life

The non-rigid Flexspline is subjected to repeated deflections, and its strength determines the torque capacity of the Harmonic Drive® gear. The values given for Rated Torque at Rated Speed and for the allowable Repeated Peak Torque are based on an infinite fatigue life for the Flexspline.

The torque that occurs during a collision must be below the momentary peak torque (impact torque). The maximum number of occurrences is given by the equation below.

[Equation 1]

$$N = \frac{1.0 \times 10^4}{2 \times \frac{n}{60} \times t}$$

n: Input speed before collision

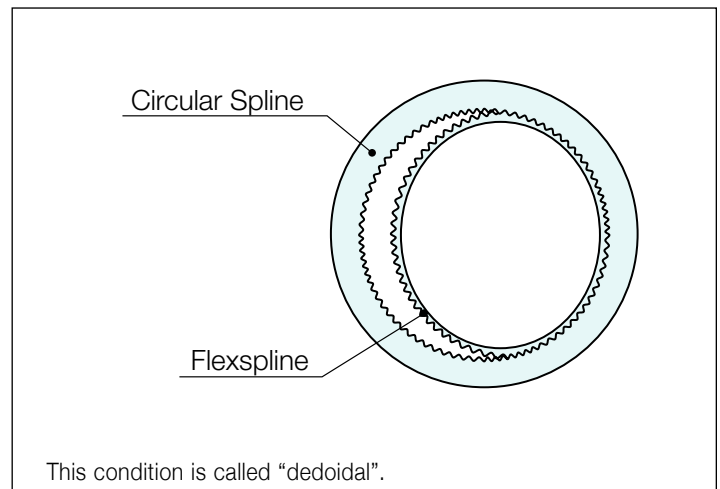t: Time interval during collision

Please note:

If this number is exceeded, the Flexspline may experience a fatigue failure.

Ratcheting phenomenon

When excessive torque is applied while the gear is in motion, the teeth between the Circular Spline and Flexspline may not engage properly. This phenomenon is called ratcheting and the torque at which this occurs is called ratcheting torque. Ratcheting may cause the Flexspline to become non-concentric with the Circular Spline. (See figure 1 & 2 on page 12) Operating in this condition may result in shortened life and a Flexspline fatigue failure.

Figure 1

Figure 2

This condition is called "dedoidal".

Maximum Input Speed, Limit for average input speed

Do not exceed the allowable rating.

Moment of Inertia

The rating indicates the moment of inertia reflected to the wave generator (gear input).

Note!

When ratcheting occurs, the teeth mesh abnormally as shown above. Vibration and Flexspline damage may occur.
Once ratcheting occurs, the teeth wear excessively and the ratcheting torque may be lowered.

CSD Ratcheting Torque   Table 3   Nm

Size	Ratio		
	50	100	160
14	88	84	–
17	150	160	–
20	220	260	220
25	450	500	450
32	980	1000	980
40	1800	2100	1800
50	3700	4100	3600

Table 4   Buckling Torque   Nm

CSD	
Size	All Ratio
14	190
17	330
20	560
25	1000
32	2200
40	4300
50	8000

SHD Ratcheting Torque   Table 5   Nm

Size	Ratio		
	50	100	160
14	88	84	–
17	150	160	–
20	220	260	220
25	450	500	450
32	980	1000	980
40	1800	2100	1800

Table 6   Buckling Torque   Nm

SHD	
Size	All Ratio
14	130
17	260
20	470
25	850
32	1800
40	3600

The Life of a Wave Generator

The normal life of a gear is determined by the life of the wave generator bearing. The life may be calculated by using the input speed and the output load torque.

Rated Lifetime L_n : (n = 10 or 50) , hours

L_{10} CSD,SHD: 7,000

L_{50} CSD,SHD: 35,000

Equation for the expected life of the wave generator under normal operating conditions is given by the equation below.

[Equation 2]

$$Lh = Ln \cdot \left(\frac{Tr}{Tav}\right)^3 \cdot \left(\frac{Nr}{Nav}\right)$$

Lh : Expected Life, hours

Ln : Rated Lifetime at L_{10} or L_{50} , hours

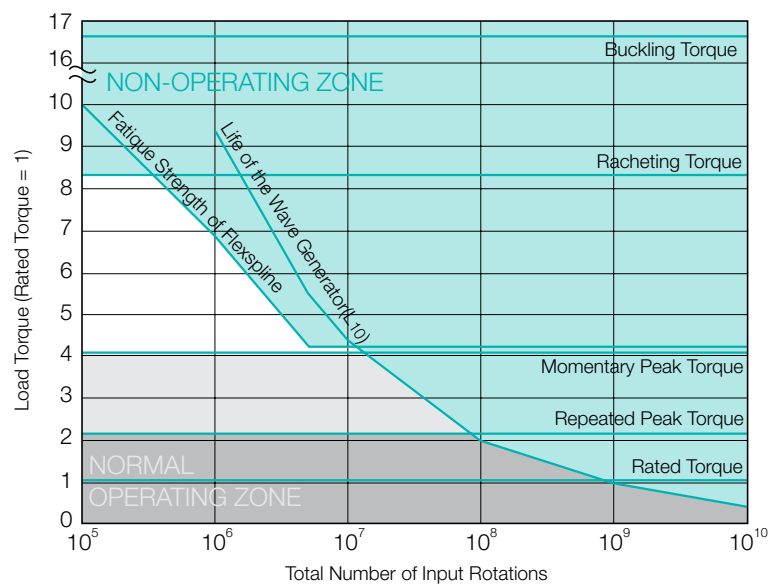Tr : Rated Torque (Tables 1, 2, 3)

Nr : Rated input speed (2000 rpm)

Tav : Average load torque on output side (page 14)

Nav : Average input speed (page 14

Relative Torque Rating

The chart below shows the various torque specifications relative to rated torque. Rated Torque has been normalized to 1 for comparison.

Figure 3

Size Selection

Generally, the operating conditions consist of fluctuating torques and output speeds. Also, an unexpected impact output torque must be considered.

The proper size can be determined by converting fluctuating load torque into average load torque and equivalent load torque. This procedure involves selecting the size based on load torque for component sets.

This procedure does not consider the life of the output bearing for housed units. Determining the life of the output bearing for various axial, radial, and moment loads is outlined on page 25.

Figure 4

n_1 n_2 n_n are an average value.
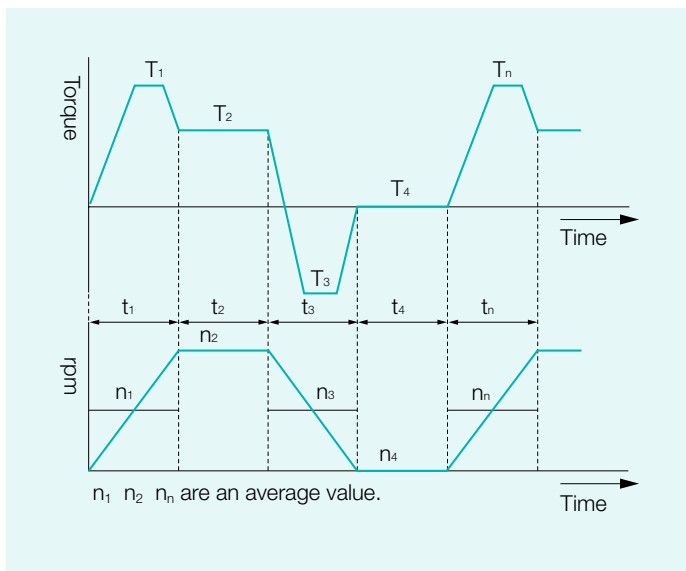
Parameters

Load Torque	T_n (Nm)
Time	t_n (sec)
Output Speed	n_n (rpm)

Normal Operating Pattern

Acceleration	T_1, t_1, n_1
Regular Operation	T_2, t_2, n_2
Deceleration	T_3, t_3, n_3
Dwell	T_4, t_4, n_4

Maximum RPM

Max output speed	n_O maximum
Max input speed	n_i maximum

Impact Torque

T_s, t_s, n_s

Ratings

Rated Torque	Tr
Rated Speed	nr = 2000 rpm

Flow Chart for selecting a size

Please use the flowchart shown below for selecting a size. Operating conditions must not exceed the performance ratings as described on page 12.

Calculation of the average output torque

$$Tav = \sqrt[3]{\frac{n_1 \cdot t_1 \cdot |T_1|^3 + n_2 \cdot t_2 \cdot |T_2|^3 + \cdots \, n_n \cdot t_n \cdot |T_n|^3}{n_1 \cdot t_1 + n_2 \cdot t_2 + \cdots \, n_n \, t_n}}$$

Selection of tentative size under the condition shown below.

Average Output Speed

$$n_O \, av = \frac{n_1 \cdot t_1 \cdot n_2 \cdot t_2 + \cdots \, n_n t_n}{t_1 + t_2 \cdot t_2 + \cdots t_n}$$

Determine Gear Ratio

$$\frac{n_i \, max}{n_O \, max} \leqq R$$

n_i max may be limited by the motor.

Calculation of the average input speed
$n_i \, av = n_O \, av \cdot R$

Calculation of maximum input speed
$n_i \, max = n_O \, max \cdot R$

Consider a different size or change operating requirements

NG — $n_i \, av \leqq$ Limit for average speed
$n_i \, max \leqq$ Limit for maximum speed

OK

NG — Confirm if T_1 and T_3 are less than the repeated peak torque specification.

OK

NG — Confirm if T_s (impact torque) is less than the momentary peak torque specification.

OK

NG — Calculate the allowable number of rotations during impact torque.

$$N_S = \frac{10^4}{2 \cdot \frac{n_s \cdot R}{60} \cdot t_s} \quad \cdots \cdots N_S \leqq 1.0 \times 10^4$$

OK

Calculate wave generator life.

$$L_h = L_n \cdot \left(\frac{Tr}{Tav}\right)^3 \cdot \left(\frac{nr}{n_i \, av}\right)$$

NG — Make sure that the calculated life is suitable for the application.

OK

Gear is suitable for torque and speed requirements

Also consider output bearing, environment, etc.

Values of an each Load Torque Pattern

Load Torque T_n (Nm)   no max = 14 rpm

Time t_n (sec)   ni max = 1800 rpm

Output Speed n_n (rpm)

Normal Operating Pattern

Acceleration $T_1 = 400$ Nm, $t_1 = 0.3$ sec, $n_1 = 7$ rpm $T_s = 500$ N_m, $t_s = 0.15$ sec, $n_s = 14$ rpm

Regular Operation Stop $T_2 = 320$ Nm, $t_2 = 3$ sec, $n_2 = 14$ rpm

Deceleration $T_3 = 200$ Nm, $t_3 = 0.4$ sec, $n_3 = 7$ rpm $L_{10} > 7000$ hrs.

Dwell $T_4 = 0$ Nm, $t_4 = 0.2$ sec, $n_4 = 0$ rpm   Oil Lubrication

---

Tav (Nm)

$$Tav = \sqrt[3]{\frac{7rpm \bullet 0.3sec \bullet |400Nm|^3 + 14rpm \bullet 3sec \bullet |320Nm|^3 + 7rpm \bullet 0.4sec \bullet |200Nm|^3}{7rpm \bullet 0.3sec + 14rpm \bullet 3sec + 7rpm \bullet 0.4sec}}$$

Tav = 319Nm < 466Nm (for CSD-50-100-2A-GR)

---

no av (rpm)

$$\frac{7rpm \bullet 0.3sec + 14rpm \bullet 3sec + 7rpm \bullet 0.4sec}{\bullet 0.3sec + 3sec + 0.4sec + 0.2sec} = 12 \text{ rpm}$$

(R)

$$\frac{1800 \text{ RPM}}{14 \text{ rpm}} = 128.6 > 100$$

n_i av = 12rpm • 100 = 1200rpm

n_O max   ni max (rpm)

n_i max = 14rpm • 100 = 1400rpm

---

n_i av = 1440rpm < 3600rpm (for CSD-50-100-2A-GR)

n_i max = 1680rpm < 5600rpm (for CSD-50-100-2A-GR)   NG

Confirm that T1 and T3 are within a   OK

T_1, T_3 (Nm)

$T_1 = 400$Nm < 686Nm (for CSD-50-100-2A-GR)

$T_3 = 200$Nm < 686Nm (for CSD-50-100-2A-GR)   NG

OK

T_S (Nm)

$T_{S)} = 500$Nm < 1440Nm (for CSD-50-100-2A-GR)   NG

OK

Ns   Calculate an allowable number of rotation(Ns) and confirm $\leqslant 1.0 \times 10^4$

$$N_S = \frac{10^4}{2 \bullet \dfrac{14rpm \bullet 100}{60} \bullet 0.15} \quad N_S = 1429 < 1.0 \times 10^4$$ NG

OK

Calculate a life time.

$$L_{10} = 7000 \frac{(329Nm)^3}{1319Nm} \bullet \frac{(2000rpm)}{1440rpm}$$

$L_{10} = 10665 > 7000$ (L_{B10})   NG

OK

CSD-50-100-2A-GR

Consider a different size or change operating requirements

CSD External Dimension & Shape

øZ3   U-øV

øT

øK H6

øJ

øa

*1
*2   C0.5
C0.3   *1
C0.5

*4

G1

Expanded G Section

C
D   F
E
O
øP

H

øBH7
øAh7
øa

G
C0.4

Ⓐ   c
b

2-N
15°
L-øM   øZ1

øQ
øR

4-S   øZ2

1. #14 and 17 are co.4.
2. #40 and 50 are co.5.
3. #14 is 30°, #17 is 22.5°.
4. #14 -32 are co.3, #40 and #50 are co.5.

① ② ③   ① ② ① ③

① Ball Separator

② Wave Generator Bearing

③ Wave Generator Plug

Size: 14, 17   Size: 20, 25, 32, 40, 50
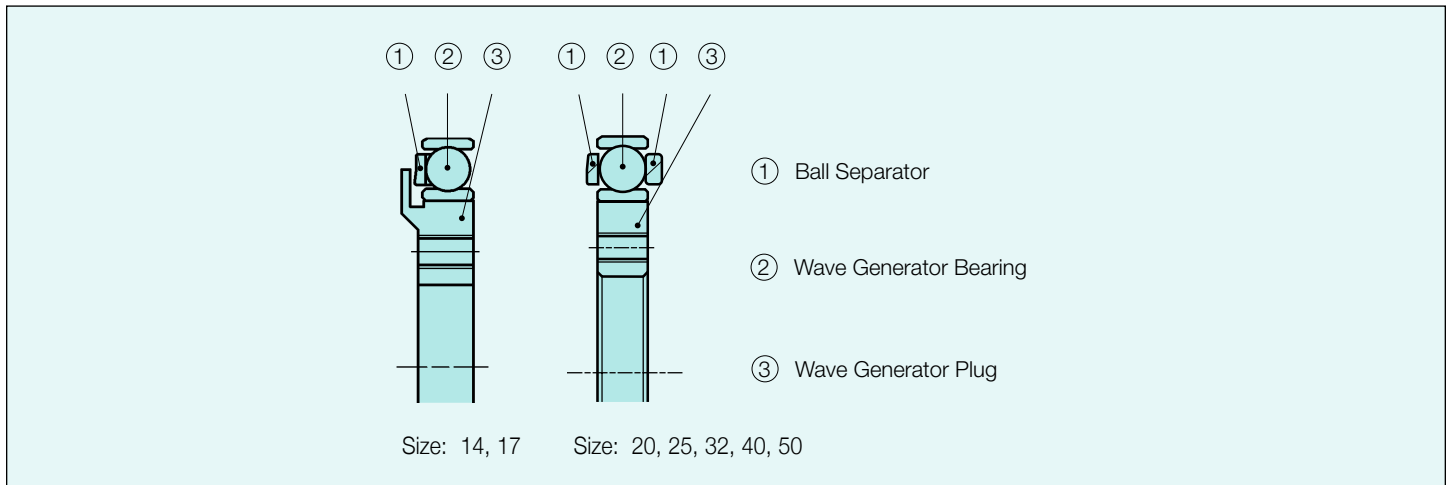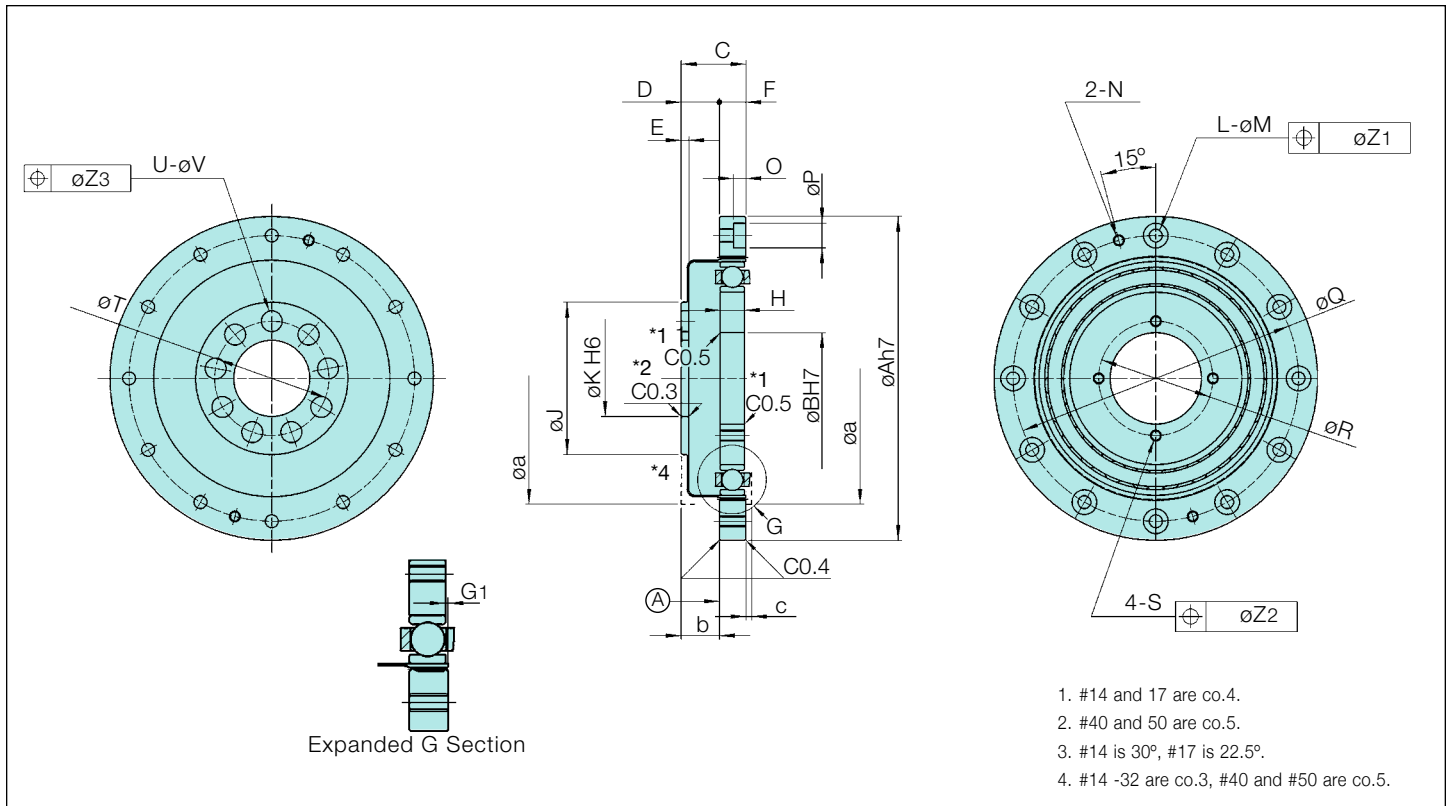
Outside appearance varies depending on size.

Size: 14, 17   Size: 20, 25, 32, 40, 50

CSD External Dimension & Shape
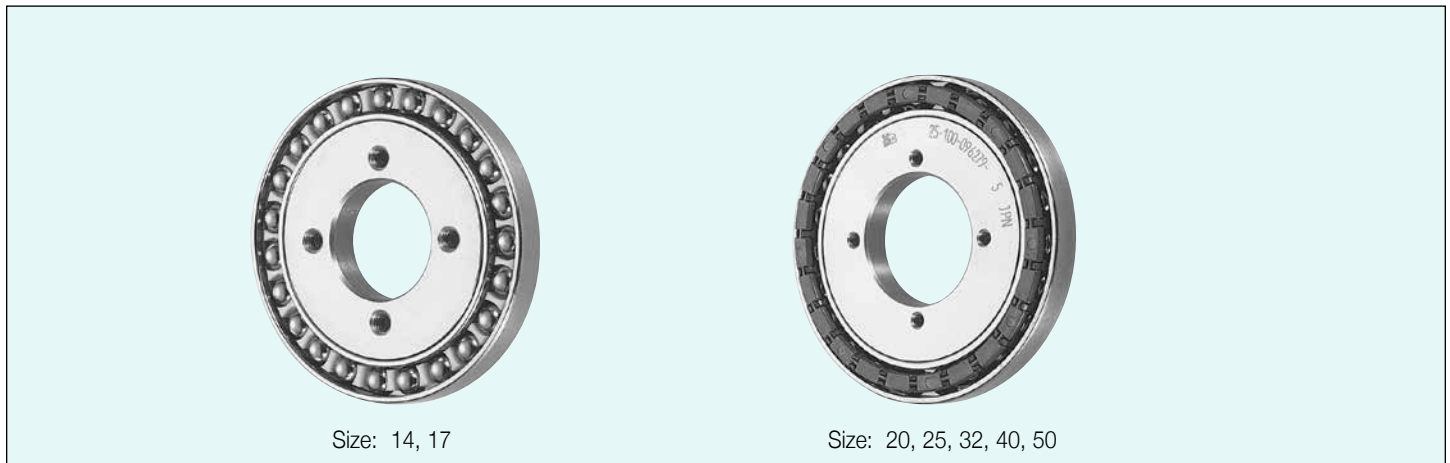
CSD Dimensions Table 7   unit: (mm)

Size	14	17	20	25	32	40	50
øA h7	$50\,^{0}_{-0.025}$	$60\,^{0}_{-0.030}$	$70\,^{0}_{-0.030}$	$85\,^{0}_{-0.035}$	$110\,^{0}_{-0.035}$	$135\,^{0}_{-0.040}$	$170\,^{0}_{-0.040}$
øBH7	$11\,^{+0.018}_{0}$	$15\,^{+0.018}_{0}$	$20\,^{+0.021}_{0}$	$24\,^{+0.021}_{0}$	$32\,^{+0.025}_{0}$	$40\,^{+0.025}_{0}$	$50\,^{+0.025}_{0}$
C	11	12.5	14	17	22	27	33
D	$6.5\,^{+0.2}_{0}$	$7.5\,^{+0.2}_{0}$	$8\,^{+0.3}_{0}$	$10\,^{+0.3}_{0}$	$13\,^{+0.3}_{0}$	$16\,^{+0.3}_{0}$	$19.5\,^{+0.3}_{0}$
E	1.4	1.7	2	2	2.5	3	3.5
F	4.5	5	6	7	9	11	13.5
G1	0.3	0.3	0.3	0.4	0.5	0.6	0.8
H	4	5	5.2	6.3	8.6	10.3	12.7
øJ	23	27.2	32	40	52	64	80
øK H6	$11\,^{+0.011}_{0}$	$11\,^{+0.011}_{0}$	$16\,^{+0.011}_{0}$	$20\,^{+0.013}_{0}$	$30\,^{+0.013}_{0}$	$32\,^{+0.016}_{0}$	$44\,^{+0.016}_{0}$
L	6	8	12	12	12	12	12
øM	3.4	3.4	3.4	3.4	4.5	5.5	6.6
N	M3	M3	M3	M3	M4	M5	M6
O	–	–	3.3	3.3	4.4	5.4	6.5
øP	–	–	6.5	6.5	8	9.5	11
øQ	44	54	62	75	100	120	150
øR	17	21	26	30	40	50	60
S	M3	M3	M3	M3	M4	M5	M6
øT	17	19.5	24	30	41	48	62
U	9	8	9	9	11	10	11
øV	3.4	4.5	4.5	5.5	6.6	9	11
øZ$_1$	0.2	0.2	0.2	0.2	0.25	0.25	0.3
øZ$_2$	0.25	0.25	0.2	0.2	0.25	0.25	0.3
øZ$_3$	0.2	0.25	0.25	0.25	0.3	0.5	0.5
Minimum housing clearance øa	38	45	53	66	86	106	133
b	6.5	7.5	8	10	13	16	19.5
c	1	1	1.5	1.5	2	2.5	3.5
weight (kg)	0.06	0.10	0.13	0.24	0.51	0.92	1.9

Weight

Note: Standard dimension for size 14 and 17 is the maximum bore.

Dimensions for BB Table 8   unit:mm

Size	20	25	32	40	50
ø KH6	$20\,^{+0.013}_{0}$	$24\,^{+0.013}_{0}$	$32\,^{+0.016}_{0}$	$40\,^{+0.016}_{0}$	$50\,^{+0.016}_{0}$
U	12	12	12	14	14
ø V	3.4	4.5	5.5	6.6	9
ø T	26	32	42	52	65
ø Z$_3$	0.2	0.25	0.25	0.3	0.5

Note: Standard dimension for size 14 and 17 is the maximum bore.

- Installed surface on Circular Spline is shown as A.
  Use this surface for installation in case.
- Dimensions shown below may be modified as a special order.
  - B: Dimension of Wave generator
  - U and V: Dimension of Flexspline
  - L and M: Dimension of Circular spline

- Dimensions for C•D•G must meet the tolerance values shown above.
- øa, b, c must exceed the values shown above due to deformation of the flexspline.

CSD SERIES

Harmonic Drive LLC 800-921-3332   15

Lubrication

Lubricant

Grease lubricant is the standard for the CSD unit. The temperature range is shown below. (Exceptions are shown on page 17.)

Lubricant		
Grease	Harmonic Grease	SK-1A
Grease	Harmonic Grease	SK-2
Grease	Harmonic Grease	4B-No.2
Oil	Industrial gear oil #2(high pressure)	ISO VG68

Lubricant		
Grease	SK-1A	0°C~+40°C
Grease	SK-2	0°C~+40°C
Grease	4B-No.2	-10°C~+70°C
Oil	ISO VG68	0°C~+40°C

Harmonic Grease SK-1A
This grease is developed for a Harmonic Drive® gear and features good durability and efficiency.

Harmonic Grease SK-2
This grease is developed for a small size Harmonic Drive® gear and features smooth rotation of the Wave Generator since high pressure additive is liquefied.

Harmonic Grease 4BNo.2
This grease is developed for Harmonic Drive® gear and features long life and a wide range of temperature.

Note 1
Grease lubrication must have proper sealing, this is essential for 4B No.2.

Rotating part: Oil seal with spring is needed.
Mating part: O ring or seal adhesive is needed.

Note 2
The grease has the highest deterioration rate in the region where the grease is subjected to the greatest shear (near wave generator).
Its viscosity is between JIS No.0 and No.00 depending on the operation.

Recommended Grease

Size	14	17	20	25	32	40	50
SK-1A	–	–	O	O	O	O	O
SK-2	O	O	Δ	Δ	Δ	Δ	–
4BNo.2	•	•	•	•	•	•	•

•: recommended grease for long life and high load   O: Standard   Δ: Semistandard

Characteristics of Grease

Grease	SK-1A	SK-2	4BNo.2
Durability	O	O	•
Fretting Resistance	O	O	•
Low Temp	Δ	Δ	•
Grease Leakage	•	•	Δ

•: Excellent   O: Good   Δ: Exercise Caution

Recommended Grease

Grease	SK-1A	SK-2	4B No.2
Base Oil	Refined mineral hydrocarbon base oil	Refined mineral hydrocarbon base oil	Hydrocarbon type synthetic oil and polymer
Thickening Agent	Lithium soap thickener	Lithium soap thickener	Urea
Additive	Organic molybdenum, etc.	Organic molybdenum, etc.	Organic molybdenum, etc.s
NLGI Consistency No.	No.2	No.2	No.1.5
Viscosity (25C) cSt	265 to 295	265 to 295	290 to 320
Melting Point	197°C	198°C	247°C
Color	Yellow	Green	Light Yellow
Life	5 Years in Airtight Container		

Recommended Housing Dimensions

Recommended housing dimensions must meet with numbers shown below. These dimensions must be maintained to prevent damage to the gear and to maintain a proper grease cavity.
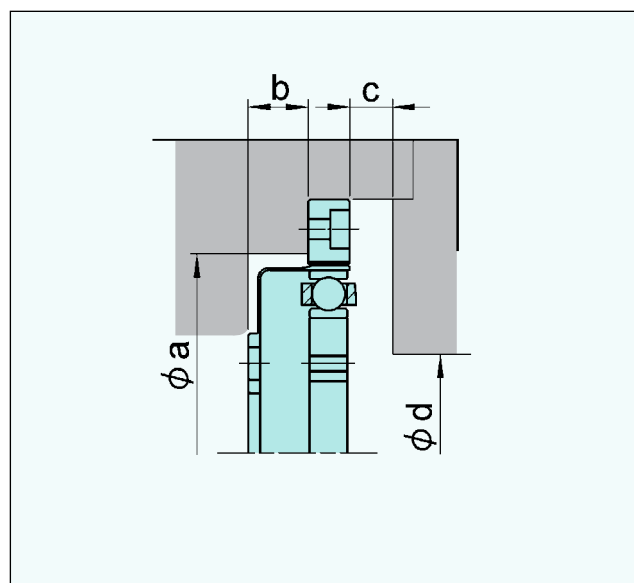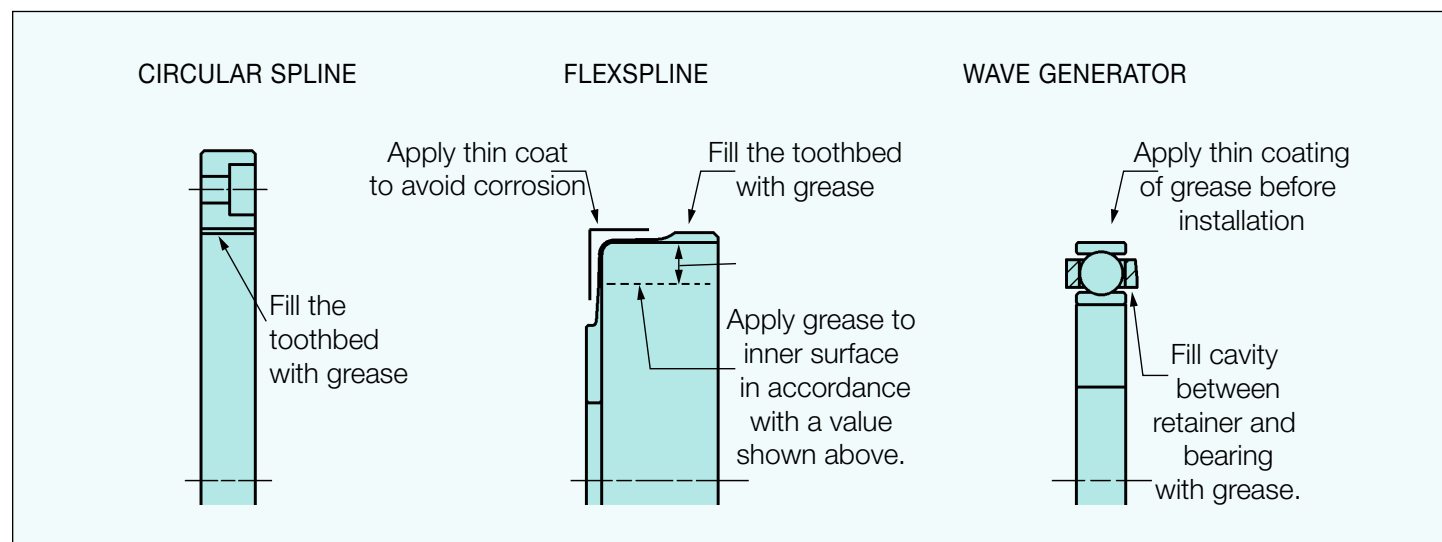
Recommended Housing Dimensions   Table 9   Unit: mm

Size	14	17	20	25	32	40	50
ø a	38	45	53	66	86	106	133
b	6.5	7.5	8	10	13	16	19.5
c	1(3)	1(3)	1.5(4.5)	1.5(4.5)	2(6)	2.5(7.5)	3.5
ød $^{+0.5}_{0}$	16	26	30	37	37	45	45

Note: Values in parenthesis show the value when the Wave Generator is pointing up.

Figure 5

CIRCULAR SPLINE

Fill the toothbed with grease

FLEXSPLINE

Apply thin coat to avoid corrosion

Fill the toothbed with grease

Apply grease to inner surface in accordance with a value shown above.

WAVE GENERATOR

Apply thin coating of grease before installation

Fill cavity between retainer and bearing with grease.

Grease Usage   Table 10   Unit: g

Size	14	17	20	25	32	40	50
amount	3.5	5.2	9.0	17	37	68	131

Grease Change

The wear characteristics of the gear is strongly influenced by the condition of the grease lubrication. The condition of the grease is affected by the ambient temperature. The graph shows the maximum number of input rotations for various temperatures. This graph applies to applications where the average load torque does not exceed the rated torque.

In cases where the average load torque exceeds rated torque, calculate the grease change interval using the equation shown below.

Equation where average load torque exceeds rated torque
[Equation [3]

$$L_{GT} = L_{GTn} \times \left(\frac{T_r}{T_{av}}\right)^3$$

Symbol of Equation [2]

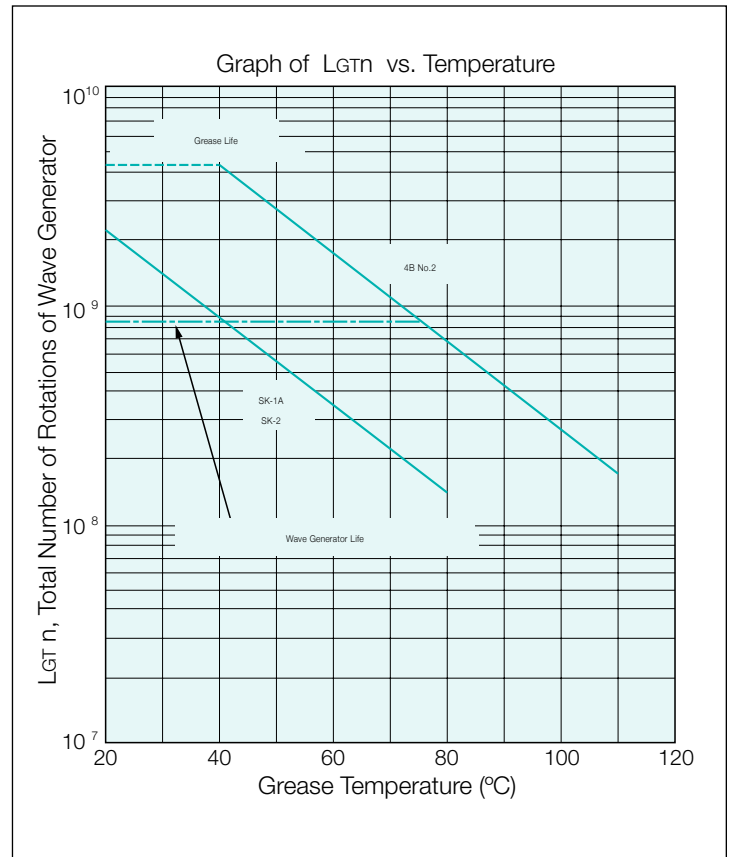|	
L_{GT}	Grease change (average torque is over rated torque), input rotations
L_{GTn}	Grease change (average torque is below rated torque), input rotations (From Graph)
T_r	Rated Torque
T_{av}	Average load torque on output

Graph of L_{GTn} vs. Temperature

Figure 6

Oil Temperature

In normal use, the oil temperature must not exceed 90°C, Above this temperature oil quickly loses its lubricating capabilities.

Other notes: Avoid mixing different kinds of oil. The gear should be in an individual case when installed.
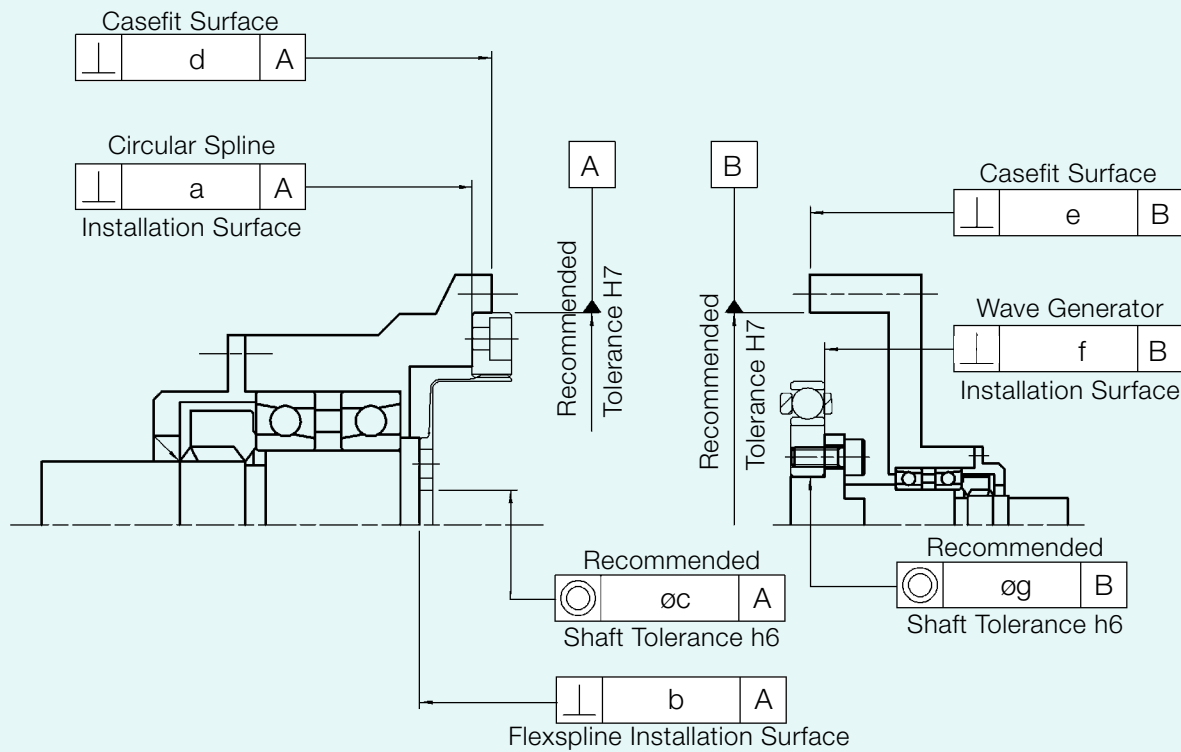
Oil Change

The first oil change should be performed after 100 hours of operation. The need to perform subsequent oil changes will depend on operating conditions, but should take place at intervals of approximately 1000 running hours.

High Temperature Lubricants

Harmonic Grease 4B No.2

Type of lubricant	Standard temperature range	Possible temperature range
grease	−10°C~+110°C	−50°C~+130°C

High Temperature Lubricant

Type of lubricant	Name of lubricant and manufacturer	Possible temperature range
grease	Mobil Grease 28	−5°C~+160°C
oil	Mobil SHC-626	−5°C~+140°C

Standard temperature is the grease temperature during operation. It is not the ambient temperature.

Low Temperature Lubricant

Type of lubricant	Name of lubricant and manufacturer	Possible temperature range
Grease	Multemp SH-K2 Kyodo Yushi	−30°C~+50°C
	Iso Flex LDS-18 special A NOK kluber	−25°C~+80°C
Oil	SH-200-100CS Tore Silicon	−10°C~+110°C
	Shintesso D-32EP NOK kluber	−25°C~+90°C

The temperature range of the grease can be extended as indicated in the possible temperature range shown. At the low end of this range the efficiency will be low due to an increase in viscosity of the lubricant. At the high end of this range the lubricant life will be low due to an increased deterioration rate from the high temperature.

Recommended Tolerances for Assembly

Casefit Surface
⊥ | d | A

Circular Spline
⊥ | a | A
Installation Surface

A

B

Casefit Surface
⊥ | e | B

Wave Generator
⊥ | f | B
Installation Surface

Recommended
Tolerance H7

Recommended
Tolerance H7

Recommended
⊚ | øc | A
Shaft Tolerance h6

Recommended
⊚ | øg | B
Shaft Tolerance h6

⊥ | b | A
Flexspline Installation Surface

Tolerance for Assembly   Table 11   unit:mm

Size	14	17	20	25	32	40	50
a	0.011	0.012	0.013	0.014	0.016	0.016	0.018
b	0.008	0.011	0.014	0.018	0.022	0.025	0.030
ø c	0.015	0.018	0.019	0.022	0.022	0.024	0.030
d	0.011	0.015	0.017	0.024	0.026	0.026	0.028
e	0.011	0.015	0.017	0.024	0.026	0.026	0.028
f	0.008	0.010	0.010	0.012	0.012	0.012	0.015
ø g	0.016	0.018	0.019	0.022	0.022	0.024	0.030

Sealing structure

A seal structure is needed to maintain the high durability of the gear and prevent grease leakage.

Key Points to Verify

- Rotating parts should have an oil seal (with spring), surface should be smooth (no scratches)
- Mating flanges should have an O Ring, seal adhesive
- Screws should have a thread lock
  (Loctite 242 recommended) or seal adhesive.

  Note: If you use Harmonic Grease 4BNo.2, strict sealing is required.

Direction for Thrust Force of Wave Generator

CSD

direction for thrust force in acceleration
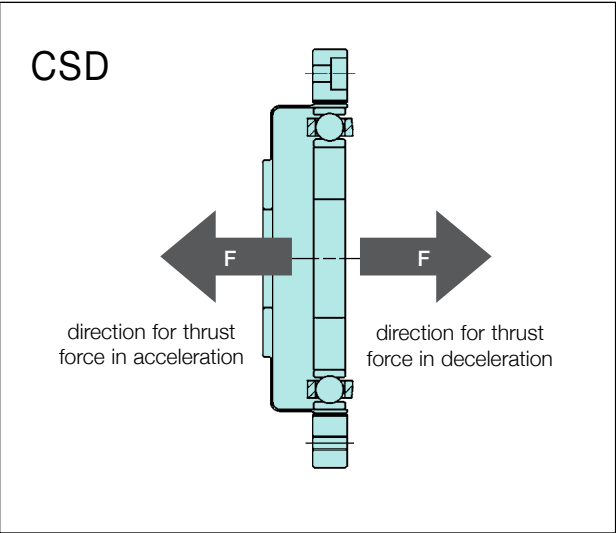
direction for thrust force in deceleration

Figure 7

Axial Force of Wave Generator

When a CSD gear is used to accelerate a load, the deflection of the Flexspline leads to an axial force acting on the Wave Generator. This axial force, which acts in the direction of the closed end of the Flexspline, must be supported by the bearings of the input shaft (motor shaft).

When a CSD gear is used to decelerate a load, an axial force acts to push the Wave Generator out of the Flexspline cup. Maximum axial force of the Wave Generator can be calculated by the equation shown below.
The axial force may vary depending on its operating condition. The value of axial force tends to be a larger number when using high torque, extreme low speed and constant operation. The force is calculated (approximately) by the equation. In all cases, the Wave Generator must be axially (in both directions), as well as torsionally, fixed to the input shaft.

Note: Please contact us for further information on attaching the Wave Generator to the input (motor) shaft.

Equation [4] for axial force

Gear Ratio	equation
i=1/50	$F=2 \times \frac{T}{D} \times 0.07 \times \tan 30° + 2\mu PF$
i=1/100 and up	$F=2 \times \frac{T}{D} \times 0.07 \times \tan 20° + 2\mu PF$

Symbols for equation [4]

F	thrust force	N
D	Gear Size x 0.00254	m
T	output torque	Nm
2μPF	thrust force by bearing	Nm (see table)

Calculation Example

size	:	32
Ratio	:	i=1/50
Output Torque	:	200Nm

$$F=2 \times \frac{200}{(32 \times 0.00254)} \times 0.07 \tan 30° + 16$$

$$F=215N$$

Table 12

Thrust Force by Bearing		
	Size	2μPF (Nm)
CSD	14	2.1
	17	4.1
	20	5.6
	25	9.8
	32	16
	40	24
	50	39

Boss diameter of Flexspline

Table 13

Size	14	17	20	25	32	40	50
øJ	23	27.2	32	40	52	64	80

Diaphragm

Avoid

Head of bolt, nut and washer should not exceed the diameter of J
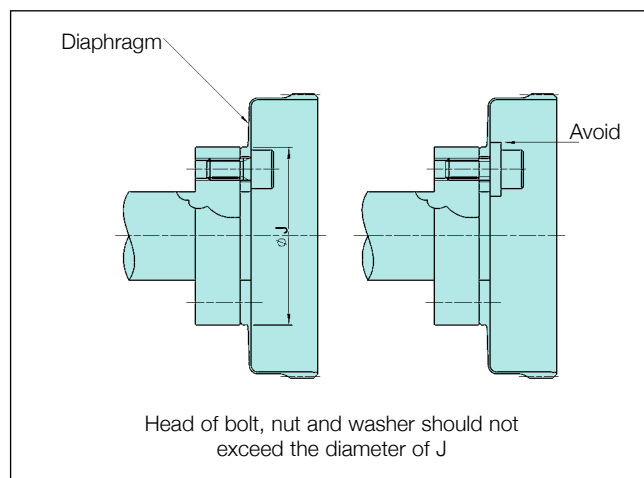
Figure 8

Number of Holes and Location (Standard)

Number of Holes: 8 — CSD-17

Number of Holes: 9 — CSD-14, 20, 25

Number of Holes: 10 — CSD-40

Number of Holes: 11 — CSD-32, 50
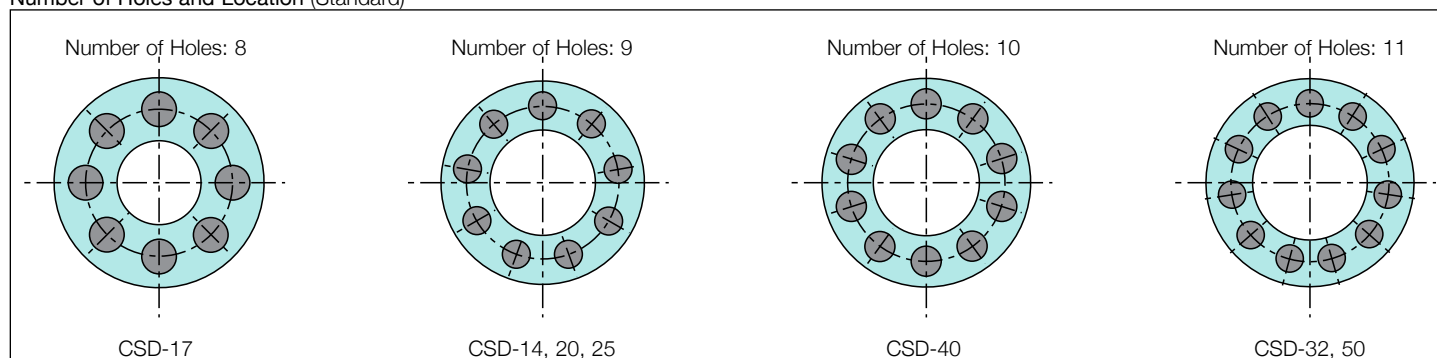
Number of Holes and Location (Big Bore Option)

Number of Holes: 12 — CSD-20.25

Number of Holes: 14 — CSD-32, 40, 50

Flexspline Bolts Table 14
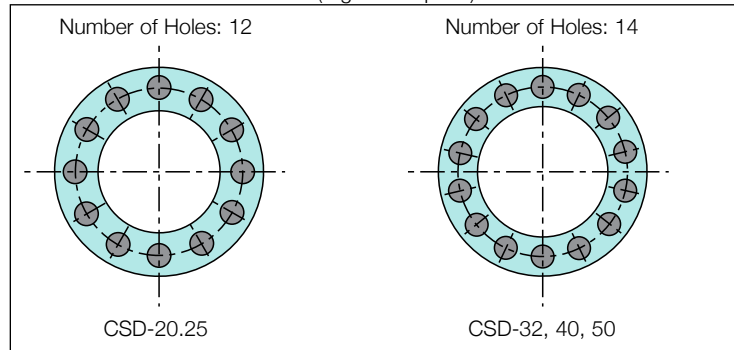
Size		14	17	20	25	32	40	50	BB 20	BB 25	BB 32	BB 40	BB 50
					Standard					Big Bore Option			
Number of Bolts		9	8	9	9	11	10	11	12	12	14	14	14
Size		M3	M4	M4	M5	M6	M8	M10	M3	M4	M5	M6	M8
Pitch Circle Diameter	mm	17	19.5	24	30	41	48	62	26	32	42	52	65
Clamp Torque	N•m	2.0	4.5	4.5	9.0	15.3	37	74	2	4.5	9.0	15.3	37
Torque transmission	N•m	32	55	76	152	359	694	1577	65	135	331	580	1315

Note:

1. The material of the thread must withstand the clamp torque.

2. Recommended bolt : JIS B 1176 socket head cap screw strength range : JIS B 1051 over 12.9

3. Torque coefficient : K=0.2

4. Clamp coefficient A=1.4

5. Friction coefficient on the surface contacted: 0.15

6. Momentary peak torque is limited in Big Bore since bolt torque transmission of Big Bore is smaller than standard.
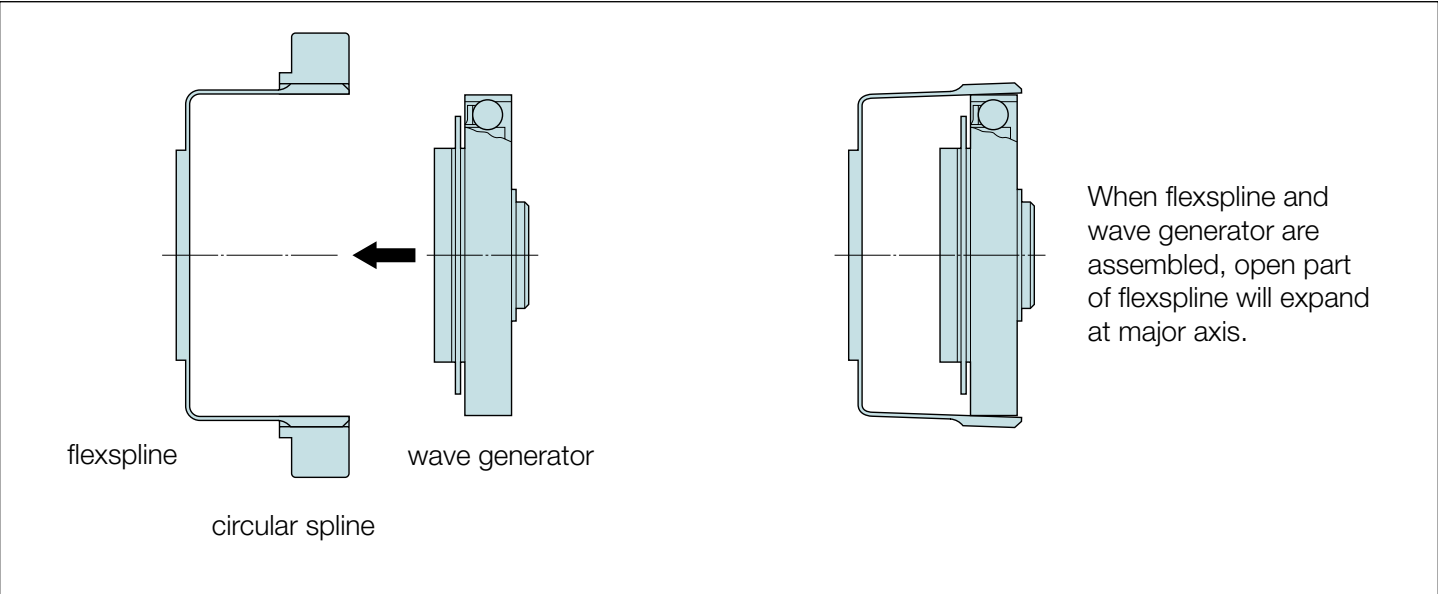
Circular Spline Bolt Installation Table 15

Size	Standard	14	17	20	25	32	40	50
Number of Bolts		6	8	12	12	12	12	12
Size		M3	M3	M3	M3	M4	M5	M6
Pitch Circle Diameter	mm	44	54	62	75	100	120	150
Clamp Torque	Nm	2.0	2.0	2.0	2.0	4.5	9.0	15.3
Torque transmission	Nm	55	90	155	188	422	810	1434

Note:

1. The material of the thread must withstand the clamp torque.
2. Recommended bolt: JIS B 1176 socket head cap screw strength range : JIS B 1051 over 12.9.
3. Torque coefficient : K=0.2
4. Clamp coefficient A=1.4
5. Friction coefficient on the surface contacted : 0.15

Component Assembly Procedure

When flexspline and wave generator are assembled, open part of flexspline will expand at major axis.

flexspline

wave generator

circular spline

Please see the following notes.

CSD assembly procedure

Note for assembly structure for CSD

Wave Generator

1. Avoid overloading the Wave Generator bearing during installation, rotate the Wave Generator as you easily install.

2. Since the Wave Generator of the CSD does not have an Oldham coupling, make sure that the position is within the recommended tolerance shown on page18.

3. Installation bolts on Wave Generator and installation bolt on Flexspline should not interfere each other.

Circular Spline

1. Be sure flatness and skewness are minimized.

2. Make sure there are no burrs or foreign substances.

3. Make sure there is enough room to have the minimum clearance in the housing.

4. Make sure that the Circular Spline can rotate in the housing when it is installed

5. When a bolt is inserted into a bolt hole, make sure that the bolt hole is located properly.

7. Bolts should not be tightened at the same time. Apply half of the recommended torque to tighten bolts, and then tighten bolts at the recommended torque. The order of tightening bolts should be done diagonally.

   Avoid using pins to secure the Circular Spline if possible.

Flexspline

1. Be sure flatness and skewness are minimized.

2. Make sure there are no burrs or foreign substances.

3. Make sure there is enough room to have the minimum clearance in the housing.

4. When a bolt is inserted into a bolt hole, make sure that the bolt hole is located properly.

5. Bolts should not be tightened at the same time. Apply half of the recommended torque to tighten bolts, and then tighten bolts at recommended torque. The order of tightening bolts should be done diagonally.

Make sure that Circular Spline and Flexspline mesh properly.

Do not damage the Flexspline during assembly.

Note to prevent corrosion

The standard CSD has not been treated for preventing corrosion. If needed, apply rust prevention on metal surfaces. As a special order, Harmonic Drive LLC can provide stainless steel components or surface treatments.

SHD External Dimensions

øN
L-øM equally spaced
øO
P4

D
E1 E2
F
f (O Ring provided)
h Usable length
g(seal)
e (O Ring provided)
Z2
Z1
øJ h7
øK H7
d
H
B2
øc
X1
I
G
øC H7
øa
øB1
øA h6
C0.3
Y
P1-P2 length P3
Do not remove these screws.
X2
b

equally spaced
R1-R2   øS
U1-U2 depth V
equally spaced   øW
øT
øQ

R
Y3
Y2 min.
Y1 min.
detailed drawings for Y

Detailed drawings are also available

① ② ③   ① ② ① ③

① Ball Separator

② Wave Generator Bearing

③ Wave Generator Plug

Size: 14, 17   Size: 20, 25, 32, 40

Size: 14, 17

Size: 20, 25, 32, 40
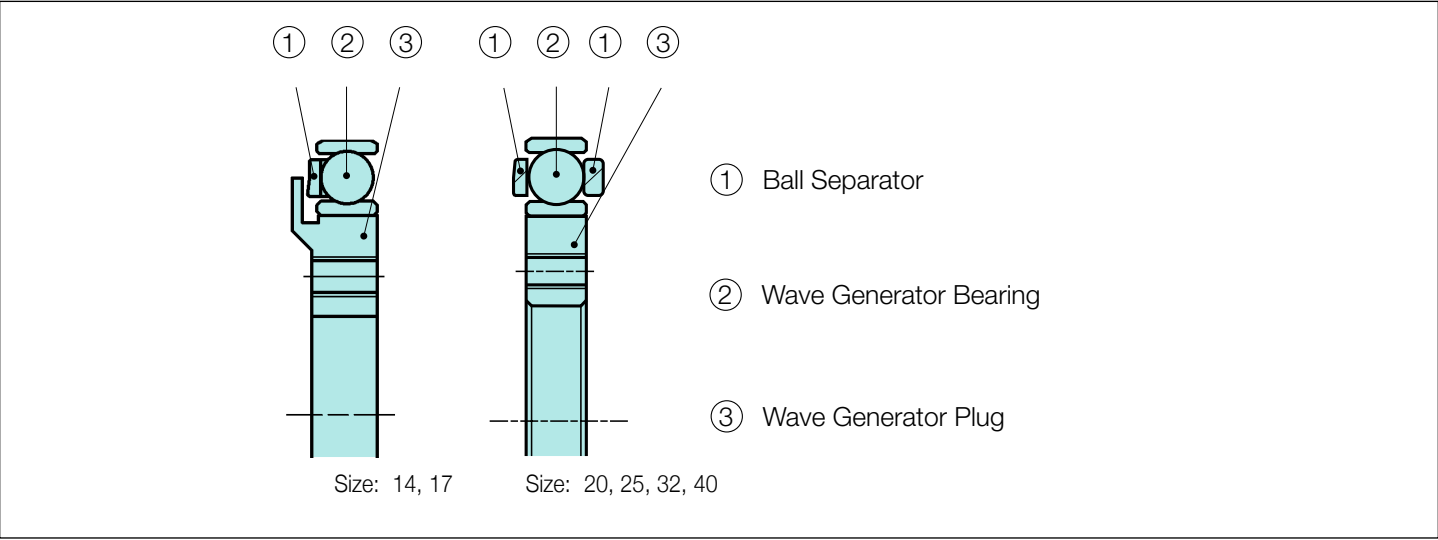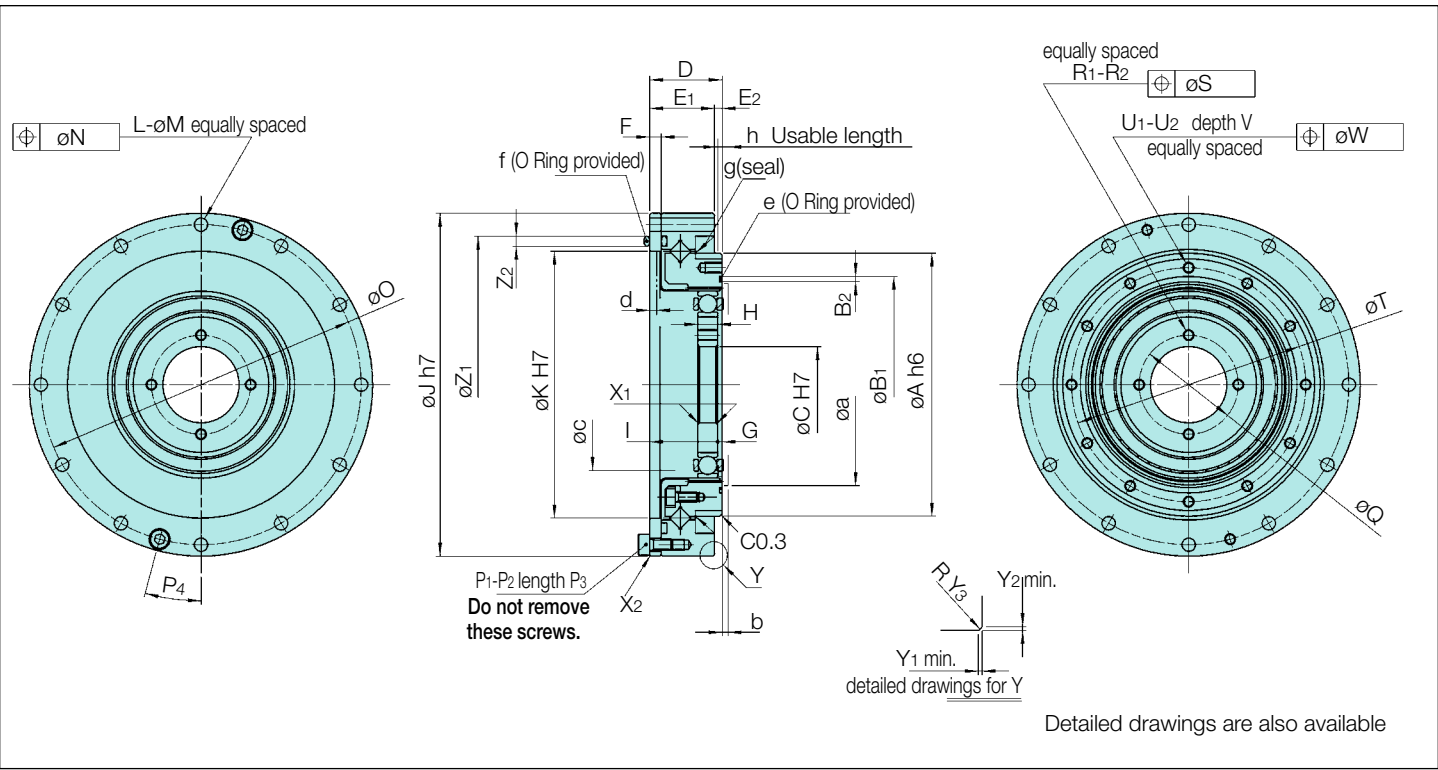
SHD Dimensions Table 16 (mm)

	14	17	20	25	32	40
$\varnothing A$ h6	$49\,^{0}_{-0.016}$	$59\,^{0}_{-0.019}$	$69\,^{0}_{-0.019}$	$84\,^{0}_{-0.022}$	$110\,^{0}_{-0.022}$	$132\,^{0}_{-0.025}$
$\varnothing B_1$	$39.1\,^{+0.1}_{0}$	$48\,^{+0.1}_{0}$	$56.8\,^{+0.1}_{0}$	$70.5\,^{+0.1}_{0}$	$92\,^{+0.1}_{0}$	$112.4\,^{+0.1}_{0}$
B_2	$0.8\,^{+0.15}_{0}$	$1.1\,^{+0.25}_{0}$	$1.4\,^{+0.25}_{0}$	$1.7\,^{+0.25}_{0}$	$2\,^{+0.25}_{0}$	$2.2\,^{+0.25}_{0}$
$\varnothing C$ H7	$11\,^{+0.018}_{0}$	$15\,^{+0.018}_{0}$	$20\,^{+0.021}_{0}$	$24\,^{+0.021}_{0}$	$32\,^{+0.025}_{0}$	$40\,^{+0.025}_{0}$
D	$17.5\,\pm0.1$	$18.5\,\pm0.1$	$19\,\pm0.1$	$22\,\pm0.1$	$27.9\,\pm0.1$	$33\,\pm0.1$
E_1	15.5	16.5	17	20	23.6	28
E_2	2	2	2	2	4.3	5
F	2.4	3	3	3.3	3.6	4
G	1.8	1.6	1.2	0.4	0.6	0.8
H	$4\,^{0}_{-0.1}$	$5\,^{0}_{-0.1}$	$5.2\,^{0}_{-0.1}$	$6.35\,^{0}_{-0.1}$	$8.6\,^{0}_{-0.1}$	$10.3\,^{0}_{-0.1}$
I	$15.7\,^{0}_{-0.2}$	$16.9\,^{0}_{-0.2}$	$17.8\,^{0}_{-0.2}$	$21.6\,^{0}_{-0.2}$	$27.3\,^{0}_{-0.2}$	$32.2\,^{0}_{-0.2}$
$\varnothing J$ h7	$70\,^{0}_{-0.030}$	$80\,^{0}_{-0.030}$	$90\,^{0}_{-0.035}$	$110\,^{0}_{-0.035}$	$142\,^{0}_{-0.040}$	$170\,^{0}_{-0.040}$
$\varnothing K$ H7	$50\,^{+0.025}_{0}$	$61\,^{+0.030}_{0}$	$71\,^{+0.030}_{0}$	$88\,^{+0.035}_{0}$	$114\,^{+0.035}_{0}$	$140\,^{+0.040}_{0}$
L	8	12	12	12	12	12
$\varnothing M$	3.5	3.5	3.5	4.5	5.5	6.6
$\varnothing N$	0.25	0.25	0.25	0.25	0.25	0.3
$\varnothing O$	64	74	84	102	132	158
P_1	2	2	2	4	4	4
P_2	M3	M3	M3	M3	M4	M4
P_3	6	6	6	8	10	10
P_4	22.5°	15°	15°	15°	15°	15°
$\varnothing Q$	17	21	26	30	40	50
R_1	4	4	4	4	4	4
R_2	M3	M3	M3	M3	M4	M5
$\varnothing S$	0.25	0.25	0.25	0.25	0.25	0.25
$\varnothing T$	43	52	61.4	76	99	120
U_1	8	12	12	12	12	12
U_2	M3	M3	M3	M4	M5	M6
V	4.5	4.5	4.5	6	8	9
$\varnothing W$	0.25	0.25	0.25	0.25	0.25	0.3
X_1	C0.4	C0.4	C0.5	C0.5	C0.5	C0.5
X_2	C0.4	C0.4	C0.5	C0.5	C0.5	C0.5
Y · Y_1	0.4	0.4	0.5	0.5	0.5	0.5
Y · Y_2	0.4	0.4	0.5	0.5	0.5	0.5
Y · RY_3	1.2	1.2	1.5	1.5	1.5	1.5
Z_1	$57\,^{+0.1}_{0}$	$68.1\,^{+0.1}_{0}$	$78\,^{+0.1}_{0}$	$94.8\,^{+0.1}_{0}$	$123\,^{+0.1}_{0}$	$148\,^{+0.1}_{0}$
Z_2	$2\,^{+0.25}_{0}$	$2\,^{+0.25}_{0}$	$2.7\,^{+0.25}_{0}$	$2.4\,^{+0.25}_{0}$	$2.7\,^{+0.25}_{0}$	$2.7\,^{+0.25}_{0}$
minimum housing clearance · $\varnothing a$	36.5	45	53	66	86	106
minimum housing clearance · b	1	1	1.5	1.5	2	2.5
minimum housing clearance · $\varnothing c$	31	38	45	56	73	90
minimum housing clearance · d	1.4	1.8	1.7	1.8	1.8	1.8
e	d37.1d0.6	d45.4d0.8	d53.28d0.99	d66.5d1.3	d87.5d1.5	d107.5d1.6
f	d54.38d1.19	d64.0d1.5	d72.0d2.0	d88.62d1.78	d117.0d2.0	d142d2.0
g	D49585	D59685	D69785	D84945	D1101226	D1321467
h	1.5	1.5	1.5	1.5	3.3	4
Weight (kg)	0.33	0.42	0.52	0.91	1.87	3.09

• The following parameters can be modified to accommodate customer specific requirements.

Wave generator : $\varnothing C$

Flexspline : $\varnothing O$

Circular Spline : X_1, X_2

• Minimum housing clearance parameters ø a, b, øc, d must be maintained to prevent damage to the gear during operation.
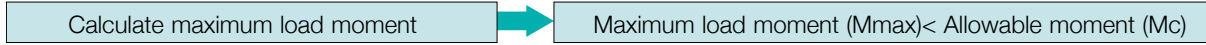
Specifications for Cross Roller Bearing

Specification for Cross Roller Bearing

Housed units incorporate a precise cross roller bearing to directly support a load. The inner race of the bearing forms the output flange.
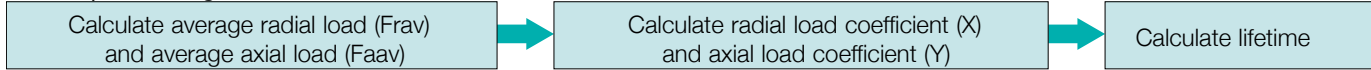
Please calculate maximum load moment, life of cross roller bearing, and static safety factor to fully maximize the performance of the housed unit (gearhead).
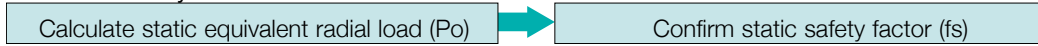
Calculation Procedure

1. Maximum Load Moment (Mmax)

| Calculate maximum load moment | ➡ | Maximum load moment (Mmax)< Allowable moment (Mc) |

2. Output Bearing Life

| Calculate average radial load (Frav) and average axial load (Faav) | ➡ | Calculate radial load coefficient (X) and axial load coefficient (Y) | ➡ | Calculate lifetime |

3. Static Safety Factor

| Calculate static equivalent radial load (Po) | ➡ | Confirm static safety factor (fs) |

Specification for cross roller bearing

Specification for cross roller bearing is shown on figure.

Table 17

Size	Pitch Circle dp m	Offset R mm	Basic Dynamic Rated Load C X10²N	Basic Dynamic Rated Load C lb	Basic Static Rated Load Co X10²N	Basic Static Rated Load Co lb	Allowable Moment Load Mc Nm	Allowable Moment Load Mc in-lb	Moment Rigidity Km x10⁴ Nm/rad	Moment Rigidity Km in-lb/ arc-min
14	0.0503	11.1	29	652	43	967	37	327	7.08	182
17	0.061	11.5	52	1169	81	1821	62	548	12.7	326
20	0.070	11.0	73	1641	110	2473	93	823	21	540
25	0.086	12.1	109	2451	179	4024	129	1141	31	796
32	0.112	17.3	191	4294	327	7352	290	2566	82.1	2110
40	0.133	19.5	216	4856	408	9173	424	3752	145	3726

Basic dynamic rated load is a constant radial load where the basic dynamic rated life of CRB is 1 x 10⁶ rotations.
Basic static rated load is a static load where the value of moment rigidity is the average value.

For the following size and gear ratio combinations,the life of the cross roller bearing operating at the allowable moment load is less than the life of the wave generator bearing (L$_{10}$ = 7000 hr) operating at 2000rpm and rated torque.

Table 18

Size	Gear Ratio	
14	50	100
17	50	
20	50	

How to Calculate the Maximum Load Moment

How to calculate the Maximum load moment is shown below. Please be sure that Mc is equal or greater than M max.

$$Mmax = Frmax \cdot (Lr+R) + Famax \cdot La$$

How to Calculate an Average Load

To calculate average radial load, average axial load or average output speed, follow steps below.

When the radial load and axial load vary, the life of cross roller bearing can be determined by converting to an average load. (see figure 10)

equation (5)   Calculate Average Radial Load

$$Frav = \sqrt[10/3]{\frac{n_1 t_1 |Fr_1|^{10/3} + n_2 t_2 |Fr_2|^{10/3} \cdots + n_n t_n |Fr_n|^{10/3}}{n_1 t_1 + n_2 t_2 \cdots + n_n t_n}}$$

Fr_1 is radial load in t_1, Fr_3 is radial load in t_3.

equation (6)   Calculate Average Axial Load(Faav)

$$Faav = \sqrt[10/3]{\frac{n_1 t_1 |Fa_1|^{10/3} + n_2 t_2 |Fa_2|^{10/3} \cdots + n_n t_n |Fa_n|^{10/3}}{n_1 t_1 + n_2 t_2 \cdots + n_n t_n}}$$

Fa_1 is axial load in t_1, Fa_3 is axial load in t_3.

Figure 9

equation (7)   Calculate Average Output Speed

Figure 10

$$Nav = \frac{n_1 t_1 + n_2 t_2 \cdots + n_n t_n}{t_1 t_2 \cdots + t_n}$$

Calculate radial load coefficient (X) axial load (Y)

$\dfrac{Faav}{Frav+2\,(Frav\,(Lr+R) + Faav \cdot La)\,/dp}$	≤ 1.5	1	0.45
$\dfrac{Faav}{Frav+2\,(Frav\,(Lr+R) + Faav \cdot La)\,/dp}$	> 1.5	0.67	0.67

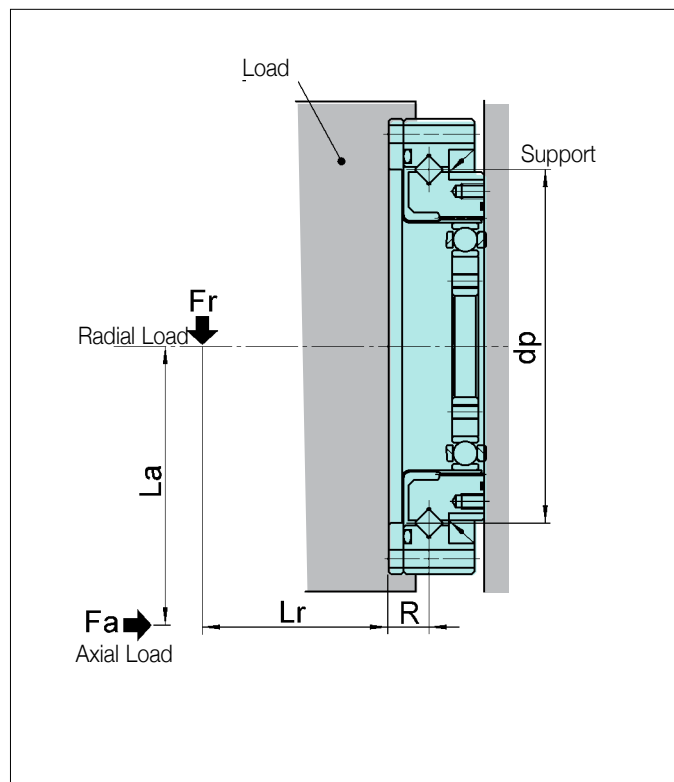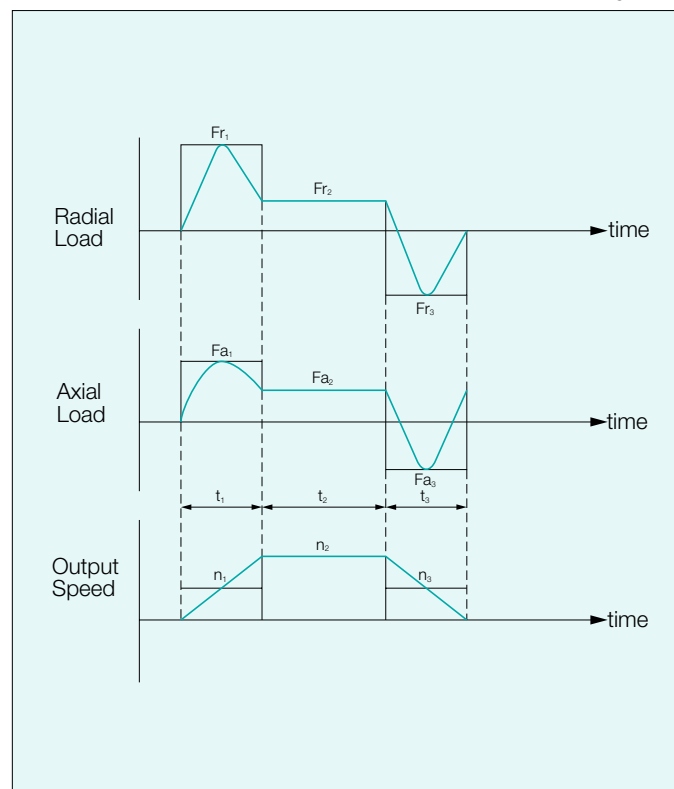| Frmax	Max. radial load	N	Figure 10
Famax	Max. axial load	N	Figure 10
Lr, La	Moment arm	m	Figure 9
R	amount of offset	m	Table 17
dp	pitch circle	m	Table 17

Output bearing Life

How to Calculate Life of the Output Bearing

The life of a cross roller bearing can be calculated by equation (8).

equation (8)

$$L_{a-10} = \frac{10^6}{60 \times Nav} \times \left(\frac{C}{fw \cdot Pc}\right)^{10/3}$$

List 1

L $_{a10}$	Life	Hour	equation 8
Nav	Average Output Speed	rpm	equation 7
C	Basic Dynamic Rated Load	N	table 17
Pc	Dynamic Equivalent	N	equation 9
fw	Load Coefficient	——	list 2

List 2

Load Coefficient,	fw
Steady operation without impact and vibration	1~1.2
Normal operation	1.2~1.5
Operation with impact and vibration	1.5~3

Dynamic Equivalent Radial Load

equation (9)

$$Pc = X \cdot \left(\frac{Frav + 2(Frav(Lr + R) + Faav \cdot La)}{dp}\right) + Y \cdot Faav$$

Symbol of equation (8)

Frav	Average radial load	N	equation 5
Faav	Average axial load	N	equation 6
dp	Pitch diameter	m	table 17
X	Radial load coefficient	——	list page 26
Y	Axial load coefficient	——	list page 26
Lr, La	Moment Arm	m	figure 9
R	Offset	m	figure 9 and table 17

How to Calculate Static Safety Coefficient

Basic static rated load is an allowable limit for static load, but its limit is determined by usage. In this case, static safety coefficientof the cross roller bearing can be calculated by equation 10.
Reference values under general conditions are shown on list 3.
Static equivalent radial load can be calculated by equation (12)

equation (10)

$$fs = \frac{Co}{Po}$$

equation (12)

$$Po = Frmax + \frac{2Mmax}{d} + 0.44 \cdot Famax$$

Symbols for equation (9)

Co	Basic static rated load	N	table 17
Po	Static equivalent radial load	N	refer to equation 12

list 3

Load Conditions	Lower Limit Value for f$_s$
Impact loads	1-1.5 ≥ 2
Normal loads	≥ 1.5
High accuracy required	≥ 3

How to Calculate Life for Oscillating Motion

The Life of a cross roller bearing in a oscillating operation can be calculated by equation 11
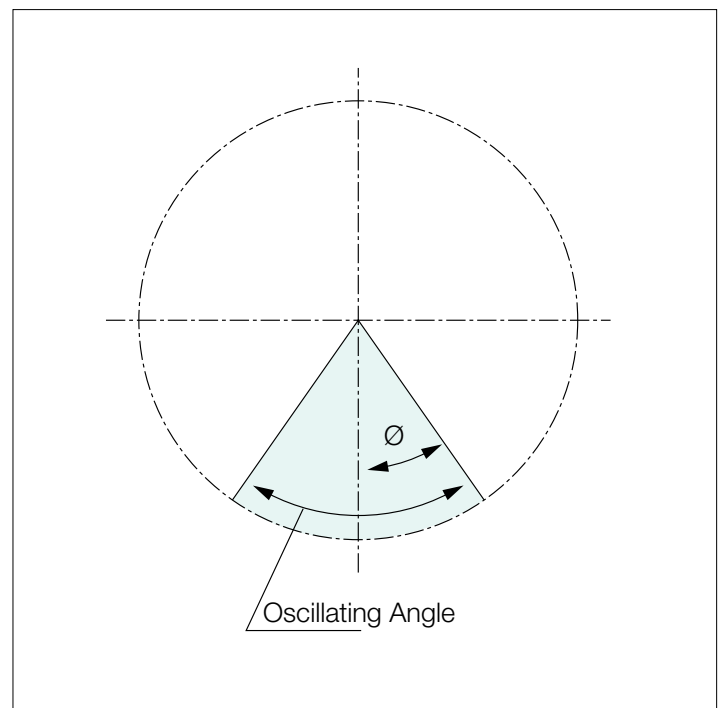
equation (11)

$$Loc = \frac{10^6}{60 \times n1} \times \frac{90}{\emptyset} \times \left(\frac{C}{fw \cdot Pc}\right)^{10/3}$$

Symbol of equation (11)

List 4

Loc	Rated life for oscillating motion	Hour	equation 11
n1	Round trip oscillation each minute	rpm	——
C	Basic dynamic rated load	N	table 17
Pc	Dynamic equivalent radial load	N	equation 9
fw	Load Coefficient	——	list 2
Ø	Angle of oscillation/2	degrees	figure 11

figure 11

Oscillating Angle

A small angle of oscillation (less than 5 degrees) may cause fretting corrosion to occur since lubrication may not circulate properly.

Lubricant

Grease lubricant is the standard for the SHD unit. The temperature range is shown below. (Exceptions are shown on page 17.)

Lubricant		
Grease	Harmonic Grease	SK-1A
Grease	Harmonic Grease	SK-2
Grease	Harmonic Grease	4B-No.2

Lubricant		
Grease	SK-1A	0ºC~+40ºC
Grease	SK-2	0ºC~+40ºC
Grease	4B-No.2	-10ºC~+70ºC

Harmonic Grease SK-1A
This grease is developed for a Harmonic Drive® gear and features good durability and efficiency.

Harmonic Grease SK-2
This grease is developed for a small size Harmonic Drive® gear and features smooth rotation of the Wave Generator since high pressure additive is liquefied.

Harmonic Grease 4B No.2
This grease is developed for Harmonic Drive® gearing and features long life and a wide range of temperature.

Note 1
Grease lubrication must have proper sealing, this is essential for 4BNo. 2.

Rotating part: Oil seal with spring is needed.
Mating part: O ring or seal adhesive is needed.

Note 2
The grease has the highest deterioration rate where the grease is subjected to the greatest shear (near wave generator).
Its viscosity is between JIS No.0 and No. 00 depending on the operation.

Recommended Grease

Size	14	17	20	25	32	40
SK-1A	–	–	O	O	O	O
SK-2	O	O	Δ	Δ	Δ	Δ
4BNo.2	•	•	•	•	•	•

•: recommended grease for long life and high load   O: Standard   Δ: Semistandard

Characteristics of Grease

Grease	SK-1A	SK-2	4BNo.2
Durability	O	O	•
Fretting Resistance	O	O	•
Low Temp	Δ	Δ	•
Grease Leakage	•	•	Δ

•: Excellent   O: Good   Δ: Exercise Caution

Recommended Grease

Grease	SK-1A	SK-2	4B No.2
Base Oil	Refined mineral hydrocarbon base oil	Refined mineral hydrocarbon base oil	Hydrocarbon type synthetic oil and polymer
Thickening Agent	Lithium soap thickener	Lithium soap thickener	Urea
Additive	Organic molybdenum, etc.	Organic molybdenum, etc.	Organic molybdenum, etc.s
NLGI Consistency No.	No.2	No.2	No.1.5
Viscosity (25C), cSt	265 to 295	265 to 295	290 to 320
Melting Point	197ºC	198ºC	247ºC
Color	Yellow	Green	Light Yellow
Life	5 Years in Airtight Container		

Note: Proper lubrication of the gearing is essential for high performance and reliability.

Lubrication

Recommended Dimensions for Inner Case

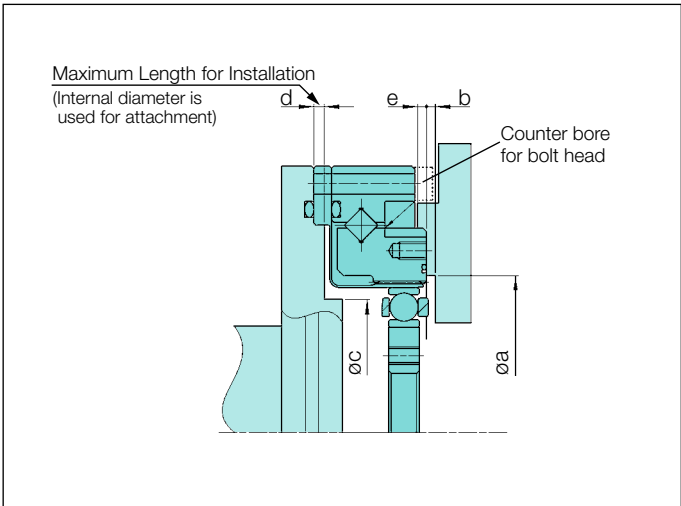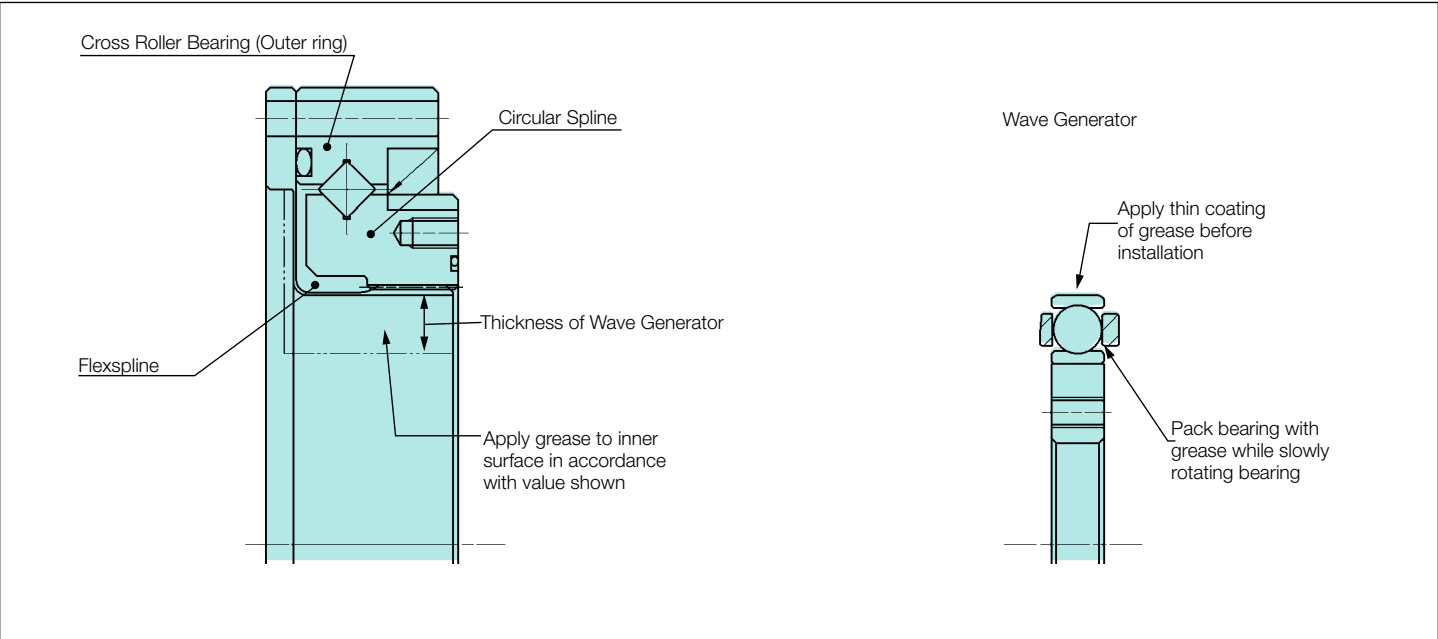These dimensions must be maintained to prevent damage to the gear and to maintain a proper grease cavity.

Maximum Length for Installation
(Internal diameter is used for attachment)

Counter bore for bolt head

Figure 12

Recommended Dimensions for Inner Case   Table 19   Unit: mm

Size	14	17	20	25	32	40
ø a	36.5	45	53	66	86	106
b	1(3)	1(3)	1.5(4.5)	1.5(4.5)	2(6)	2.5(7.5)
ø c	31	38	45	56	73	90
d	1.4	1.8	1.7	1.8	1.8	1.8
e	1.5	1.5	1.5	1.5	3.3	4

Note: Values in parenthesis show the value when the Wave Generator is pointing up.

Grease Usage   Table 20   Unit: g

Size	14	17	20	25	32	40
grease amount	5	9	13	24	51	99

The Flexspline teeth, Circular spline teeth and Cross roller bearing are grease lubricated at the Factory.

Figure 13

Cross Roller Bearing (Outer ring)

Circular Spline

Wave Generator

Apply thin coating of grease before installation

Thickness of Wave Generator

Flexspline

Pack bearing with grease while slowly rotating bearing

Apply grease to inner surface in accordance with value shown

Grease Change

The wear characteristics of the gear are strongly influenced by the condition of the grease lubrication. The condition of the grease is affected by the ambient temperature. The graph shows the maximum number of input rotations for various temperatures. This graph applies to applications where the average load torque does not exceed the rated torque.

In cases where the average load torque exceeds, calculate the grease change interval using the equation shown below.

Equation where average load torque exceeds rated torque

[Equation 13]

$$L_{GT} = L_{GTn} \times \left(\frac{T_r}{T_{av}}\right)^3$$

Symbol of Equation [13]	
L_{GT}	Grease change (Torque is over rated torque), input rotations
L_{GTn}	Grease change (Torque is below rated torque), input rotations (From Graph)
T_r	Rated Torque
T_{av}	Average load torque on output

Graph of L_{GTn} vs. Temperature

Grease Life

4B No.2

SK-1A
SK-2

Wave Generator Life

L_{GT} n, Total Number of Rotations of Wave Generator

Grease Temperature (ºC)
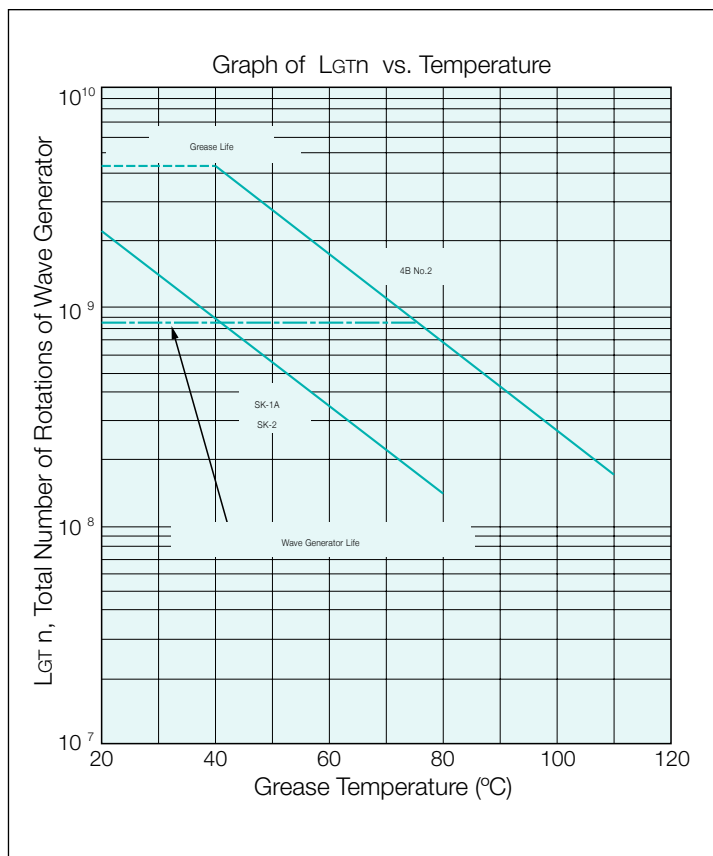
Figure 14

Recommended Tolerances for Assembly

For peak performance of the SHD it is essential that the following tolerances be observed when assembly is complete.

Recommended tolerances for assembly

Recommended Shaft Tolerance
H6 or h6 ◎ ø b A

Recommended Housing Tolerance H7

Attached Surface
⊥ c B

Flexspline Interface
⊥ a A

Wave Generator Interface
⊥ d B

◎ ø e B
Recommended Shaft Tolerance h6
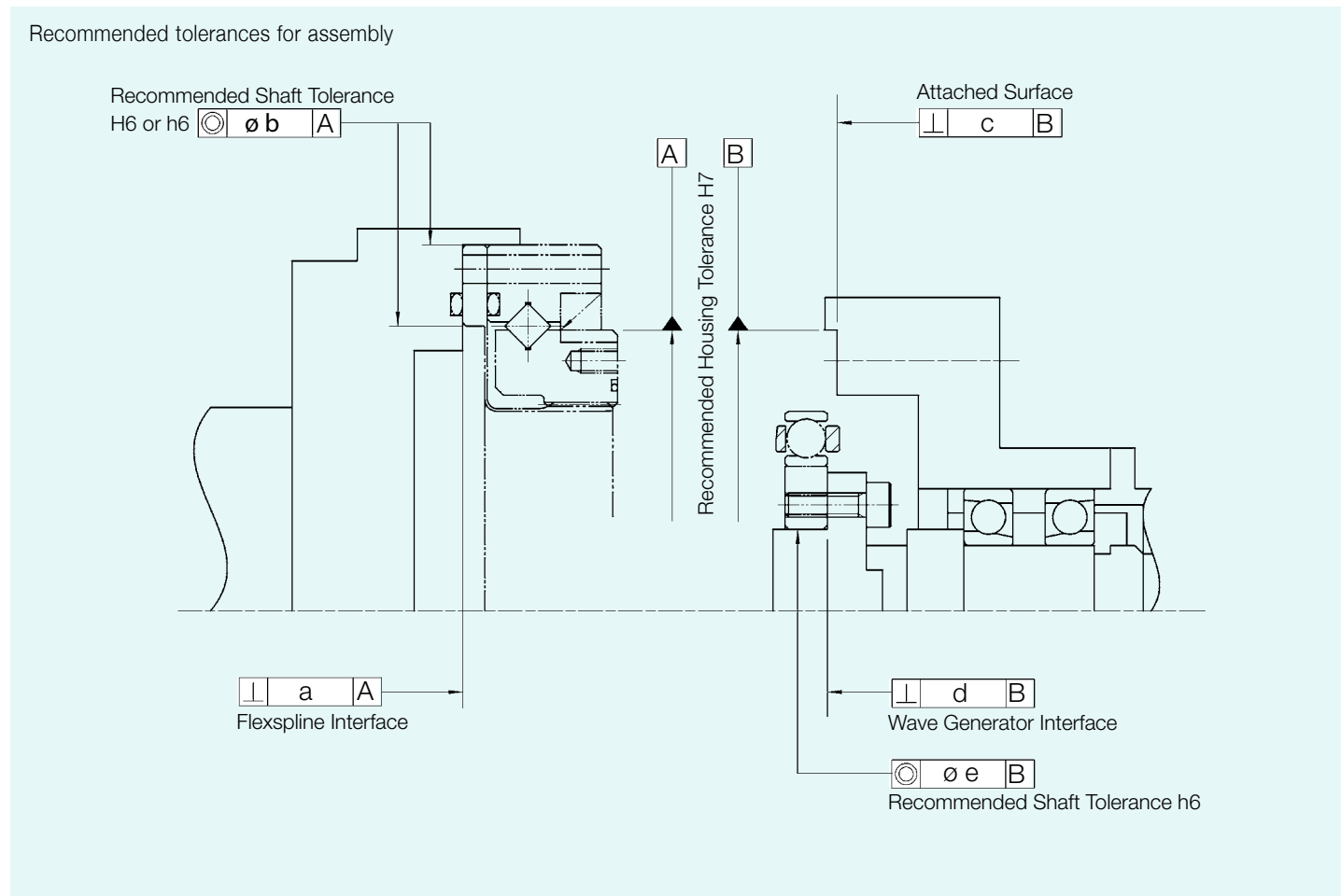
Tolerances for Assembly Table 21   Unit:mm

Size	14	17	20	25	32	40
a	0.016	0.021	0.027	0.035	0.042	0.048
øb	0.015	0.018	0.019	0.022	0.022	0.024
c	0.011	0.012	0.013	0.014	0.016	0.016
d	0.008	0.010	0.012	0.012	0.012	0.012
øe	0.016	0.018	0.019	0.022	0.022	0.024

Sealing structure

A seal structure is needed to maintain the high durability of the gear and prevent grease leakage.

Key Points to Verify

- Rotating parts should have an oil seal (with spring), surface should be smooth (no scratches)
- Mating flanges should have an O Ring, seal adhesive
- Screws should have a thread lock
  (Loctite 242 recommended) or seal adhesive.

  Note: If you use Harmonic grease 4BNo.2, strict sealing is required.

Direction for Thrust Force of Wave Generator

SHD

F ← direction for thrust force in acceleration

F → direction for thrust force in deceleration
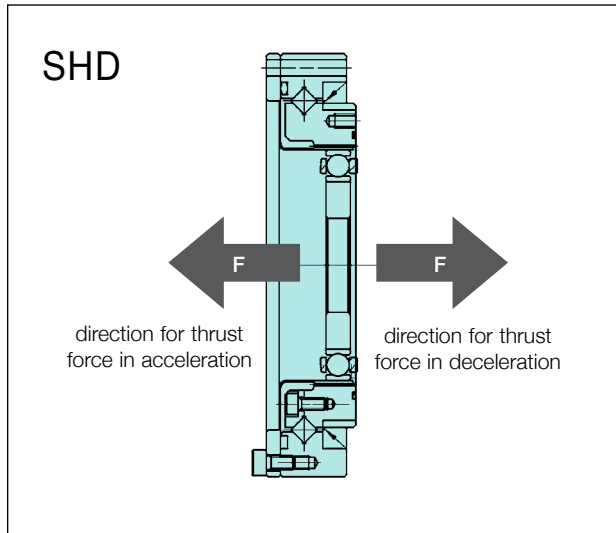
Figure 15

Axial Force of Wave Generator

When a SHD gear is used to accelerate a load, the deflection of the Flexspline leads to an axial force acting on the Wave Generator. This axial force, which acts in the direction of the back end of the Flexspline, (toward the left in fig.15) must be supported by the bearings of the input shaft (motor shaft).

When a SHD gear is used to decelerate a load, an axial force acts to push the Wave Generator out of the Flexspline (toward the right in fig.15). Maximum axial force of the Wave Generator can be calculated by the equation shown below. The axial force may vary depending on its operating condition. The value of axial force tends to be a larger number when using high torque, extreme low speed and constant operation. The force is calculated (approximately) by the equation. In all cases, the Wave Generator must be axially (in both directions), as well as torsionally, fixed to the input shaft.

(note) Please contact us for detailed information on attaching the Wave Generator to the input (motor) shaft.

Equation [14] for axial force

Gear Ratio	equation
i=1/50	$F=2 \times \frac{T}{D} \times 0.07 \times \tan 30° + 2\mu PF$
i=1/100 and up	$F=2 \times \frac{T}{D} \times 0.07 \times \tan 20° + 2\mu PF$

Symbols for equation [4]

F	thrust force	N	
D	Gear Size x 0.00254	m	
T	output torque	Nm	
2μPF	thrust force by bearing	Nm	(see table)

Calculation Example

size	:	32
Ratio	:	i=1/50
Output Torque	:	200Nm

$$F=2 \times \frac{200}{(32 \times 0.00254)} \times 0.07 \times \tan 30° + 16$$

$$F=215N$$

Thrust Force by Bearing SHD

Model Name	Model Number	2μPF (N)
SHD	14	1.2
	17	3.3
	20	5.6
	25	9.3
	32	16
	40	24

Assembly Notes

Output for SHD varies depending on which component is fixed.
Gear ratio and rotational direction also vary. see page 5

Fixed	Output	Ratio and Rotation
Flexspline	Circular Spline	② on page 5
Circular Spline	Flexspline	① on page 5

Flexspline
(Outer cross roller bearing)

Circular Spline
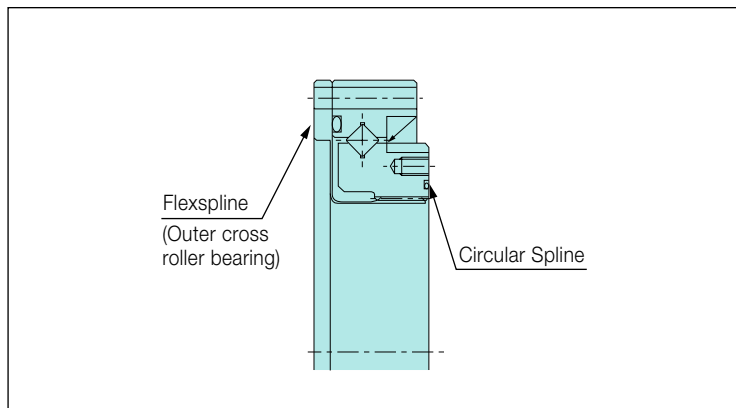
Figure 16

Installation and Torque Transmission for Flexspline Bolts   Table 23

Size	Standard	14	17	20	25	32	40
Number of Bolts		8	12	12	12	12	12
Size		M3	M3	M3	M4	M5	M6
Pitch Circle Diameter	mm	64	74	84	102	132	158
Clamp Torque	Nm	2.0	2.0	2.0	4.5	9.0	15.3
Torque transmission	Nm	108	186	210	431	892	1509

Note:

1. The material of the thread must withstand the clamp torque.

2. Recommended bolt : JIS B 1176 socket head cap screw strength range : JIS B 1051 over 12.9

3. Torque coefficient : K=0.2

4. Clamp coefficient A=1.4

5. Friction coefficient on the surface contacted: 0.15

Installation and Torque Transmission for Circular Spline Bolts   Table 24

Size	Standard	14	17	20	25	32	40
Number of Bolts		6	12	12	12	12	12
Size		M3	M3	M3	M4	M5	M6
Pitch Circle Diameter	mm	43	52	61.4	76	99	120
Clamp Torque	Nm	2.0	2.0	2.0	4.5	9.0	15.3
Torque transmission	Nm	72	130	154	321	668	1148

Note:

1. The material of the thread must withstand the clamp torque.

2. Recommended bolt : JIS B 1176 socket head cap screw strength range : JIS B 1051 over 12.9

3. Torque coefficient : K=0.2

4. Clamp coefficient A=1.4

5. Friction coefficient on the surface contacted: 0.15

Manufacturing for Mating Part and Housing

When the housing interferes with corner "A" shown in fig. 17, an undercut in the housing is recommended as shown in fig. 18.

Figure 17

Figure 18

A

60°
0.2
R 0.4
0.2

Recommended Housing Undercut
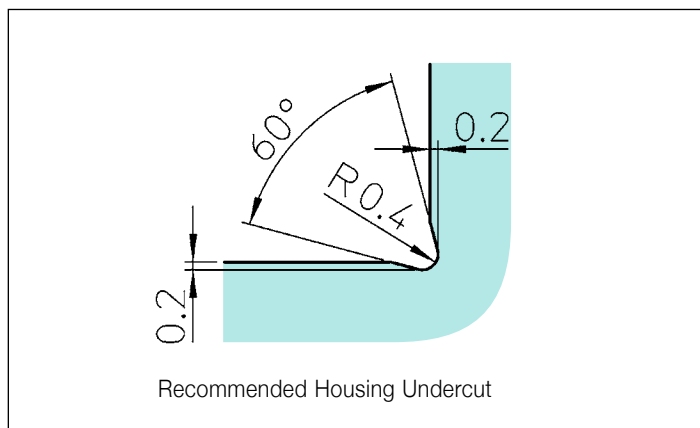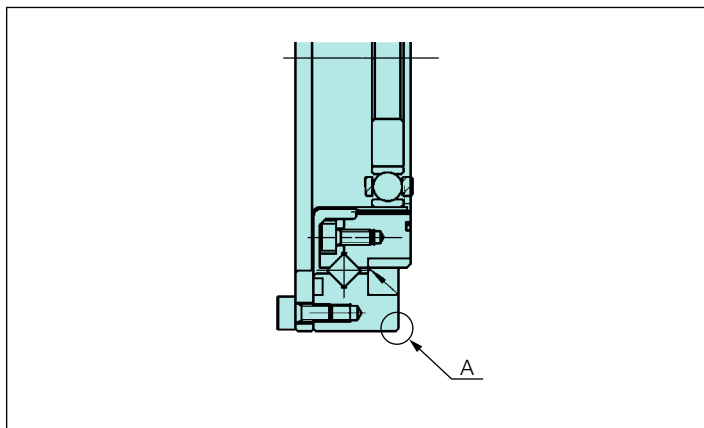
Assembly Order for Basic Three Elements

The recommended sequence of assembly is illustrated below.
Only after the Circular Spline and Flexspline are assembled in equipment is the Wave Generator assembled. If assembly is performed using a different method, Dedoidal assembly or teeth breakage may occur. It is essential that teeth of the Flexspline and Circular Spline mesh symmetrically for proper function. An eccentric tooth mesh (Dedoidal), will result in noise and may lead to early failure of the gear.

Note:
Do not assemble
Wave Generator from
Diaphram of Flexspline

Wave Generator   Wave Generator

Circular Spline
Flexspline
Cross Roller Bearing
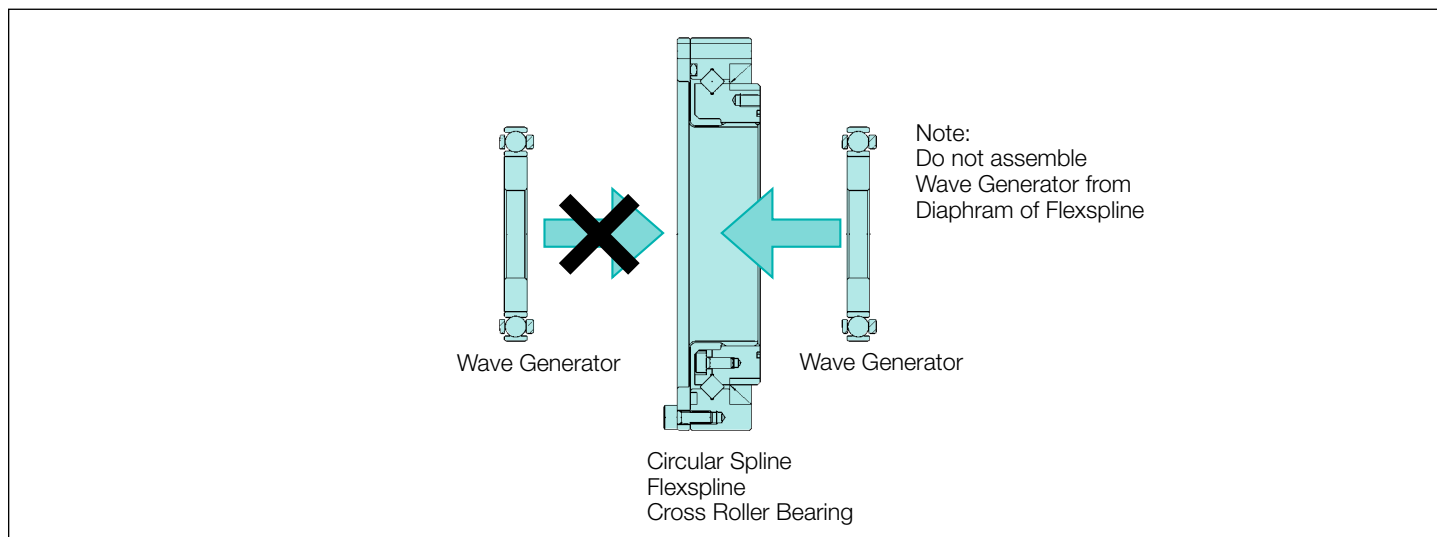
Figure 19

SHD assembly procedure

Note for assembly structure for SHD

Wave Generator

1. Avoid overloading the Wave Generator bearing during installation, rotate the Wave Generator as you easily install.

2. Since the Wave Generator of the CSD does not have an Oldham coupling, make sure that the position is within the recommended tolerance shown on page 32.

3. Installation bolts on Wave Generator and installation bolt on Flexspline should not interfere each other.

Circular Spline

1. Be sure flatness and skewness are minimized.

2. Make sure there are no burrs or foreign substances.

3. Make sure there is enough room to have the minimum clearance in the housing.

4. Make sure that the Circular Spline can rotate in the housing when it is installed.

5. When a bolt is inserted into a bolt hole, make sure that the bolt hole is located properly.

7. Bolts should not be tightened at the same time. Apply half of the recommended torque to tighten bolts, and then tighten bolts at the recommended torque. The order of tightening bolts should be done diagonally.

    Avoid using pins to secure the Circular Spline if possible.

Flexspline

1. Be sure flatness and skewness are minimized.

2. Make sure there are no burrs or foreign substances.

3. Make sure there is enough room to have the minimum clearance in the housing.

4. When a bolt is inserted into a bolt hole, make sure that the bolt hole is located properly.

5. Bolts should not be tightened at the same time. Apply half of the recommended torque to tighten bolts, and then tighten bolts at recommended torque. The order of tightening bolts should be done diagonally.

Make sure that Circular Spline and Flexspline mesh properly.

Do not damage the Flexspline during assembly.

Note to prevent corrosion

The standard SHD has not been treated for preventing corrosion. If needed, apply rust prevention on metal surfaces. As a special order, Harmonic Drive LLC can provide stainless steel components or surface treatments.

Efficiency

The efficiency depends on the conditions shown below. Efficiency depends on gear ratio, input speed, load torque, temperature, quantity of lubricant and type of lubricant.

Measurement Condition for Efficiency Graphs

Installation:	Based on recommended tolerance
Load Torque:	Rated Torque
Lubricant:	Harmonic Grease SK-1A (size 20 and up)
	Harmonic Grease SK-2 (size 14, 17)
	Harmonic Grease 4B No.2 (SHD Output Bearing)
Grease quantity:	Recommended quantity

Please contact us for details pertaining to recommended oil lubricant for CSD.

CSD Series

Ratio 50

Size 14
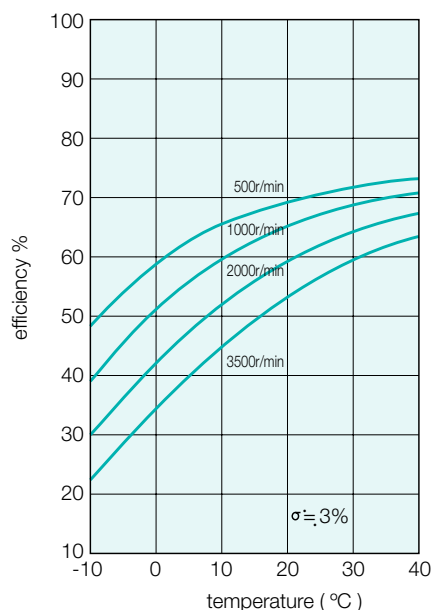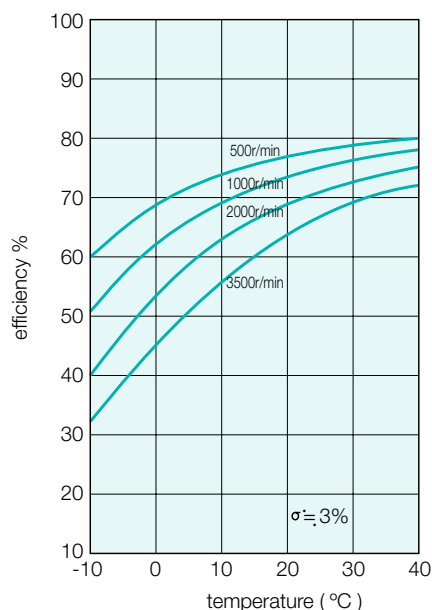
Size 17, 20

Size 25, 32, 40, 50
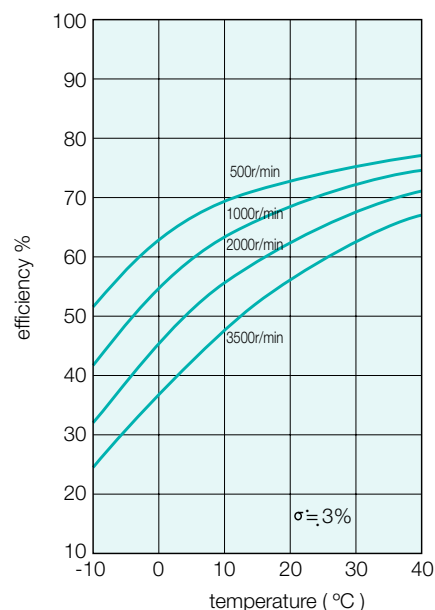
Ratio 100

Size 14
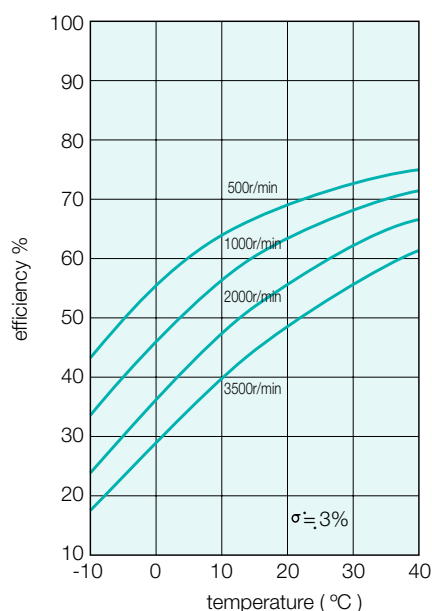
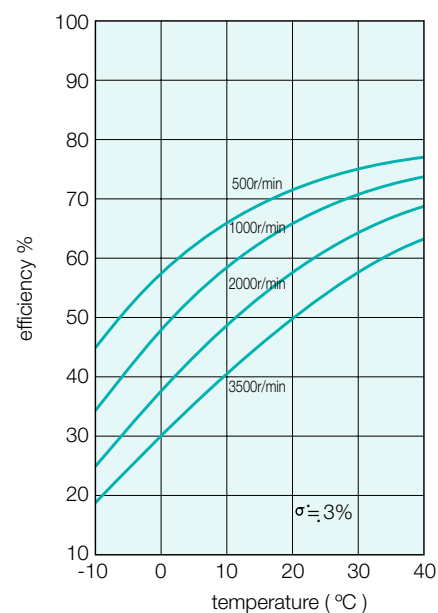
Size 17, 20, 25, 32, 40, 50
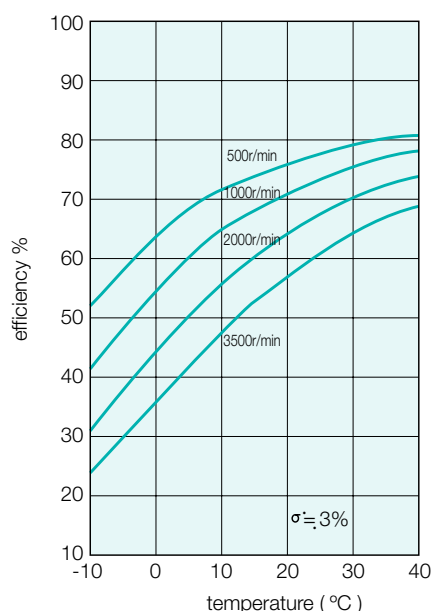
Ratio 160

Size 20, 25, 32, 40, 50
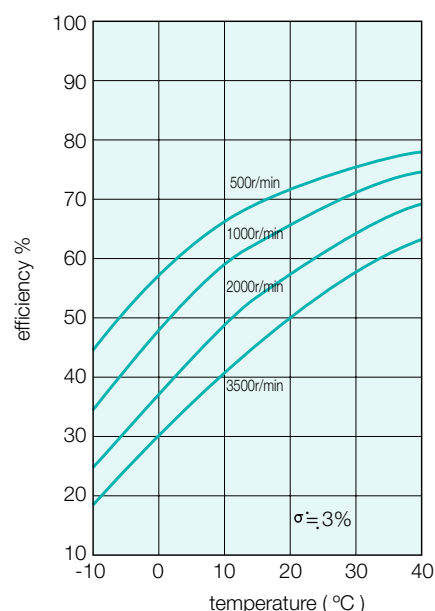
Efficiency (@ Torque ≠ Rated Torque) = Efficiency (from graph) x Compensation Coefficient (from graph page 36)

Compensation Coefficient for Other Load Conditions

The efficiency varies with load torque.
For the efficiency at various torque loads, use the appropriate compensation coefficient.

CSD Series

SHD Series

SHD Series

Ratio 50

Size 14
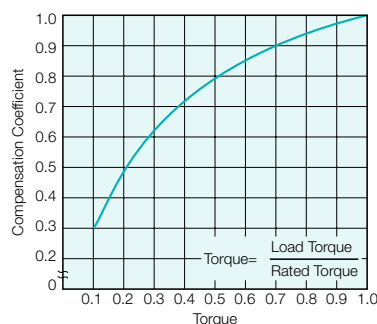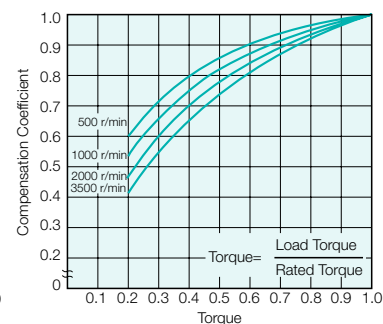
Size 17, 20, 25, 32, 40
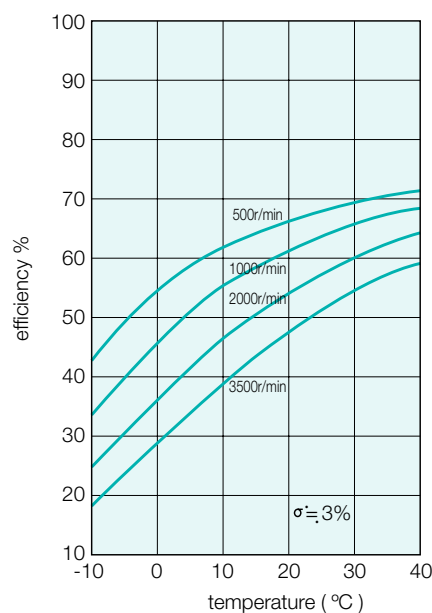
Ratio 100

Size 14

Size 17, 20, 25, 32, 40
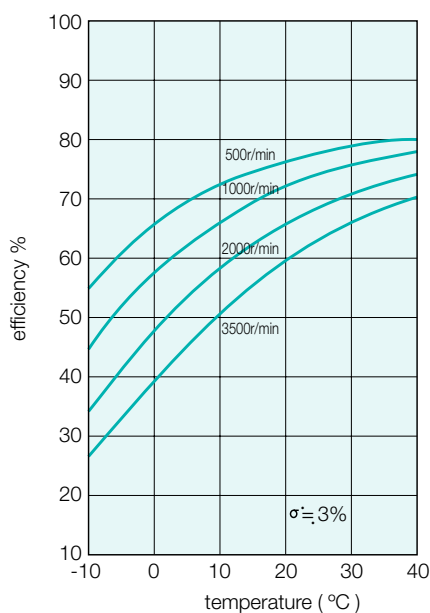
Ratio 160

Size 20, 25, 32, 40

Efficiency (@ Torque ≠ Rated Torque) = Efficiency (from graph) x Compensation Coefficient (from graph)

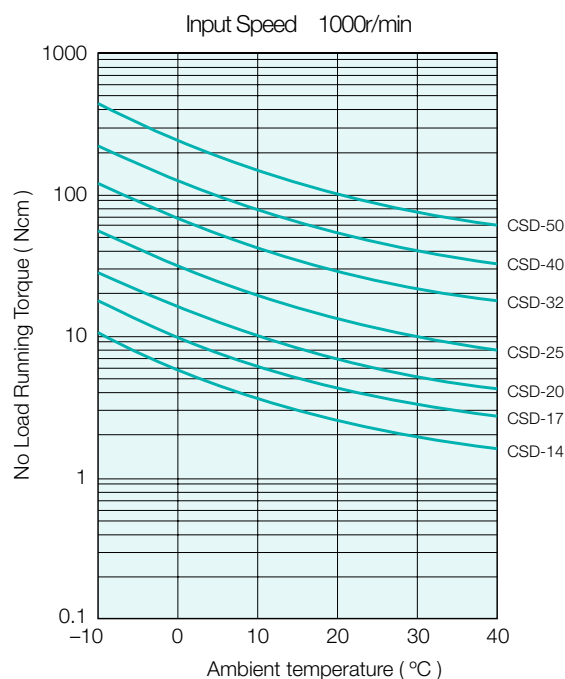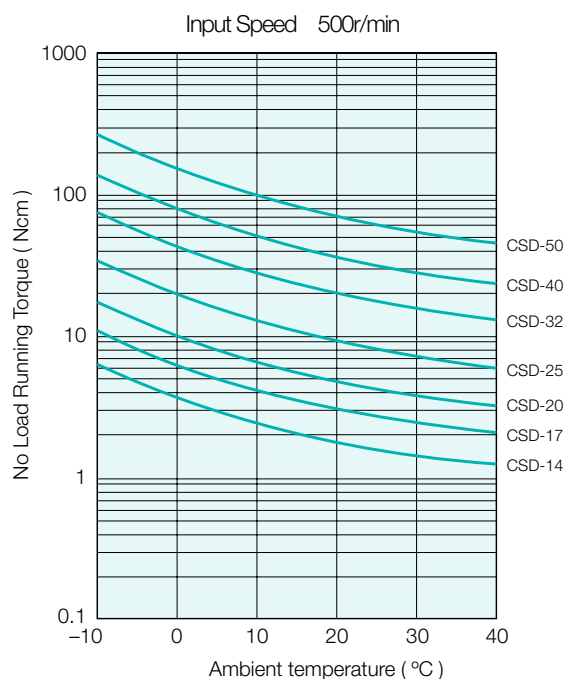# No Load Running Torque

No Load Running Torque (NLRT)

No load running torque indicates the torque which is needed to rotate input of the gear, "Wave Generator", with no load on the output side (low speed side). Please contact us regarding details.

Measurement Condition for NLRT Graphs

Ratio: 100 : 1
Lubricant: Harmonic Grease SK-1A (size 20 and up)
                    Harmonic Grease SK-2 (size 14, 17)
                    Harmonic Grease 4B No.2 (SHD Output Bearing)
Grease quantity: Recommended quantity

Torque value is measured after 2 hours at 2000rpm input.
Please contact us for details pertaining to recommended oil lubricant for CSD.

CSD Series

Input Speed   500r/min

Input Speed   1000r/min

Input Speed   2000r/min

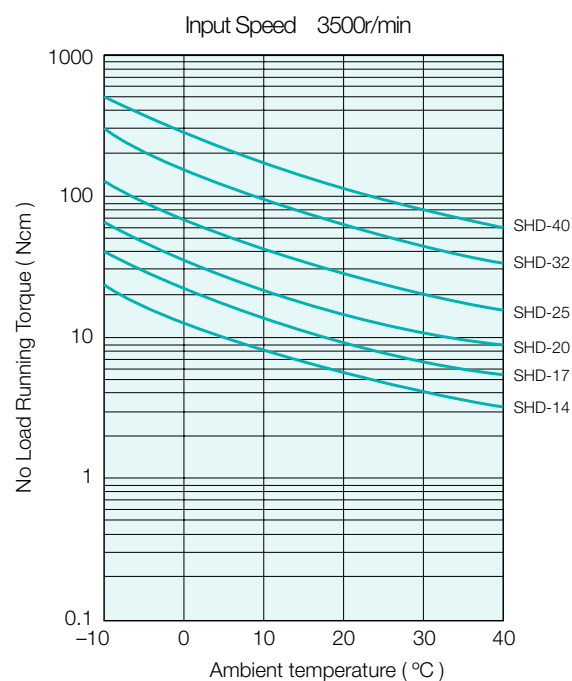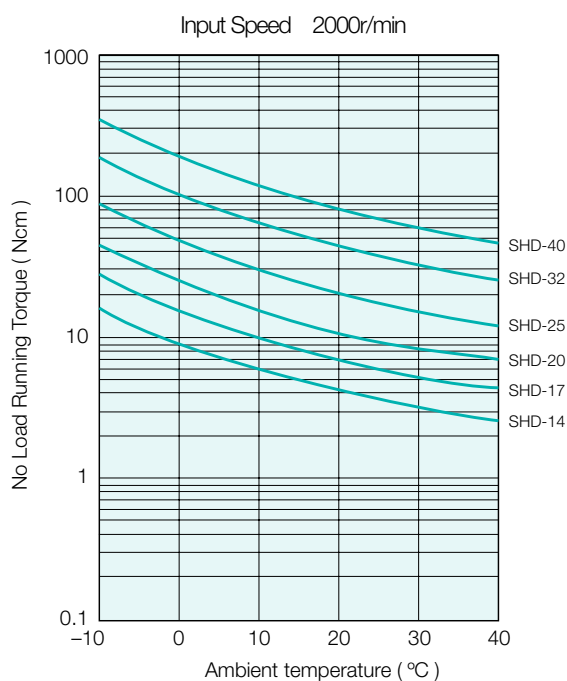### Input Speed   3500r/min
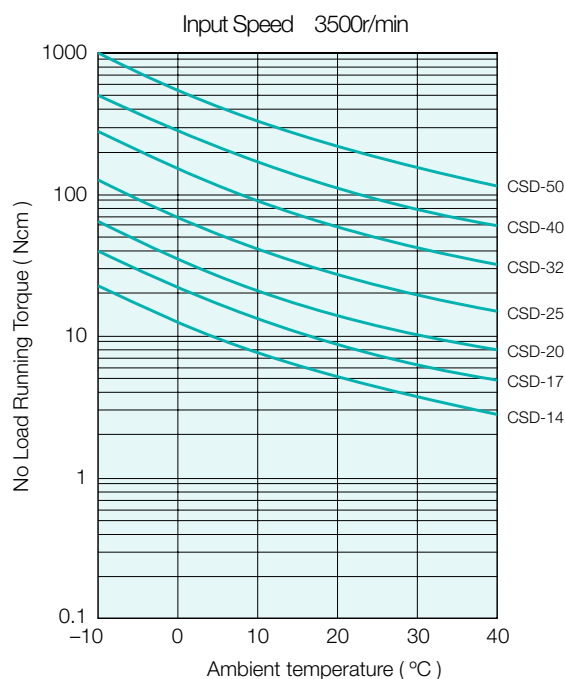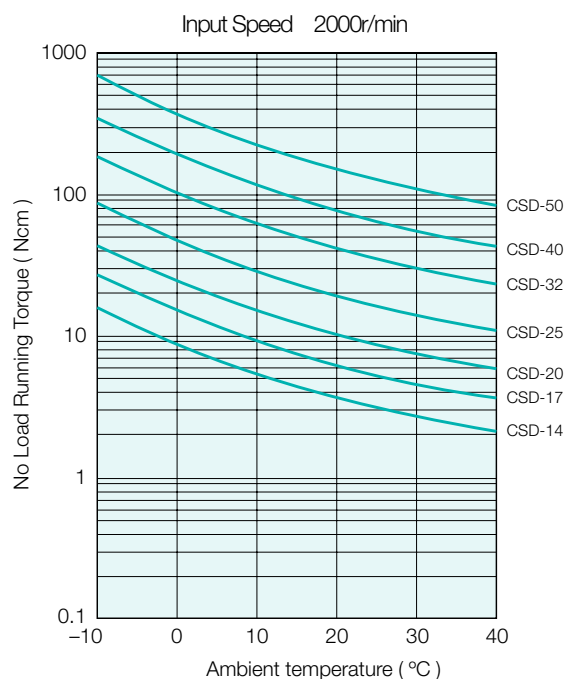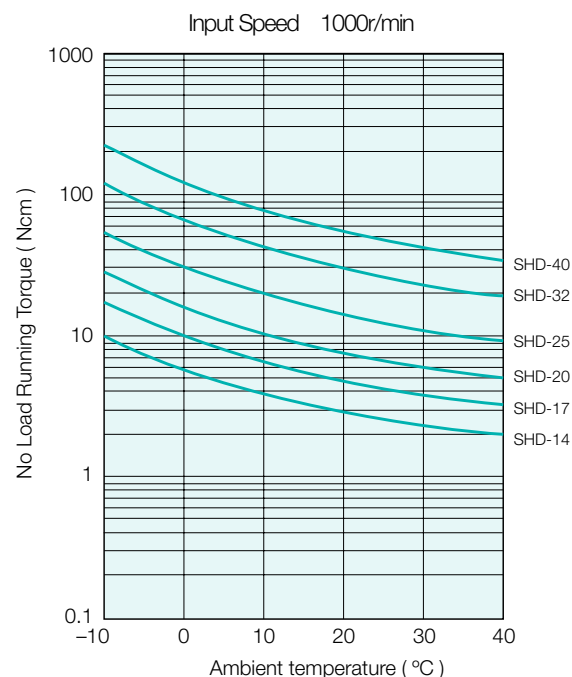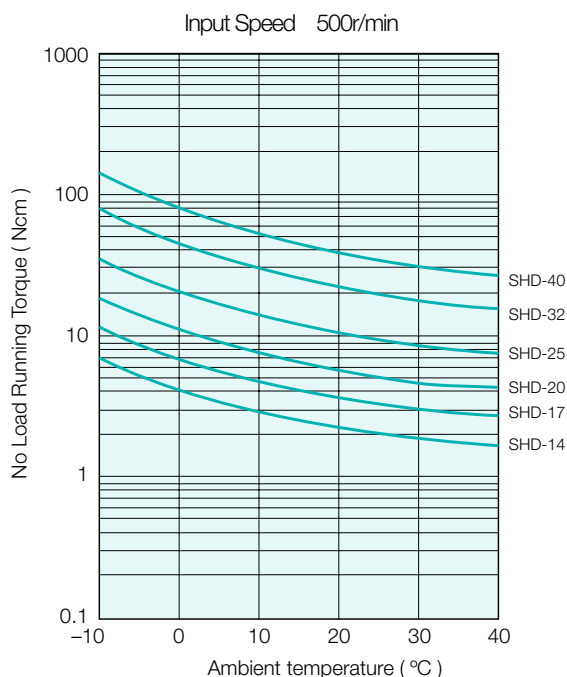
Compensation Value in Each Ratio

No load running torque of the gear varies with ratio. The graphs indicate a value for ratio 100. For other ratios, add the compensation values from the table on the right.

No Load Running Torque Compensation Value   N•cm

Ratio Size	50		160	
	CSD	SHD	CSD	SHD
14	+0.56	+1.0	–	–
17	+0.95	+1.6	–	–
20	+1.4	+2.4	-0.39	-0.7
25	+2.6	+4.0	-0.72	-1.2
32	+5.4	+7.0	-1.5	-2.4
40	+9.6	+13	-2.6	-3.9
50	+18	–	-4.8	–

SHD Series

Input Speed   500r/min

Input Speed   1000r/min

Input Speed   2000r/min

Input Speed   3500r/min

Starting Torque

Starting torque is the torque required to commence rotation of the input element (high speed side), with no load being applied to the output. The table below indicates the maximum values. The lower values are approximately 1/2 to 1/3 of the maximum values.

Component Type Backdriving Torque

Backdriving torque is the torque required to commence rotation of input element (high speed side) when torque is applied on the output side (low speed side). The table below indicates the maximum values. The typical values are approximately 1/2 to 1/3 of the maximum values. The backdriving torque should not be relied upon to provide a holding torque to prevent the output from backdriving. A failsafe brake should be used for this purpose.

Measurement condition: Ambient temperature 20ºC

Values shown below vary depending on condition.
Please use values as a reference.

Starting Torque for Component Sets (Ncm)   Table 25

Ratio	Size	14	17	20	25	32	40	50
50	CSD	3.7	5.7	7.3	14	28	50	94
	SHD	6.2	19	25	39	60	95	-
100	CSD	2.4	3.3	4.3	7.9	18	29	56
	SHD	4.8	17	22	34	50	78	-
160	CSD	-	-	3.4	6.4	14	24	44
	SHD	-	-	22	33	47	74	-

Backdriving Torque for Component Sets (Nm)   Table 26

Ratio	Size	14	17	20	25	32	40	50
50	CSD	2.5	3.8	4.4	8.3	17	30	57
	SHD	3.7	11	15	24	36	57	-
100	CSD	3.1	4.1	5.2	9.6	21	35	67
	SHD	5.8	21	27	41	60	94	-
160	CSD	-	-	6.6	12	28	45	85
	SHD	-	-	42	64	91	143	-

Positioning Accuracy

The positioning accuracy of the gear represents a linearity error between the input and output angle. The position error is the difference between theoretical and actual output rotation angle.

The positioning accuracy is measured for one complete output revolution using a high resolution measurement system. The measurements are carried out without reversing direction.

The positioning accuracy is defined as the difference between the maximum positive and maximum negative deviation from the theoretical position.

θ_{er} ....Positioning Accuracy
θ_1...............................Input Angle
θ_2...............................Actual Output Angle
R ....Gear Ratio (i= I:R)

$$\theta_{er} = \theta_2 - \frac{\theta_1}{R} \qquad \text{equation [15]}$$

Typical Positional Accuracy Curve
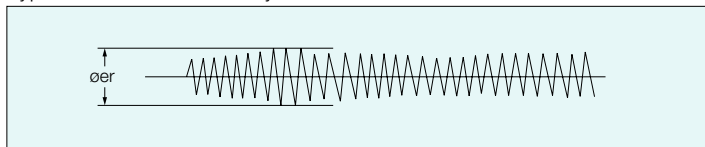
Positioning Accuracy

CSD   Table 27

Size		14	17	20	25	32	40	50
Positioning Accuracy	X10 rad	4.4	4.4	2.9	2.9	2.9	2.9	2.9
	arc min	1.5	1.5	1.0	1.0	1.0	1.0	1.0

SHD   Table 28

Size		14	17	20	25	32	40
Positioning Accuracy	X10^{-4} rad	4.4	4.4	2.9	2.9	2.9	2.9
	arc min	1.5	1.5	1.0	1.0	1.0	1.0

Torsional Stiffness

Torsional stiffness is determined by applying a load to the output of the gear, with the input rotationally locked. The angular rotation is measured as the load is increased. The typical curve (shown in the figure 21) is non-linear. The stiffness is determined by the slope of this curve. For simplicity, the curve is approximated by 3 straight lines having stiffness of K_1, K_2, and K_3. Stiffness K_1 applies for output torque of 0 to T_1. Stiffness K_3 applies for output torque greater than T_2. Stiffness K_2 applies for output torque between T_1 and T_2. Typical stiffness values are shown in tables 29 to 32.
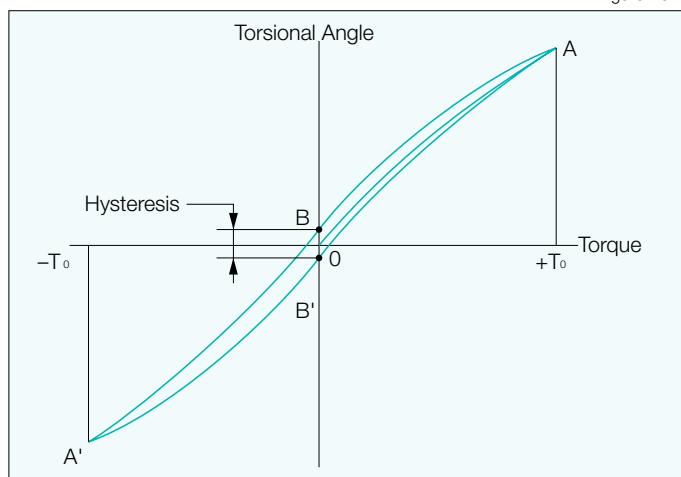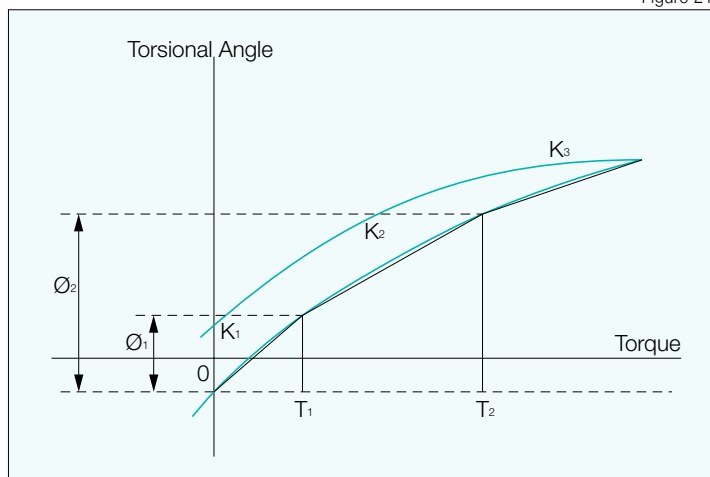

Figure 20

Figure 21

Torsional Stiffness

CSD - Torsional Stiffness for Ratio 50:1 — Table 29

Size		14	17	20	25	32	40	50
T_1	Nm	2.0	3.9	7.0	14	29	54	108
K_1	$\times 10^4$ Nm/rad	0.29	0.67	1.1	2.0	4.7	8.8	17
$\emptyset_1$	$\times 10^{-4}$ rad	6.9	5.8	6.4	7.0	6.2	6.1	6.4
	arc min	2.4	2.0	2.2	2.4	2.1	2.1	2.2
T_2	Nm	6.9	12	25	48	108	196	382
K_2	$\times 10^4$ Nm/rad	0.37	0.88	1.3	2.7	6.1	11	21
$\emptyset_2$	$\times 10^{-4}$ rad	19	14	19	18	18	18	18
	arc min	6.4	4.6	6.6	6.1	6.1	5.9	6.2
K_3	$\times 10$ Nm/rad	0.47	1.2	2.0	3.7	8.4	15	30

Numbers are average value.

CSD - Torsional Stiffness for Ratio 100:1 and up — Table30

Size		14	17	20	25	32	40	50
T_1	Nm	2.0	3.9	7.0	14	29	54	108
K_1	$\times 10^4$ Nm/rad	0.4	0.84	1.3	2.7	6.1	11	21
$\emptyset_1$	$\times 10^{-4}$ rad	5.0	4.6	5.4	5.2	4.8	4.9	5.1
	arc min	1.7	1.6	1.8	1.8	1.7	1.7	1.7
T_2	Nm	6.9	12	25	48	108	196	382
K_2	$\times 10^4$ Nm/rad	0.44	0.94	1.7	3.7	7.8	14	29
$\emptyset_2$	$\times 10^{-4}$ rad	16	13	15	13	14	14	13
	arc min	5.4	4.3	5.0	4.5	4.8	4.8	4.6
K_3	$\times 10$ Nm/rad	0.61	1.3	2.5	4.7	11	20	37

Numbers are average value.

SHD - Torsional Stiffness for Ratio 50:1 — Table 31

Size		14	17	20	25	32	40	
T_1	Nm	2.0	3.9	7.0	14	29	54	
K_1	$\times 10^4$ Nm/rad	0.29	0.67	1.1	2.0	4.7	8.8	
$\emptyset_1$	$\times 10^{-4}$ rad	6.9	5.8	6.4	7.0	6.2	6.1	
	arc min	2.4	2.0	2.2	2.3	2.1	2.1	
T_2	Nm	6.9	12	25	48	108	196	
K_2	$\times 10^4$ Nm/rad	0.37	0.88	1.3	2.7	6.1	11	
$\emptyset_2$	$\times 10^{-4}$ rad	19	14	19	18	18	18	
	arc min	6.4	4.6	6.3	6.1	6.1	5.9	
K_3	$\times 10$ Nm/rad	0.47	1.2	2.0	3.7	8.4	15	

Numbers are average value.

SHD - Torsional Stiffness for Ratio 100:1 and up — Table 32

Size		14	17	20	25	32	40	
T_1	Nm	2.0	3.9	7.0	14	29	54	
K_1	$\times 10^4$ Nm/rad	0.4	0.84	1.3	2.7	6.1	11	
$\emptyset_1$	$\times 10^{-4}$ rad	5.0	4.6	5.4	5.2	4.8	4.9	
	arc min	1.7	1.6	1.8	1.8	1.7	1.7	
T_2	Nm	6.9	12	25	48	108	196	
K_2	$\times 10^4$ Nm/rad	0.44	0.94	1.7	3.7	7.8	14	
$\emptyset_2$	$\times 10^{-4}$ rad	16	13	15	13	14	14	
	arc min	5.4	4.3	5.0	4.5	4.8	4.8	
K_3	$\times 10$ Nm/rad	0.61	1.3	2.5	4.7	11	20	

Numbers are average value.

Calculate Torsion Angle

1. For $T<T_1$: $\emptyset = T/K_1$
2. For $T_1<T<T_2$: $\emptyset = T_1/K_1 + (T-T_2)/K_2$
3. For $T_2<T$: $\emptyset = T_1/K_1 + (T_2-T_1)/K_2 + (T-T_2)/K_3$

Note: Units for T, T_1, T_2, K, K_1, K_2, K_3, and $\emptyset$ must be consistent.

Hysteresis Loss

A typical hysteresis curve is shown in figure 20. With the input locked, a torque is applied from 0 to ± Rated Torque. Hysteresis measurement is shown in the figure. The following table shows typical hysteresis values.

Hysteresis Loss								Table 33
Size		14	17	20	25	32	40	50
50	$X10^{-4}$ rad	7.3	4.4	4.4	4.4	4.4	4.4	4.4
	arc min	2.5	1.5	1.5	1.5	1.5	1.5	1.5
100	$X10^{-4}$ rad	5.8	2.9	2.9	2.9	2.9	2.9	2.9
and up	arc min	2.0	1.0	1.0	1.0	1.0	1.0	1.0

Notes

Notes