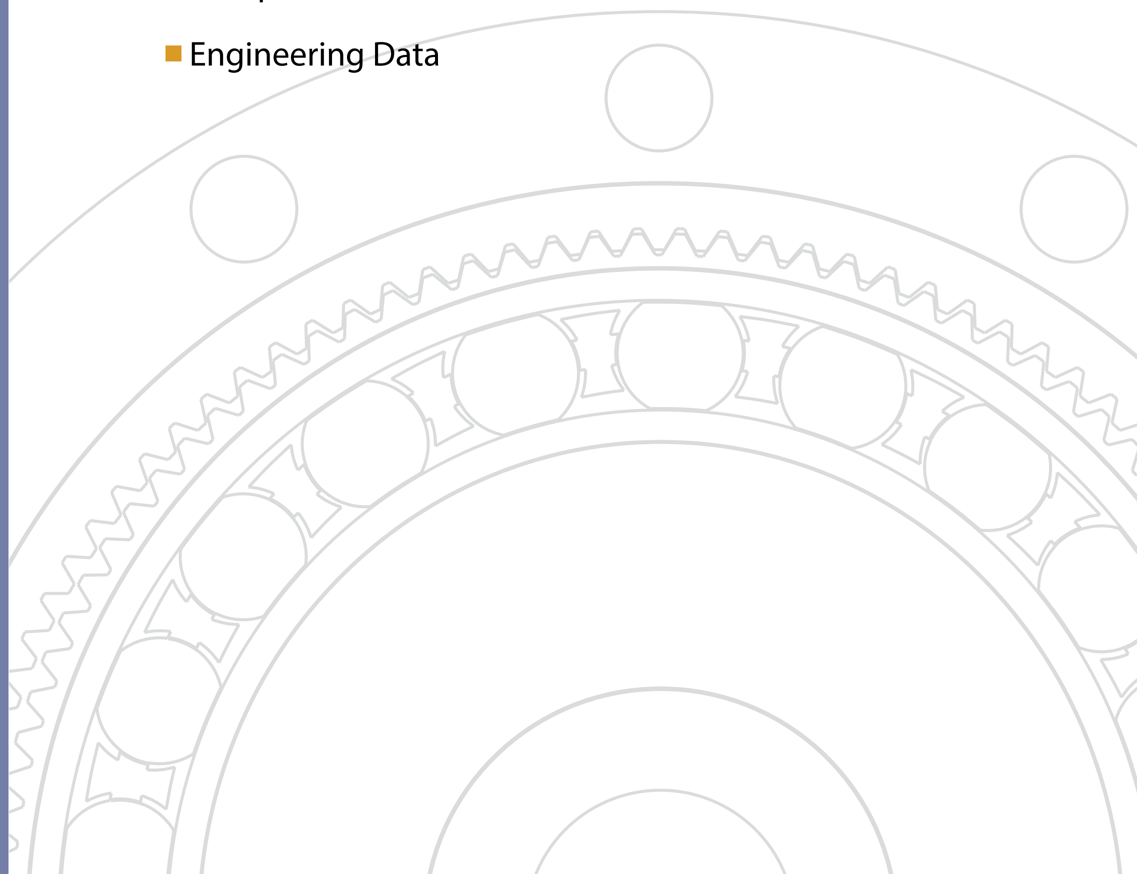
HarmonicDrive®

Speed Reducers for Precision Motion Control

HarmonicDrive®

Reducer Catalog

- Component Sets CSG/CSF
- Engineering Data

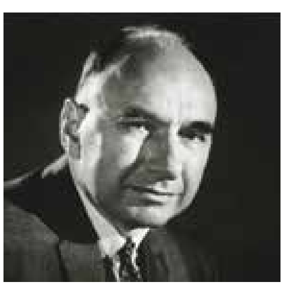


Excellent Technology for Evolving Industries

Harmonic Drive® actuators utilize high-precision, zero-backlash Harmonic Drive® precision gears and play critical roles in robotics, semiconductor manufacturing equipment, factory automation equipment, medical diagnostics and surgical robotics. Additionally, our products are frequently used in mission-critical spaceflight applications which capture the human spirit.

With over 50 years of experience, our expert engineering and production teams continually develop enabling technologies for the evolving motion control market. We are proud of our outstanding engineering capabilities and successful history of providing customer specific solutions to meet their application requirements.

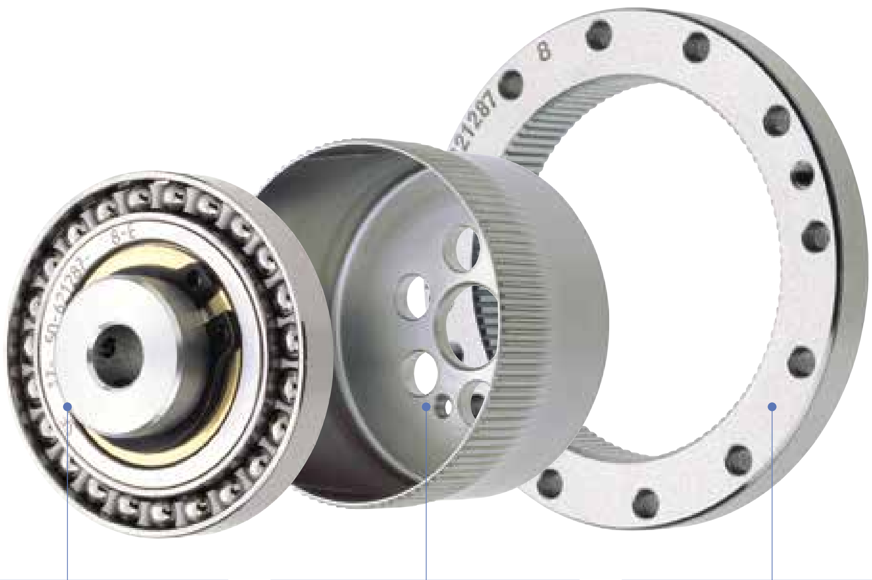
Harmonic Drive LLC continues to develop enabling technologies for the evolving motion control market, which drives the pace of global innovation.



C. Walton Musser
Patented Strain Wave
Gearing in 1955

Operating Principle of HarmonicDrive® Gears

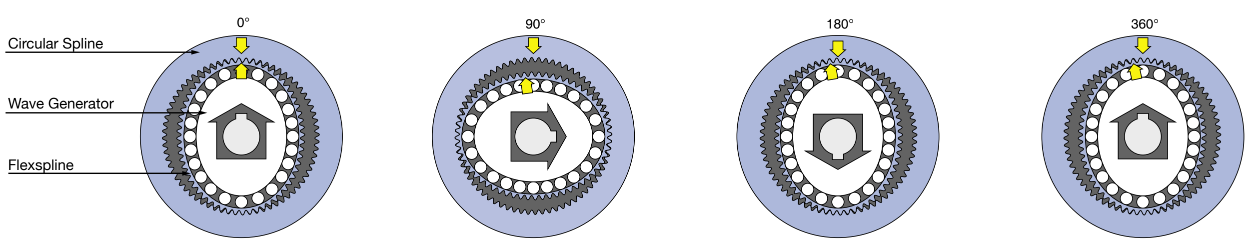
A simple three-element construction combined with the unique operating principle puts extremely high reduction ratio capabilities into a very compact and lightweight package. The high-performance attributes of this gearing technology including, zero-backlash, high-torque-to-weight ratio, compact size, and excellent positional accuracy, are a direct result of the unique operating principles.



Wave Generator
The Wave Generator is a thin, raced-ball bearing fitted onto an elliptical hub. This serves as a high-efficiency torque converter and is generally mounted onto the input or motor shaft.

Flexspline
The Flexspline is a non-rigid, thin cylindrical cup with external teeth on the open end of the cup. The Flexspline fits over the Wave Generator and takes on its elliptical shape. The Flexspline is generally used as the output of the gear.

Circular Spline
The Circular Spline is a rigid ring with internal teeth. It engages the teeth of the Flexspline across the major axis of the Wave Generator ellipse. The Circular Spline has two more teeth than the Flexspline and is generally mounted onto a housing.



The Flexspline is slightly smaller in diameter than the Circular Spline and usually has two fewer teeth than the Circular Spline. The elliptical shape of the Wave Generator causes the teeth of the Flexspline to engage the Circular Spline at two opposite regions across the major axis of the ellipse.

As the Wave Generator rotates the teeth of the Flexspline engage with the Circular Spline at the major axis.

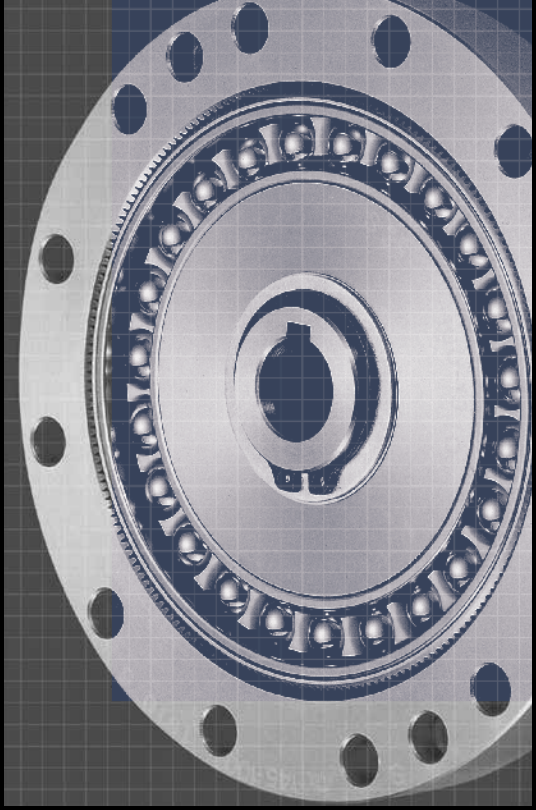
For every 180 degree clockwise movement of the Wave Generator, the Flexspline rotates counterclockwise by one tooth in relation to the Circular Spline.

Each complete clockwise rotation of the Wave Generator results in the Flexspline moving counterclockwise by two teeth from its original position, relative to the Circular Spline. Normally, this motion is taken out as output.

■ Development of HarmonicDrive® Speed Reducers

Harmonic Drive® gears have been evolving since the strain wave gear was first patented in 1955. Our innovative development and engineering teams have led us to significant advances in our gear technology. In 1988, Harmonic Drive successfully designed and manufactured a new tooth profile, the "S" tooth. Since implementing the "S" tooth profile, improvement in life, strength and torsional stiffness have been realized. In the 1990s, we focused engineering efforts on designing gears featuring space savings, higher speed, higher load capacity and higher reliability. Then in the 2000s, significant reduction in size and thickness were achieved, all while maintaining high precision specifications.

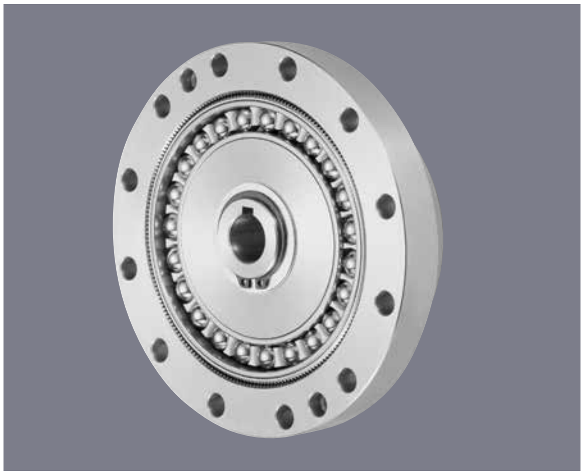
HarmonicDrive®



CSG/CSF Series

Component Set CSG/CSF

Features



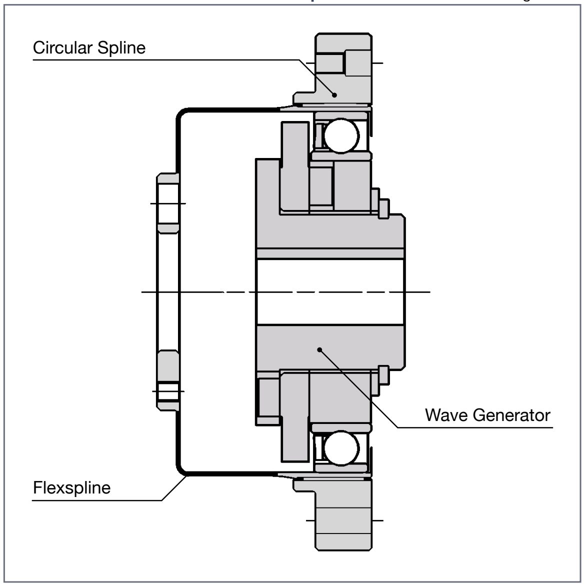
CSG/CSF component set

Harmonic Drive® zero backlash, precision component sets are the core motion control mechanisms. The CSF standard torque version, and CSG high-torque version component sets are available in a wide variety of sizes and ratios. These high accuracy gearing components are often used as the core building block for high performance, custom servo actuators and motion control systems. Customer-supplied servo motors can also be easily integrated. These compact gears are extremely customizable and can be seamlessly integrated into your design.

Features

- Zero backlash
- Compact and simple design
- High torque capacity
- High stiffness
- High positioning and rotational accuracies
- Coaxial input and output

Structure of CSG/CSF series component set Fig. 036-1



Series

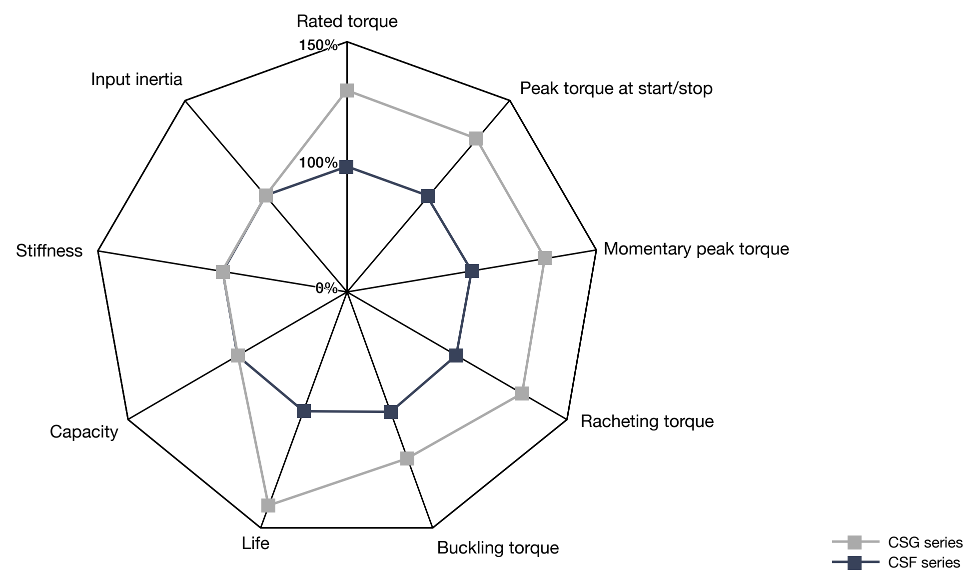
CSG

- CSG high torque version offers 30% higher torque than CSF series.
- Life for CSG series has been improved by 43% (10,000 hours) compared to the CSF series
- Ratios: 50:1 ~160:1
- Peak Torque 1.8~9200 Nm
- Sizes 73~260mm

CSF

- Ratios 30:1 ~ 160:1 (30:1 reduction ratio on 7 sizes)
- Peak Torque 23~3400 Nm
- Sizes 30~330mm

Comparison between CSG series and CSF series Graph 036-1



Ordering Code

CSG - 25 - 100 - 2A - GR - SP

Table 037-1

Series	Size	Ratio*1					Model		Special specification
CSG = High Torque	14	50	80	100	—	—	2A=component set 2UH=housed unit	GR= component set * (2A-R for Size 14, 17) * Not indicated on 2UH	SP= Special specification code Blank= Standard product
	17	50	80	100	120	—			
	20	50	80	100	120	160			
	25	50	80	100	120	160			
	32	50	80	100	120	160			
	40	50	80	100	120	160			
	45	50	80	100	120	160			
	50	—	80	100	120	160			
	58	—	80	100	120	160			
	65	—	80	100	120	160			

*1 The reduction ratio value is based on the following configuration:
Input: wave generator, fixed: circular spline, output: flexspline

CSF - 25 - 100 - 2A - GR - SP

Table 037-2

Series	Size	Ratio*1						Model		Special specification
CSF = Standard Torque	8	30	50	—	100	—	—	2A=component set 2UH=housed unit	GR= component set * 2A-R for Size 8, 14, 17 * Not indicated on 2UH	SP= Special specification code Blank= Standard product
	11	30	50	—	100	—	—			
	14	30	50	80	100	—	—			
	17	30	50	80	100	120	—			
	20	30	50	80	100	120	160			
	25	30	50	80	100	120	160			
	32	30	50	80	100	120	160			
	40	—	50	80	100	120	160			
	45	—	50	80	100	120	160			
	50*2	—	50	80	100	120	160			
	58*2	—	50	80	100	120	160			
	65*2	—	50	80	100	120	160			
	80*2	—	50	80	100	120	160			
	90*2	—	50	80	100	120	160			
	100*2	—	50	80	100	120	160			

*1 The reduction ratio value is based on the following configuration:
Input: wave generator, fixed: circular spline, output: flexspline
*2 Oil lubrication is required for component-sets size 50 or larger with a reduction ratio of 50:1.

Technical Data

Rating table

CSG series

Table 038-1

Size	Ratio	Rated Torque at 2000rpm		Limit for Repeated Peak Torque		Limit for Average Torque		Limit for Momentary Peak Torque		Maximum Input Speed (rpm)		Limit for Average Input Speed (rpm)		Moment of Inertia	
		Nm	kgfm	Nm	kgfm	Nm	kgfm	Nm	kgfm	Oil	Grease	Oil	Grease	I $\times10^{-4}kgm^2$	J $\times10^{-5}kgfms^2$
14	50	7.0	0.7	23	2.3	9.0	0.9	46	4.7	14000	8500	6500	3500	0.033	0.034
	80	10	1.0	30	3.1	14	1.4	61	6.2						
	100	10	1.0	36	3.7	14	1.4	70	7.2						
17	50	21	2.1	44	4.5	34	3.4	91	9	10000	7300	6500	3500	0.079	0.081
	80	29	2.9	56	5.7	35	3.6	113	12						
	100	31	3.2	70	7.2	51	5.2	143	15						
	120	31	3.2	70	7.2	51	5.2	112	11						
20	50	33	3.3	73	7.4	44	4.5	127	13	10000	6500	6500	3500	0.193	0.197
	80	44	4.5	96	9.8	61	6.2	165	17						
	100	52	5.3	107	10.9	64	6.5	191	20						
	120	52	5.3	113	11.5	64	6.5	191	20						
	160	52	5.3	120	12.2	64	6.5	191	20						
25	50	51	5.2	127	13	72	7.3	242	25	7500	5600	5600	3500	0.413	0.421
	80	82	8.4	178	18	113	12	332	34						
	100	87	8.9	204	21	140	14	369	38						
	120	87	8.9	217	22	140	14	395	40						
	160	87	8.9	229	23	140	14	408	42						
32	50	99	10	281	29	140	14	497	51	7000	4800	4600	3500	1.69	1.72
	80	153	16	395	40	217	22	738	75						
	100	178	18	433	44	281	29	841	86						
	120	178	18	459	47	281	29	892	91						
	160	178	18	484	49	281	29	892	91						
40	50	178	18	523	53	255	26	892	91	5600	4000	3600	3000	4.50	4.59
	80	268	27	675	69	369	38	1270	130						
	100	345	35	738	75	484	49	1400	143						
	120	382	39	802	82	586	60	1530	156						
	160	382	39	841	86	586	60	1530	156						
45	50	229	23	650	66	345	35	1235	126	5000	3800	3300	3000	8.68	8.86
	80	407	41	918	94	507	52	1651	168						
	100	459	47	982	100	650	66	2041	208						
	120	523	53	1070	109	806	82	2288	233						
	160	523	53	1147	117	819	84	2483	253						
50	80	484	49	1223	125	675	69	2418	247	4500	3500	3000	2500	12.5	12.8
	100	611	62	1274	130	866	88	2678	273						
	120	688	70	1404	143	1057	108	2678	273						
	160	688	70	1534	156	1096	112	3185	325						
58	80	714	73	1924	196	1001	102	3185	325	4000	3000	2700	2200	27.3	27.9
	100	905	92	2067	211	1378	141	4134	422						
	120	969	99	2236	228	1547	158	4329	441						
	160	969	99	2392	244	1573	160	4459	455						
65	80	969	99	2743	280	1352	138	4836	493	3500	2800	2400	1900	46.8	47.8
	100	1236	126	2990	305	1976	202	6175	630						
	120	1236	126	3263	333	2041	208	6175	630						
	160	1236	126	3419	349	2041	208	6175	630						

(Note) 1. Oil lubrication is required for size 50 or higher with a reduction ratio of 50:1. Use grease lubrication within half the rated torque.
2. Moment of inertia: $I = \frac{1}{4} GD^2$
3. See Rating Table Definitions on Page 12 for details of the terms.
4. If maximum allowable momentary torque is applied, see "Installation of the flexspline" of each series.

CSF series

Table 038-2

Size	Ratio	Rated Torque at 2000rpm		Limit for Repeated Peak Torque		Limit for Average Torque		Limit for Momentary Peak Torque		Maximum Input Speed (rpm)		Limit for Average Input Speed (rpm)		Moment of Inertia	
		Nm	kgfm	Nm	kgfm	Nm	kgfm	Nm	kgfm	Oil	Grease	Oil	Grease	I $\times10^{-4}kgm^2$	J $\times10^{-5}kgfms^2$
8	30	0.9	0.09	1.8	0.18	1.4	0.14	3.3	0.34	14000	8500	6500	3500	0.003	0.0031
	50	1.8	0.18	3.3	0.34	2.3	0.24	6.6	0.67						
	100	2.4	0.25	4.8	0.49	3.3	0.34	9.0	0.92						
11	30	2.2	0.22	4.5	0.46	3.4	0.35	8.5	0.87	14000	8500	6500	3500	0.012	0.012
	50	3.5	0.36	8.3	0.85	5.5	0.56	17	1.7						
	100	5.0	0.51	11	1.1	8.9	0.91	25	2.6						
14	30	4.0	0.41	9.0	0.92	6.8	0.69	17	1.7	14000	8500	6500	3500	0.033	0.034
	50	5.4	0.55	18	1.8	6.9	0.70	35	3.6						
	80	7.8	0.80	23	2.4	11	1.1	47	4.8						
	100	7.8	0.80	28	2.9	11	1.1	54	5.5						

■ CSF series

Table 039-1

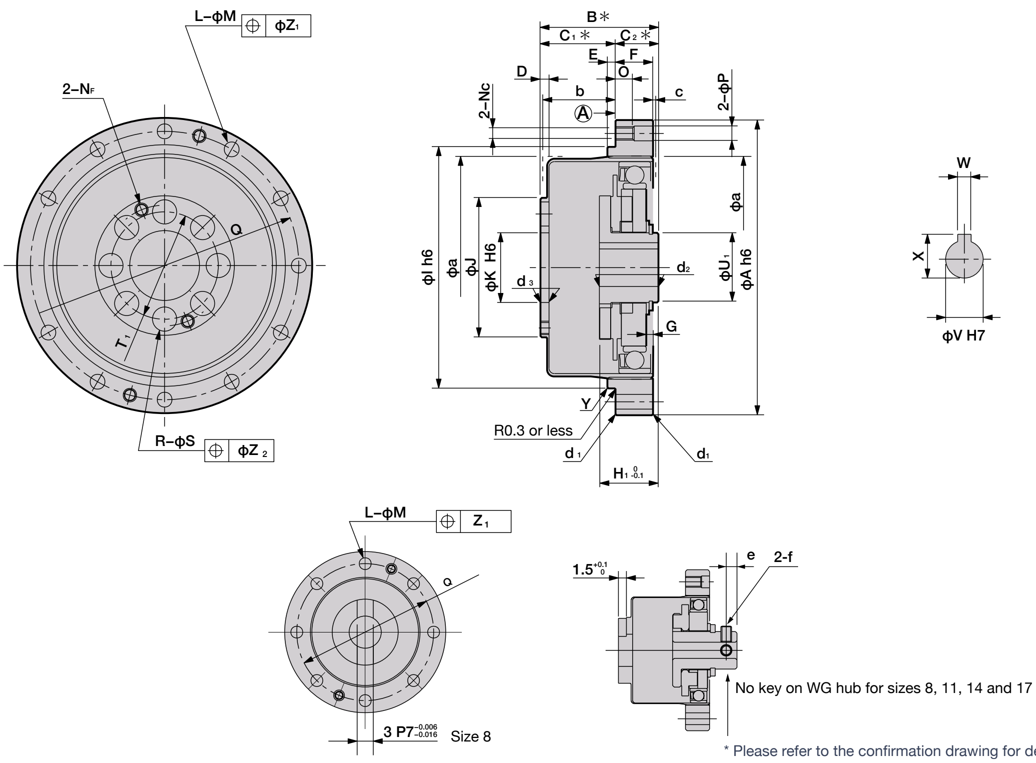
Size	Ratio	Rated Torque at 2000rpm		Limit for Repeated Peak Torque		Limit for Average Torque		Limit for Momentary Peak Torque		Maximum Input Speed (rpm)		Limit for Average Input Speed (rpm)		Moment of Inertia	
		Nm	kgfm	Nm	kgfm	Nm	kgfm	Nm	kgfm	Oil	Grease	Oil	Grease	I $\times10^{-4}kgm^2$	J $\times10^{-5}kgfms^2$
17	30	8.8	0.9	16	1.6	12	1.2	30	3.1	10000	7300	6500	3500	0.079	0.081
	50	16	1.6	34	3.5	26	2.6	70	7.1						
	80	22	2.2	43	4.4	27	2.7	87	8.9						
	100	24	2.4	54	5.5	39	4.0	108	11						
	120	24	2.4	54	5.5	39	4.0	86	8.8						
20	30	15	1.5	27	2.8	20	2.0	50	5.1	10000	6500	6500	3500	0.193	0.197
	50	25	2.5	56	5.7	34	3.5	98	10						
	80	34	3.5	74	7.5	47	4.8	127	13						
	100	40	4.1	82	8.4	49	5.0	147	15						
	120	40	4.1	87	8.9	49	5.0	147	15						
	160	40	4.1	92	9.4	49	5.0	147	15						
25	30	27	2.8	50	5.1	38	3.9	95	9.7	7500	5600	5600	3500	0.413	0.421
	50	39	4.0	98	10	55	5.6	186	19						
	80	63	6.4	137	14	87	8.9	255	26						
	100	67	6.8	157	16	108	11	284	29						
	120	67	6.8	167	17	108	11	304	31						
	160	67	6.8	176	18	108	11	314	32						
32	30	54	5.5	100	10	75	7.7	200	20	7000	4800	4600	3500	1.69	1.72
	50	76	7.8	216	22	108	11	382	39						
	80	118	12	304	31	167	17	568	58						
	100	137	14	333	34	216	22	647	66						
	120	137	14	353	36	216	22	686	70						
	160	137	14	372	38	216	22	686	70						
40	50	137	14	402	41	196	20	686	70	5600	4000	3600	3000	4.50	4.59
	80	206	21	519	53	284	29	980	100						
	100	265	27	568	58	372	38	1080	110						
	120	294	30	617	63	451	46	1180	120						
	160	294	30	647	66	451	46	1180	120						
45	50	176	18	500	51	265	27	950	97	5000	3800	3300	3000	8.68	8.86
	80	313	32	706	72	390	40	1270	130						
	100	353	36	755	77	500	51	1570	160						
	120	402	41	823	84	620	63	1760	180						
	160	402	41	882	90	630	64	1910	195						
50	50	245	25	715	73	350	36	1430	146	4500	3500	3000	2500	12.5	12.8
	80	372	38	941	96	519	53	1860	190						
	100	470	48	980	100	666	68	2060	210						
	120	529	54	1080	110	813	83	2060	210						
	160	529	54	1180	120	843	86	2450	250						
58	50	353	36	1020	104	520	53	1960	200	4000	3000	2700	2200	27.3	27.9
	80	549	56	1480	151	770	79	2450	250						
	100	696	71	1590	162	1060	108	3180	325						
	120	745	76	1720	176	1190	121	3330	340						
	160	745	76	1840	188	1210	123	3430	350						
65	50	490	50	1420	145	720	73	2830	289	3500	2800	2400	1900	46.8	47.8
	80	745	76	2110	215	1040	106	3720	380						
	100	951	97	2300	235	1520	155	4750	485						
	120	951	97	2510	256	1570	160	4750	485						
	160	951	97	2630	268	1570	160	4750	485						
80	50	872	89	2440	249	1260	129	4870	497	2900	2300	2200	1500	122	124
	80	1320	135	3430	350	1830	187	6590	672						
	100	1700	173	4220	431	2360	241	7910	807						
	120	1990	203	4590	468	3130	319	7910	807						
	160	1990	203	4910	501	3130	319	7910	807						
90	50	1180	120	3530	360	1720	176	6660	680	2700	2000	2100	1300	214	218
	80	1550	158	3990	407	2510	256	7250	740						
	100	2270	232	5680	580	3360	343	9020	920						
	120	2570	262	6160	629	4300	439	9800	1000						
	160	2700	276	6840	698	4300	439	11300	1150						
100	50	1580	161	4450	454	2280	233	8900	908	2500	1800	2000	1200	356	363
	80	2380	243	6060	618	3310	338	11600	1180						
	100	2940	300	7350	750	4630	472	14100	1440						
	120	3180	324	7960	812	5720	584	15300	1560						
	160	3550	362	9180	937	5720	584	15500	1580						

(Note) 1. Oil lubrication is required for size 50 or higher with a reduction ratio of 50:1. Use grease lubrication within half the rated torque.
2. Moment of inertia: $I = \frac{1}{4} GD^2$
3. See Rating Table Definitions on Page 12 for details of the terms.
4. If maximum allowable momentary torque is applied, see "Installation of the flexspline" of each series.

Outline Dimensions

You can download the CAD files from our website: harmonicdrive.net

Fig. 040-1

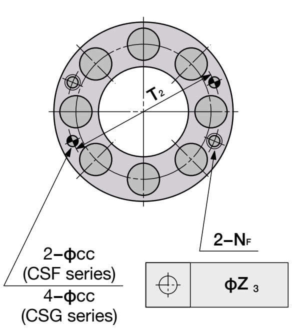


* Please refer to the confirmation drawing for detailed dimensions.

■ Dowel Pin Option

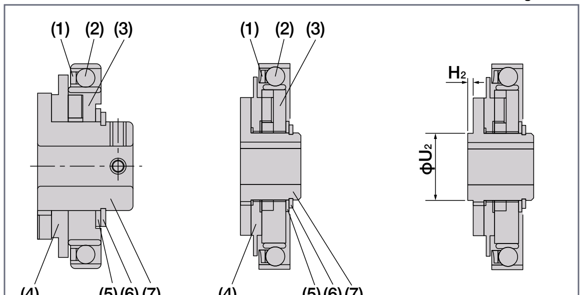
In cases where the gear will see loads near the Momentary Peak Torque level, the use of additional dowel pins in addition to the screws is recommended. Dowel pin holes are manufactured by reamer and the dimensions are shown. Note: the CSF has a different number of dowel pin holes than the CSG.

Fig. 040-2



* Provision is possible for the holes under pins. Please specify when ordering.

Fig. 040-3



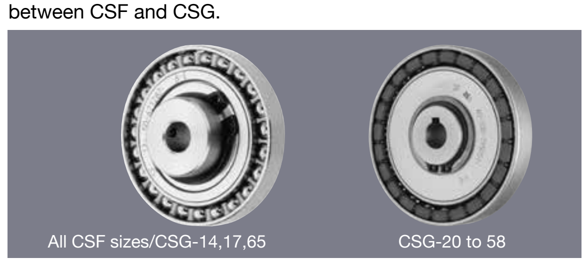
CSF-8, 11, 14, 17 | CSF-20, 25, 32, 45, 58, 90 | CSF-40, 50, 65, 80, 100

■ Wave generator components

The wave generator utilizes an Oldham coupling.

(1) Ball separator
(2) Wave generator bearing
(3) Wave generator plug
(4) Insert
(5) Rub washer
(6) Snap ring
(7) Wave generator hub

There is a difference in appearance of the the ball separator between CSF and CSG.



Dimensions

Table 041-1
Unit : mm

Symbol		8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
ϕA h6		30	40	50	60	70	85	110	135	155	170	195	215	265	300	330
B*	CSG Series	—	—	$28.5^{0}_{-0.4}$	$32.5^{0}_{-0.4}$	$33.5^{0}_{-0.4}$	$37^{0}_{-0.5}$	$44^{0}_{-0.6}$	$53^{0}_{-0.6}$	$58.5^{0}_{-0.6}$	$64^{0}_{-0.6}$	$75.5^{0}_{-0.6}$	$83^{0}_{-0.6}$	—	—	—
	CSF Series	$22.1^{0}_{-0.3}$	$25.8^{0}_{-0.7}$	$28.5^{0}_{-0.8}$	$32.5^{0}_{-0.9}$	$33.5^{0}_{-1.0}$	$37^{0}_{-1.0}$	$44^{0}_{-1.1}$	$53^{0}_{-1.1}$	$58.5^{0}_{-1.2}$	$64^{0}_{-1.3}$	$75.5^{0}_{-1.3}$	$83^{0}_{-1.3}$	$101^{0}_{-1.3}$	$112.5^{0}_{-1.4}$	$125^{0}_{-1.6}$
C_1*		$12.5^{+0.2}_{0}$	$14.5^{+0.4}_{0}$	$17.5^{+0.4}_{0}$	$20^{+0.5}_{0}$	$21.5^{+0.6}_{0}$	$24^{+0.6}_{0}$	$28^{+0.6}_{0}$	$34^{+0.6}_{0}$	$38^{+0.6}_{0}$	$41^{+0.6}_{0}$	$48^{+0.6}_{0}$	$52.5^{+0.6}_{0}$	$64^{+0.6}_{0}$	$71.5^{+0.8}_{0}$	$79^{+1.0}_{0}$
C_2*		9.6	11.3	11	12.5	12	13	16	19	20.5	23	27.5	30.5	37	41	46
D		2.7	2	2.4	3	3	3	3.2	4	4.5	5	5.8	6.5	8	9	10
E		—	2	2	2.5	3	3	3	4	4	4	5	5	6	6	6
F		4.5	5	6	6.5	7.5	10	14	17	19	22	25	29	36	41	46
G	CSG Series	—	—	1.4	1.6	1.5	3.5	4.2	5.6	6.3	7	8.2	9.5	—	—	—
	CSF Series	—	—	0.4	0.3	0.1	2.1	2.5	3.3	3.7	4.2	4.8	5.8	6.6	7.5	8.3
$H_1{}^{0}_{-0.1}$	CSG Series	—	—	18.5	20.7	21.5	21.6	23.6	29.7	30.5	34.8	38.3	44.6	—	—	—
	CSF Series	12	16	17.6	19.5	20.1	20.2	22	27.5	27.9	32	34.9	40.9	49.1	48.2	56.7
H_2		—	—	—	—	—	—	—	0.4	—	0.8	—	2.2	3.1	—	4.5
ϕI h6	Ratios > 30:1	—	31	38	48	54	67	90	110	124	135	156	177	218	245	272
	Ratio 30:1	—	31	38	48	55	68	90	—	—	—	—	—	—	—	—
ϕJ		12.3	17.8	23	27.2	32	40	52	64	72	80	92.8	104	128	144	160
ϕK H6		6	6	11	10	16	20	26	32	36	40	46	52	65	72	80
L	CSG Series	—	—	8	16	16	16	16	16	16	16	16	16	—	—	—
	CSF Series	8	8	6	12	12	12	12	12	12	12	12	12	16	16	16
ϕM		2.2	2.9	3.5	3.4	3.5	4.5	5.5	6.6	9	9	11	11	11	14	14
N_C		M2	M2.5	M3	M3	M3	M4	M5	M6	M8	M8	M10	M10	M10	M12	M12
N_F		—	—	M3	M3	M3	M4	M5	M6	M6	M8	M8	M8	M8	M12	M10
O		3	3	6	6.5	4	6	7	9	12	13	15	15	15	18	20
ϕP		2.2	2.9	—	—	3.5	4.5	5.5	6.6	9	9	11	11	11	14	14
Q (PCD)		25.5	35	44	54	62	75	100	120	140	150	175	195	240	270	300
R		—	6	6	6	8	8	8	8	8	8	8	8	10	8	12
ϕS		—	3.4	4.5	5.5	5.5	6.6	9	11	13.5	15.5	15.5	18	18	22	22
T_1 (PCD)		—	12	17	19	24	30	40	50	54	60	70	80	100	110	130
T_2 (PCD)		—	15.2	18.5	21.5	27	34	45	56	61	68	79	90	114	120	142
$ϕU_1$		7	11	14	18	21	26	26	32	32	32	40	48	55	60	65
$ϕU_2$		—	—	—	—	—	—	—	32	—	32	—	48	55	—	65
ϕV	Standard (H7)	3	5	6	8	9	11	14	14	19	19	22	24	28	28	28
	Max. size	—	—	8	10	13	15	15	20	20	20	25	30	35	37	40
WJs9		—	—	—	—	3	4	5	5	6	6	6	8	8	8	8
X		—	—	—	—	$10.4^{+0.1}_{0}$	$12.8^{+0.1}_{0}$	$16.3^{+0.1}_{0}$	$16.3^{+0.1}_{0}$	$21.8^{+0.1}_{0}$	$21.8^{+0.1}_{0}$	$24.8^{+0.1}_{0}$	$27.3^{+0.2}_{0}$	$31.3^{+0.2}_{0}$	$31.3^{+0.2}_{0}$	$31.3^{+0.2}_{0}$
Y		—	C0.2	C0.3	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.8	C0.8	C0.8	C0.8	C0.8	C0.8
$ϕZ_1$		0.1	0.20	0.20	0.20	0.25	0.25	0.25	0.30	0.50	0.50	0.5	0.5	0.5	1.0	1.0
$ϕZ_2$		—	0.20	0.25	0.25	0.25	0.30	0.50	0.50	0.75	0.75	0.75	1.0	1.0	1.0	1.0
$ϕZ_3$		—	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
ϕa	minimum housing clearance	21.5	30	38	45	53	66	86	106	119	133	154	172	212	239	265
b	minimum housing clearance	11.34	14	17.1	19	20.5	23	26.8	33	36.5	39	46.2	50	61	68.5	76
c	minimum housing clearance	—	—	1	1	1.5	1.5	1.5	2	2	2	2.5	2.5	3	3	3
ϕccH7	CSG Series	—	—	3	3	3	4	5	6	6	8	8	8	—	—	—
	CSF Series	—	2	3	3	3	4	5	6	6	8	8	8	8	12	10
d_1		C0.3	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4
d_2		C0.3	C0.3	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4	C0.4
d_3		C0.3	C0.3	C0.5	C0.5	C0.5	C0.5	C0.5	C0.5	C0.5	C0.5	C0.5	C0.5	C0.5	C0.5	C0.5
e		2	3	2.5	3	—	—	—	—	—	—	—	—	—	—	—
f		M2×3	M3×4	M3×4	M3×6	—	—	—	—	—	—	—	—	—	—	—
Mass (kg)		0.026	0.05	0.09	0.15	0.28	0.42	0.89	1.7	2.3	3.2	4.7	6.7	12.4	17.6	23.5

- The pilot diameter for the Circular spline can be either ØI or ØA. Surface A is the recommended mounting surface.
- The following dimensions can be modified to accommodate customer-specific requirements.

  Wave Generator: ØV, X, W
  Flexspline: R, ØS
  Circular Spline: ØM, L
- *Dimensions B, C_1 and C_2 must meet the tolerance values shown above.
- Due to the deformation of the Flexspline during operation, it is necessary to provide a minimum housing clearance, dimensions ϕa, b, c.

Positional accuracy

See "Engineering data" for a description of terms.

Table 042-1

Ratio	Specification	Unit	8	11	14	17	20	25	32	40～100
30	Standard	$\times10^{-4}$rad	5.8	5.8	5.8	4.4	4.4	4.4	4.4	—
		arc min	2	2	2	1.5	1.5	1.5	1.5	—
	Special	$\times10^{-4}$rad	—	—	—	—	2.9	2.9	2.9	—
		arc min	—	—	—	—	1	1	1	—
50 or more	Standard	$\times10^{-4}$rad	5.8	5.8	4.4	4.4	2.9	2.9	2.9	2.9
		arc min	2	2	1.5	1.5	1	1	1	1
	Special	$\times10^{-4}$rad	—	—	2.9	2.9	1.5	1.5	1.5	1.5
		arc min	—	—	1	1	0.5	0.5	0.5	0.5

*Positioning accuracy for Size 11, 100:1 is 4.4×10^{-4} rad/1.5arc min.

Hysteresis loss

See "Engineering data" for a description of terms.

Table 042-2

Ratio	Unit	8	11	14	17	20	25	32	40 or more
30	$\times10^{-4}$rad	8.7	8.7	8.7	8.7	8.7	8.7	8.7	—
	arc min	3.0	3.0	3.0	3.0	3.0	3.0	3.0	—
50	$\times10^{-4}$rad	8.7	5.8	5.8	5.8	5.8	5.8	5.8	5.8
	arc min	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
80 or more	$\times10^{-4}$rad	5.8	5.8	2.9	2.9	2.9	2.9	2.9	2.9
	arc min	2.0	2.0	1.0	1.0	1.0	1.0	1.0	1.0

Backlash

See "Engineering data" for a description of terms.

Table 042-3

Ratio	Unit	8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
30	$\times10^{-5}$rad	28.6	23.8	29.1	16.0	13.6	13.6	11.2	—	—	—	—	—	—	—	—
	arc sec	59	49	60	33	28	28	23	—	—	—	—	—	—	—	—
50	$\times10^{-5}$rad	17.0	14.1	17.5	9.7	8.2	8.2	6.8	6.8	5.8	5.8	4.8	4.8	4.8	3.9	2.9
	arc sec	35	24	36	20	17	17	14	14	12	12	10	10	10	8	6
80	$\times10^{-5}$rad	—	—	11.2	6.3	5.3	5.3	4.4	4.4	3.9	3.9	2.9	2.9	2.9	2.4	2.4
	arc sec	—	—	23	13	11	11	9	9	8	8	6	6	6	5	5
100	$\times10^{-5}$rad	8.7	7.3	8.7	4.8	4.4	4.4	3.4	3.4	2.9	2.9	2.4	2.4	2.4	1.9	1.5
	arc sec	18	15	18	10	9	9	7	7	6	6	5	5	5	4	3
120	$\times10^{-5}$rad	—	—	—	3.9	3.9	3.9	2.9	2.9	2.4	2.4	1.9	1.9	1.9	1.5	1.5
	arc sec	—	—	—	8	8	8	6	6	5	5	4	4	4	3	3
160	$\times10^{-5}$rad	—	—	—	—	2.9	2.9	2.4	2.4	1.9	1.9	1.5	1.5	1.5	1.0	1.0
	arc sec	—	—	—	—	6	6	5	5	4	4	3	3	3	2	2

Torsional stiffness

See "Engineering data" for a description of terms.

Table 042-4

Ratio	Symbol	Unit	8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
	T_1	Nm	0.29	0.80	2.0	3.9	7.0	14	29	54	76	108	168	235	430	618	843
		kgfm	0.03	0.082	0.20	0.40	0.70	1.4	3.0	5.5	7.8	11	17	24	44	63	86
	T_2	Nm	0.75	2.0	6.9	12	25	48	108	196	275	382	598	843	1570	2260	3040
		kgfm	0.077	0.20	0.7	1.2	2.5	4.9	11	20	28	39	61	86	160	230	310
Ratio 30	K_1	$\times10^4$Nm/rad	0.034	0.084	0.19	0.34	0.57	1.0	2.4	—	—	—	—	—	—	—	—
		kgfm/arc min	0.010	0.025	0.056	0.10	0.17	0.30	0.70	—	—	—	—	—	—	—	—
	K_2	$\times10^4$Nm/rad	0.044	0.13	0.24	0.44	0.71	1.3	3.0	—	—	—	—	—	—	—	—
		kgfm/arc min	0.013	0.037	0.07	0.13	0.21	0.40	0.89	—	—	—	—	—	—	—	—
	K_3	$\times10^4$Nm/rad	0.054	0.16	0.34	0.67	1.1	2.1	4.9	—	—	—	—	—	—	—	—
		kgfm/arc min	0.016	0.047	0.10	0.20	0.32	0.62	1.5	—	—	—	—	—	—	—	—
	θ_1	$\times10^{-4}$rad	8.5	9.5	10.5	11.5	12.3	14	12.1	—	—	—	—	—	—	—	—
		arc min	3.0	3.3	3.6	4.0	4.1	4.7	4.3	—	—	—	—	—	—	—	—
	θ_2	$\times10^{-4}$rad	19	19	31	30	38	40	38	—	—	—	—	—	—	—	—
		arc min	6.6	6.5	10.7	10.2	12.7	13.4	13.3	—	—	—	—	—	—	—	—
Ratio 50	K_1	$\times10^4$Nm/rad	0.044	0.22	0.34	0.81	1.3	2.5	5.4	10	15	20	31	44	81	118	162
		kgfm/arc min	0.013	0.066	0.1	0.24	0.38	0.74	1.6	3.0	4.3	5.9	9.3	13	24	35	48
	K_2	$\times10^4$Nm/rad	0.067	0.30	0.47	1.1	1.8	3.4	7.8	14	20	28	44	61	115	162	222
		kgfm/arc min	0.020	0.090	0.14	0.32	0.52	1.0	2.3	4.2	6.0	8.2	13	18	34	48	66
	K_3	$\times10^4$Nm/rad	0.084	0.32	0.57	1.3	2.3	4.4	9.8	18	26	34	54	78	145	206	283
		kgfm/arc min	0.025	0.096	0.17	0.4	0.67	1.3	2.9	5.3	7.6	10	16	23	43	61	84
	θ_1	$\times10^{-4}$rad	6.6	3.6	5.8	4.9	5.2	5.5	5.5	5.2	5.2	5.5	5.2	5.2	5.2	5.2	5.2
		arc min	2.3	1.2	2.0	1.7	1.8	1.9	1.9	1.8	1.8	1.9	1.8	1.8	1.8	1.8	1.8
	θ_2	$\times10^{-4}$rad	13	8	16	12	15.4	15.7	15.7	15.4	15.1	15.4	15.1	15.1	15.1	15.4	15.1
		arc min	4.7	2.6	5.6	4.2	5.3	5.4	5.4	5.3	5.2	5.3	5.2	5.2	5.2	5.2	5.2

* The values in this table are reference values. The minimum value is approximately 80% of the displayed value.

Table 043-1

Symbol \ Size			8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
T_1		Nm	0.29	0.80	2.0	3.9	7.0	14	29	54	76	108	168	235	430	618	843
		kgfm	0.03	0.082	0.2	0.4	0.7	1.4	3.0	5.5	7.8	11	17	24	44	63	86
T_2		Nm	0.75	2.0	6.9	12	25	48	108	196	275	382	598	843	1570	2260	3040
		kgfm	0.077	0.2	0.7	1.2	2.5	4.9	11	20	28	39	61	86	160	230	310
Reduction ratio 80 or more	K_1	$\times 10^4$Nm/rad	0.091	0.27	0.47	1	1.6	3.1	6.7	13	18	25	40	54	100	145	200
		kgfm/arc min	0.027	0.080	0.14	0.3	0.47	0.92	2.0	3.8	5.4	7.4	12	16	30	43	59
	K_2	$\times 10^4$Nm/rad	0.10	0.34	0.61	1.4	2.5	5.0	11	20	29	40	61	88	162	230	310
		kgfm/arc min	0.031	0.10	0.18	0.4	0.75	1.5	3.2	6.0	8.5	12	18	26	48	68	93
	K_3	$\times 10^4$Nm/rad	0.12	0.44	0.71	1.6	2.9	5.7	12	23	33	44	71	98	185	263	370
		kgfm/arc min	0.036	0.13	0.21	0.46	0.85	1.7	3.7	6.8	9.7	13	21	29	55	78	110
	θ_1	$\times 10^{-4}$rad	3.2	3.0	4.1	3.9	4.4	4.4	4.4	4.1	4.1	4.4	4.1	4.4	4.4	4.4	4.4
		arc min	1.1	1.0	1.4	1.3	1.5	1.5	1.5	1.4	1.4	1.5	1.4	1.5	1.5	1.5	1.5
	θ_2	$\times 10^{-4}$rad	8	6	12	9.7	11.3	11.1	11.6	11.1	11.1	11.1	11.1	11.3	11.3	11.6	11.3
		arc min	2.6	2.2	4.2	3.3	3.9	3.8	4.0	3.8	3.8	3.8	3.8	3.9	3.9	4.0	3.9

* The values in this table are reference values. The minimum value is approximately 80% of the displayed value.

Starting torque

See "Engineering data" for a description of terms. Values shown vary depending on condition. Please use values as a reference.

■ CSG Series

Table 043-2
Unit: Ncm

Ratio \ Size	14	17	20	25	32	40	45	50	58	65
30	—	—	—	—	—	—	—	—	—	—
50	3.6	5.6	7.3	13	29	51	69	—	—	—
80	2.6	3.6	4.5	8.5	18	32	45	59	90	121
100	2.3	3.2	4.1	7.6	17	29	40	53	80	108
120	—	3.0	3.6	6.9	14	26	36	50	74	101
160	—	—	3.2	6.1	13	23	32	43	64	88

■ CSF Series

Table 043-3
Unit: Ncm

Ratio \ Size	8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
30	1.3	2.7	4.3	6.5	11	19	45	—	—	—	—	—	—	—	—
50	0.8	1.6	3.3	5.1	6.6	12	26	46	63	86	130	180	320	450	590
80	—	—	2.4	3.3	4.1	7.7	16	29	41	54	82	110	200	280	380
100	0.59	1.1	2.1	2.9	3.7	6.9	15	26	36	48	73	98	180	250	340
120	—	—	—	2.7	3.3	6.3	13	24	33	45	67	92	170	230	310
160	—	—	—	—	2.9	5.5	12	21	29	39	58	80	140	200	270

Backdriving torque

See "Engineering data" for a description of terms. Values shown vary depending on condition. Please use values as a reference.

■ CSG Series

Table 043-4
Unit: Nm

Ratio \ Size	14	17	20	25	32	40	45	50	58	65
30	—	—	—	—	—	—	—	—	—	—
50	1.5	2.8	4.4	8.3	18	31	41	—	—	—
80	1.5	2.8	4.6	8.5	18	31	43	58	89	132
100	1.9	3.1	5.0	9.2	20	34	46	63	97	143
120	—	3.4	5.4	10	21	37	52	69	107	154
160	—	—	6.4	12	25	44	63	85	132	187

■ CSF Series

Table 043-5
Unit: Nm

Ratio \ Size	8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
30	0.65	1.3	2	3.2	5.5	10	21	—	—	—	—	—	—	—	—
50	0.5	1	1.4	2.5	4	7.5	16	28	37	52	80	110	200	270	360
80	—	—	1.4	2.5	4.2	7.7	16	28	39	53	81	120	200	270	370
100	0.7	1.4	1.7	2.8	4.5	8.4	18	31	42	57	88	130	220	300	400
120	—	—	—	3.1	4.9	9.2	19	34	47	63	97	140	240	330	440
160	—	—	—	—	5.8	11	23	40	57	77	120	170	290	390	540

Engineering Data
Component Sets
Gear Units
Phase Adjusters
Gearheads & Actuators

Ratcheting torque

See "Engineering data" for a description of terms.

CSG Series

Table 044-1
Unit: Nm

Ratio \ Size	14	17	20	25	32	40	45	50	58	65
50	110	190	280	580	1200	2300	3500	—	—	—
80	140	260	450	880	1800	3600	5000	7000	10000	14000
100	100	200	330	650	1300	2700	4000	5300	8300	12000
120	—	150	310	610	1200	2400	3600	4900	7500	10000
160	—	—	280	580	1200	2300	3300	4600	7200	10000

CSF Series

Table 044-2
Unit: Nm

Ratio \ Size	8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
30	11	29	59	100	170	340	720	—	—	—	—	—	—	—	—
50	12	34	88	150	220	450	980	1800	2700	3700	5800	7800	14000	20000	29000
80	—	—	110	200	350	680	1400	2800	3900	5400	8200	11000	22000	30000	44000
100	14	43	84	160	260	500	1000	2100	3100	4100	6400	9400	16000	23000	33000
120	—	—	—	120	240	470	980	1900	2800	3800	5800	8300	15000	21000	30000
160	—	—	—	—	220	450	980	1800	2600	3600	5600	8000	14000	20000	28000

Buckling torque

See "Engineering data" for a description of terms.

CSG Series

Table 044-3
Unit: Nm

Size	14	17	20	25	32	40	45	50	58	65
All ratios	260	500	800	1700	3500	6700	8900	12200	19000	26600

CSF Series

Table 044-4
Unit: Nm

Size	8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
All ratios	35	90	190	330	560	1000	2200	4300	5800	8000	12000	17000	31000	45000	58000

No-load running torque

No-load running torque is the torque which is required to rotate the input side (high speed side), when there is no load on the output side (low speed side).

* Contact us for detailed values.

Measurement condition

Table 044-5

<table>
<tr><th colspan="4">Ratio 100:1</th></tr>
<tr><td rowspan="3">Lubricant</td><td rowspan="3">Grease lubrication</td><td rowspan="2">Name</td><td>Harmonic Grease SK-1A</td></tr>
<tr><td>Harmonic Grease SK-2</td></tr>
<tr><td>Quantity</td><td>Recommended quantity (See page 049)</td></tr>
<tr><td colspan="4">Torque value is measured after 2 hours at 2000rpm input.</td></tr>
</table>

* Contact us for oil lubrication.

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 gear ratios, add the compensation values from table on the right.

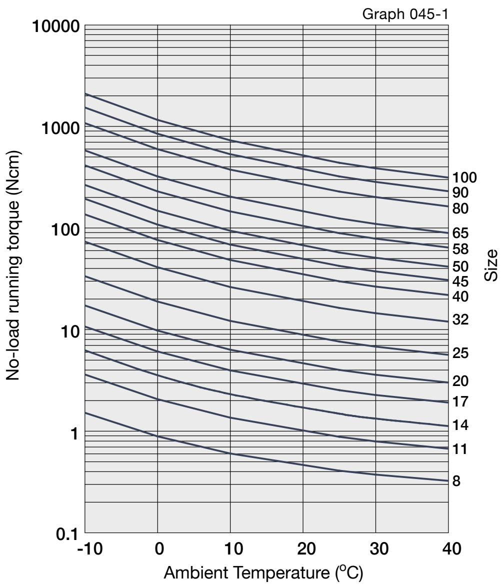
Component Set No Load Torque Compensation

Table 044-6
Unit: Ncm

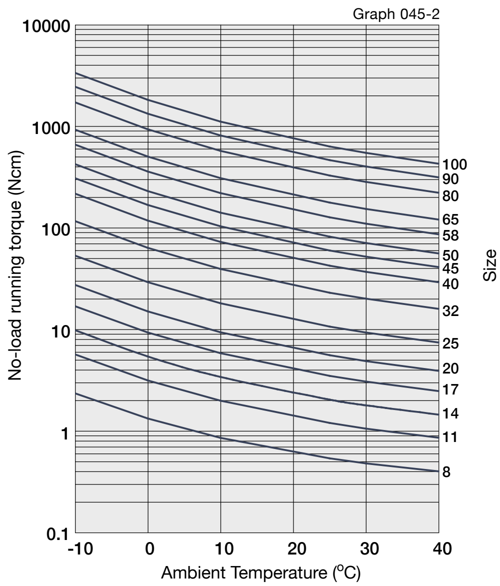
Size \ Ratio	30	50	80	120	160
8	0.4	0.2	—	—	—
11	0.7	0.3	—	—	—
14	1.1	0.5	0.1	—	—
17	1.8	0.8	0.1	-0.1	—
20	2.7	1.2	0.2	-0.1	-0.3
25	5.0	2.2	0.3	-0.2	-0.6
32	10	4.5	0.7	-0.5	-1.2
40	—	8.0	1.2	-0.9	-2.2
45	—	11	1.7	-1.3	-3.0
50	—	15	2.3	-1.7	-4.0
58	—	22	3.4	-2.5	-6.1
65	—	31	4.7	-3.5	-8.4
80	—	55	8.5	-6.2	-15
90	—	77	12	-8.7	-21
100	—	100	16	-12	-28

■ No-load running torque for a reduction ratio of 100:1

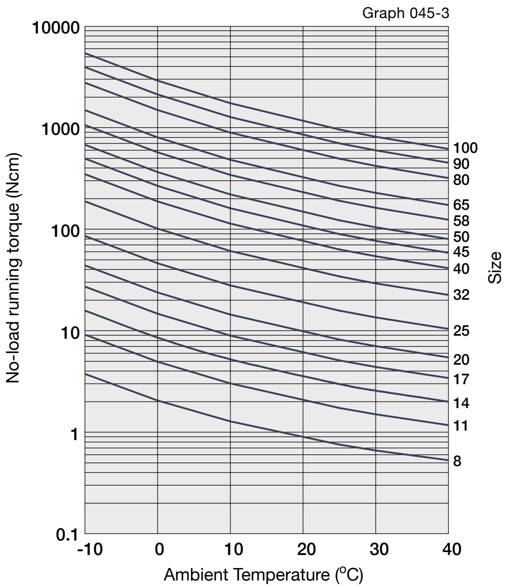
Input speed: 500rpm



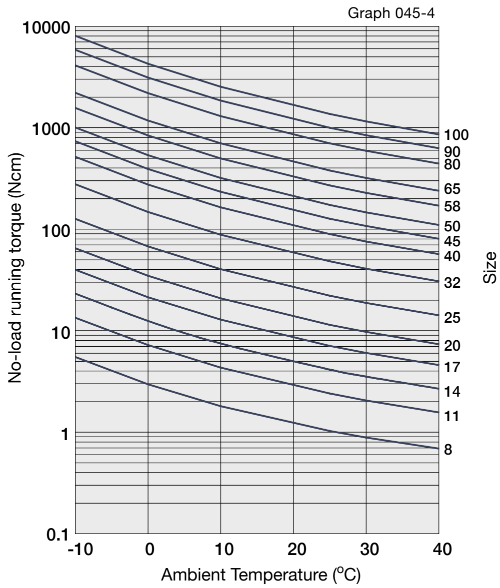
Input speed: 1000rpm



Input speed: 2000rpm



Input speed: 3500rpm



*The values in this graph are average values ($\overline{X}$). σ≈20%

Efficiency

The efficiency varies depending on the following conditions.

- Reduction ratio
- Input rotational speed
- Load torque
- Temperature
- Lubrication (type and quantity)

Measurement condition Table 046-1

Installation	Based on recommended tolerance.		
Load torque	The rated torque (see page 038 and 039)		
Lubricant	Grease lubrication	Name	Harmonic Grease SK-1A
			Harmonic Grease SK-2
		Quantity	Recommended quantity (see page 049)

* Contact us for oil lubrication.

Efficiency compensation coefficient

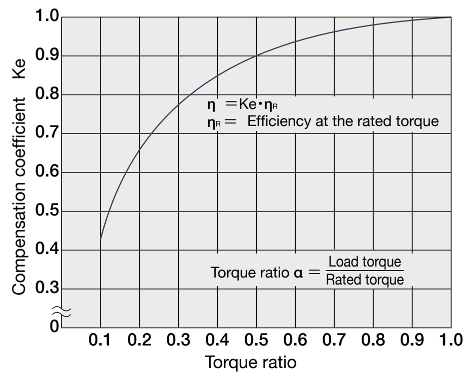
Find the Compensation Coefficient (Ke) and calculate the efficiency.

Example of calculation

Efficiency η (%) under the following condition is obtained from the example of CSF-20-80-2A-GR.
Input speed: 1000 rpm
Load torque: 19.6 Nm
Lubrication: Harmonic Grease SK-1A
Lubricant temperature: 20°C
Since the rated torque of size 20 with a reduction ratio of 80 is 34 Nm (Ratings: Page 039), the torque ratio α is 0.58.
(α=19.6/34=0.58)

- The efficiency compensation coefficient is Ke=0.93 from Graph 046-1.
- Efficiency η at load torque 19.6 Nm: η=Ke•ηR=0.93 x 78=73%

Efficiency compensation coefficient Graph 046-1



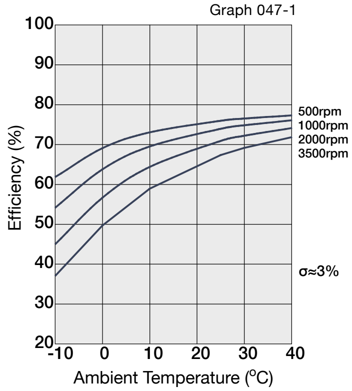
* Efficiency compensation coefficient Ke=1 holds when the load torque is greater than the rated torque.

■ Efficiency at rated torque

Size: 8, 11, 14

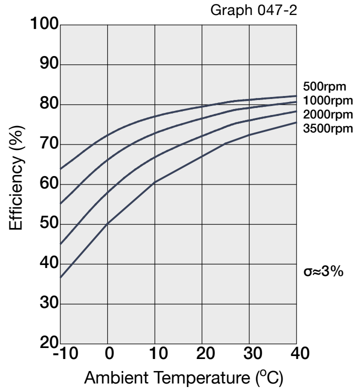
Reduction ratio 30

Graph 047-1



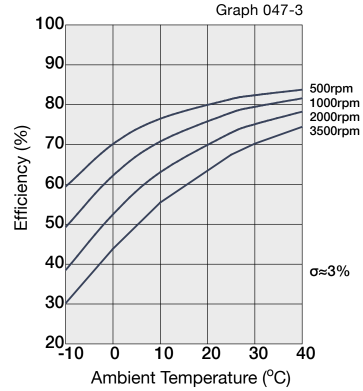
Reduction ratio 50, 80

Graph 047-2



Reduction ratio 100

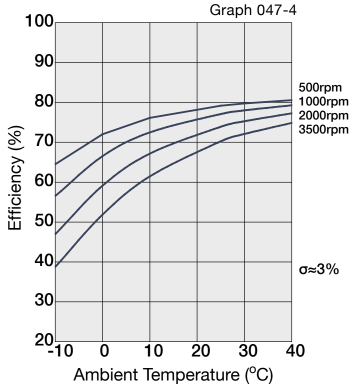
Graph 047-3



Size: 17 to 100

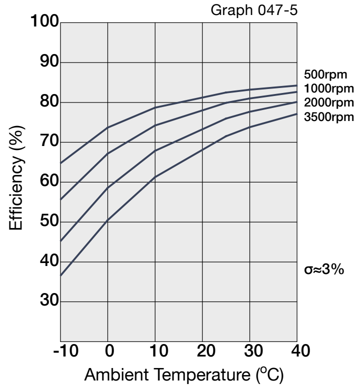
Reduction ratio 30

Graph 047-4



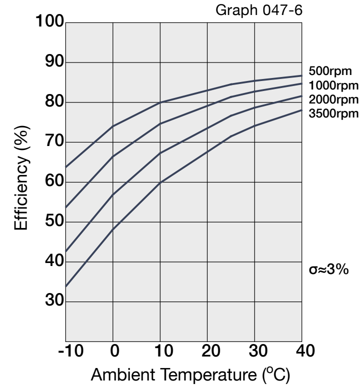
Reduction ratio 50

Graph 047-5



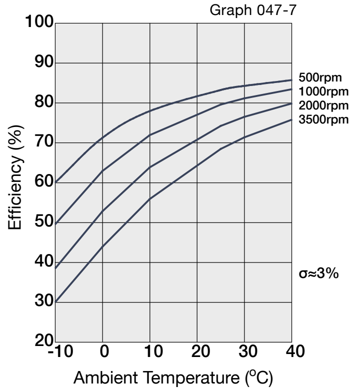
Reduction ratio 80, 100

Graph 047-6



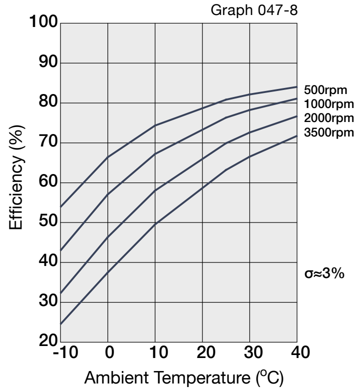
Reduction ratio 120

Graph 047-7



Reduction ratio 160

Graph 047-8



Design Guide

Lubrication

■ Grease lubrication[*1]

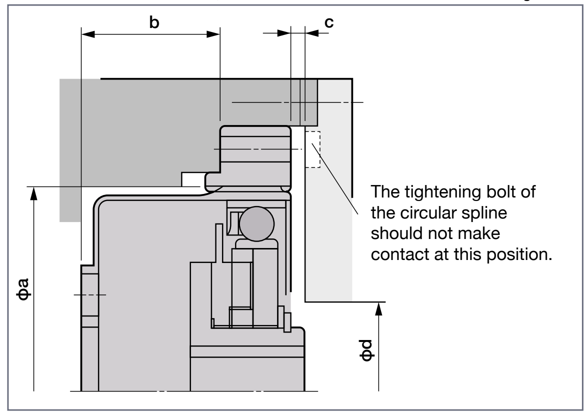
See "Engineering data" on Page 016 for details of the lubricant.

Recommended housing dimensions

See table below for recommended housing dimensions. These dimensions must be maintained to prevent damage to the gear and to maintain a proper grease cavity.

Recommended housing dimensions

Fig. 048-1



Recommended housing dimensions

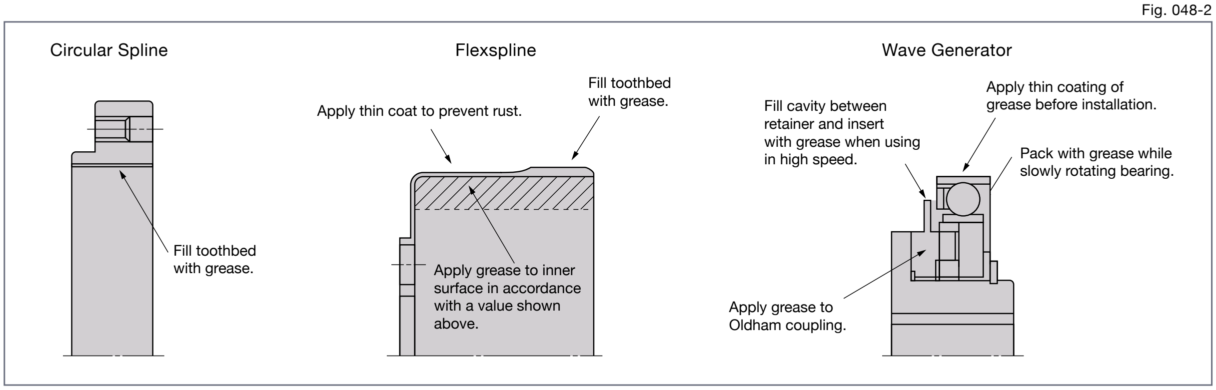
Table 048-1
Unit: mm

Symbol \ Size	8	11	14	17	20	25	32	40	45	50[*1]	58[*1]	65[*1]	80[*1]	90[*1]	100[*1]
φa	21.5	30	38	45	53	66	86	106	119	133	154	172	212	239	265
b	11.34	14	17.1	19	20.5	23	26.8	33	36.5	39	46.2	50	61	68.5	76
c	0.5	0.5	1	1	1.5	1.5	1.5	2	2	2	2.5	2.5	3	3	3
φd	13	16	16	26	30	37	37	45	45	45	56	62	67	73	79

(Note) Double Size c if you use the wave generator facing upward.
*1 Oil lubrication is required for component-sets size 50 or larger with a reduction ratio of 50:1.

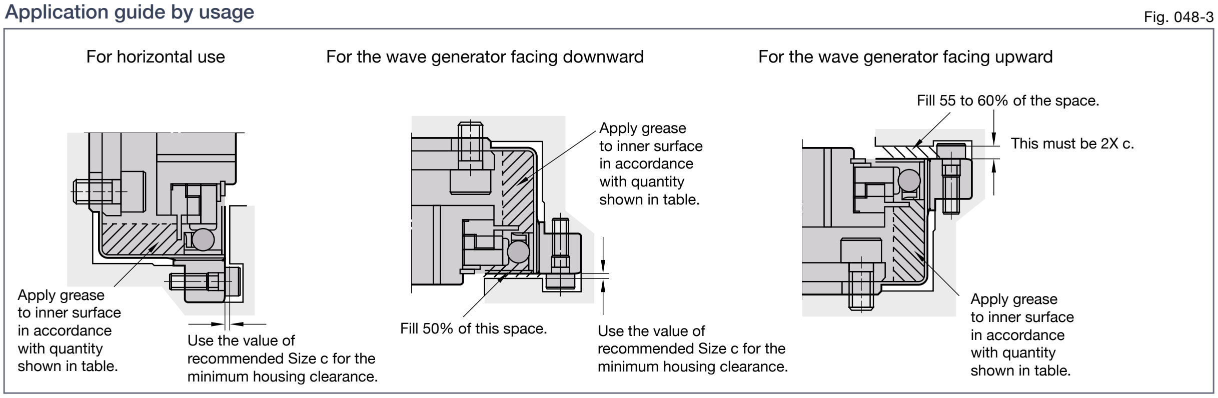
Application guide

Fig. 048-2



Application guide by usage

Fig. 048-3



Application quantity

Table 049-1
Unit: g

Usage \ Size		8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
Horizontal use		1.2	2.9	5.5	10	16	30	60	110	170	220	360	460	850	1150	1500
Vertical use	Output shaft facing upward	1.4	3.5	7	12	18	35	70	125	190	240	380	500	900	1300	1700
	Output shaft facing downward	1.8	4.4	8.5	14	21	40	80	145	220	275	460	600	1000	1500	1900

When to replace grease

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 rated torque is exceeded, calculate the grease change interval using the equation shown below.
(Note) Recommended Grease: SK-1A or SK-2

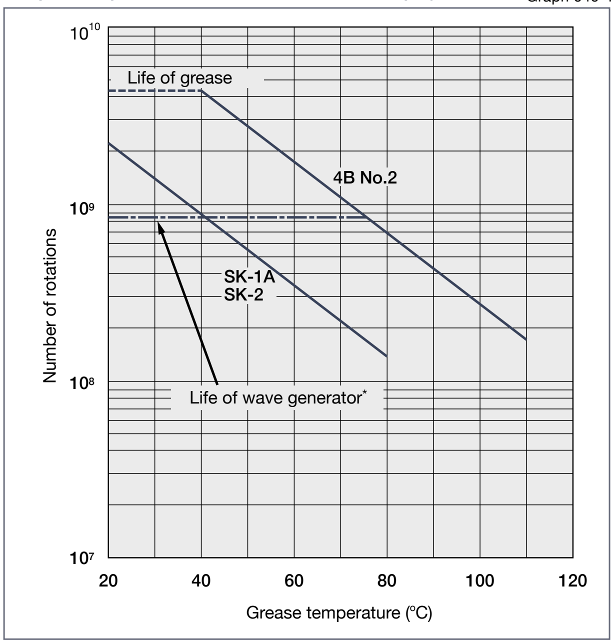
Formula when load torque exceeds rated torque Formula 049-1

$$L_{GT} = L_{GTn} \times \left(\frac{Tr}{Tav}\right)^3$$

Symbols for Formula 049-1 Table 049-2

L_{GT}	Replacement timing if average load torque exceeds rated torque	Number of input revolutions	–––––
L_{GTn}	Replacement timing if average load torque is equal to or less than rated torque (or use formulas, i.e. Tav ≤ Tr)	Number of input revolutions	See the right-hand figure.
Tr	Rated torque	Nm	See the "Rating table" on page 38 and 39.
T*av*	Average load torque	Nm	Calculation formula: See Page 14.

When to replace grease: L_{GTn} (when the average load torque is equal to or less than the rated torque) Graph 049-1



* Life of wave generator is based on L10 life of the bearing.

■ Other precautions

1. Avoid using it with other grease. The gear should be in an individual case when installed.

2. If you use the gear with the wave generator facing upward (see Figure 050-2 on Page 50) at low-speed rotation (input rotational speed: 1000 rpm or less) and in one direction, please contact us as it may cause lubrication problems.

3. Oil lubrication is required for component-sets size 50 or larger with a reduction ratio of 50:1. Use grease lubrication within half the rated torque.

Engineering Data
Component Sets
Gear Units
Phase Adjusters
Gearheads & Actuators

■ Oil lubrication

See "Engineering data" on Page 18 for details of the lubricant.

Usage and oil level

1. For horizontal installation

Oil level should be maintained at the level “A” as shown. Figure 050-1.

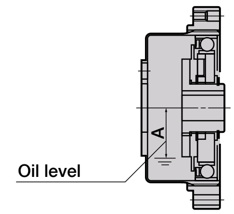
Oil level for horizontal use

Table 050-1
Unit: mm

Size	8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
A	6	8	10	12	14	17	24	31	35	38	44	50	59	66	74

Oil level for horizontal use

Fig. 050-1

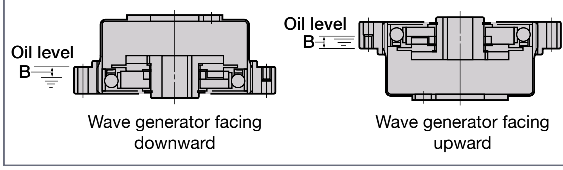


2. For vertical installation

Fill the center of the ball of the wave generator facing upward or downward with oil (Oil level "B" of Figure 050-2). An oil groove should be added to the flexspline. Contact us for details.

Oil level for vertical use

Fig. 050-2



Oil level for vertical use

Table 050-2
Unit: mm

Size	8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
B	2	2.3	2.5	3	3	5	7	9	10	12	13	15	19	22	25

Dimension of lube hole of the flexspline

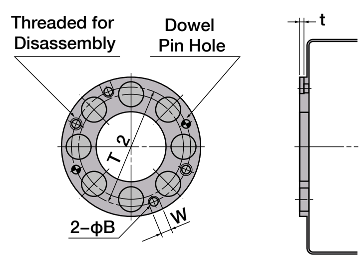
Table 050-3
Unit: mm

Symbol \ Size	20	25	32	40	45	50	58	65	80	90	100
T_2	27	34	45	56	61	68	79	90	114	120	142
B	2.5	2.5	3.5	3.5	3.5	5.5	5.5	5.5	6.5	6.5	6.5
W	2.8	3.5	4.0	4.0	4.0	6.0	6.0	6.0	7.0	7.0	7.0
t	1.2	1.2	1.4	1.4	1.4	2	2	2	3	3	3

Size 8, 11, 14, 17 do not have any lube holes.

Dimension of lube hole of the flexspline

Fig. 050-3



Oil quantity

Table 050-4
Unit: ℓ

Size	8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
Oil quantity	0.004	0.006	0.01	0.02	0.03	0.07	0.13	0.25	0.32	0.4	0.7	1.0	2.0	2.8	3.8

When to replace oil

First time ·····························100 hours after starting operation
Second time or later ···········Every 1000 operation hours or every 6 months
Note that you should replace oil earlier than specified if the operating conditions are demanding.

Other precautions

1. Avoid mixing different kinds of oil. The gear should be in an individual case when installed.

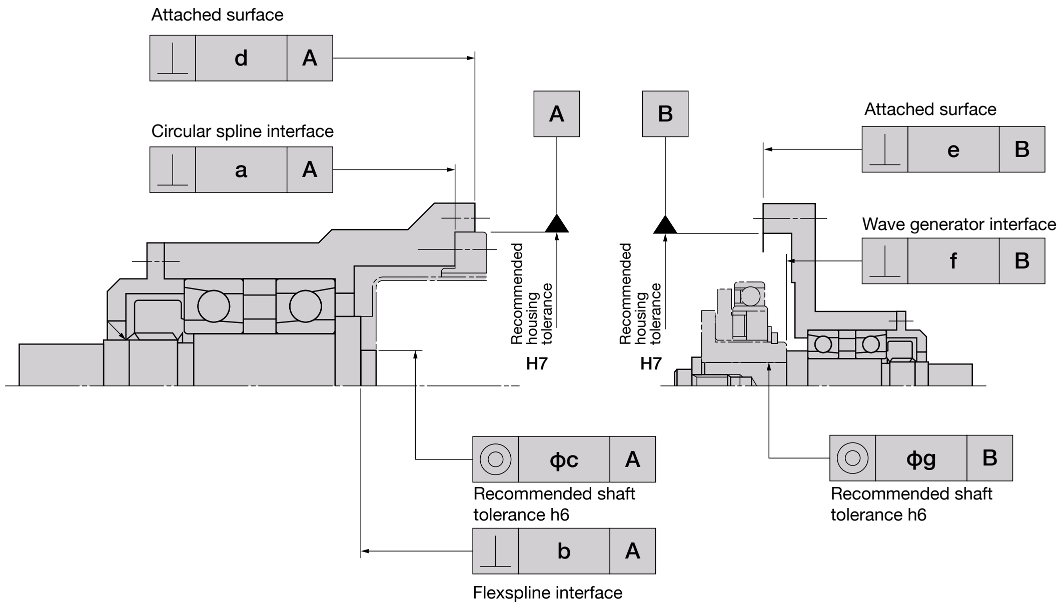
2. If you use size 50 or above at allowable input speed, please contact us as it may cause lubrication problems.

Recommended tolerances for assembly

Maintain the recommended tolerances shown in Figure 051-1 and Table 051-1 for peak performance.

Recommended tolerances for assembly

Fig. 051-1



Tolerances for assembly

Table 051-1
Unit: mm

Symbol \ Size	8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
a	0.008	0.011	0.011	0.012	0.013	0.014	0.016	0.016	0.017	0.018	0.020	0.023	0.027	0.029	0.031
b	0.006	0.006	0.008	0.011	0.014	0.018	0.022	0.025	0.028	0.030	0.032	0.035	0.040	0.043	0.045
ϕc	0.005	0.008	0.015	0.018	0.019	0.022	0.022	0.024	0.027	0.030	0.032	0.035	0.043	0.046	0.049
d	0.010	0.010	0.011	0.015	0.017	0.024	0.026	0.026	0.027	0.028	0.031	0.034	0.043	0.050	0.057
e	0.010	0.010	0.011	0.015	0.017	0.024	0.026	0.026	0.027	0.028	0.031	0.034	0.043	0.050	0.057
f	0.012	0.012	0.017 (0.008)	0.020 (0.010)	0.020 (0.010)	0.024 (0.012)	0.024 (0.012)	0.032 (0.012)	0.032 (0.013)	0.032 (0.015)	0.032 (0.015)	0.032 (0.015)	0.036 (0.015)	0.036 (0.015)	0.036 (0.015)
ϕg	0.015	0.015	0.030 (0.016)	0.034 (0.018)	0.044 (0.019)	0.047 (0.022)	0.050 (0.022)	0.063 (0.024)	0.065 (0.027)	0.066 (0.030)	0.068 (0.033)	0.070 (0.035)	0.090 (0.043)	0.091 (0.046)	0.092 (0.049)

* The values in parentheses indicate that Wave Generator does not have an Oldham coupling.

Sealing

Sealing is needed to maintain the high durability of the gear and prevent grease leakage.

- 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.

Installation of the three basic elements

■ Installation of the wave generator

Maximum hole diameter size

Hole diameter range of the wave generator hub with Oldham coupling

Table 052-1
Unit: mm

Item \ Size	8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
Stand. dimension (H7)	3	5	6	8	9	11	14	14	19	19	22	24	28	28	28
Minimum hole dimension	—	—	3	4	5	6	6	10	10	10	13	16	16	19	22
Maximum hole dimension	—	—	8	10	13	15	15	20	20	20	25	30	35	37	40

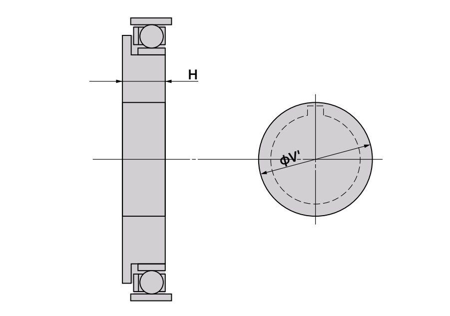
The standard hole diameter of the wave generator is as shown in the dimensional outline drawing (fig 040-01) and may be changed within a range up to the maximum dimension shown in the table. The JIS standard is recommended for the keyway. It is necessary that the dimension of keyways should sustain the transmission torque.

Please note: Tapered holes are also available.

In cases where a larger hole is required, use the Wave Generator without the Oldham coupling. The maximum diameter of the hole should be considered to prevent deformation of the Wave Generator plug by load torque.
(This is the value including the dimension of the keyway.)

Hole diameter of the wave generator with Oldham coupling

Fig. 052-1



Maximum hole diameter without Oldham Coupling

Table 052-2
Unit: mm

Item \ Size	8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
Maximum Diameter ΦV'	10	14	17	20	23	28	36	42	47	52	60	67	72	84	95
Min. plug thickness $H^{0}_{-0.1}$	5.7	6.7	7.2	7.6	11.3	11.3	13.7	15.9	17.8	19	21.4	23.5	28.5	31.3	34.9

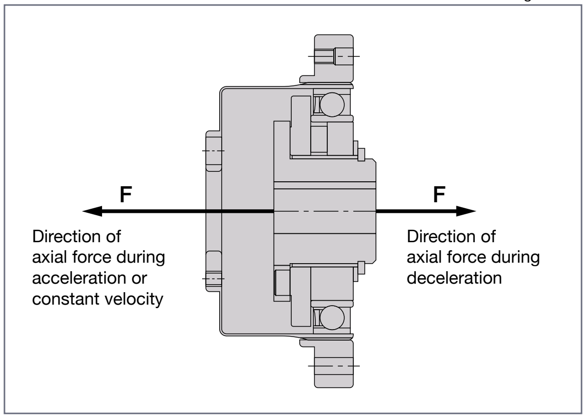
Axial force of the wave generator

When a CSF/CSG 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 CSF/CSG 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 if you plan to attach the Wave Generator to the input (motor) shaft using bolts.

Axial force direction of the wave generator

Fig. 052-2



Formula for Axial Force

Table 052-3

Ratio	Calculation formula
30	$F=2\times\frac{T}{D}\,0.07\times\tan32°$
50	$F=2\times\frac{T}{D}\,0.07\times\tan30°$
80 or more	$F=2\times\frac{T}{D}\,0.07\times\tan20°$

Symbols for Formula

Table 052-4

F	Axial force	N	See Fig. 052-2.
D	(Size) ×0.00254	m	
T	Output torque	Nm	

Example of Calculation

Formula 052-1

Model name : CSF series
Size : 32
Ratio : i = 50:1
Output torque : 382 Nm (max. allowable momentary torque)

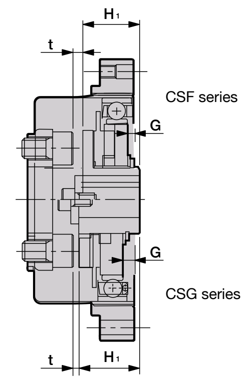
$$F=2\times\frac{382}{(32\times0.00254)}\times0.07\times\tan30°$$

$$F=380N$$

Shapes and dimensions of the wave generator

The shapes and dimensions of the wave generator of the CSF series are different from those of the CSG series. Exercise extreme care in design and installation. Please ensure there is no interference between the bolt of the Wave Generator and Flexspline.
Table 053-1 and Figure 053-1 show a comparison of the shapes and sizes of the wave generator.

Comparison of shapes and sizes of the wave generator Fig. 053-1



Comparison of Dimension of Wave Generator

Table 053-1
Unit: mm

Symbol	Size	14	17	20	25	32	40	45	50	58	65
G	CSG Series	1.4	1.6	1.5	3.5	4.2	5.6	6.3	7	8.2	9.5
	CSF Series	0.4	0.3	0.1	2.1	2.5	3.3	3.7	4.2	4.8	5.8
$H1^{0}_{-0.1}$	CSG Series	18.5	20.7	21.5	21.6	23.6	29.7	30.5	34.8	38.3	44.6
	CSF Series	17.6	19.5	20.1	20.2	22	27.5	27.9	32	34.9	40.9
t	CSG Series	1.6	1.3	1.5	1.4	2.2	2.3	3.5	2.2	5.4	3.9
	CSF Series	2.5	2.5	2.9	2.8	3.8	4.5	6.1	5.0	8.8	7.6

(Note) "t" indicates the size for Table 054-1 of the flexspline mounting flange.

■ Installation of the flexspline

For size 8

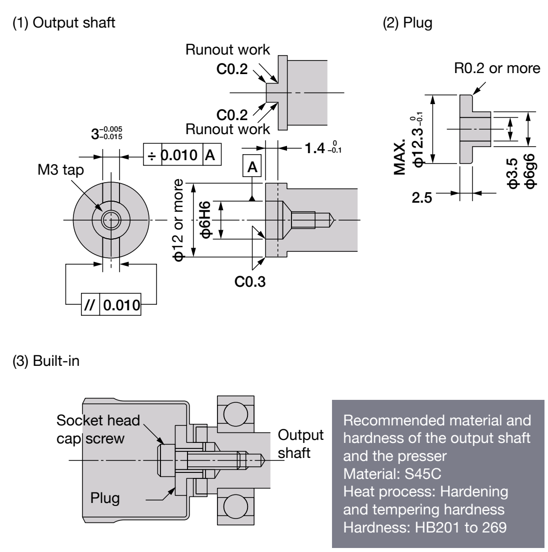
(a) For installation of the Flexspline on the output shaft use the plug shown on the right.

(b) The positioning of the output shaft and the Flexspline should be determined using the plug.

(c) We recommend using an M3 socket head cap screw for connecting the plug to the output shaft. We also recommend using LOCTITE® 242.

d) The open end of the Flexspline must be located axially on the same plane as the top surface of the circular spline.

Installation of flexspline for size 8 Fig. 053-2



Recommended material and hardness of the output shaft and the presser
Material: S45C
Heat process: Hardening and tempering hardness
Hardness: HB201 to 269

Recommended size for the mounting flange for size 11 or larger

The mounting flange diameter should not exceed the boss diameter of the flexspline as shown in Figure 054-1. The flange which contacts the diaphragm should have radius, R. A large diameter and flange without a radius may cause damage to the diaphragm.

Flexspline Clamp Ring Dimensions

Table 054-1
Unit: mm

Symbol \ Size	11	14	17	20	25	32	40	45	50	58	65	80	90	100
$\phi D^{0}_{-0.1}$	17.8	24.5	29	34	42	55	68	74	83	95.8	106	130	145	162
$R^{+0.1}_{0}$	0.5	1.2	1.2	1.4	1.5	2	2.5	2	2.5	2.5	2.5	2.5	2.5	2.5
t	2	2	2.5	2.5	5	7	7	8	8	12	12	15	20	25

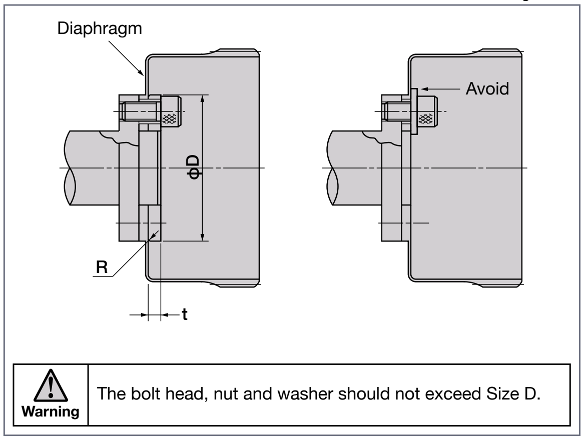
Material and hardness of the mounting flange

Use the following material and hardness.

Material: S45C (DINHC45)
Heat process: Hardening and tempering
Hardness: HB200 to 270

Recommended Dimension of Flexspline Clamp Ring

Fig. 054-1



Installation of the flexspline

Use bolts or bolts and pins (pin: option) for installing the flexspline.

- Strength of the selected bolt
- Tightening of bolts and the tightening torque
- Surface condition of bolts and tapped holes
- Friction coefficient of the contact surface

The load is normally attached to the Flexspline using a bolt or screw. For high load torques dowel pins can be used in addition to bolts or screws. The strength of the selected bolt, clamp torque, surface condition of bolt and thread, and coefficient of friction on the contact surface are important factors to consider. To determine transmission torque of the fastened part consider conditions indicated below. Please fasten bolts with the proper torque for each size as indicated. Please use the tables to determine if dowel pins are needed.

(1) If the load torque is less than momentary peak torque shown in tables 055-1 and 056-1 then only bolts are needed.
(2) If load torque is expected to reach momentary peak torque, both bolts and pins should be used. see Table 055-2 and Figure 055-1 and Table 056-2 and Figure 056-1.

* Use the value in the table as a reference value.

CSF series: Flexspline bolts

Table 055-1

Item \ Size		11	14	17	20	25	32	40	45	50	58	65	80	90	100
Number of bolts		6	6	6	8	8	8	8	8	8	8	8	8	8	12
Bolt size		M3	M4	M5	M5	M6	M8	M10	M12	M14	M14	M16	M16	M20	M20
Pitch circle	mm	12	17	19	24	30	40	50	54	60	70	80	100	110	130
Clamp torque	Nm	2.0	4.5	9.0	9.0	15.3	37	74	128	205	205	319	319	622	622
Torque transmission capacity (bolt only)	Nm	15	35	64	108	186	460	910	1440	2160	2550	3980	6220	8560	15170

CSF series: Flexspline bolts and optional dowel pins

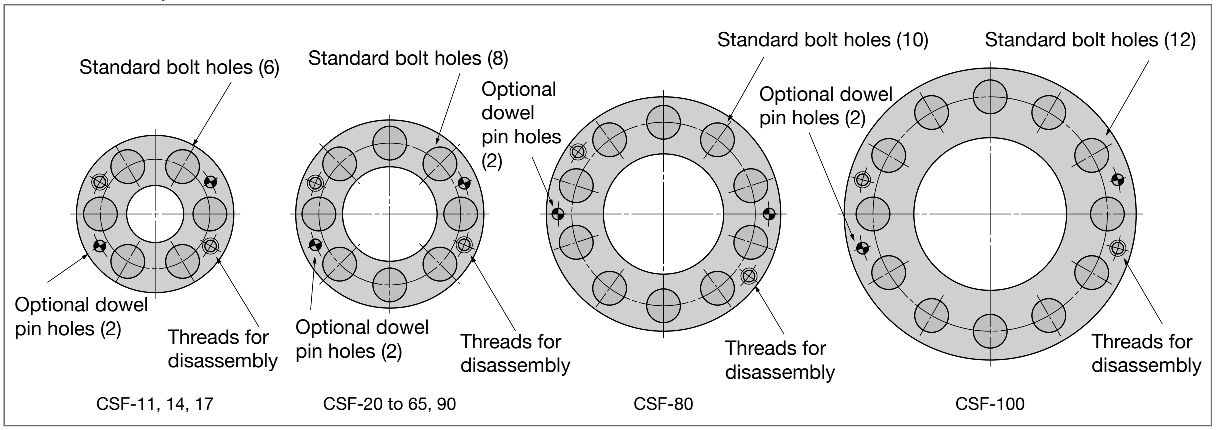
Table 055-2

Item \ Size		11	14	17	20	25	32	40	45	50	58	65	80	90	100
Number of pins		2	2	2	2	2	2	2	2	2	2	2	2	2	2
Diameter	mm	2	3	3	3	4	5	6	6	8	8	8	8	12	10
Pitch circle	mm	15.2	18.5	21.5	27	34	45	56	61	68	79	90	114	120	142
Torque transmission capacity (bolt only)	Nm	29	74	108	167	314	725	1370	1950	3160	3710	5310	7910	12540	18450

(Table 055-1, 055-2/Notes)
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: μ=0.15
6. Dowel Pin: Parallel pin, material: S45C-Q, shearing stress: τ=30 kg/mm^2

CSF series: Flexspline Bolts

Fig. 055-1



CSG series: Flexspline bolts

Table 056-1

Item \ Size		14	17	20	25	32	40	45	50	58	65
Number of bolts		6	6	8	8	8	8	8	8	8	8
Bolt size		M4	M5	M5	M6	M8	M10	M12	M14	M14	M16
Pitch circle	mm	17	19	24	30	40	50	54	60	70	80
Clamp torque	Nm	5.4	10.8	10.8	18.4	44.4	88.8	154	246	246	383
Torque transmission capacity (bolt only)	Nm	43	77	130	230	555	1110	1728	2636	3075	4785

CSG series: Flexspline, bolts and optional dowel pins

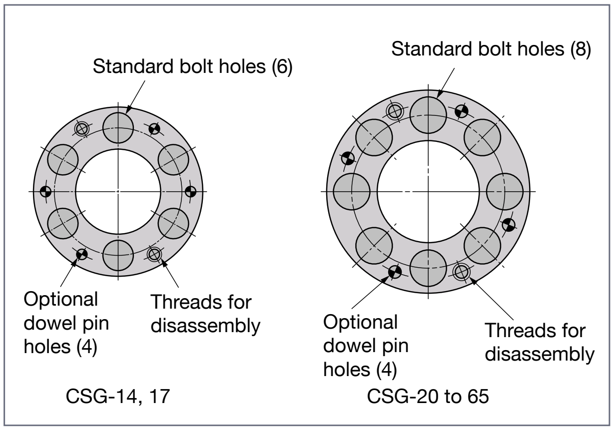
Table 056-2

Item \ Size		14	17	20	25	32	40	45	50	58	65
Number of pins		4	4	4	4	4	4	4	4	4	4
Pin size	mm	3	3	3	4	5	6	6	8	8	8
Pitch circle	mm	18.5	21.5	27	34	45	56	61	68	79	90
Torque transmission capacity	Nm	120	166	242	481	1070	2040	2742	4646	5410	7445

(Table 056-1, 056-2/Notes)
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. Tightening friction coefficient μ=0.15
6. Pin type: Parallel pin, material: S45C-Q, shearing stress: τ=30 kg/mm^2

CSF series: Hole positions of bolts and optional dowel pins

Fig. 056-1



■ Installation of the circular spline

Perform design and part control corresponding to the load condition for installation of the circular spline in the same way as the flexspline. Transmission torques by the recommended bolts and tightening torque are shown in Table 058-2. When the transmission torque is lower than the load torque, the additional use of pins and bolts should be reviewed. Perform installation to meet the requirements of each series.

CSG series: Bolt installation

Table 057-1

Item \ Size		14	17	20	25	32	40	45	50	58	65
Number of bolts		8	16	16	16	16	16	16	16	16	16
Bolt size		M3	M3	M3	M4	M5	M6	M8	M8	M10	M10
Pitch circle	mm	44	54	62	75	100	120	140	150	175	195
Clamp torque	Nm	2.0	2.0	2.0	4.5	9.0	15.3	37	37	74	74
Torque transmission capacity	Nm	72	175	196	419	901	1530	3238	3469	6475	7215

CSF series: Bolt installation

Table 057-2

Item \ Size		8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
Number of bolts		8	8	6	12	12	12	12	12	12	12	12	12	16	16	16
Bolt size		M2	M2.5	M3	M3	M3	M4	M5	M6	M8	M8	M10	M10	M10	M12	M12
Pitch circle	mm	25.5	35	44	54	62	75	100	120	140	150	175	195	240	270	300
Clamp torque	Nm	0.54	1.1	2.0	2.0	2.0	4.5	9.0	15.3	37	37	74	74	74	128	128
Torque transmission capacity	Nm	17	39	54	131	147	314	676	1150	2440	2620	4820	5370	8820	14450	16050

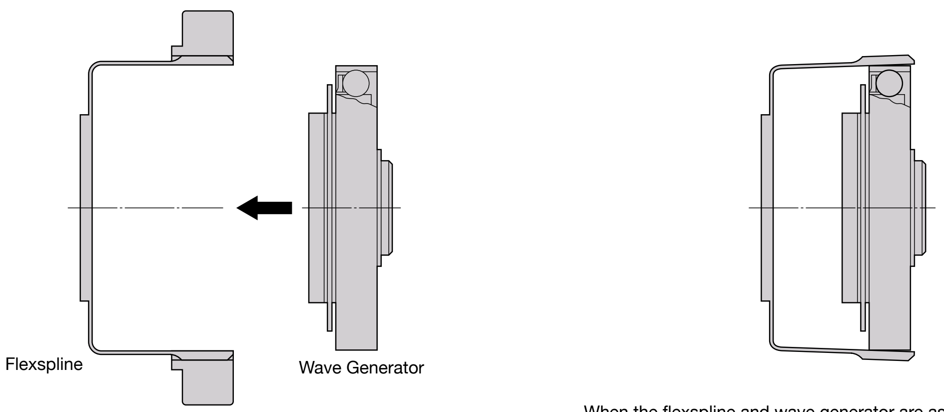
(Table 057-1, 057-2/Notes)
1. The material of the thread must withstand the clamp torque.
2. Recommended bolt: JIS B 1176 socket head cap screw / Strength range: JIS B 1051 over 12.9.
3. Torque coefficient: K=0.2
4. Clamp coefficient: A=1.4
5. Tightening friction coefficient μ=0.15

■ Assembly order for basic three elements

The wave generator is installed after the flexspline and circular spline. If the wave generator is not inserted into the flexspline last, gear teeth scuffing damage or improper eccentric gear mesh may result. Installation resulting in an eccentric tooth mesh (Dedoidal) will cause noise and vibration, and can lead to early failure of the gear. For proper function, the teeth of the flexspline and Circular Spline mesh symmetrically.

Assembly order for basic three elements

Table 058-1



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

■ Precautions on assembly

It is extremely important to assemble the gear accurately and in proper sequence. For each of the three components, utilize the following precautions.

Wave generator

1. Avoid applying undue axial force to the wave generator during installation. Rotating the wave generator bearing while inserting it is recommended and will ease the process.
2. If the wave generator does not have an Oldham coupling, extra care must be given to ensure that concentricity and inclination are within the specified limits (see page 51).

Circular spline

The circular Spline must not be deformed in any way during the assembly. It is particularly important that the mounting surfaces are prepared correctly.

1. Mounting surfaces need to have adequate flatness, smoothness, and no distortion.
2. Especially in the area of the screw holes, burrs or foreign matter should not be present.
3. Adequate relief in the housing corners is needed to prevent interference with the corner of the circular spline.
4. The circular spline should be rotatable within the housing. Be sure there is not interference and that it does not catch on anything.
5. Bolts should not rotate freely when tightening and should not have any irregularity due to the bolt hole being misaligned or oblique.
6. Do not tighten the bolts with the specified torque all at once. Tighten the bolts temporarily with about half the specified torque, and then tighten them with the specified torque. Tighten them in an even, crisscross pattern.
7. Avoid pinning the circular spline if possible as it can reduce the rotational precision and smoothness of operation.

Flexspline

1. Mounting surfaces need to have adequate flatness, smoothness, and no distortion.
2. Especially in the area of the screw holes, burrs or foreign matter should not be present.
3. Adequate clearance with the housing is needed to ensure no interference especially with the major axis of flexspline
4. Bolts should rotate freely when installing through the mounting holes of the flexspline and should not have any irregularity due to the shaft bolt holes being misaligned or oblique.
5. Do not tighten the bolts with the specified torque all at once. Tighten the bolts temporarily with about half the specified torque, and then tighten them to the specified torque. Tighten them in an even, crisscross pattern.
6. The flexspline and circular spline are concentric after assembly. After installing the wave generator bearing, if it rotates in unbalanced way, check the mounting for dedoidal or non-concentric installation.
7. Care should be taken not to damage the flexspline diaphragm or gear teeth during assembly.
   Avoid hitting the tips of the flexpline teeth and circular spline teeth. Avoid installing the CS from the open side of the flexspline after the wave generator has been installed.

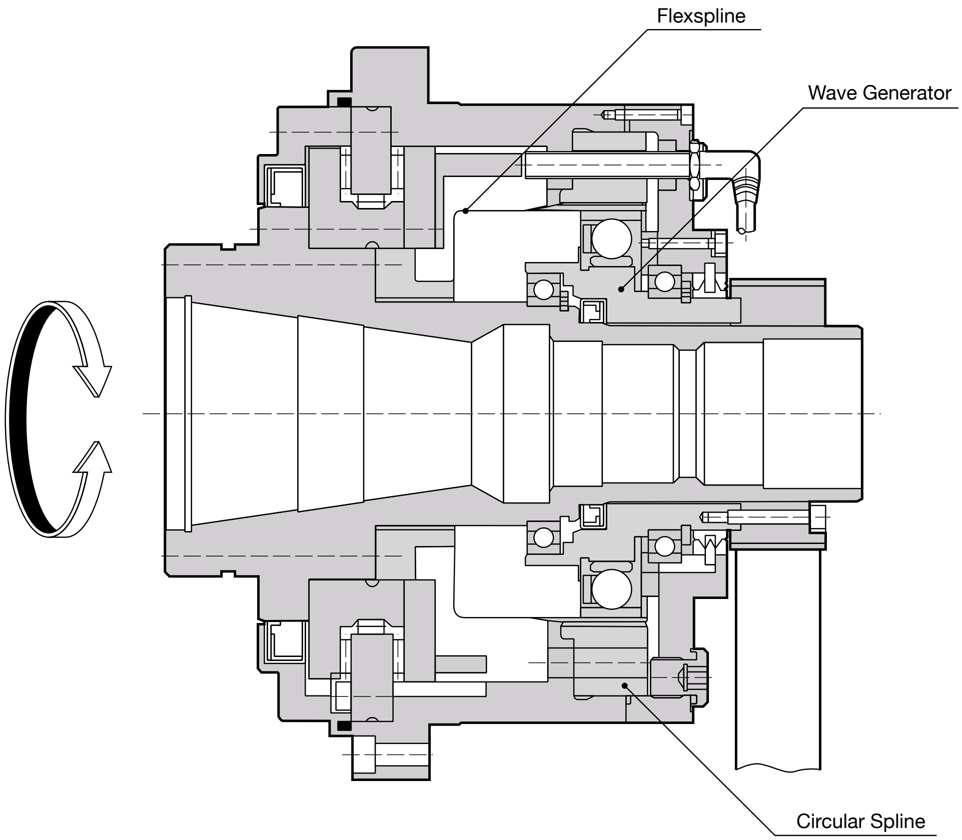
Rust prevention

Although Harmonic Drive® gears come with some corrosion protection, the gear can rust if exposed to the environment. The gear external surfaces typically have only a temporary corrosion inhibitor and some oil applied. If an anti-rust product is needed, please contact us to review the options.

Application

Tool changer

Fig. 059-1



Engineering Data

Engineering Data

Tooth Profile

■ S tooth profile

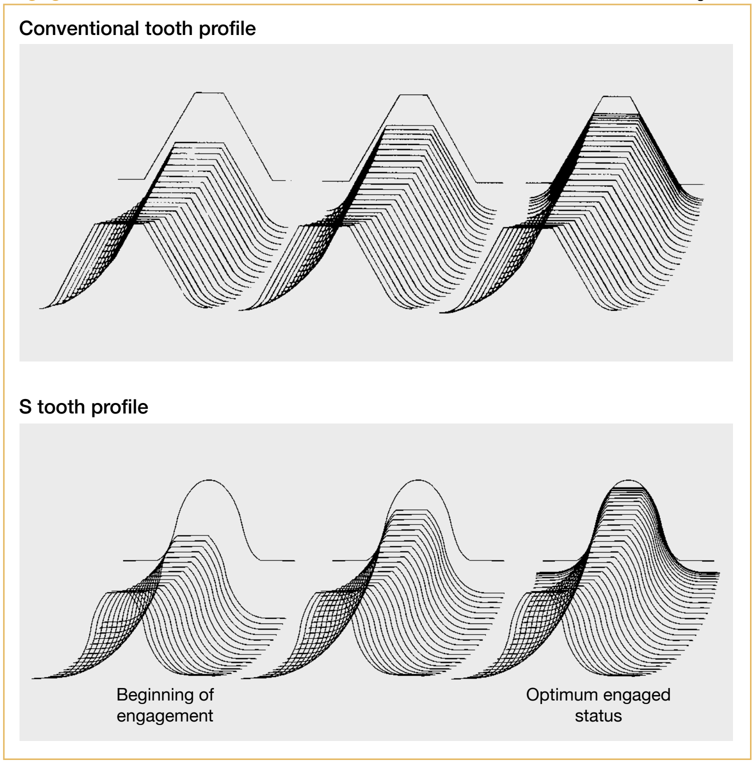
Harmonic Drive developed a unique gear tooth profile that optimizes the tooth engagement. It has a special curved surface unique to the S tooth profile that allows continuous contact with the tooth profile. It also alleviates the concentration of stress by widening the width of the tooth groove against the tooth thickness and enlarging the radius on the bottom. This tooth profile (the “S tooth”) enables up to 30% of the total number of teeth to be engaged simultaneously.

Additionally the large tooth root radius increases the tooth strength compared with an involute tooth. This technological innovation results in high torque, high torsional stiffness, long life and smooth rotation.

*Patented

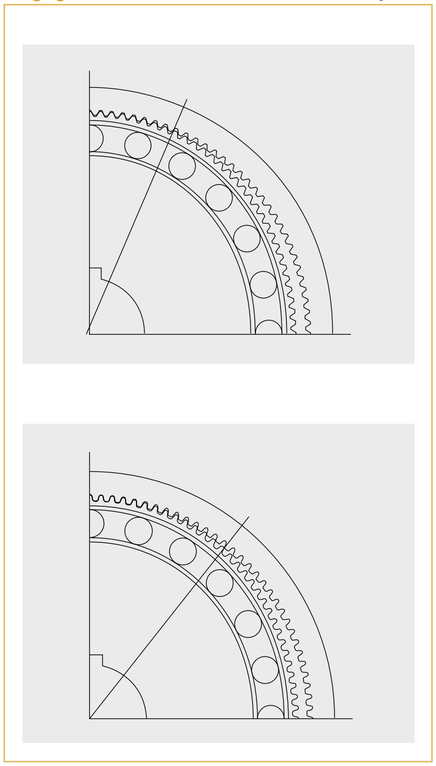
Engaged route of teeth

Fig. 009-1



Engaged area of teeth

Fig. 009-2



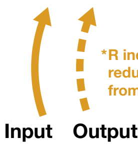
Rotational direction and reduction ratio

Cup Style

Series: CSG, CSF, CSD, CSF-mini

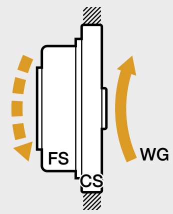
■ Rotational direction

Fig. 010-1



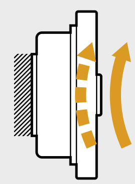
*R indicates the reduction ratio value from the ratings table.

(Note) Contact us if you use the product as Accelerator (5) and (6).



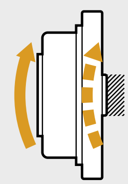
(1) Reducer
Input: Wave Generator (WG)
Output: Flexspline (FS)
Fixed: Circular Spline (CS)

$i = \frac{-1}{R}$



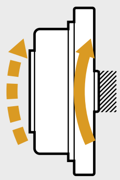
(2) Reducer
Input: Wave Generator
Output: Circular Spline
Fixed: Flexspline

$i = \frac{1}{R+1}$



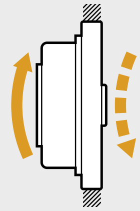
(3) Reducer
Input: Flexspline
Output: Circular Spline
Fixed: Wave Generator

$i = \frac{R}{R+1}$



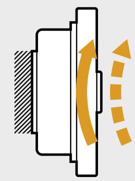
(4) Overdrive
Input: Circular Spline
Output: Flexspline
Fixed: Wave Generator

$i = \frac{R+1}{R}$



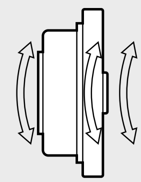
(5) Overdrive
Input: Flexspline
Output: Wave Generator
Fixed: Circular Spline

$i = -R$



(6) Overdrive
Input: Circular Spline
Output: Wave Generator
Fixed: Flexspline

$i = R+1$



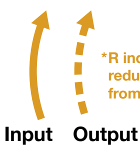
(7) Differential
When all of the wave generator, the flexspline and the circular spline rotate, combinations (1) through (6) are available.

Silk hat

Series: SHG, SHF, SHD

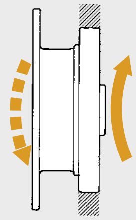
■ Rotational direction

Fig. 010-2



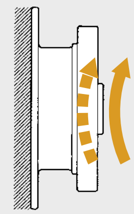
*R indicates the reduction ratio value from the ratings. table

(Note) Contact us if you use the product as an overdrive of (5) or (6).



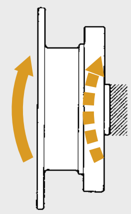
(1) Reducer
Input: Wave Generator
Output: Flexspline
Fixed: Circular Spline

$i = \frac{-1}{R}$



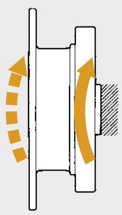
(2) Reducer
Input: Wave Generator
Output: Circular Spline
Fixed: Flexspline

$i = \frac{1}{R+1}$



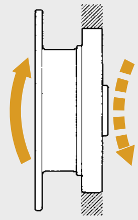
(3) Reducer
Input: Flexspline
Output: Circular Spline
Fixed: Wave Generator

$i = \frac{R}{R+1}$



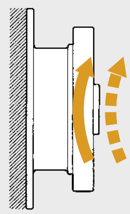
(4) Overdrive
Input: Circular Spline
Output: Flexspline
Fixed: Wave Generator

$i = \frac{R+1}{R}$



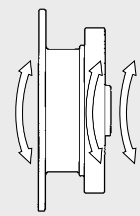
(5) Overdrive
Input: Flexspline
Output: Wave Generator
Fixed: Circular Spline

$i = -R$



(6) Overdrive
Input: Circular Spline
Output: Wave Generator
Fixed: Flexspline

$i = R+1$



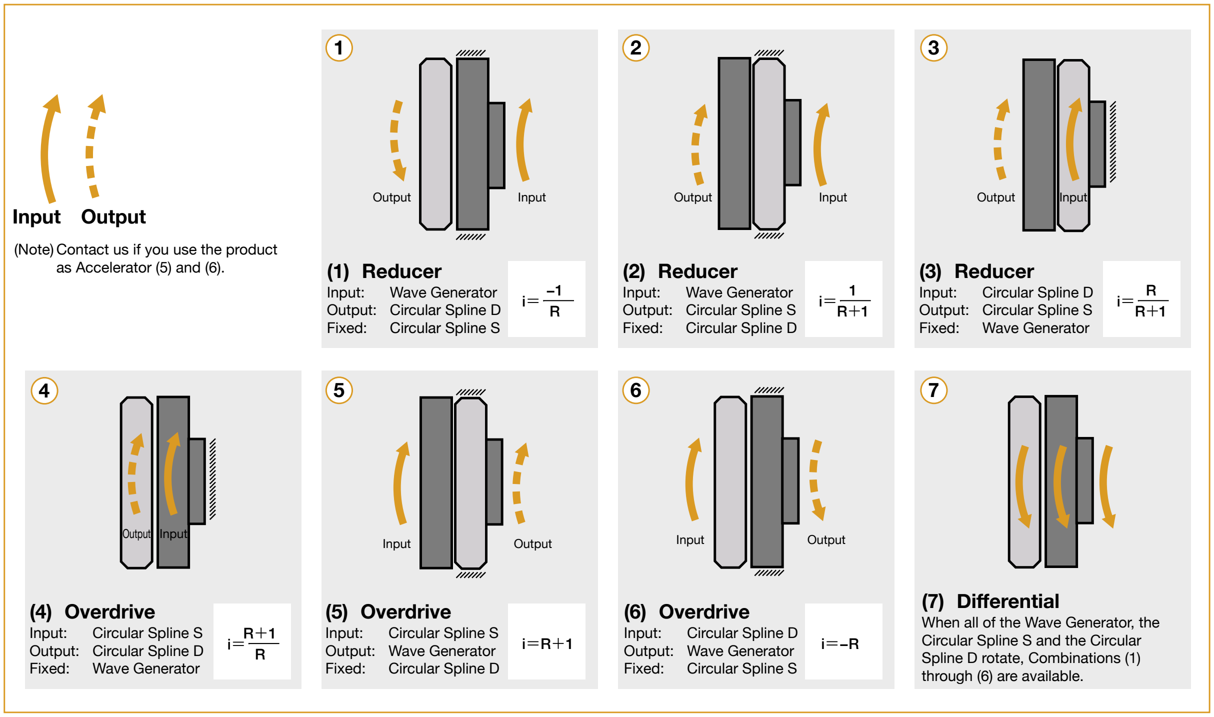
(7) Differential
When all of the wave generator, the flexspline and the circular spline rotate, Combinations (1) through (6) are available.

Pancake

Series: FB and FR

Rotational direction

Fig. 11-1



Reduction ratio

The reduction ratio is determined by the number of teeth of the Flexspline and the Circular Spline

Number of teeth of the Flexspline: Zf
Number of teeth of the Circular Spline: Zc

▶ Input: Wave Generator
Output: Flexspline
Fixed: Circular Spline

Reduction ratio $i_1 = \frac{1}{R_1} = \frac{Zf-Zc}{Zf}$

▶ Input: Wave Generator
Output: Circular Spline
Fixed: Flexspline

Reduction ratio $i_2 = \frac{1}{R_2} = \frac{Zc-Zf}{Zc}$

■ R_1 indicates the reduction ratio value from the ratings table.

Example

Number of teeth of the Flexspline: 200
Number of teeth of the Circular Spline: 202

▶ Input: Wave Generator
Output: Flexspline
Fixed: Circular Spline

Reduction ratio $i_1 = \frac{1}{R_1} = \frac{200-202}{200} = \frac{-1}{100}$

▶ Input: Wave Generator
Output: Circular Spline
Fixed: Flexspline

Reduction ratio $i_2 = \frac{1}{R_2} = \frac{202-200}{202} = \frac{1}{101}$

Rating Table Definitions

See the corresponding pages of each series for values.

■ Rated torque

Rated torque indicates allowable continuous load torque at rated input speed.

■ Limit for Repeated Peak Torque (see Graph 12-1)

During acceleration and 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. (calculation formula: Page 14)

■ Limit for Momentary Peak Torque (see Graph 12-1)

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 formula 13-1.

■ Maximum Average Input Speed Maximum Input Speed

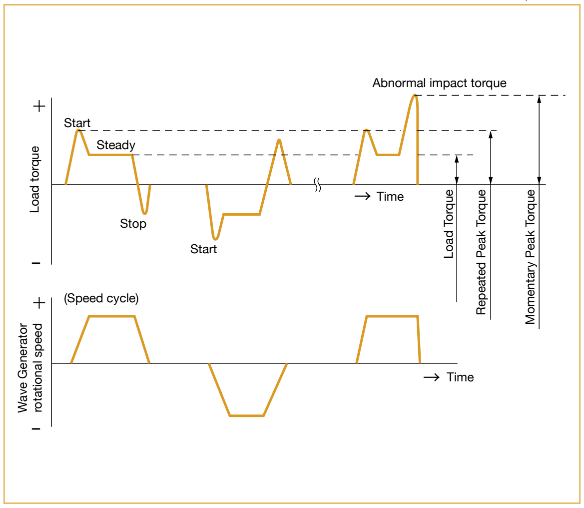
Do not exceed the allowable rating. (calculation formula of the average input speed: Page 14).

■ Moment of Inertia

The rating indicates the moment of inertia reflected to the gear input.

Example of application motion profile

Graph 012-1



Life

■ Life of the wave generator

The 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.

Table 012-1

	Life	
Series name	CSF, CSD, SHF, SHD, CSF-mini	CSG, SHG
L_{10}	7,000 hours	10,000 hours
L_{50} (average life)	35,000 hours	50,000 hours

* Life is based on the input speed and output load torque from the rating table.

Calculation formula for Rated Lifetime

Formula 012-1

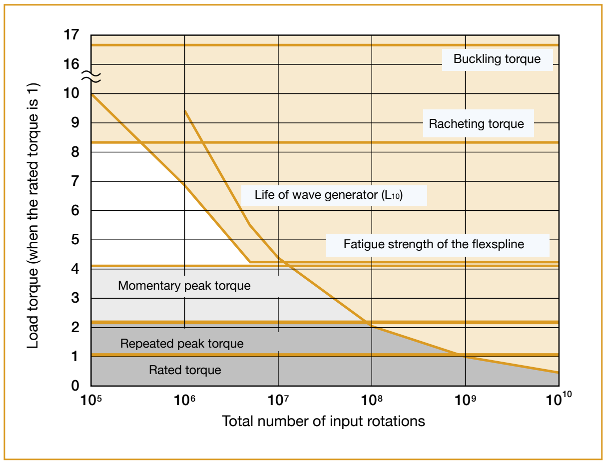
$$L_h = L_n \cdot \left(\frac{Tr}{Tav}\right)^3 \cdot \left(\frac{Nr}{Nav}\right)$$

Table 012-2

Ln	Life of L_{10} or L_{50}
Tr	Rated torque
Nr	Rated input speed
Tav	Average load torque on the output side (calculation formula: Page 14)
Nav	Average input speed (calculation formula: Page 14)

Relative torque rating

Graph 012-2



* Lubricant life not taken into consideration in the graph described above.
* Use the graph above as reference values.

Torque Limits

■ Strength of flexspline

The 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.

> Allowable limit of the bending cycles of the flexspline during rotation of the wave generator while the impact torque is applied: 1.0 x 10^4 (cycles)

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.

Calculation formula — Formula 013-1

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

Allowable occurances	N occurances
Time that impact torque is applied	t sec
Rotational speed of the wave generator	n rpm
The flexspline bends two times per one revolution of the wave generator.	

⚠ Caution	If the number of occurances is exceeded, the Flexspline may experience a fatigue failure.

■ Buckling torque

When a highly excessive torque (16 to 17 times rated torque) is applied to the output with the input stationary, the flexspline may experience plastic deformation. This is defined as buckling torque.

* See the corresponding pages of each series for buckling torque values.

⚠ Warning	When the flexspline buckles, early failure of the HarmonicDrive® gear will occur.

■ Ratcheting torque

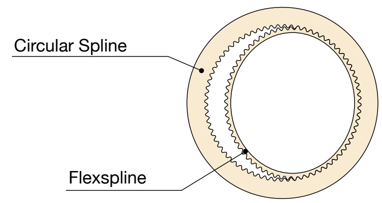
When excessive torque (8 to 9 times rated torque) is applied while the gear is in motion, the teeth between the Circular Spline and Flexspline may not engage properly.
This phenomenon is called ratcheting and the torque at which this occurs is called ratcheting torque. Ratcheting may cause the Flexspline to become non-concentric with the Circular Spline. Operating in this condition may result in shortened life and a Flexspline fatigue failure.

* See the corresponding pages of each series for ratcheting torque values.
* Ratcheting torque is affected by the stiffness of the housing to be used when installing the circular spline. Contact us for details of the ratcheting torque.

⚠ Caution	When ratcheting occurs, the teeth may not be correctly engaged and become out of alignment as shown in Figure 013-1. Operating the drive in this condition will cause vibration and damage the flexspline.

⚠ Caution	Once ratcheting occurs, the teeth wear excessively and the ratcheting torque may be lowered.

Figure 013-1



"Dedoidal" condition.

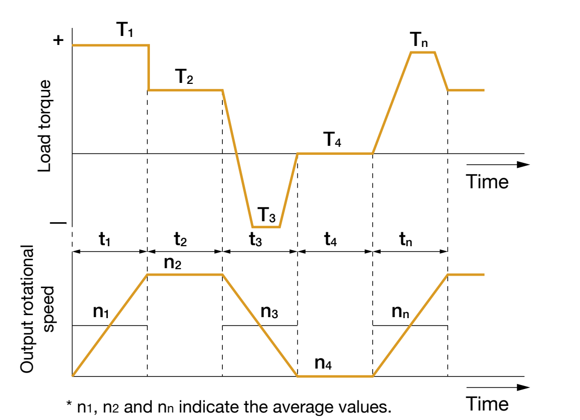
Product Sizing & Selection

In general, a servo system rarely operates at a continuous load and speed. The input rotational speed, load torque change and comparatively large torque are applied at start and stop. Unexpected impact torque may be applied.
These fluctuating load torques should be converted to the average load torque when selecting a model number.
As an accurate cross roller bearing is built in the direct external load support (output flange), the maximum moment load, life of the cross roller bearing and the static safety coefficient should also be checked.

■ Checking the application motion profile

Review the application motion profile. Check the specifications shown in the figure below.

Graph 14-1



* n_1, n_2 and n_n indicate the average values.

Obtain the value of each application motion profile.

Load torque	T_n (Nm)
Time	t_n (sec)
Output rotational speed	n_n (rpm)
Normal operation pattern	
Starting (acceleration)	T_1, t_1, n_1
Steady operation (constant velocity)	T_2, t_2, n_2
Stopping (deceleration)	T_3, t_3, n_3
Dwell	T_4, t_4, n_4
Maximum rotational speed	
Max. output speed	no ***max***
Max. input rotational speed (Restricted by motors)	ni ***max***
Emergency stop torque	
When impact torque is applied	T_s, t_s, n_s
Required life	L_{10} = L (hours)

■ Flowchart for selecting a size

Please use the flowchart shown below for selecting a size.
Operating conditions must not exceed the performance ratings.

Calculate the average load torque applied on the output side from the application motion profile: T***av*** (Nm).

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

↓

Make a preliminary model selection with the following conditions.
T***av*** ≦ Limit for average torque torque
(See the rating table of each series).

↓

Calculate the average output speed: no ***av*** (rpm)

$$no\,av = \frac{n_1 \cdot t_1 + n_2 \cdot t_2 + \cdots n_n \cdot t_n}{t_1 + t_2 + \cdots t_n}$$

Obtain the reduction ratio (R). A limit is placed on "ni ***max***" by motors.

$$\frac{ni\,max}{no\,max} \geqq R$$

Calculate the average input rotational speed from the average output rotational speed (no ***av***) and the reduction ratio (R): ni ***av*** (rpm)

$$ni\,av = no\,av \cdot R$$

Calculate the maximum input rotational speed from the max. output rotational speed (no ***max***) and the reduction ratio (R): ni ***max*** (rpm)

$$ni\,max = no\,max \cdot R$$

↓

Check whether the preliminary model number satisfies the following condition from the rating table.
Ni ***av*** ≦ Limit for average speed (rpm)
Ni ***max*** ≦ Limit for maximum speed (rpm)
→ NG

OK ↓

Check whether T_1 and T_3 are less than the repeated peak torque specification.
→ NG

OK ↓

Check whether T_s is less than the the momentary peak torque specification.
→ NG

OK ↓

Calculate (Ns) the allowable number of rotations during impact torque.

$$N_S = \frac{10^4}{2 \cdot \frac{n_S \cdot R}{60} \cdot t} \quad \cdots\cdots N_S \leqq 1.0\times10^4$$

→ NG

OK ↓

Calculate the lifetime.

$$L_{10} = 7000 \cdot \left(\frac{Tr}{Tav}\right)^3 \cdot \left(\frac{nr}{ni\,av}\right) \text{(hours)}$$

↓

Check whether the calculated life is equal to or more than the life of the wave generator (see Page 13).
→ NG

OK ↓

The model number is confirmed.

NG → Review the operation conditions and model number

■ Example of model number selection

Value of each application motion profile

Load torque	T_n (Nm)
Time	t_n (sec)
Output speed	n_n (rpm)

Normal operation pattern

Starting (acceleration)	T1 = 400 Nm, t1 = 0.3sec, n1 = 7rpm
Steady operation (constant velocity)	T2 = 320 Nm, t2 = 3sec, n2 = 14rpm
Stopping (deceleration)	T3 = 200 Nm, t3 = 0.4sec, n3 = 7rpm
Dwell	T_4 = 0 Nm, t_4 = 0.2 sec, n_4 = 0 rpm

Maximum rotational speed

Max. output speed	no ***max*** = 14 rpm
Max. input speed (Restricted by motors)	ni ***max*** = 1800 rpm

Emergency stop torque

When impact torque is applied: T_s = 500 Nm, t_s = 0.15 sec, n_s = 14 rpm

Required life

L_{10} = 7000 (hours)

Calculate the average load torque to the output side based on the application motion profile: T***av*** (Nm).

$$T_{av} = \sqrt[3]{\frac{7\text{ rpm}\cdot 0.3\text{ sec}\cdot|400\text{Nm}|^3+14\text{ rpm}\cdot 3\text{ sec}\cdot|320\text{Nm}|^3+7\text{ rpm}\cdot 0.4\text{ sec}\cdot|200\text{Nm}|^3}{7\text{ rpm}\cdot 0.3\text{ sec}+14\text{ rpm}\cdot 3\text{ sec}+7\text{ rpm}\cdot 0.4\text{ sec}}}$$

Make a preliminary model selection with the following conditions. T***av*** = 319 Nm ≦ 451 Nm
(Limit for average torque for model number CSF-40-120-2A-GR: See the rating table on Page 39.)
Thus, **CSF-40-120-2A-GR** is tentatively selected.

Calculate the average output rotational speed: no ***av*** (rpm)

$$n_{o\,av} = \frac{7\text{ rpm}\cdot 0.3\text{ sec}+14\text{ rpm}\cdot 3\text{ sec}+7\text{ rpm}\cdot 0.4\text{ sec}}{0.3\text{ sec} + 3\text{ sec} + 0.4\text{ sec} + 0.2\text{ sec}} = 12\text{ rpm}$$

Obtain the reduction ratio (R).

$$\frac{1800\text{ rpm}}{14\text{ rpm}} = 128.6 \geqq 120$$

Calculate the average input rotational speed from the average output rotational speed (no ***av***) and the reduction ratio (R): ni ***av*** (rpm)

$$n_{i\,av} = 12\text{ rpm}\cdot 120 = 1440\text{ rpm}$$

Calculate the maximum input rotational speed from the maximum output rotational speed (no ***max***) and the reduction ratio (R): ni ***max*** (rpm)

$$n_{i\,max} = 14\text{ rpm}\cdot 120 = 1680\text{ rpm}$$

Check whether the preliminary selected model number satisfies the following condition from the rating table.
Ni ***av*** = 1440 rpm ≦ 3600 rpm (Max average input speed of size 40)
Ni ***max*** = 1680 rpm ≦ 5600 rpm (Max input speed of size 40)

NG / OK

Check whether T_1 and T_3 are equal to or less than the repeated peak torque specification.
T_1 = 400 Nm ≦ 617 Nm (Limit of repeated peak torque of size 40)
T_3 = 200 Nm ≦ 617 Nm (Limit of repeated peak torque of size 40)

NG / OK

Check whether Ts is equal to or less than the momentary peak torque specification.
T_s = 500 Nm ≦ 1180 Nm (Limit for momentary torque of size 40)

NG / OK

Calculate the allowable number (Ns) rotation during impact torque and confirm ≦ 1.0×10^4

$$N_S = \frac{10^4}{2\cdot\frac{14\text{ rpm}\cdot 120}{60}\cdot 0.15\text{ sec}} = 1190 \leqq 1.0\times10^4$$

NG / OK

Calculate the lifetime.

$$L_{10} = 7000\cdot\left(\frac{294\text{ Nm}}{319\text{ Nm}}\right)^3\cdot\left(\frac{2000\text{ rpm}}{1440\text{ rpm}}\right)\text{(hours)}$$

Check whether the calculated life is equal to or more than the life of the wave generator (see Page 12).
L_{10} =7610 hours ≧ 7000 (life of the wave generator: L_{10})

NG / OK

The selection of model number **CSF-40-120-2A-GR** is confirmed from the above calculations.

Review the operation conditions, size and reduction ratio

Engineering Data
Component Sets
Gear Units
Phase Adjusters
Gearheads & Actuators

Lubrication

Component Sets: CSD-2A, CSF-2A, CSG-2A, FB-2, FB-0, FR-2, SHF-2A, SHG-2A and SHD and SHG/SHF -2SO and -2SH gear units: Grease lubricant and oil lubricant are available for lubricating the component sets and SHD gear unit. It is extremely important to properly grease your component sets and SHD gear unit. Proper lubrication is essential for high performance and reliability. Harmonic Drive® component sets are shipped with a rust- preventative oil. The characteristics of the lubricating grease and oil types approved by Harmonic Drive are not changed by mixing with the preservation oil. It is therefore not necessary to remove the preservation oil completely from the gear components. However, the mating surfaces must be degreased before the assembly.

Gear Units: CSG/CSF 2UH and 2UH-LW; CSD-2UF and -2UH; SHG/SHF-2UH and 2UH- LW; SHG/SHF-2UJ; CSF Supermini, CSF Mini, and CSF-2UP.
Grease lubricant is standard for lubricating the gear units. You do not need to apply grease during assembly as the product is lubricated and shipped.
See Page 19 for using lubricant beyond the temperature range in table 16-2.

* Contact us if you want consistency zero (NLGI No.0) for maintenance reasons.

Name of lubricant

Table 016-1

Grease	Harmonic Grease® SK-1A
	Harmonic Grease® SK-2
	Harmonic Grease® 4B No.2
Oil	Industrial gear oil class-2 (extreme pressure) ISO VG68

Temperature

Table 016-2

Grease	SK-1A 0ºC to + 40ºC
	SK-2 0ºC to + 40ºC
	4B No.2 –10ºC to + 70ºC
Oil	ISO VG68 0ºC to + 40ºC

* The hottest section should not be more than 40° above the ambient temperature.

Note: The three basic components of the gear - the Flexspline, Wave Generator and Circular Spline - are matched and serialized in the factory. Depending on the product they are either greased or prepared with preservation oil. Then the individual components are assembled. If you receive several units, please be careful not to mix the matched components. This can be avoided by verifying that the serial numbers of the assembled gear components are identical.

Grease lubricant

■ Types of lubricant

Harmonic Grease® SK-1A

This grease was developed for Harmonic Drive® gears and features good durability and efficiency.

Harmonic Grease® SK-2

This grease was developed for small sized Harmonic Drive® gears and features smooth rotation of the Wave Generator since high pressure additive is liquefied.

Harmonic Grease® 4B No.2

This has been developed exclusively for the CSF and CSG and features long life and can be used over 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.

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.

Table 016-3

NLGI consistency No.	Mixing consistency range
0	355 to 385
00	400 to 430

Grease specification

Table 016-4

Grease	SK-1A	SK-2	4B No.2
Base oil	Refined oil	Refined oil	Composite hydrocarbon oil
Base Viscosity cSt (25ºC)	265 to 295	265 to 295	290 to 320
Thickening agent	Lithium soap base	Lithium soap base	Urea
NLGI consistency No.	No. 2	No. 2	No. 1.5
Additive	Extreme-pressure additive, others	Extreme-pressure additive, others	Extreme-pressure additive, others
Drop Point	197ºC	198ºC	247ºC
Appearance	Yellow	Green	Light yellow
Storage life	5 years in sealed condition	5 years in sealed condition	5 years in sealed condition

■ Compatible grease by size

Compatible grease varies depending on the size and reduction ratio. See the following compatibility table. We recommend SK-1A and SK-2 for general use.

Ratios 30:1

Table 016-5

Size	8	11	14	17	20	25	32
SK-1A	–	–	–	–	○	○	○
SK-2	○	○	○	○	–	–	–
4B No.2	△	△	△	△	□	□	□

Ratios 50:1* and above

Table 016-6

Size	8	11	14	17	20	25	32
SK-1A	–	–	–	–	○	○	○
SK-2	○	○	○	○	△	△	△
4B No.2	–	–	□	□	□	□	□

Size	40	45	50	58	65	80	90	100
SK-1A	○	○	○	○	○	○	○	○
SK-2	△	–	–	–	–	–	–	–
4B No.2	□	□	□	□	□	□	□	□

○: Standard grease
△: Semi-standard grease
□: Recommended grease for long life and high load

*** Oil lubrication is required for component-sets size 50 or larger with a reduction ratio of 50:1.**

Grease characteristics

Table 016-7

Grease	SK-1A	SK-2	4B No.2
Durability	○	○	◎
Fretting resistance	○	○	◎
Low-temperature performance	△	△	◎
Grease leakage	◎	◎	△

Excellent :◎
Good :○
Use Caution :△

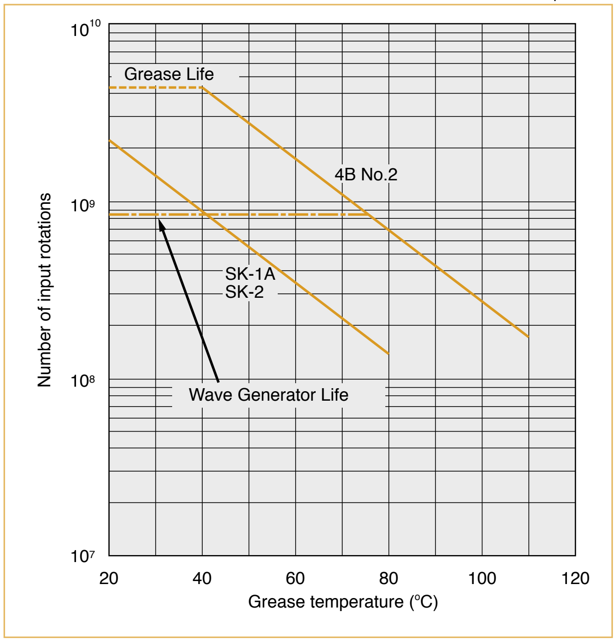
■ When to replace grease

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 017-1 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.

Note: Recommended Grease: SK-1A or SK-2

When to replace grease: L_{GTn} (when the average load torque is equal to or less than the rated torque)

Graph 017-1



Calculation formula when the average load torque exceeds the rated torque

Formula 017-1

$$L_{GT} = L_{GTn} \times \left(\frac{Tr}{Tav} \right)^3$$

Formula Symbols

Table 017-1

L_{GT}	Grease change (if average load torque exceeds rated torque)	input revolutions	————
L_{GTn}	Grease change (if average load torque is equal to or less than rated torque)	input revolutions (From Graph)	See the Graph 017-1.
Tr	Rated torque	Nm	See the "Ratings Table" of each series.
Tav	Average load torque	Nm	Calculation formula: See Page 014.

■ Other precautions

1. Avoid mixing different kinds of grease. The gear should be in an individual case when installed.

2. Please contact us when you use HarmonicDrive® gears at constant load or in one direction continuously, as it may cause lubrication problems.

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

■ See the corresponding pages of the design guide of each series for “Recommended minimum housing clearance,” Application guide” and “Application quantity.”

Precautions on using Harmonic Grease® 4B No.2

Harmonic Grease® 4B No.2 lubrication is ideally suited for Harmonic Drive® gears.

(1) Apply the grease to each contacting joint at the beginning of operation.
(2) Remove any contaminents created by abrasion during running-in period.

■ See the corresponding pages of the design guide of each series for “recommended minimum housing clearance,” Application guide” and “Application quantity.”

■ Precautions

(1) Stir Grease
When storing Harmonic Grease 4B No.2 lubrication in the container, it is common for the oil to weep from the thickener. Before greasing, stir the grease in the container to mix and soften.

(2) Aging (running-in)
The aging before the main operation softens the applied grease. More effective greasing performance can be realized when the grease is distributed around each contact surface.
Therefore, the following aging methods are recommended.

- Keep the internal temperature at 80°C or cooler. Do not start the aging at high temperature rapidly.
- Input rotational speed should be 1000rpm to 3000rpm. However, the lower rotational speed of 1000rpm is more effective. Set the speed as low as possible within the indicated range.
- The time required for aging is 20 minutes or longer.
- Operation range for aging: Keep the output rotational angle as large as possible.

Contact us if you have any questions for handling Harmonic Grease 4B No.2 lubrication.

Note: Strict sealing is required to prevent grease leakage.

Oil lubricant

■ Types of oil

The specified standard lubricant is “Industrial gear oil class-2 (extreme pressure) ISO VG68.”
We recommend the following brands as a commercial lubricant.

Table 018-1

Standard	Mobil Oil	Exxon	Shell	COSMO Oil	Japan Energy	NIPPON Oil	Idemitsu Kosan	General Oil	Klüber
Industrial gear oil class-2 (extreme pressure) ISO VG68	Mobilgear 600XP68	Spartan EP68	Omala Oil 68	Cosmo gear SE68	ES gear G68	Bonock M68, Bonock AX68	Daphne super gear LW68	General Oil SP gear roll 68	Syntheso D-68EP

■ When to replace oil

First time ························ 100 hours after starting operation
Second time or after ······· Every 1000 operation hours or every 6 months
Note that you should replace the oil earlier than specified if the operating condition is demanding.

■ See the corresponding pages of the design guide of each series for specific details.

■ Other precautions

1. Avoid mixing different kinds of oil. The gear should be in an individual case when installed.

2. When you use size 50 or above at max allowable input speed, please contact us as it may cause lubrication problems.

*** Oil lubrication is required for component-sets size 50 or larger with a reduction ratio of 50:1.**

Lubricant for special environments

When the ambient temperature is special (other than the "temperature range of the operating environment" on Page 016-2), you should select a lubricant appropriate for the operating temperature range.

Harmonic Grease 4B No.2

Table 019-1

Type of lubricant	Operating temperature range	Available temperature range
Grease	−10˚C to + 110˚C	−50˚C to + 130˚C

High temperature lubricant

Table 019-2

Type of lubricant	Lubricant and manufacturer	Available temperature range
Grease	Mobil grease 28: Mobil Oil	−5˚C to + 160˚C
Oil	Mobil SHC-626: Mobil Oil	−5˚C to + 140˚C

Low temperature lubricant

Table 019-3

Type of lubricant	Lubricant and manufacturer	Available temperature range
Grease	Multemp SH-KII: Kyodo Oil	−30˚C to + 50˚C
	Isoflex LDS-18 special A: KLÜBER	−25˚C to + 80˚C
Oil	SH-200-100CS: Toray Silicon	−40˚C to + 140˚C
	Syntheso D-32EP: KLÜBER	−25˚C to + 90˚C

Harmonic Grease 4B No.2

The operating temperature range of Harmonic Grease 4B No.2 lubrication is the temperature at the lubricating section with the performance and characteristics of the gear taken into consideration. (It is not ambient temperature.)

As the available temperature range indicates the temperature of the independent lubricant, restriction is added on operating conditions (such as load torque, rotational speed and operating cycle) of the gear. When the ambient temperature is very high or low, materials of the parts of the gear need to be reviewed for suitability. Contact us if operating in high temperature.

Harmonic Grease 4B No.2 can be used in the available temperature range shown in table 019-1. However, input running torque will increase at low temperatures, and grease life will be decreased at high temperatures due to oxidation and lubricant degradation.

Torsional Stiffness

Stiffness and backlash of the drive system greatly affects the performance of the servo system. Please perform a detailed review of these items before designing your equipment and selecting a model number.

■ Stiffness

Fixing the input side (wave generator) and applying torque to the output side (flexspline) generates a torsional angle almost proportional to the torque on the output side. Figure 020-1 shows the torsional angle at the output side when the torque applied on the output side starts from zero, increases up to $+T_0$ and decreases down to $-T_0$. This is called the "Torque – torsion angle diagram," which normally draws a loop of 0 – A – B – A′ – B′ – A. The slope described in the "Torque – torsion angle diagram" is represented as the spring constant for the stiffness of the HarmonicDrive® gear (unit: Nm/rad).
As shown in Figure 020-2 "Spring Constant Diagram" is divided into 3 regions, and the spring constants in the area are represented by K_1, K_2 and K_3.

K_1 ···· The spring constant when the torque changes from [zero] to [T_1]
K_2 ···· The spring constant when the torque changes from [T_1] to [T_2]
K_3 ···· The spring constant when the torque changes from [T_2] to [T_3]

■ See the corresponding pages of each series for values of the spring constants (K_1, K_2, K_3) and the torque-torsional angles (T_1, T_2, - θ_1, θ_2).

■ Example for calculating the torsion angle

The torsion angle (θ) is calculated here using CSF-25-100-2A-GR as an example.

When the applied torque is T_1 or less, the torsion angle θ_{L1} is calculated as follows:
When the load torque T_{L1}=2.9 Nm

$$\theta_{L1} = T_{L1}/K_1$$
$$= 2.9/3.1\times10^4$$
$$= 9.4\times10^{-5}\ \text{rad}\ (0.33\ \text{arc min})$$

When the applied torque is between T_1 and T_2, the torsion angle θ_{L2} is calculated as follows:
When the load torque is T_{L2}=39 Nm

$$\theta_{L2} = \theta_1 + (T_{L2} - T_1)/K_2$$
$$= 4.4\times10^{-4} + (39-14)/5.0\times10^4$$
$$= 9.4\times10^{-4}\ \text{rad}\ (3.2\ \text{arc min})$$

When a bidirectional load is applied, the total torsion angle will be 2 x θ_{LX} plus hysteresis loss.

* The torsion angle calculation is for the gear component set only and does not include any torsional windup of the output shaft.

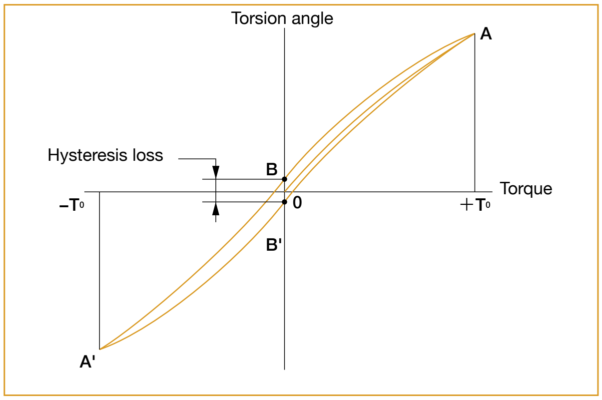
Note: See p.120 for torsional stiffness for pancake gearing .

■ Hysteresis loss (Silk hat and cup style only)

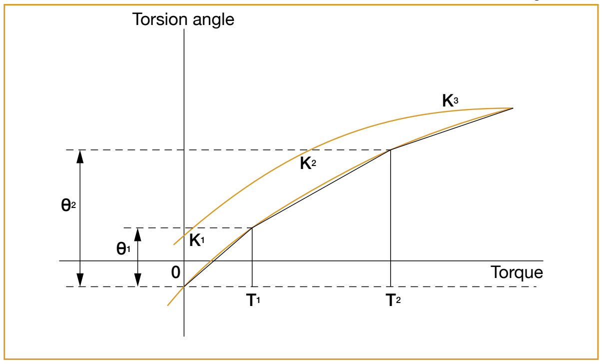
As shown in Figure 020-1, when the applied torque is increased to the rated torque and is brought back to [zero], the torsional angle does not return exactly back to the zero point This small difference (B – B') is called hysteresis loss.

■ See the corresponding page of each series for the hysteresis loss value.

Torque - torsion angle diagram — Figure 020-1



Spring constant diagram — Figure 020-2



■ Backlash (Silk hat and cup style only)

Hysteresis loss is primarily caused by internal friction. It is a very small value and will vary roughly in proportion to the applied load. Because HarmonicDrive® gears have zero backlash, the only true backlash is due to the clearance in the Oldham coupling, a self-aligning mechanism used on the wave generator. Since the Oldham coupling is used on the input, the backlash measured at the output is extremely small (arc-seconds) since it is divided by the gear reduction ratio.

Positional Accuracy

Positional Accuracy values represent the difference between the theoretical angle and the actual angle of output for any given input. The values shown in the table are maximum values.

■ See the corresponding pages of each series for transmission accuracy values.

Example of measurement

Graph 021-1

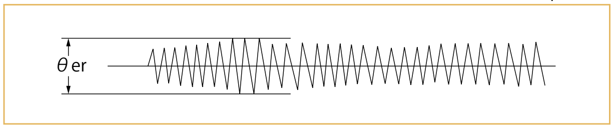


Table 021-1

θer	Transmission accuracy
θ_1	Input angle
θ_2	Actual output angle
R	Reduction ratio

Formula 021-1

$$\theta er = \theta_2 - \frac{\theta_1}{R}$$

Vibration

The primary frequency of the transmission error of the HarmonicDrive® gear may cause a vibration of the load inertia. This can occur when the driving frequency of the servo system including the HarmonicDrive® gear is at, or close to the resonant frequency of the system. Refer to the design guide of each series.

The primary component of the transmission error occurs twice per input revolution of the input. Therefore, the frequency generated by the transmission error is 2x the input frequency (rev / sec).

If the resonant frequency of the entire system, including the HarmonicDrive® gear, is F=15 Hz, then the input speed (N) which would generate that frequency could be calculated with the formula below.

Formula 021-2

$$N = \frac{15}{2} \cdot 60 = 450 \text{ rpm}$$

The resonant frequency is generated at an input speed of 450 rpm.

How to the calculate resonant frequency of the system

Formula 021-3

$$f = \frac{1}{2\pi} \sqrt{\frac{K}{J}}$$

Formula variables

Table 021-2

f	The resonant frequency of the system	Hz	
K	Spring constant	Nm/rad	See pages of each series
J	Load inertia	kgm^2	

Starting Torque

Starting torque is the torque value applied to the input side at which the output first starts to rotate. The values in the table of each series indicate the maximum value, and the lower-limit value indicates approximately $^1/_2$ to $^1/_3$ of the maximum value.

Measurement conditions:
No-load, ambient temperature: +20°C

■ See the corresponding pages of each series for starting torque values.

* Use the values in the table of each series as reference values as they vary depending on the usage conditions.

Backdriving Torque

Backdriving torque is the torque value applied to the output side at which the input first starts to rotate. The values in the table are maximum values, typical values are approximately $^1/_2$ of the maximum values.
Note: Never rely on these values as a margin in a system that must hold an external load. A brake must be used where back driving is not permissible.

Measurement conditions:
No-load, ambient temperature: +20°C

■ See the corresponding pages of each series for backdriving torque values.

* Use the values in the table of each series as reference values as they vary depending on the usage conditions.

No-Load Running Torque

No-load running torque is the torque which is required to rotate the input side (high speed side), when there is no load on the output side (low speed side). The graph of the no-load running torque shown in this catalog depends on the measurement conditions shown in Table 023-1.
Add the compensation values shown by each series to all reduction ratios except 100:1.

■ See the corresponding pages of each series for no-load running torque values.

Measurement condition Table 023-1

Reduction ratio 100			
Lubricant	Grease lubrication	Name	Harmonic Grease SK-1A
			Harmonic Grease SK-2
		Quantity	(See pages of each series)
Torque value is measured after 2 hours at 2000 rpm input			

* Contact us for oil lubrication.

Efficiency

The efficiency varies depending on the following conditions.
- Reduction ratio
- Input speed
- Load torque
- Temperature
- Lubrication (type and quantity)

The efficiency characteristics of each series shown in this catalog depends on the measurement condition shown in Table 023-2.

■ See the corresponding pages of each series for efficiency values.

Measurement condition Table 023-2

Installation	Based on recommended tolerance		
Load torque	The rated torque shown in the rating table (see the corresponding pages on each series)		
Lubricant	Grease lubrication	Name	Harmonic Grease SK-1A
			Harmonic Grease SK-2
		Quantity	Recommended quantity (see the pages on each series)

* Contact us for oil lubrication.

■ Efficiency compensation coefficient

If load torque is below rated torque, a compensation factor must be employed. Calculate the compensation coefficient Ke from the efficiency compensation coefficient graph of each series and use the following example for calculation.

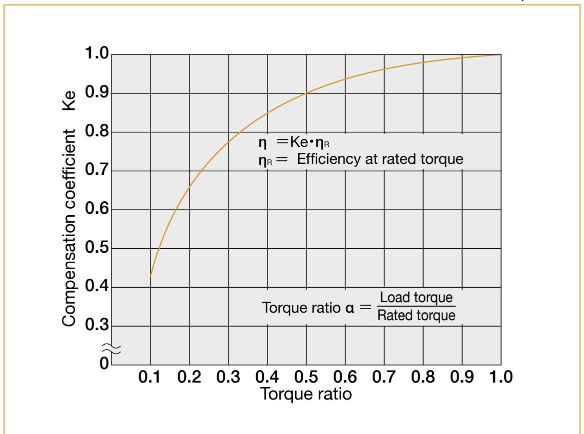
Example of calculation

Efficiency **η** (%) under the following condition is obtained from the example of CSF-20-80-2A-GR.
Input rotational speed: 1000 rpm
Load torque: 19.6 Nm
Lubrication method: Grease lubrication (Harmonic Grease SK-1A)
Lubricant temperature: 20°C
Since the rated torque of size 20 with a reduction ratio of 80 is 34 Nm (Ratings: Page 039), the torque ratio **α** is 0.58.
(**α**=19.6/34=0.58)

■ The efficiency compensation coefficient is Ke=0.93 from Graph 023-1.

■ Efficiency **η** at load torque 19.6 Nm: **η**=Ke・**η**R=0.93 x 78=73%

Efficiency compensation coefficient (CSF series) Graph 023-1



* Efficiency compensation coefficient Ke=1 when the load torque is greater than the rated torque.

Design Guidelines

Design guideline

The relative perpendicularity and concentricity of the three basic Harmonic Drive® elements have an important influence on accuracy and service life.

Misalignments will adversely affect performance and reliability. Compliance with recommended assembly tolerances is essential in order for the advantages of Harmonic Drive® gearing to be fully realized. Please consider the following when designing:

(1) Input shaft, Circular Spline and housing must be concentric.

(2) When operating, an axial force is generated on the wave generator. Input bearings must be selected to accommodate this axial load. See page 27.

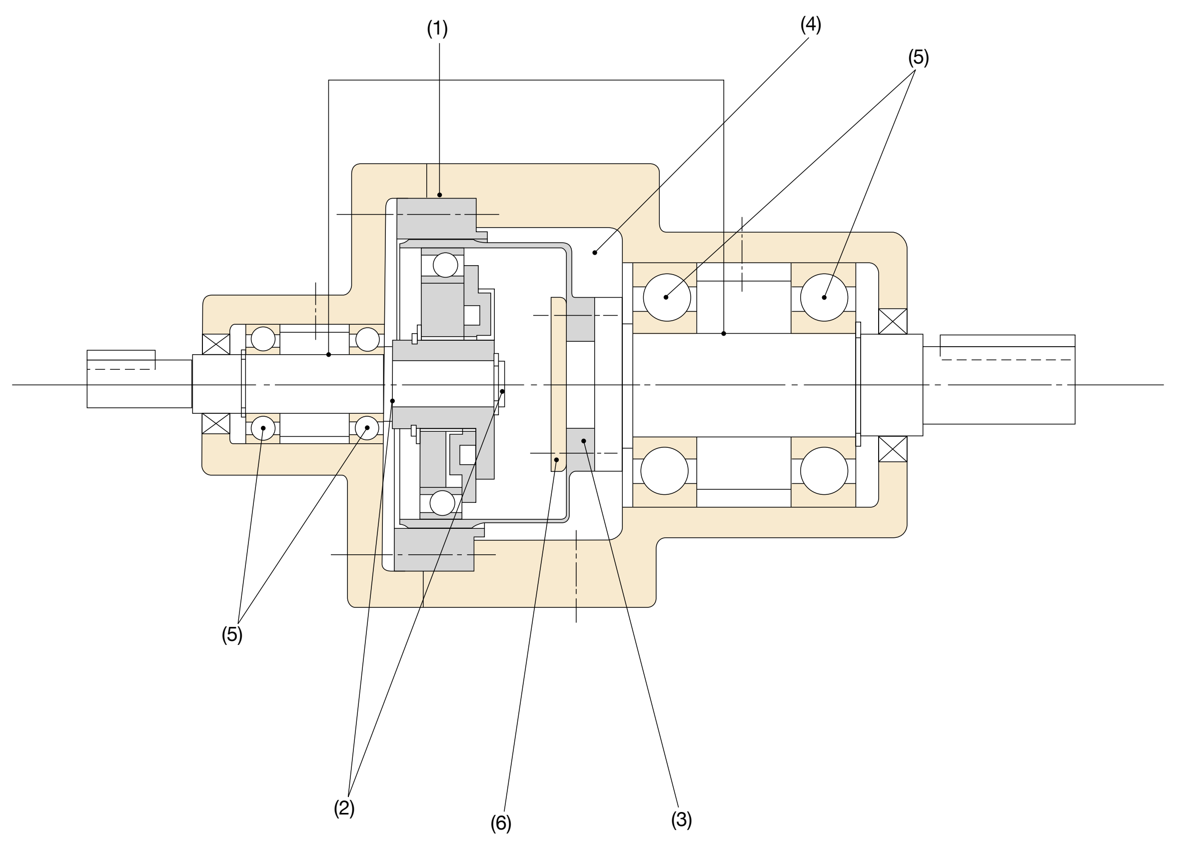
(3) Even though a HarmonicDrive® gear is compact, it transmits large torques. Therefore, assure that all required bolts are used to fasten the circular spline and flexspline and that they are tightened to the recommended torque.

(4) As the flexspline is subject to elastic deformation, the A minimal clearance between the flexspline and housing is required. Refer to "Minimum Housing Clearance" on the drawing dimension tables.

(5) The input shaft and output shaft are supported by anti-friction bearings. As the wave generator and flexspline elements are meant to transmit pure torque only, the bearing arrangement needs to isolate the harmonic gearing from external forces applied to either shaft. A common bearing arrangement is depicted in the diagram.

(6) A clamping plate is recommended (item 6). Its purpose is to spread fastening forces and to avoid any chance of making physical contact with the thin section of the flexspline diaphragm. The clamping plate shall not exceed the diaphragm's boss diameter and is to be designed in accordance with catalog recommendations.

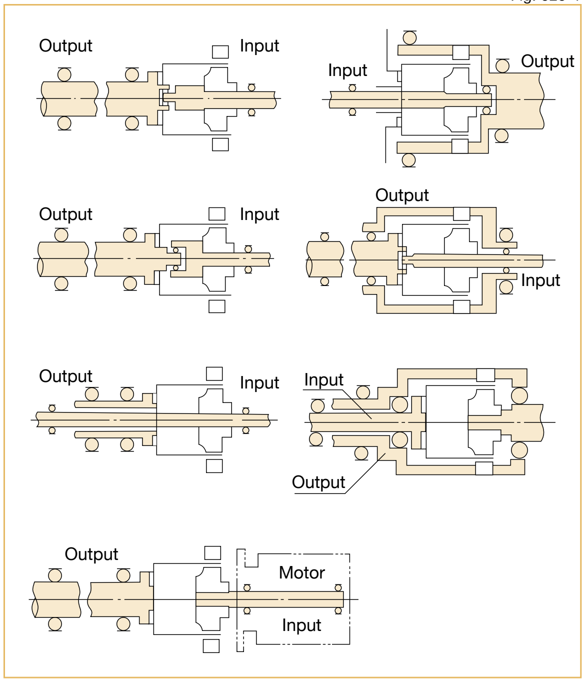
Fig. 024-1



Bearing support for the input and output shafts

For the component sets, both input and output shafts must be supported by two adequately spaced bearings in order to withstand external radial and axial forces without excessive deflection.
In order to avoid damage to the component set when limited external loads are anticipated, both input and output shafts must be axially fixed.
Bearings must be selected whose radial play does not exceed ISO-standard C 2 class or "normal" class. The bearings should be axially and radially preloaded to eliminate backlash.
Examples of correct bearing arrangements are shown in fig 025-1.

Fig. 025-1

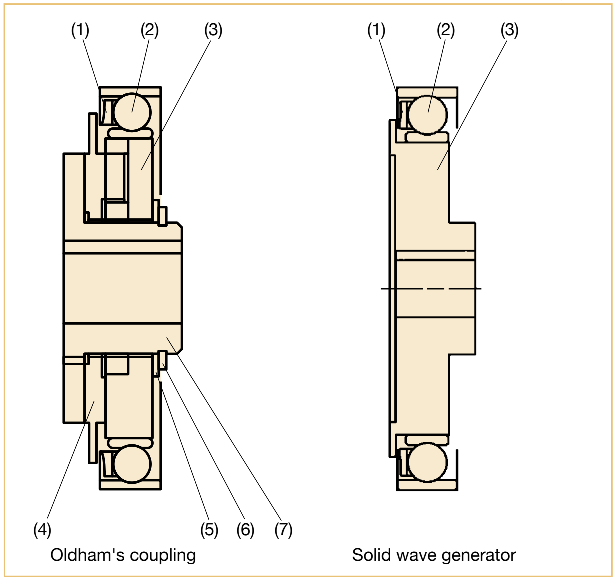


Wave generator

■ Structure of the wave generator

The wave generator includes an Oldham's coupling type with a self-aligning structure and an integrated solid wave generator without a self-aligning structure, and which is used depends on the series.
See the diagram of each series for details. The basic structure of the wave generator and the shape are shown below.

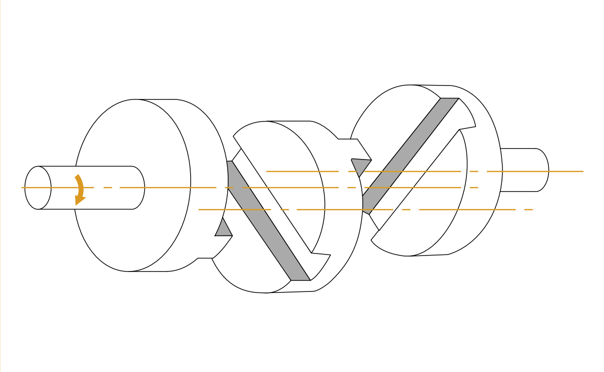
Fig. 026-1



(1) Ball Separator
(2) Wave generator bearing
(3) Wave generator plug
(4) Insert
(5) Rubwasher
(6) Snap ring
(7) Wave generator hub

Structure of Oldham's coupling

Fig. 026-2



■ Maximum hole diameter of wave generator

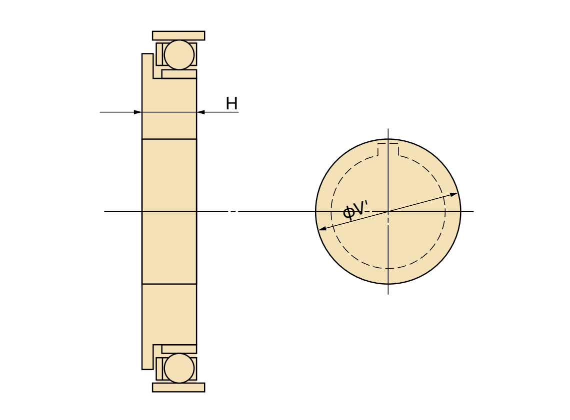
The standard hole dimension of the wave generator is shown for each size. The dimension can be changed within a range up to the maximum hole dimension. We recommend the dimension of keyway based on JIS standard. It is necessary that the dimension of keyways should sustain the transmission torque.

* Tapered holes are also available.

In cases where a larger hole is required, use the wave generator without the Oldham coupling. The maximum diameter of the hole should be considered to prevent deformation of the Wave Generator plug by load torque. The dimension is shown in the table below and includes the dimension of depth of keyway.
(This is the value including the dimension of the depth of keyway.)

Hole diameter of the wave generator

Fig. 027-1



Hole diameter of the wave generator hub with Oldham coupling

Table 027-1
Unit: mm

Size	8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
Standard dim. (H7)	3	5	6	8	9	11	14	14	19	19	22	24	28	28	28
Minimum hole dim.	—	—	3	4	5	6	6	10	10	10	13	16	16	19	22
Maximum hole dim.	—	—	8	10	13	15	15	20	20	20	25	30	35	37	40

Maximum hole diameter without Oldham Coupling

Table 027-2
Unit: mm

Size	8	11	14	17	20	25	32	40	45	50	58	65	80	90	100
Max. hole dia.ϕV'	10	14	17	20	23	28	36	42	47	52	60	67	72	84	95
Min. plug thick.$H^{0}_{-0.1}$	5.7	6.7	7.2	7.6	11.3	11.3	13.7	15.9	17.8	19	21.4	23.5	28.5	31.3	34.9

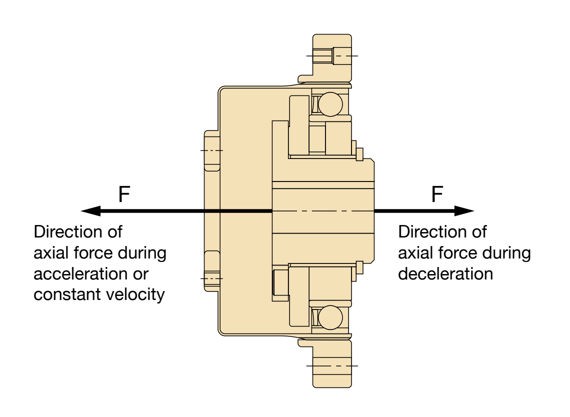
■ Axial Force of Wave Generator

When the 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 the 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.

Axial force direction of the wave generator

Fig. 027-2



Formula for Axial Force

Table 027-3

Reduction ratio	Calculation formula
30	$F=2\times\frac{T}{D}\times0.07\times\tan 32°$
50	$F=2\times\frac{T}{D}\times0.07\times\tan 30°$
80 or more	$F=2\times\frac{T}{D}\times0.07\times\tan 20°$

Symbols for Formula

Table 027-4

F	Axial force	N	See Figure 027-2
D	Size	m	
T	Output torque	Nm	

Calculation example

Formula 027-1

Model name: CSF series
Size: 32
Reduction ratio: 50
Output torque: 382 Nm
(maximum allowable momentary torque)

$$F=2\times\frac{382}{(32\times0.00254)}\times0.07\times\tan 30°$$

$$F=380N$$

Assembly Precautions

Sealing

Sealing is needed to maintain the high durability of the gear and prevent grease leakage. Recommended for all mating surfaces, if the o-ring is not used. Flanges provided with o-ring grooves must be sealed when a proper seal cannot be achieved using the o-ring alone.

- Rotating Parts .... Oil seal with spring is needed.
- Mating flange .... O-ring or seal adhesive is needed.
- Screw hole area .... Screws should have a thread lock (LOCTITE® 242 is recommended) or seal adhesive.

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

Sealing recommendations for gear units

Table 028-1

Area requiring sealing		Recommended sealing method
Output side	Holes which penetrate housing	Use O-ring (supplied with the product)
	Installation screw / bolt	Screw lock adhesive which has effective seal (LOCTITE® 242 is recommended)
Input side	Flange surfaces	Use O-ring (supplied with the product)
	Motor output shaft	Please select a motor which has an oil seal on the output shaft.

Assembly precautions

The wave generator is installed after the flexspline and circular spline. If the wave generator is not inserted into the flexspline last, gear teeth scuffing damage or improper eccentric gear mesh may result. Installation resulting in an eccentric tooth mesh (Dedoidal) will cause noise and vibration, and can lead to early failure of the gear. For proper function, the teeth of the flexspline and Circular Spline mesh symmetrically.

■ Precautions on the wave generator

1. Avoid applying undue axial force to the wave generator during installation. Rotating the wave generator bearing while inserting it is recommended and will ease the process.
2. If the wave generator does not have an Oldham coupling, extra care must be given to ensure that concentricity and inclination are within the specified limits

■ Precautions on the circular spline

The circular Spline must not be deformed in any way during the assembly. It is particularly important that the mounting surfaces are prepared correctly

1. Mounting surfaces need to have adequate flatness, smoothness, and no distortion.
2. Especially in the area of the screw holes, burrs or foreign matter should not be present.
3. Adequate relief in the housing corners is needed to prevent interference with the corner of the circular spline.
4. The circular spline should be rotatable within the housing. Be sure there is not interference and that it does not catch on anything.
5. When a bolt is inserted into a bolt hole during installation, make sure that the bolt fits securely and is not in an improper position or inclination.
6. Do not apply torque at recommended torque all at once. First, apply torque at about half of the recommended value to all bolts, then tighten at recommended torque. Order of tightening bolts must be diagonal.
7. Avoid pinning the circular spline if possible as it can reduce the rotational precision and smoothness of operation.

■ Precautions on the flexspline

1. Mounting surfaces need to have adequate flatness, smoothness, and no distortion.
2. Especially in the area of the screw holes, burrs or foreign matter should not be present.
3. Adequate clearance with the housing is needed to ensure no interference especially with the major axis of flexspline
4. Bolts should rotate freely when installing through the mounting holes of the flexspline and should not have any irregularity due to the shaft bolt holes being misaligned or oblique.
5. Do not tighten the bolts with the specified torque all at once. Tighten the bolts temporarily with about half the specified torque, and then tighten them to the specified torque. Tighten them in an even, crisscross pattern.
6. The flexspline and circular spline are concentric after assembly. After installing the wave generator bearing, if it rotates in unbalanced way, check the mounting for dedoidal or non-concentric installation.
7. Care should be taken not to damage the flexspline diaphragm or gear teeth during assembly.

   Avoid hitting the tips of the flexpline teeth and circular spline teeth. Avoid installing the CS from the open side of the flexspline after the wave generator has been installed.

■ Rust prevention

Although the Harmonic Drive® gears come with some corrosion protection, the gear can rust if exposed to the environment. The gear external surfaces typically have only a temporary corrosion inhibitor and some oil applied. If an anti-rust product is needed, please contact us to review the options.

"Dedoidal" state

It is normal for the flexspline to engage with the circular spline symmetrically as shown in Figure 029-1. However, if the ratcheting phenomenon, which is described on Page 013, is caused or if the three parts are forcibly inserted and assembled, engagement of the teeth may be out of alignment as shown in Figure 029-2. This is called "dedoidal". Note: Early failure of the gear will occur.

■ How to check "dedoidal"

By performing the following methods, check whether the gear engagement is "dedoidal".

(1) Judging by the irregular torque generated when the wave generator turns

1) Slowly turn the input shaft with your hand in a no-load condition. If you can turn it with average force, it is normal. If it turns irregularly, it may be "dedoidal".

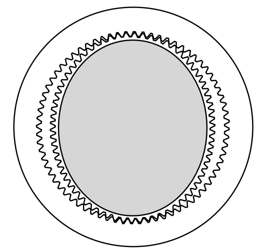
2) Turn the wave generator in a no-load condition if it is attached to a motor. If the average current value of the motor is about 2 to 3 times the normal value, it may be "dedoidal".

(2) Judging by measuring vibration on the body of the flexspline

The scale deflection of the dial gauge draws a sine wave as shown by the solid line in Graph 029-3 when it is normally assembled. When "dedoidal" occurs, the gauge draws a deflected wave shown by the dotted line as the flexspline is out of alignment.

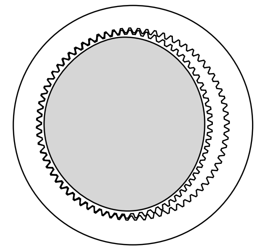
Normal engagement status

Fig. 029-1



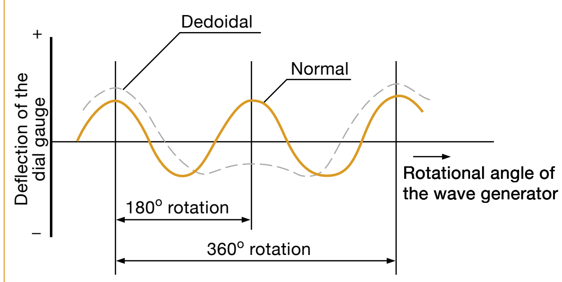
"Dedoidal" status

Fig. 029-2



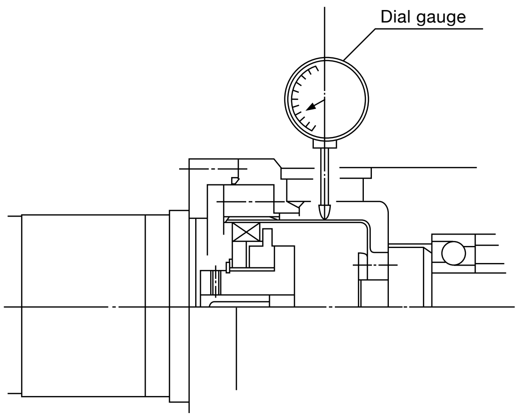
Deflection of the dial gauge

Graph 029-3



Measuring the deflection on the body of the flexspline

Fig. 029-4



Checking Output Bearing

A precision cross roller bearing is built in the unit type and the gear head type to directly support the external load (output flange) (precision 4-point contact ball bearing for the CSF-mini series).
Please calculate maximum moment load, life of cross roller bearing, and static safety factor to fully maximize the performance of a housed unit (gearhead).

■ See the corresponding pages on each series for cross roller bearing specifications.

Checking procedure

(1) Checking the maximum moment load (M_{max})

Calculate maximum moment load (M_{max}). → Maximum moment load (M_{max}) ≦ allowable moment (Mc)

(2) Checking the life

Calculate the radial load (Fr_{av}) and the average axial load (Fa_{av}). → Calculate the radial load coefficient (x) and the axial load coefficient (y). → Calculate lifetime

(3) Checking the static safety coefficient

Calculate the static equivalent radial load coefficient (Po). → Check the static safety coefficient. (fs)

How to calculate the maximum moment load

Maximum moment load (M_{max}) is obtained as follows.
Make sure that M_{max} ≦ Mc.

Formula 030-1

$$M_{max} = Fr_{max}\ (Lr+R) + Fa_{max} \cdot La$$

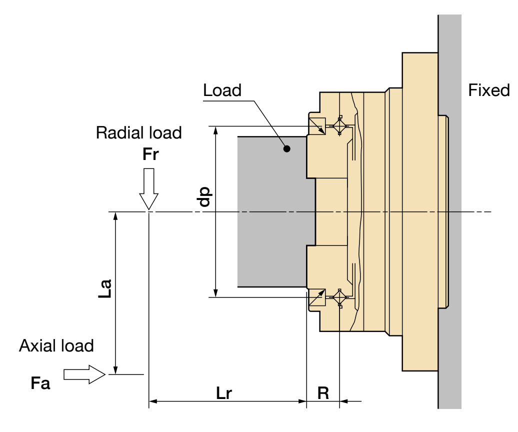
Symbols for Formula 030-1

Table 030-1

Fr_{max}	Max. radial load	N(kgf)	See Fig. 030-1.
Fa_{max}	Max. axial load	N(kgf)	See Fig. 030-1.
Lr, La	————	m	See Fig. 030-1.
R	Offset amount	m	See Fig. 030-1 and "Specification of the output bearing" of each series.

External load influence diagram

Fig. 030-1



How to calculate the average load

(Average radial load, average axial load, average output speed)

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

How to calculate the average radial load (Fr_{av})

Formula 031-1

(Cross roller bearing)

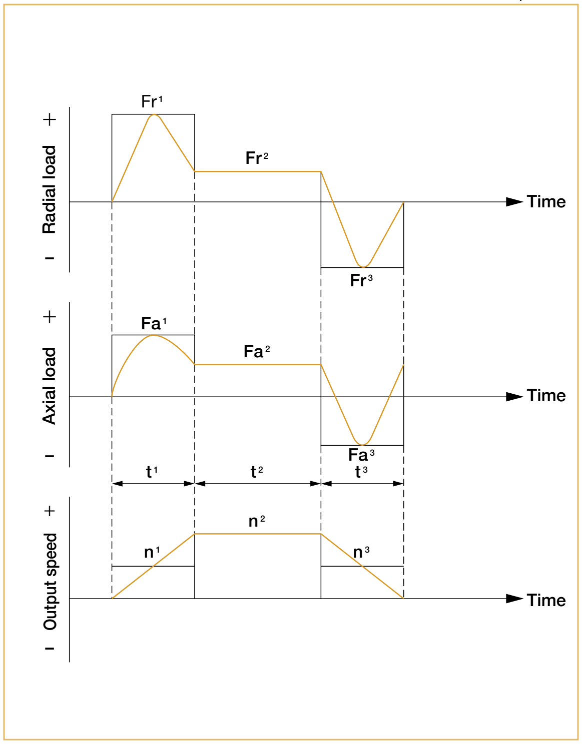
$$Fr_{av} = \sqrt[10/3]{\frac{n_1 t_1 (|Fr_1|)^{10/3} + n_2 t_2 (|Fr_2|)^{10/3} \cdots + n_n t_n (|Fr_n|)^{10/3}}{n_1 t_1 + n_2 t_2 \cdots + n_n t_n}}$$

(4-point contact ball bearing)

$$Fr_{av} = \sqrt[3]{\frac{n_1 t_1 (|Fr_1|)^{3} + n_2 t_2 (|Fr_2|)^{3} \cdots + n_n t_n (|Fr_n|)^{3}}{n_1 t_1 + n_2 t_2 \cdots + n_n t_n}}$$

Note that the maximum radial load in t_1 is Fr_1 and the maximum radial load in t_3 is Fr_3.

Graph 031-1



How to calculate the average axial load (Fa_{av})

Formula 031-2

(Cross roller bearing)

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

(4-point contact ball bearing)

$$Fa_{av} = \sqrt[3]{\frac{n_1 t_1 (|Fa_1|)^{3} + n_2 t_2 (|Fa_2|)^{3} \cdots + n_n t_n (|Fa_n|)^{3}}{n_1 t_1 + n_2 t_2 \cdots + n_n t_n}}$$

Note that the maximum axial load in t_1 is Fa_1 and the maximum axial load in t_3 is Fa_3.

How to calculate the average output speed (Nav)

Formula 031-3

$$N_{av} = \frac{n_1 t_1 + n_2 t_2 \ldots + n_n t_n}{t_1 + t_2 \ldots + t_n}$$

How to calculate the radial load coefficient (X) and axial load coefficient (Y)

Formula 031-4

How to calculate the load coefficient	X	Y
$\frac{Fa_{av}}{Fr_{av} + 2(Fr_{av}(Lr+R) + Fr_{av} \cdot La)/dp} \le 1.5$	1	0.45
$\frac{Fa_{av}}{Fr_{av} + 2(Fr_{av}(Lr+R) + Fr_{av} \cdot La)/dp} > 1.5$	0.67	0.67

Symbols for Formula 031-4

Table 031-1

Fr_{av}	Average radial load	N(kgf)	See "How to calculate the average load." See Formula 031-1.
Fa_{av}	Average axial load	N(kgf)	See "How to calculate the average load." See Formula 031-2.
Lr, La	———	m	See fig. 030-1
R	Offset amount	m	See Fig. 030-1 and "Main roller bearing specifications" of each series
dp	Pitch circle diameter of a roller	m	See Fig. 030-1 and "Specification of the output bearing" of each series.

Life of the output bearing

Calculate life of the output bearing by Formula 032-1.
You can calculate the dynamic equivalent radial load (Pc) by Formula 032-2.

Formula 032-1

(Cross roller bearing)

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

(4-point contact ball bearing)

$$L_{10} = \frac{10^6}{60 \times N_{av}} \times \left(\frac{C}{fw \cdot Pc}\right)^{3}$$

Formula 032-2

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

Symbols for Formula 032-1

Table 032-1

L_{10}	Life	hour	———
N_{av}	Average output rated load speed	rpm	See "How to calculate the average load."
C	Basic dynamic rated load	N (kgf)	See "Specification of the output bearing" of each series.
Pc	Dynamic equivalent	N (kgf)	See Formula 032-2.
fw	Load coefficient	——	See Table 032-3.

Symbols for Formula 032-2

Table 032-2

Fr_{av}	Average radial load	N (kgf)	See "How to calculate the average load." See Formula 031-1.
Fa_{av}	Average axial load	N (kgf)	See "How to calculate the average load." See Formula 031-2.
dp	Pitch circle diameter	m	See Fig. 030-1 and "Specification of the output bearing" of each series.
X	Radial load coefficient	——	See Formula 031-4.
Y	Axial load coefficient	——	See Formula 031-4.
Lr, La	———	m	See Figure 030-1.
R	Offset	m	See Fig. 030-1 and "Specification of the output bearing" of each series.

Load coefficient

Table 032-3

Load status	fw
Steady operation without impact and vibration	1 to 1.2
Normal operation	1.2 to 1.5
Operation with impact and vibration	1.5 to 3

How to calculate life during oscillating motion

Calculate the life of the cross roller bearing during oscillating motion by Formula 033-1.

Formula 033-1

(Cross roller bearing)

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

(4-point contact ball bearing)

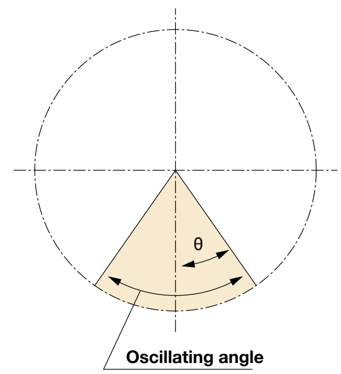
$$Loc = \frac{10^6}{60 \times n1} \times \frac{90}{\theta} \times \left(\frac{C}{fw \cdot Pc}\right)^{3}$$

Symbols for Formula 033-1

Table 033-1

Loc	Rated life for oscillating motion	hour	―――
n1	Round trip oscillation each minute	cpm	―――
C	Basic dynamic rated load	N（kgf）	―――
Pc	Dynamic equivalent radial load	N（kgf）	See Formula 032-2.
fw	Load coefficient	――	See Table 032-3.
θ	Oscillating angle /2	Degree	See Fig. 033-1.

Fig. 033-1



(Note) A small angle of oscillation (less than 5 degrees) may cause fretting corrosion to occur since lubrication may not circulate properly. Contact us if this happens.

Engineering Data
Component Sets
Gear Units
Phase Adjusters
Gearheads & Actuators

How to calculate the 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 coefficient of the cross roller bearing can be calculated by Formula 034-2.

Formula 034-1

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

Formula 034-2

$$Po = Fr\,max + \frac{2M\,max}{dp} + 0.44Fa\,max$$

Symbols for Formula 034-1

Table 034-1

Co	Basic static rated load	N(kgf)	See "Specification of the output bearing" of each series.
Po	Static equivalent radial load	N(kgf)	See Formula 034-2.

Symbols for Formula 034-2

Table 034-2

Fr*max*	Max. radial load	N(kgf)	See "How to calculate the maximum moment load" on Page 030.
Fa*max*	Max. axial load	N(kgf)	See "How to calculate the maximum moment load" on Page 030.
M*max*	Max. moment load	Nm(kgfm)	See "How to calculate the maximum moment load" on Page 030.
dp	Pitch circle diameter of a roller	m	See Fig. 030-1 and "Specification of the output bearing" of each series.

Static Safety Coefficient

Table 034-3

Operating condition of the roller bearing	fs
When high rotation precision is required	≧3
When shock and vibration are expected	≧2
Under normal operating condition	≧1.5

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