HarmonicDrive®

CSG-GH High Torque Series

Size — 5 Sizes
14, 20, 32, 45, 65

Peak torque
23Nm to 3419Nm

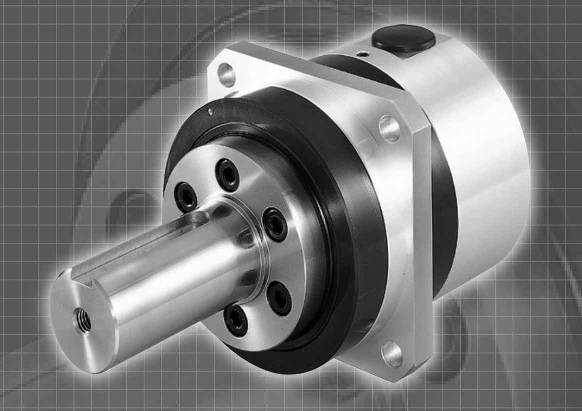
Reduction ratio
50:1 to 160:1

Zero backlash

High Accuracy
Repeatability ±4 to ±10 arc-sec

High Load Capacity Output Bearing
A Cross Roller bearing is integrated with the output flange to provide high moment stiffness, high load capacity and precise positioning accuracy.

Easy mounting to a wide variety of servomotors
Quick Connect™ coupling



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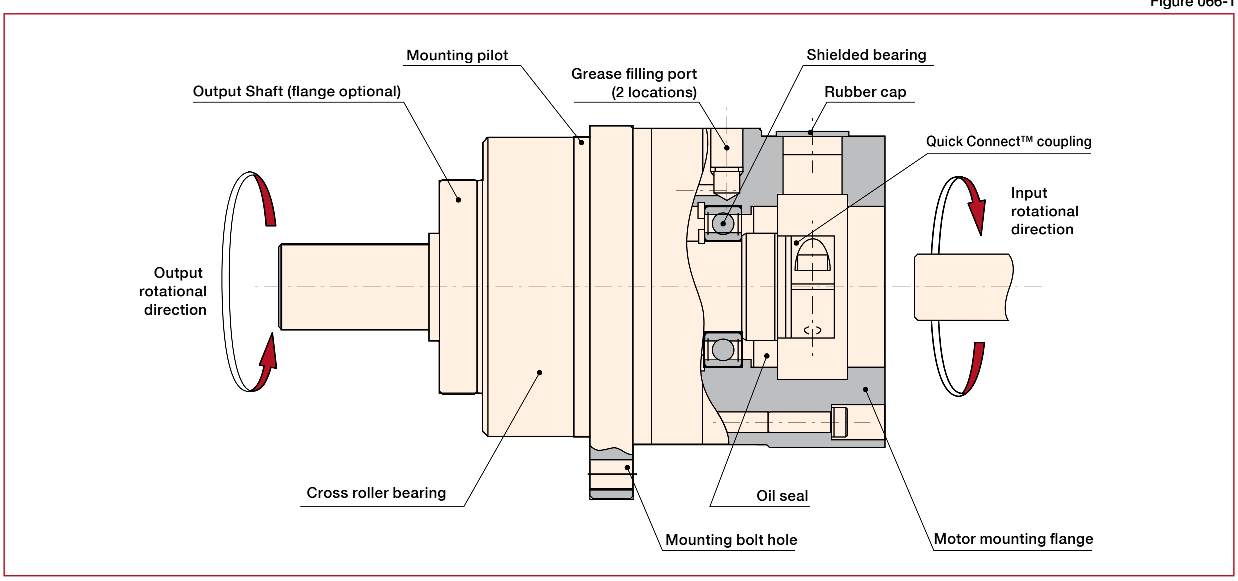
CSG - 20 - 100 - GH - F0 Motor Model Number

Model Name	Size	Reduction Ratio	Model	Output Configuration	Input Configuration
HarmonicDrive® CSG High Torque	14	50, 80, 100	GH: Gearhead	F0: Flange output J2: Straight shaft (without key) J6: Straight shaft (with key and center tapped hole)	This code represents the motor mounting configuration. Please contact us for a unique part number based on the motor you are using.
	20	50, 80, 100, 120, 160			
	32				
	45				
	65	80, 100, 120, 160			

Gearhead Construction

Figure 066-1



(The figure indicates output shaft type.)

Rating Table CSG-GH

Table 067-1

Size	Ratio	Rated Torque at 2000 rpm *1	Rated Torque at 3000 rpm *2	Limit for Average Torque *3	Limit for Repeated Peak Torque *4	Limit for Momentary Torque *5	Max. Average Input Speed *6	Max. Input Speed *7	Mass *8 Shaft	Mass *8 Flange
		Nm	Nm	Nm	Nm	Nm	rpm	rpm	kg	kg
14	50	7.0	6.1	9.0	23	46	3500	8500	0.62	0.50
	80	10	8.7	14	30	61				
	100	10	8.7	14	36	70				
20	50	33	29	44	73	127	3500	6500	1.8	1.4
	80	44	38	61	96	165				
	100	52	45	64	107	191				
	120	52	45	64	113	191				
	160	52	45	64	120	191				
32	50	99	86	140	281	497	3500	4800	4.6	3.2
	80	153	134	217	395	738				
	100	178	155	281	433	812				
	120	178	155	281	459	812				
	160	178	155	281	484	812				
45	50	229	200	345	650	1235	3000	3800	13	10
	80	407	356	507	918	1651				
	100	459	401	650	982	2033				
	120	523	457	806	1070	2033				
	160	523	457	819	1147	2033				
65	80	969	846	1352	2743	4836	1900	2800	32	24
	100	1236	1080	1976	2990	5174				
	120	1236	1080	2041	3263	5174				
	160	1236	1080	2041	3419	5174				

*1: Rated torque is based on L10 life of 7,000 hours when input speed is 2000 rpm
*2: Rated torque is based on L10 life of 7,000 hours when input speed is 3000 rpm, input rotational speed for size 65 is 2800 rpm.
*3: Maximum value of average load torque is based on the load torque pattern. Note that exceeding this value may deteriorate the life or durability of the product.
*4: The limit for torque during start and stop cycles.
*5: The limit for torque during emergency stops or from external shock loads. Always operate below this value. Calculate the number of permissible events to ensure it meets required operating conditions.
*6: Maximum average input speed is limited by heat generation in the speed reducer assuming a continuous operating speed or the average input speed of a motion profile. The actual limit for average input speed depends on the operating environment.
*7: Maximum instantaneous input speed.
*8: The mass is for the gearhead only (without input shaft coupling & motor flange). Please contact us for the mass of your specific configuration.
*9: See page 86 for more information about Torque ratings.

Ratcheting Torque CSG-GH

(Unit: Nm) Table 067-2

Reduction ratio \ Size	14	20	32	45	65
50	110	280	1200	3500	—
80	140	450	1800	5000	14000
100	100	330	1300	4000	12000
120	—	310	1200	3600	10000
160	—	280	1200	3300	10000

Buckling Torque CSG-GH

(Unit: Nm) Table 067-3

Size	14	20	32	45	65
All Ratios	260	800	3500	8900	26600

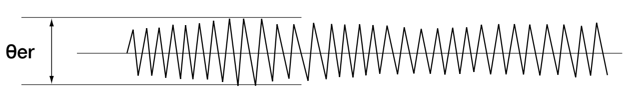
Performance Table CSG-GH

Table 068-1

Size	Flange Type	Ratio	Accuracy *1		Repeatability *2	Starting torque *3		Backdriving torque *4		No-load running torque *5	
			arc min	x10⁻⁴rad	arc sec	Ncm	kgfcm	Nm	kgfm	Ncm	kgfcm
14	All	50	1.5	4.4	±10	8.5	0.9	3.0	0.3	5.6	0.6
		80				7.1	0.7	4.0	0.4	5.1	0.5
		100				6.8	0.7	4.9	0.5	4.6	0.5
20	Type I	50	1.0	2.9	±8	14	1.4	8	0.8	11	1.2
		80				10	1.1	10	1.0	10	1.0
		100				10	1.0	13	1.3	10	1.0
		120				9.4	1.0	14	1.4	9.8	1.0
		160				8.9	0.9	18	1.8	9.6	1.0
	Type II	50	1.0	2.9	±8	21	2.1	12	1.3	11	1.2
		80				17	1.8	16	1.7	10	1.0
		100				16	1.7	20	2.0	10	1.0
		120				16	1.7	24	2.4	9.8	1.0
		160				15	1.6	30	3.0	9.6	1.0
32	Type I &II	50	1.0	2.9	±6	61	6.2	37	3.8	47	4.8
		80				48	4.9	46	4.7	42	4.3
		100				47	4.8	56	5.7	41	4.2
		120				43	4.4	63	6.4	40	4.1
		160				42	4.3	81	8.3	40	4.1
	Type III	50	1.0	2.9	±6	53	5.4	32	3.3	47	4.8
		80				40	4.1	39	4.0	42	4.3
		100				39	4.0	47	4.8	41	4.2
		120				35	3.6	51	5.2	40	4.1
		160				34	3.5	66	6.7	40	4.1
45	All	50	1.0	2.9	±5	129	13	78	8.0	120	12
		80				99	10	96	9.8	109	11
		100				93	9.5	111	11	107	11
		120				88	9.0	128	13	105	11
		160				82	8.4	158	16	103	11
65	All	80	1.0	2.9	±4	197	20	191	19	297	30
		100				176	18	213	22	289	30
		120				165	17	240	24	285	29
		160				147	15	285	29	278	28

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

Figure 068-1

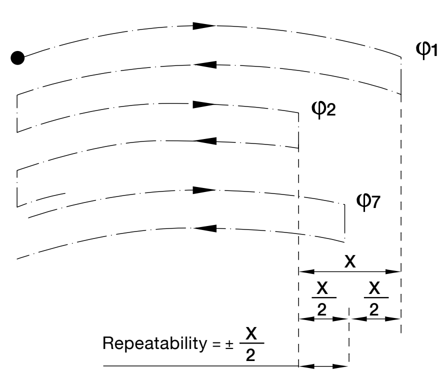


θ_{er} : Accuracy
θ_1 : Input angle
θ_2 : Actual output angle
R : Gear reduction ratio

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

*2: The repeatability is measured by moving to a given theoretical position seven times, each time approaching from the same direction. The actual position of the output shaft is measured each time and repeatability is calculated as the 1/2 of the maximum difference of the seven data points. Measured values are indicated in angles (arc-sec) prefixed with "±". The values in the table are maximum values.

Figure 068-2



*3: Starting torque is the torque value applied to the input side at which the output first starts to rotate. The values in the table are maximum values.

Table 068-2

Load	No load
Speed reducer surface temperature	25°C

*4: 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.

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.

Table 068-3

Load	No load
Speed reducer surface temperature	25°C

*5: No-load running torque is the torque required at the input to operate the gearhead at a given speed under a no-load condition. The values in the table are average values.

Table 068-4

Input speed	2000 rpm
Load	No load
Speed reducer surface temperature	25°C

Torsional Stiffness CSG-GH and CSF-GH

Table 013-1

Symbol		Size	14	20	32	45	65
	T_1	Nm	2.0	7.0	29	76	235
		kgfm	0.2	0.7	3.0	7.8	24
	T_2	Nm	6.9	25	108	275	843
		kgfm	0.7	2.5	11	28	86
Reduction ratio 50	K_1	$\times10^4$Nm/rad	0.34	1.3	5.4	15	–
		kgfm/arc min	0.1	0.38	1.6	4.3	–
	K_2	$\times10^4$Nm/rad	0.47	1.8	7.8	20	–
		kgfm/arc min	0.14	0.52	2.3	6.0	–
	K_3	$\times10^4$Nm/rad	0.57	2.3	9.8	26	–
		kgfm/arc min	0.17	0.67	2.9	7.6	–
	θ_1	$\times10^{-4}$rad	5.8	5.2	5.5	5.2	–
		arc min	2.0	1.8	1.9	1.8	–
	θ_2	$\times10^{-4}$rad	16	15.4	15.7	15.1	–
		arc min	5.6	5.3	5.4	5.2	–
Reduction ratio 80 or more	K_1	$\times10^4$Nm/rad	0.47	1.6	6.7	18	54
		kgfm/arc min	0.14	0.47	2.0	5.4	16
	K_2	$\times10^4$Nm/rad	0.61	2.5	11	29	88
		kgfm/arc min	0.18	0.75	3.2	8.5	26
	K_3	$\times10^4$Nm/rad	0.71	2.9	12	33	98
		kgfm/arc min	0.21	0.85	3.7	9.7	29
	θ_1	$\times10^{-4}$rad	4.1	4.4	4.4	4.1	4.4
		arc min	1.4	1.5	1.5	1.4	1.5
	θ_2	$\times10^{-4}$rad	12	11.3	11.6	11.1	11.3
		arc min	4.2	3.9	4.0	3.8	3.9

* The values in this table are average values. See page 88 for more information about torsional stiffness.

Hysteresis Loss CSG-GH

Reduction ratio 50: Approx. 5.8×10^{-4} rad (2arc min)
Reduction ratio 80 or more: Approx. 2.9×10^{-4} rad (1arc min)

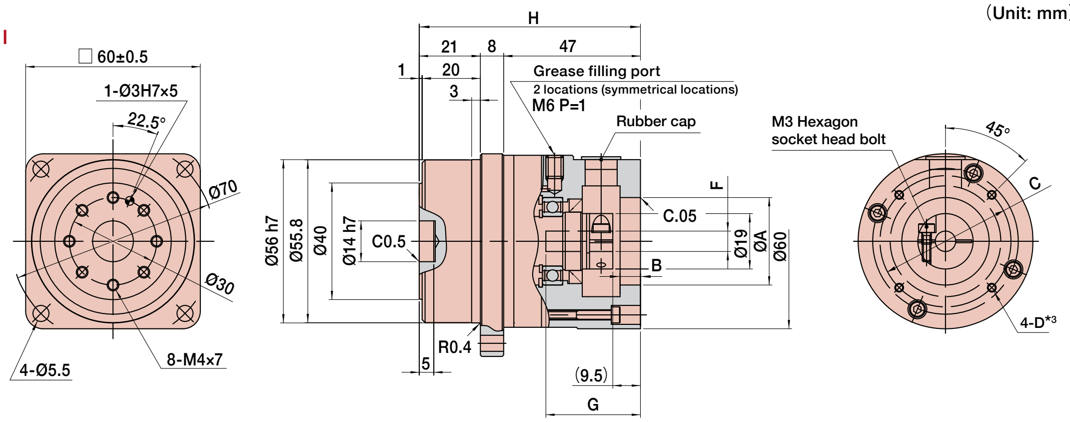
CSG-GH-14 Outline Dimensions

Only primary dimensions are shown in the drawings below. Refer to the confirmation drawing for detailed dimensions.

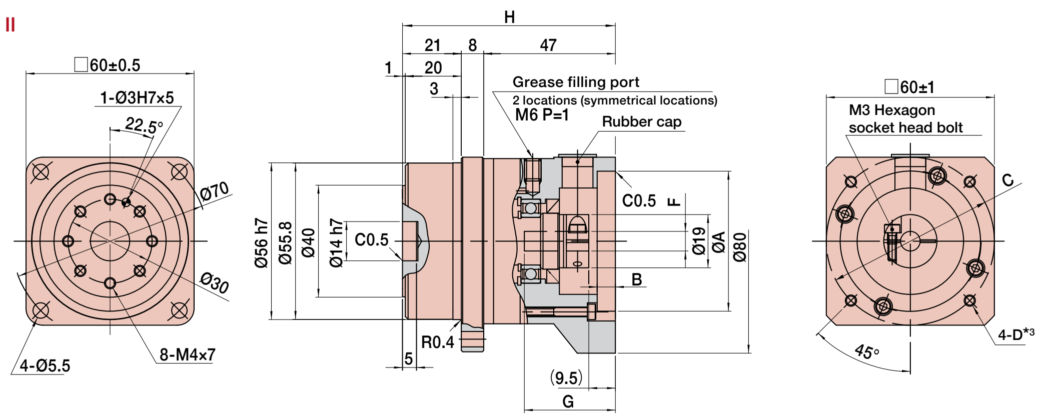
Figure 070-1

(Unit: mm)

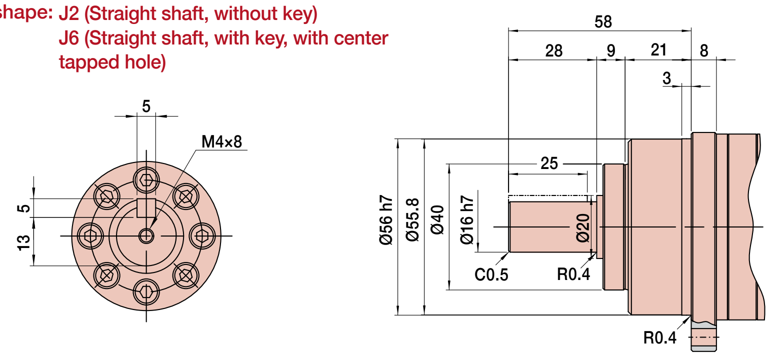
Flange Type I



Flange Type II



Output shaft shape: J2 (Straight shaft, without key)
J6 (Straight shaft, with key, with center tapped hole)



(Note) The dimension tolerances that are not specified vary depending on the manufacturing method. Please check the confirmation drawing or contact us for dimension tolerances not shown on the drawing above.

Dimension Table

(Unit: mm)

Table 070-1

Flange	Coupling	A (H7)		B	C		F (H7)		G		H *1	Moment of Inertia	Mass (kg) *2	
		Min.	Max.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Typical	(10^{-4}kgm^2)	Shaft	Flange
Type I	1	50	58	7	58	72	5.0	7.8	21.5	32.5	76	0.07	0.88	0.76
Type II	1	30	45	6.5	36	54	5.0	7.8	21.5	32.5	76	0.07	0.90	0.78

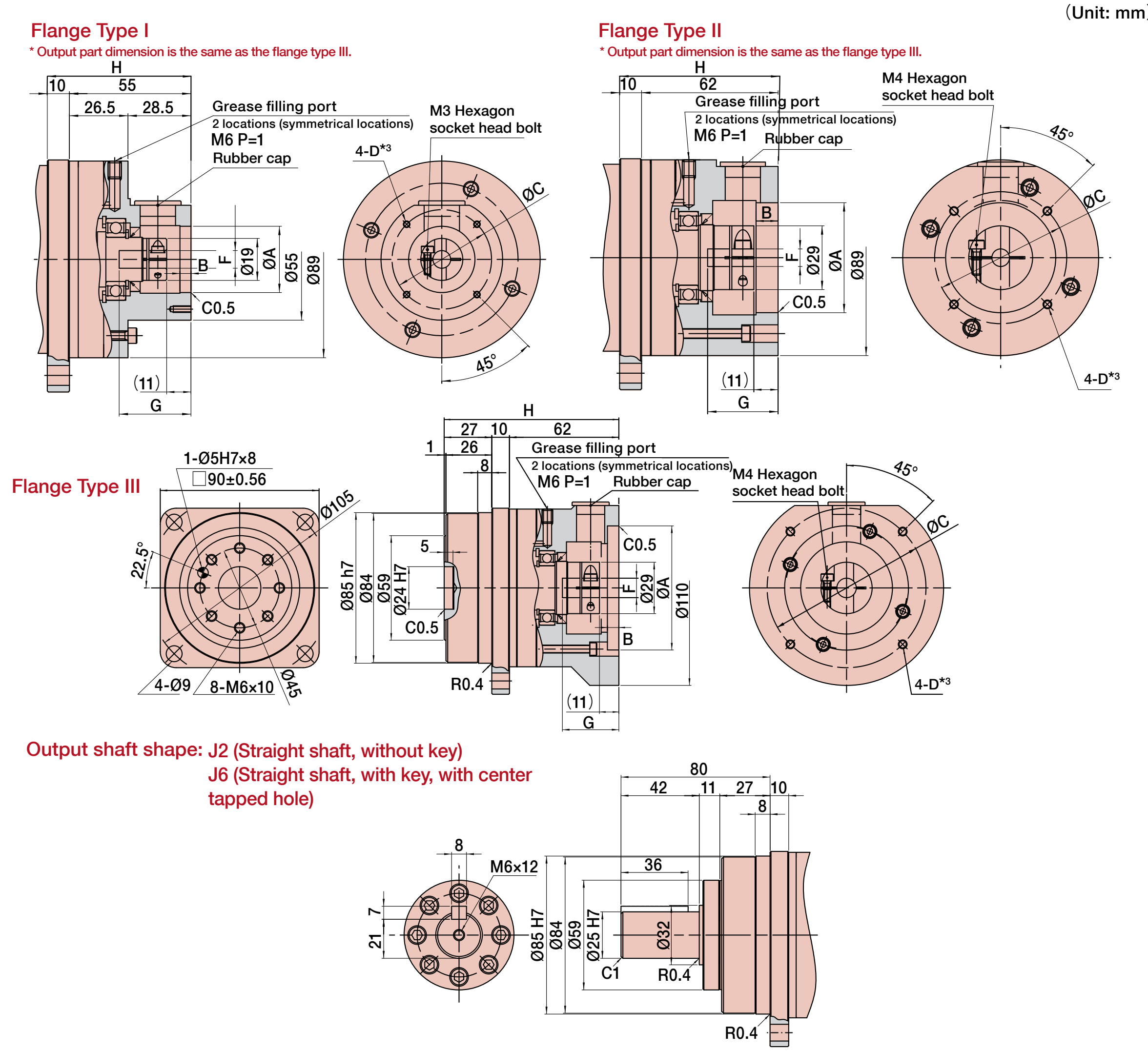
Refer to the confirmation drawing for detailed dimensions.
Dimensions of typical products are shown. Please contact us for other mounting options if the configurations shown above are not suitable for your particular motor.
*1 May vary depending on motor interface dimensions.
*2 The mass will vary slightly depending on the ratio and on the inside diameter of the input shaft coupling.
*3 Tapped hole for motor mounting screw.

CSG-GH-20 Outline Dimensions

Only primary dimensions are shown in the drawings below. Refer to the confirmation drawing for detailed dimensions.

Figure 071-1

(Unit: mm)



(Note) The dimension tolerances that are not specified vary depending on the manufacturing method. Please check the confirmation drawing or contact us for dimension tolerances not shown on the drawing above.

Dimension Table

(Unit: mm)

Table 071-1

Flange	Coupling	A (H7)		B	C		F (H7)		G		H *1	Moment of Inertia	Mass (kg) *2	
		Min.	Max.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Typical	($10^{-4}kgm^2$)	Shaft	Flange
Type I	1	30	45	5	36	48	7.0	7.8	23.0	33.0	92.0	0.28	2.3	1.9
Type II	2	50	70	10	60	80	8.0	14.6	25.0	32.0	99.0	0.42	2.6	2.2
Type III	2	50	80	10	60	100	8.0	14.6	25.0	32.0	99.0	0.42	2.8	2.4

Refer to the confirmation drawing for detailed dimensions.
Dimensions of typical products are shown. Please contact us for other mounting options if the configurations shown above are not suitable for your particular motor.

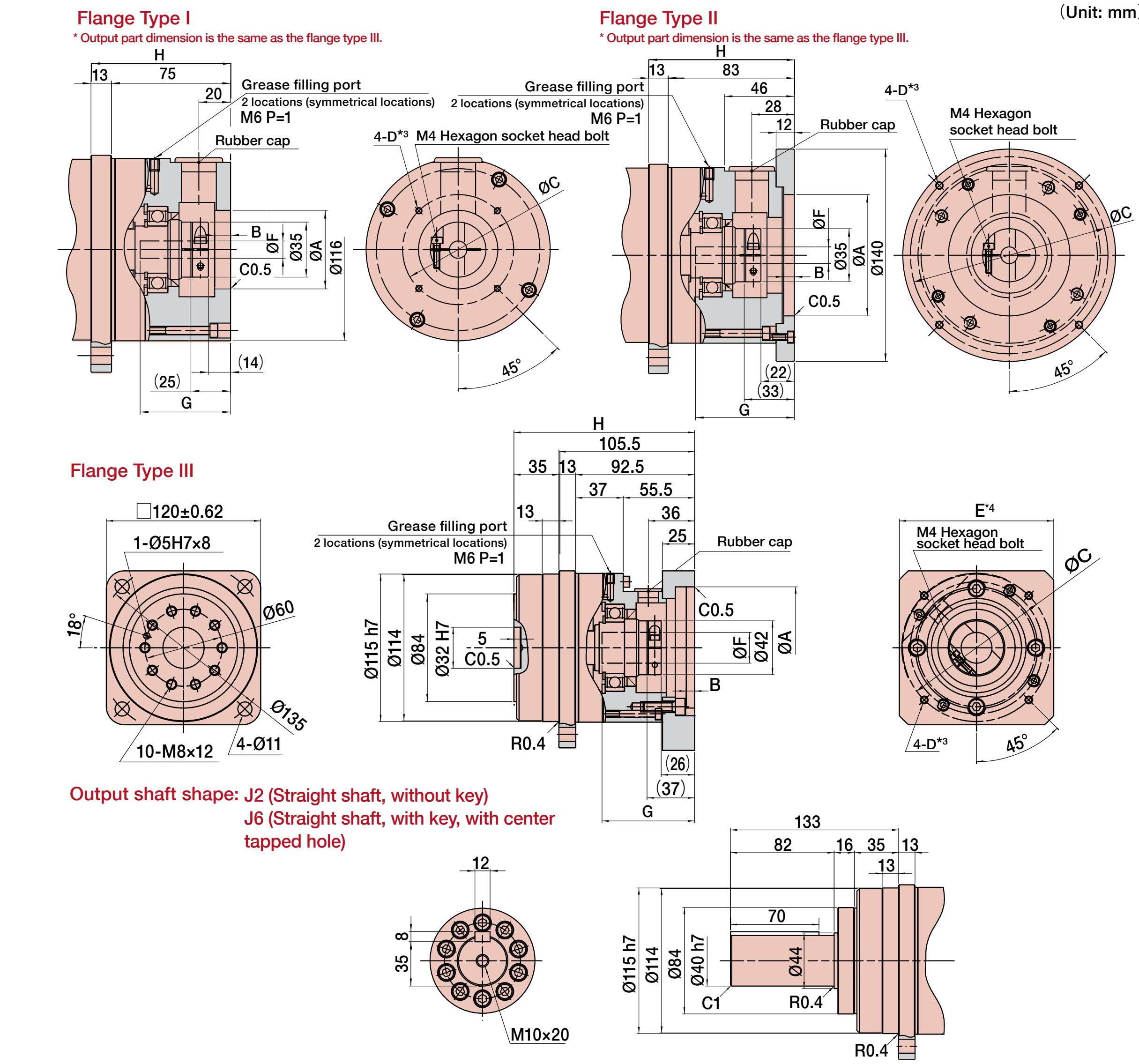
*1 May vary depending on motor interface dimensions.
*2 The mass will vary slightly depending on the ratio and on the inside diameter of the input shaft coupling.
*3 Tapped hole for motor mounting screw.

CSG-GH-32 Outline Dimensions

Only primary dimensions are shown in the drawings below. Refer to the confirmation drawing for detailed dimensions.

Figure 072-1

(Unit: mm)



(Note) The dimension tolerances that are not specified vary depending on the manufacturing method. Please check the confirmation drawing or contact us for dimension tolerances not shown on the drawing above.

Dimension Table

(Unit: mm)

Table 072-1

Flange	Coupling	A (H7)		B	C		F (H7)		G		H*1	Moment of Inertia	Mass (kg) *2	
		Min.	Max.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Max.	(10^{-4}kgm^2)	Shaft	Flange
Type I	3	50	85	10	58	105	9.0	19.6	28.0	57	133	2.7	6.4	5.0
Type II	2	70	95	5	85	115	16.0	25.8	35.0	67	145.5	2.7	6.6	5.2
Type III	1	95	130	7	115	165	11.0	19.6	36.0	65	141	2.0	7.9	6.5

Refer to the confirmation drawing for detailed dimensions.
Dimensions of typical products are shown. Please contact us for other mounting options if the configurations shown above are not suitable for your particular motor.

*1 May vary depending on motor interface dimensions.
*2 The mass will vary slightly depending on the ratio and on the inside diameter of the input shaft coupling.
*3 Tapped hole for motor mounting screw.
*4 E dimension is dependent on motor selection.

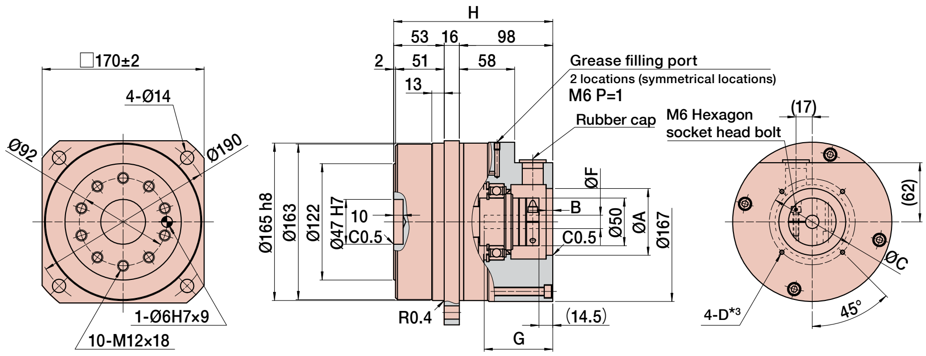
CSG-GH-45 Outline Dimensions

Only primary dimensions are shown in the drawings below. Refer to the confirmation drawing for detailed dimensions.

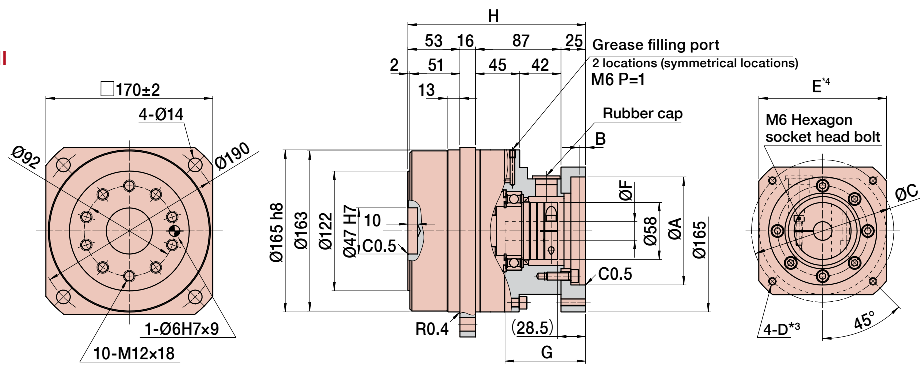
Figure 073-1

(Unit: mm)

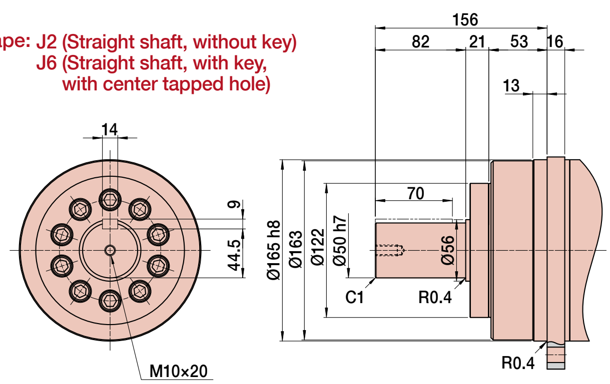
Flange Type I



Flange Type II



Output shaft shape: J2 (Straight shaft, without key)
J6 (Straight shaft, with key, with center tapped hole)



(Note)
If using size 45 or 65 gearheads with a shaft output and require torques as high as the "Limit for Momentary Peak Torque" you must use a J2 shaft configuration (straight shaft, no key) with a friction / compression coupling to the output load. This is due to the limited strength of the connection using a keyed shaft.

(Note) The dimension tolerances that are not specified vary depending on the manufacturing method. Please check the confirmation drawing or contact us for dimension tolerances not shown on the drawing above.

Dimension Table

(Unit: mm)

Table 073-1

Flange	Coupling	A (H7)		B	C		F (H7)		G		H *1	Moment of Inertia	Mass (kg) *2	
		Min.	Max.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Typical	(10^{-4}kgm^2)	Shaft	Flange
Type I	1	70	110	7	80	150	14.0	29.4	31.5	72	167	11	17.3	14.3
Type I	2	70	110	7	80	150	19.0	41	40.5	77	167	11	17.3	14.3
Type II	1	110	130	6.5	145	200	14.0	29.4	31.5	72	176	11	16.7	13.7
Type II	2	110	130	6.5	145	200	19.0	41	40.5	77	176	11	17.7	14.7

Refer to the confirmation drawing for detailed dimensions.
Dimensions of typical products are shown. Please contact us for other mounting options if the configurations shown above are not suitable for your particular motor.
*1 May vary depending on motor interface dimensions.
*2 The mass will vary slightly depending on the ratio and on the inside diameter of the input shaft coupling.
*3 Tapped hole for motor mounting screw.
*4 E dimension is dependent on motor selection.

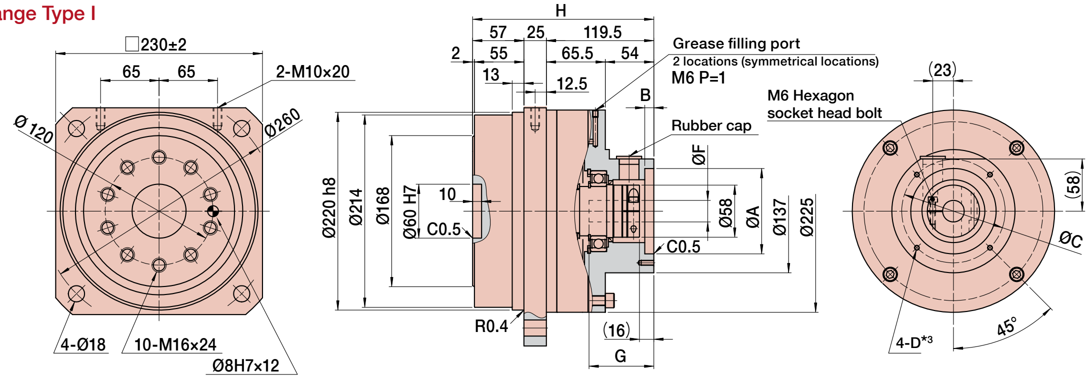
CSG-GH-65 Outline Dimensions

Only primary dimensions are shown in the drawings below. Refer to the confirmation drawing for detailed dimensions.

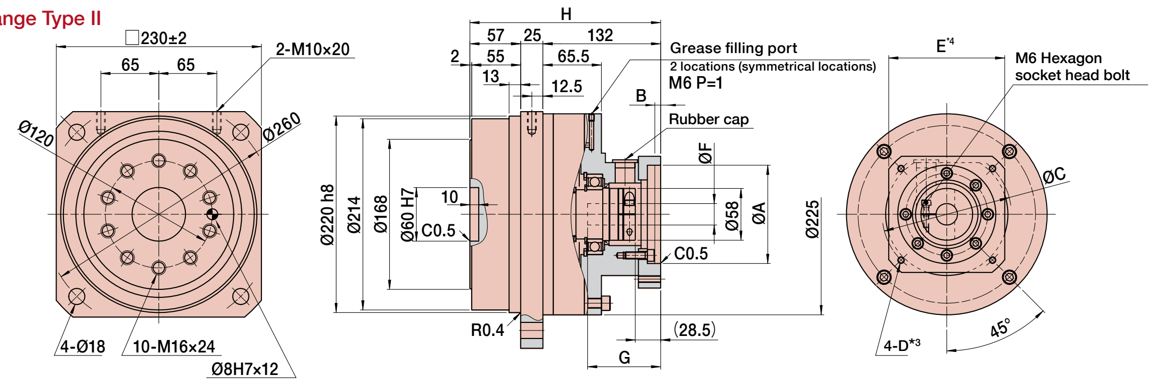
Figure 074-1

(Unit: mm)

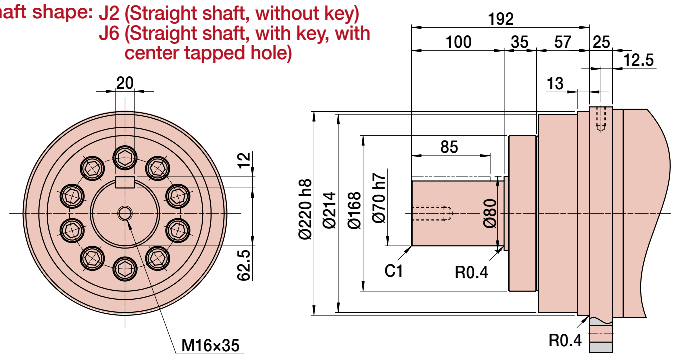
Flange Type I



Flange Type II



Output shaft shape: J2 (Straight shaft, without key)
J6 (Straight shaft, with key, with center tapped hole)



(Note)
If using size 45 or 65 gearheads with a shaft output and required torques are as high as the "Limit for Momentary Peak Torque," you must use a J2 shaft configuration (straight shaft, no key) with a friction / compression coupling to the output load. This is due to the limited strength of the connection using a keyed shaft.

(Note) The dimension tolerances that are not specified vary depending on the manufacturing method. Please check the confirmation drawing or contact us for dimension tolerances not shown on the drawing above.

Dimension Table

(Unit: mm)

Table 074-1

Flange	Coupling	A (H7)		B	C		F (H7)		G		H *1	Moment of Inertia	Mass (kg) *2	
		Min.	Max.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Max.	($10^{-4}kgm^2$)	Shaft	Flange
Type I	1	95	95	10	110	125	19.0	39.3	33.0	72	201.5	51	36.2	27.6
Type II	1	110	200	6.5	145	235	19.0	39.3	40.5	79.5	209	51	38.3	29.7

Refer to the confirmation drawing for detailed dimensions.
Dimensions of typical products are shown. Please contact us for other mounting options if the configurations shown above are not suitable for your particular motor.
*1 May vary depending on motor interface dimensions.
*2 The mass will vary slightly depending on the ratio and on the inside diameter of the input shaft coupling.
*3 Tapped hole for motor mounting screw.
*4 E dimension is dependent on motor selection.

NOTES

Rating Table Definitions

See the corresponding pages of each series for values from the ratings.

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

■ Limit for Repeated Peak Torque (see Graph 086-1)
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 91)

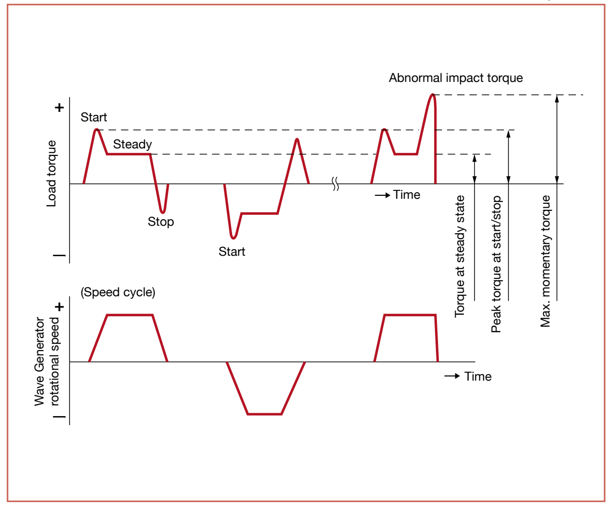
■ Limit for Momentary Torque (see Graph 086-1)
The gear may be subjected to momentary peak torques in the event of a collision or emergency stop. The magnitude and frequency of occurrence of such peak torques must be kept to a minimum and they should, under no circumstance, occur during normal operating cycle. The allowable number of occurrences of the momentary peak torque may be calculated by using formula 073-1.

■ Maximum Average Input Speed Maximum Input Speed
Do not exceed the allowable rating. (calculation formula of the average input speed: Page 91).

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

Example of load torque pattern

Graph 086-1



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 086-1

	Life	
Series name	CSF-GH	CSG-GH
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 ratings.

Calculation formula for Rated Lifetime

Formula 086-1

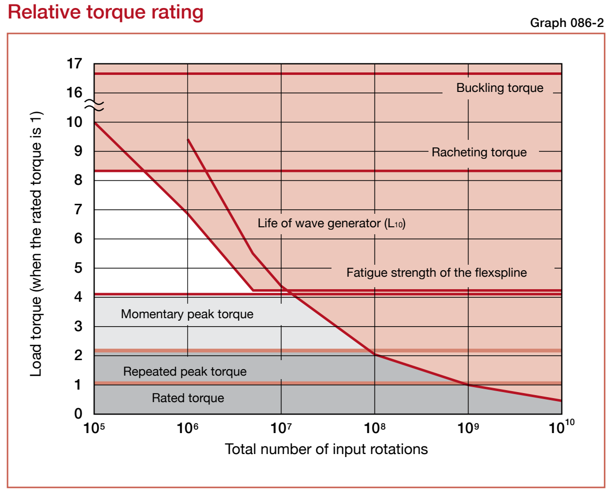
$$L_h = L_n \cdot \left(\frac{T_r}{T_{av}}\right)^3 \cdot \left(\frac{N_r}{N_{av}}\right)$$

Table 086-2

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 91)
Nav	Average input speed (calculation formula: Page 91)

Relative torque rating

Graph 086-2



* 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 087-1

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

Permissible 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 may occur.

■ Ratcheting torque

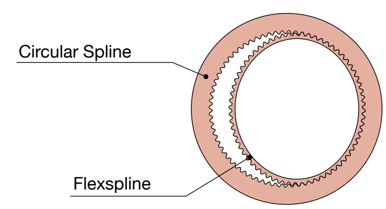
When excessive torque (8 to 9 times rated torque) is applied while the gear is in motion, the teeth between the Circular Spline and Flexspline may not engage properly.
This phenomenon is called ratcheting and the torque at which this occurs is called ratcheting torque. Ratcheting may cause the Flexspline 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 087-1. 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 087-1



"Dedoidal" condition.

CSG-GH Series HarmonicDrive® High-Performance Gearhead for Servomotors

CSF-GH Series HarmonicDrive® High-Performance Gearhead for Servomotors

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 torsion almost proportional to the torque on the output side. Figure 088-1 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 074-2, this "Torque – torsional angle 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 CSG-32-100-GH as an example.

T1 = 29 Nm
T2 = 108 Nm
K1 = 6.7 x 10^4 Nm/rad
K2 = 6.7 x 10^4 Nm/rad
K3 = 6.7 x 10^4 Nm/rad
θ1=4.4 x 10^{-4} rad
θ2=11.6 x 10^{-4} rad

When the applied torque is T_1 or less, the torsion angle θ_{L1} is calculated as follows:
When the load torque T_{L1}=6.0 Nm

$$\theta_{L1} = T_{L1}/K_1 = 6.0/6.7\times10^4 = 9.0\times10^{-5}\text{ rad (0.31 arc min)}$$

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}=50 Nm

$$\theta_{L2} = \theta_1 + (T_{L2}-T_1)/K_2 = 4.4\times10^{-4} + (50-6)/11.0\times10^4 = 4.4\times10^{-4} + 40.0\times10^{-5} = 8.4\times10^{-4}\text{ rad (2.89 arc min)}$$

When the applied torque is greater than T_2, the torsion angle θ_{L3} is calculated as follows:
When the load torque is T_{L3}=178 Nm

$$\theta_{L3} = \theta_1 + \theta_2 + (T_{L3}-T_2)/K_3 = 4.4\times10^{-4} + 11.6\times10^{-4} + (178-108)/12.0\times10^4 = 4.4\times10^{-4} + 11.6\times10^{-4} + 5.8\times10^{-4} = 2.18\times10^{-3}\text{ rad (7.5 arc min)}$$

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.

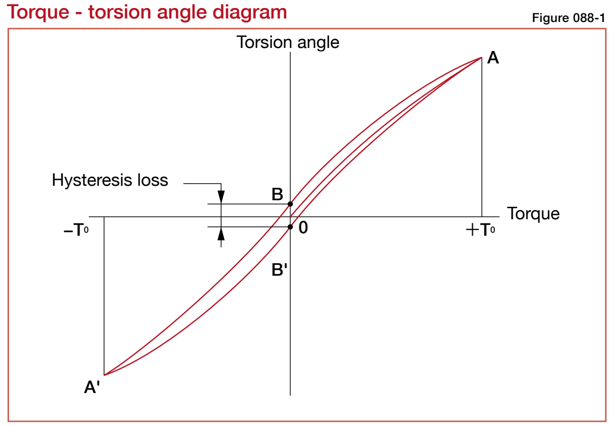
■ Hysteresis loss

As shown in Figure 088-1, 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 appropriate page for each model series for the hysteresis loss value.

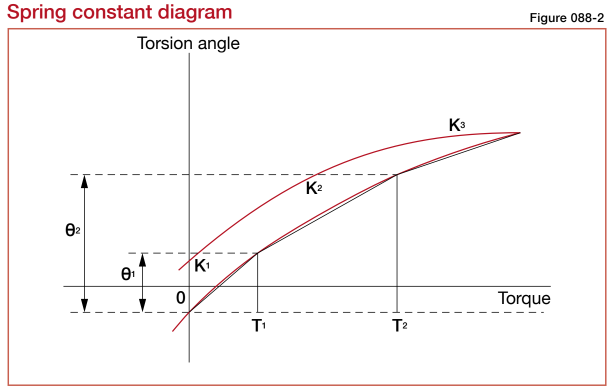
Torque - torsion angle diagram

Figure 088-1



Spring constant diagram

Figure 088-2



■ Backlash

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® gearheads 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.

Vibration

The primary frequency of the transmission error of the HarmonicDrive® gear may rarely 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 089-1

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

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

How to the calculate resonant frequency of the system

Formula 089-2

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

Formula variables

Table 089-1

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

Efficiency

The efficiency will vary depending on the following factors:

- Reduction ratio
- Input speed
- Load torque
- Temperature
- Lubrication condition (Type of lubricant and the quantity)

CSG-GH Series HarmonicDrive® High-Performance Gearhead for Servomotors

CSF-GH Series HarmonicDrive® High-Performance Gearhead for Servomotors

Product Sizing & Selection

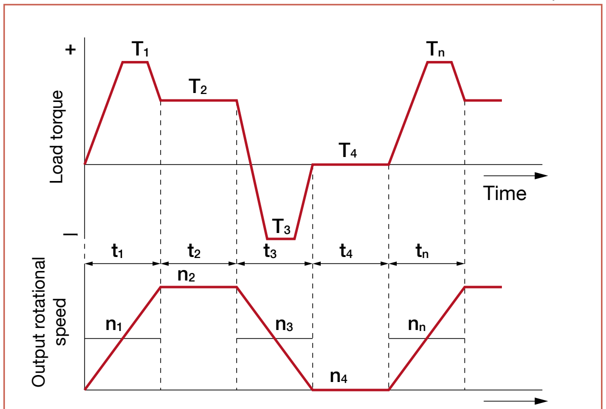
In general, a servo system rarely operates at a continuous load and speed. The input rotational speed, load torque change and comparatively large torque are applied at start and stop. Unexpected impact torque may be applied.
These fluctuating load torques should be converted to the average load torque 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.

(Note) If HarmonicDrive® CSG-GH series is installed with the output shaft facing downward (motor faces upward) and continuously operated in one direction under the constant load state, lubrication failure may occur. In this case, please contact us for details.

■ Checking the load torque pattern

Review the load torque pattern. Check the specifications shown in the figure below.

Graph 090-1



* n_1, n_2 and n_n indicate the average values.

Obtain the value of each load torque pattern.

Load torque	T_n (Nm)
Time	t_n (sec)
Output rotational speed	n_n (rpm)
<Normal operation pattern>	
Starting	T_1, t_1, n_1
Steady operation	T_2, t_2, n_2
Stopping (slowing)	T_3, t_3, n_3
Idle	T_4, t_4, n_4
<Maximum rotational speed>	
Max. output speed	no ***max***
Max. input rotational speed (Restricted by motors)	ni ***max***
<Impact 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 load torque pattern: 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 ratings 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 ratings.

Ni ***av*** ≦ Limit for average speed (rpm)
Ni ***max*** ≦ Limit for maximum speed (rpm)

NG / OK

Check whether T_1 and T_3 are equal to or less than the repeated peak torque specification.

NG / OK

Check whether T_s is equal to or less than the the momentary peak torque specification.

NG / OK

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

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

NG / OK

Calculate the lifetime.

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

Check whether the calculated lifetime is equal to or more than the life of the wave generator (see Page 086).

NG / OK

The model number is confirmed.

Review the operation conditions and model number

Example of model number selection

Value of each load torque pattern.

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

<Normal operation pattern>

Starting	T_1 = 400 Nm, t_1 = 0.3 sec, n_1 = 7 rpm
Steady operation	T_2 = 320 Nm, t_2 = 3 sec, n_2 = 14 rpm
Stopping (slowing)	T_3 = 200 Nm, t_3 = 0.4 sec, n_3 = 7 rpm
Idle	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	ni ***max*** = 1800 rpm
(Restricted by motors)	

<Impact 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 applied on the output side of the Harmonic Drive® gear from the load torque pattern: 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 ≦ 620 Nm
(Limit for average torque for model number CSF-45-120-GH: See the ratings on Page 77.)
Thus, **CSF-45-120-GH** 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 ratings.

Ni ***av*** = 1440 rpm ≦ 3000 rpm (Max average input speed of size 45)
Ni ***max*** = 1680 rpm ≦ 3800 rpm (Max input speed of size 45)

NG

OK

Check whether T_1 and T_3 are equal to or less than the repeated peak torque specification.

T_1 = 400 Nm ≦ 823 Nm (Limit of repeated peak torque of size 45)
T_3 = 200 Nm ≦ 823 Nm (Limit of repeated peak torque of size 45)

NG

OK

Check whether Ts is equal to or less than the momentary peak torque specification.

T_s = 500 Nm ≦ 1760 Nm (Limit for momentary torque of size 45)

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.

$$L_{10} = 7000\cdot\left(\frac{402\text{ Nm}}{319\text{ Nm}}\right)^3\cdot\left(\frac{2000\text{ rpm}}{1440\text{ rpm}}\right)\text{(hours)}$$

Check whether the calculated life is equal to or more than the life of the wave generator (see Page 86).
L_{10} =19,457 hours ≧ 7000 (life of the wave generator: L_{10})

NG

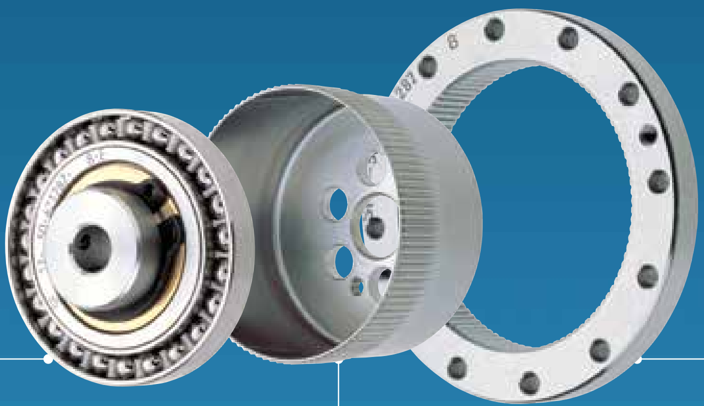
OK

The selection of model number **CSF-45-120-GH** is confirmed from the above calculations.

Review the operation conditions and model number

HarmonicDrive® CSG/CSF-GH Series

HarmonicDrive® gearing has a unique operating principle which utilizes the elastic mechanics of metals. This precision gear reducer consists of only 3 basic parts and provides high accuracy and repeatability.



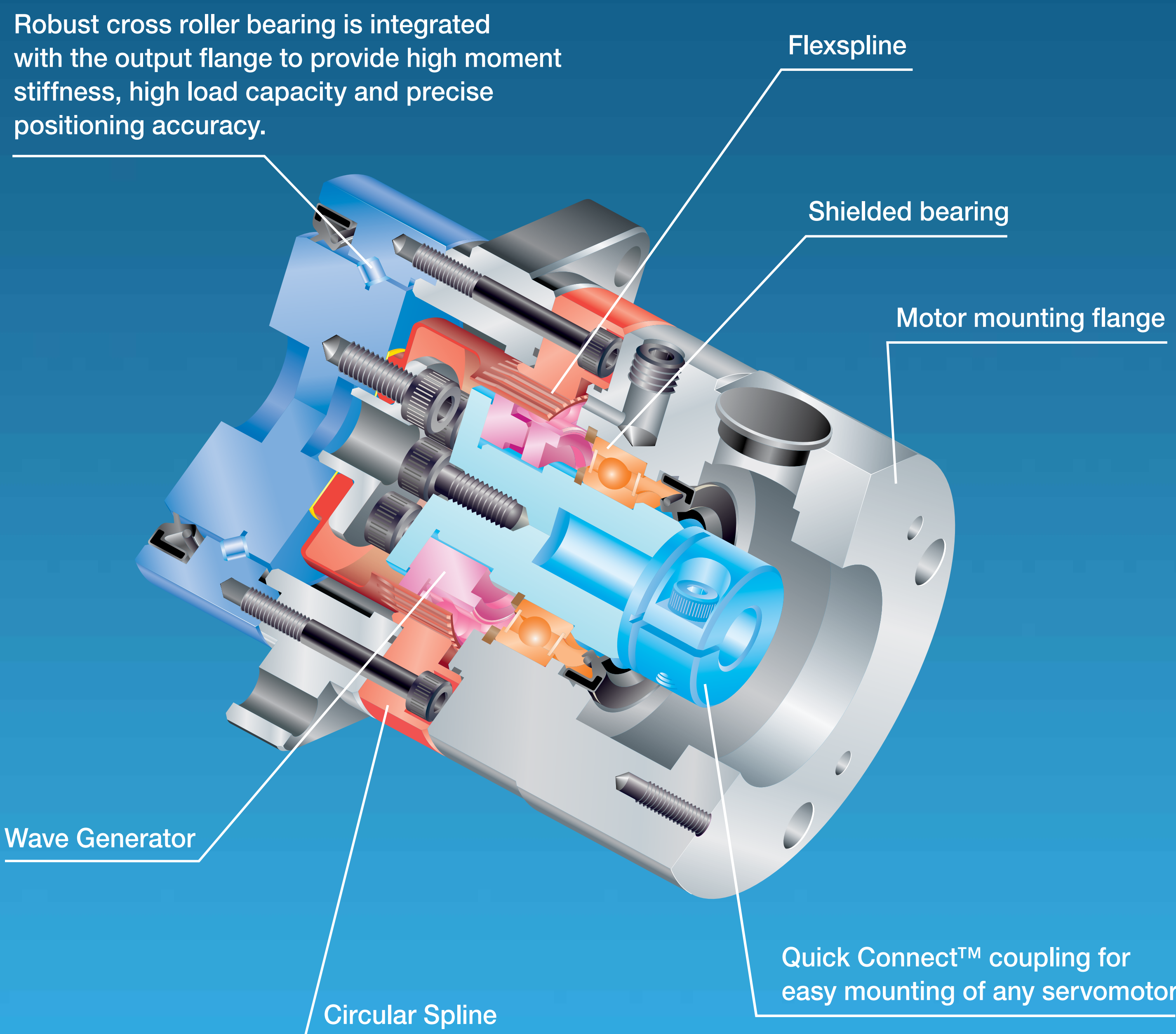
Wave Generator
The Wave Generator is a thin raced ball bearing fitted onto an elliptical shaped hub. The inner race of the bearing is fixed to the cam and the outer race is elastically deformed into an ellipse via the balls. The Wave Generator is usually mounted onto the input shaft.

Flexspline
The Flexspline is a non-rigid, thin cylindrical cup with external teeth. 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, engaging the teeth of the Flexspline across the major axis of the Wave Generator. The Circular Spline has two more teeth than the Flexspline and is generally mounted to the housing.

The greatest benefit of HarmonicDrive® gearing is the weight and space savings compared to other gearheads because it consists of only three basic parts. Since many teeth are engaged simultaneously, it can transmit higher torque and provides high accuracy. A unique S tooth profile significantly improves torque capacity, life and torsional stiffness of the gear.

- **Zero-backlash**
- **High Reduction ratios, 50:1 to 160:1 in a single stage**
- **High precision positioning (repeatability ±4 to ±10 arc-sec)**
- **High capacity cross roller output bearing**
- **High torque capacity**


Robust cross roller bearing is integrated with the output flange to provide high moment stiffness, high load capacity and precise positioning accuracy.
Flexspline
Shielded bearing
Motor mounting flange
Wave Generator
Circular Spline
Quick Connect™ coupling for easy mounting of any servomotor

Output Bearing Specifications and Checking Procedure

A precision cross roller bearing supports the external load (output flange).
Check the maximum load, moment load, life of the bearing and static safety coefficient to maximize performance.

Checking procedure

(1) Checking the maximum load moment load (M*max*)

Obtain the maximum load moment load (M*max*). → Maximum load moment load (M*max*) ≦ Permissible moment (Mc)

(2) Checking the life

Obtain the average radial load (Fr*av*) and the average axial load (Fa*av*). → Obtain the radial load coefficient (X) and the axial load coefficient (Y). → Calculate the life and check it.

(3) Checking the static safety coefficient

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

Specification of output bearing

CSG-GH/CSF-GH Series Table 130-1 indicates the specifications for cross roller bearing.

Table 130-1

Size	Pitch circle	Offset amount	Basic load rating				Allowable moment load Mc*3		Moment stiffness Km*4		Allowable radial load*5	Allowable axial load*5
	dp	R	Basic dynamic load rating C*1		Basic static load rating Co*2				$\times10^4$ Nm/rad	kgfm/arc min		
	m	m	N	kgf	N	kgf	Nm	kgfm			N	N
14	0.0405	0.011	5110	521	7060	720	27	2.76	3.0	0.89	732	1093
20	0.064	0.0115	10600	1082	17300	1765	145	14.8	17	5.0	1519	2267
32	0.085	0.014	20500	2092	32800	3347	258	26.3	42	12	2938	4385
45	0.123	0.019	41600	4245	76000	7755	797	81.3	100	30	5962	8899
65	0.170	0.0225	81600	8327	149000	15204	2156	220	323	96	11693	17454

*1 The basic dynamic load rating means a certain static radial load so that the basic dynamic rated life of the roller bearing is a million rotations.
*2 The basic static load rating means a static load that gives a certain level of contact stress (4kN/mm^2) in the center of the contact area between rolling element receiving the maximum load and orbit.
*3 The allowable moment load is a maximum moment load applied to the bearing. Within the allowable range, basic performance is maintained and the bearing is operable. Check the bearing life based on the calculations shown on the next page.
*4 The value of the moment stiffness is the average value.
*5 The allowable radial load and allowable axial load are the values that satisfy the life of a speed reducer when a pure radial load or an axial load applies to the main bearing. (Lr + R = 0 mm for radial load and La = 0 mm for axial load) If a compound load applies, refer to the calculations shown on the next page.

How to calculate the maximum load moment load

HPGP **HPG** **CSG-GH** **CSF-GH** **HPF**

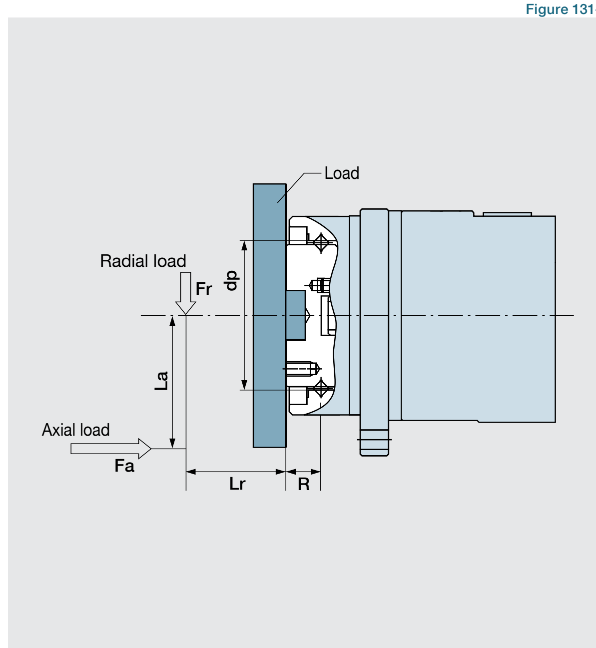
Maximum load moment load (M_{max}) is obtained as follows.
Make sure that $M_{max} \leqq Mc$.

Formula 131-1

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

Fr_{max}	Max. radial load	N (kgf)	See Fig. 131-1.
Fa_{max}	Max. axial load	N (kgf)	See Fig. 131-1.
Lr, La	—	m	See Fig. 131-1.
R	Offset amount	m	See Fig. 131-1. See "Specification of main bearing" of each series

Figure 131-1



How to calculate the radial load coefficient and the axial load coefficient

HPGP **HPG** **CSG-GH** **CSF-GH** **HPF**

The radial load coefficient (X) and the axial load coefficient (Y)

Formula 131-2

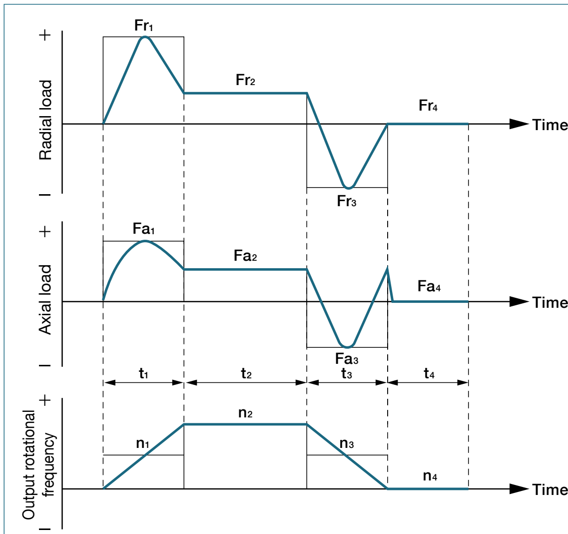
Formula	X	Y
$\dfrac{Fa_{av}}{Fr_{av}+2(Fr_{av}(Lr+R)+Fa_{av} \cdot La)/dp} \leqq 1.5$	1	0.45
$\dfrac{Fa_{av}}{Fr_{av}+2(Fr_{av}(Lr+R)+Fa_{av} \cdot La)/dp} > 1.5$	0.67	0.67

Fr_{av}	Average radial load	N (kgf)	See "How to obtain the average load."
Fa_{av}	Average axial load	N (kgf)	See "How to obtain the average load."
Lr, La	—	m	See Fig. 131-1.
R	Offset amount	m	See Fig. 131-1. See "Output Shaft Bearing Specifications" of each series.
dp	Circlar pitch of roller	m	See Fig. 131-1. See "Output Shaft Bearing Specifications" of each series.

How to calculate the average load (Average radial load, average axial load, average output rotational frequency)

HPGP **HPG** **CSG-GH** **CSF-GH** **HPF**

If the radial load and the axial load fluctuate, they should be converted into the average load to check the life of the cross roller bearing.



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

Formula 131-3

$$Fr_{av} = \sqrt[10/3]{\frac{n_1t_1(|Fr_1|)^{10/3} + n_2t_2(|Fr_2|)^{10/3} \cdots n_nt_n(|Fr_n|)^{10/3}}{n_1t_1+n_2t_2+\cdots+n_nt_n}}$$

Note that the maximum axial load within the t_1 section is Fr_1 and the maximum axial load within the t_3 section is Fr_3.

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

Formula 131-4

$$Fa_{av} = \sqrt[10/3]{\frac{n_1t_1(|Fa_1|)^{10/3} + n_2t_2(|Fa_2|)^{10/3} \cdots n_nt_n(|Fa_n|)^{10/3}}{n_1t_1+n_2t_2+\cdots+n_nt_n}}$$

Note that the maximum axial load within the t_1 section is Fr_1 and the maximum axial load within the t_3 section is Fr_3.

How to obtain the average output rotational frequency (N_{av})

Formula 131-5

$$N_{av} = \frac{n_1t_1+n_2t_2+\cdots+n_nt_n}{t_1+t_2+\cdots+t_n}$$

How to calculate the life HPGP HPG CSG-GH CSF-GH HPF

Calculate the life of the cross roller bearing using Formula 132-1. You can obtain the dynamic equivalent radial load (Pc) using Formula 132-2.

Formula 132-1

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

L_{10}	Life	hour	—
N_{av}	Ave. output speed	rpm	See “How to calculate the ave. load.”
C	Basic dynamic rated load	N (kgf)	See “Output Bearing Specs.”
Pc	Dynamic equi. radial load	N (kgf)	See Formula 132-2.
fw	Load coefficient	—	See Table 132-1.

Formula 132-2

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

Fr_{av}	Average radial load	N (kgf)	See "How to calculate the ave. load."
Fa_{av}	Average axial load	N (kgf)	
dp	Circlar pitch of roller	m	See “Output Bearing Specs.”
X	Radial load coefficient	-	See “How to calculate the radial load coefficient and the axial load coefficient.”
Y	Axial load coefficient	-	
Lr, La	—	m	See Figure 131-1. See “External load influence diagram.”
R	Offset amount	m	See Figure 131-1. See “External load influence diagram” and “Output Bearing Specs” of each series.

Load coefficient

Table 132-1

Load status	fw
During smooth operation without impact or vibration	1 to 1.2
During normal operation	1.2 to 1.5
During operation with impact or vibration	1.5 to 3

How to calculate the life during oscillating movement HPGP HPG CSG-GH CSF-GH HPF

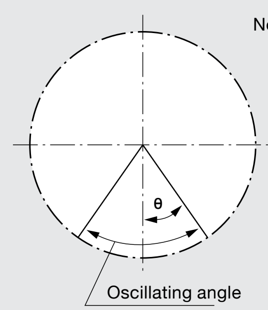
Calculate the life of the cross roller bearing during oscillating movement by Formula 132-3.

Formula 132-3

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

Loc	Rated life under oscillating movement	hour	-
n1	No. of reciprocating oscillation per min.	cpm	-
C	Basic dynamic rated load	N (kgf)	See “Output Bearing Specs.”
Pc	Dynamic equivalent radial load	N (kgf)	See Formula 132-2.
fw	Load coefficient	—	See Table 132-1.
θ	Oscillating angle /2	Deg.	See Figure 132-1.

Figure 132-1



Note: When the oscillating angle is small (5° or less), it is difficult to generate an oil film on the contact surface of the orbit ring, and the rolling element and fretting may be generated. Contact us if this happens.

Note When it is used for a long time while the rotation speed of the output shaft is in the ultra-low operation range (0.02rpm or less), the lubrication of the bearing becomes insufficient, resulting in deterioration of the bearing or increased load in the driving side. When using it in the ultra-low operation range, contact us.

How to calculate the static safety coefficient HPGP HPG CSG-GH CSF-GH HPF

In general, the basic static rated load (Co) is considered to be the permissible limit of the static equivalent load. However, obtain the limit based on the operating and required conditions. Calculate the static safety coefficient (fs) of the cross roller bearing using Formula 132-4.
General values under the operating condition are shown in Table 132-2. You can calculate the static equivalent radial load (Po) using Formula 132-5.

Formula 132-4

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

Co	Basic static rated load	N (kgf)	See “Output Bearing Specs.”
Po	Static equivalent radial load	N (kgf)	See Formula 132-5.

Formula 132-5

$$Po=Fr_{max}+\frac{2M_{max}}{dp}+0.44Fa_{max}$$

Fr_{max}	Max. radial load	N (kgf)	See “How to calculate the max. load moment load.”
Fa_{max}	Max. axial load	N (kgf)	
M_{max}	Max. load moment load	Nm (kgfm)	
dp	Circlar pitch of roller	m	See “Output Bearing Specs” of each series.

Static safety coefficient

Table 132-2

Load status	fs
When high rotation precision is required	≧3
When impact or vibration is expected	≧2
Under normal operating condition	≧1.5

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