Engineering Data

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Reducer for precision control
HarmonicDrive® General catalog
2021/08/03 Update
№.2107-21R-HD-E

On the tooth profile

■Mechanism of IH tooth profile

The IH tooth profile has been devised for HarmonicDrive® with a unique mechanism by pursuing the optimum tooth profile. It has a special curved surface unique to the IH 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 circle on the bottom. The figure shows how the teeth of flexspline that repeat elastic deformation move against the teeth of the fixed circular spline.

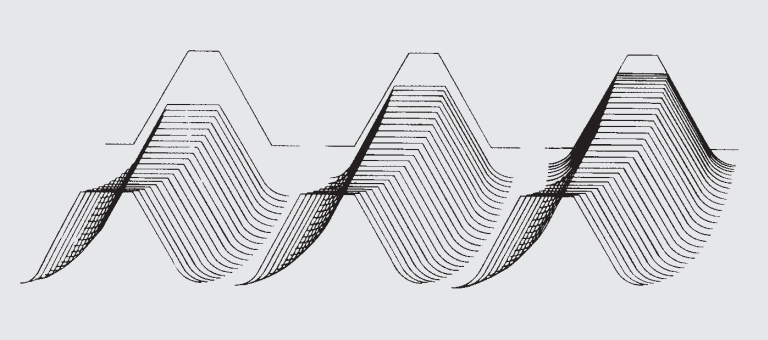
The teeth maintain contact for some time from the beginning of engagement. The number of simultaneously engaged teeth reaches 30% of the whole number of teeth by continuous contact with these teeth. HarmonicDrive® that has implemented the IH tooth profile maintains the smoothness of the conventional mechanism using the involute tooth profile, and has achieved dramatic technological innovation in precision, intensity, rigidity and life.

*Patented

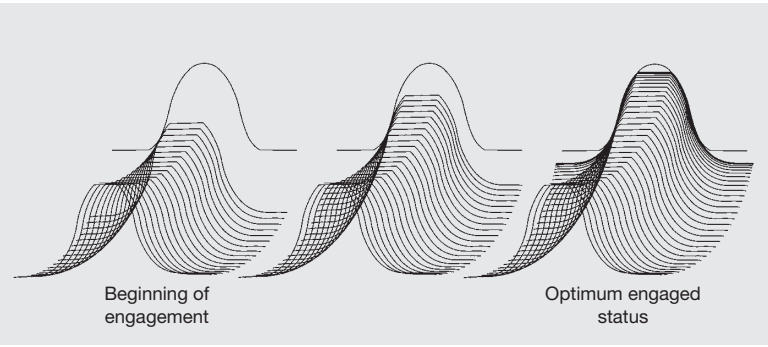
Engaged route of teeth

Fig. 009-1

Conventional tooth profile

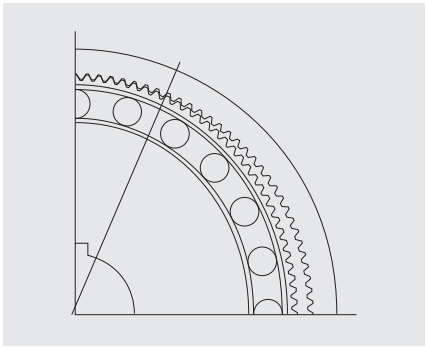


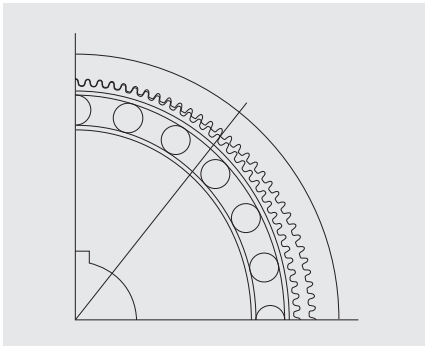
IH tooth profile



Engaged area of teeth

Fig. 009-2





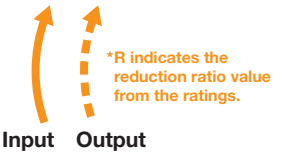
Rotational direction and reduction ratio

Cup-type

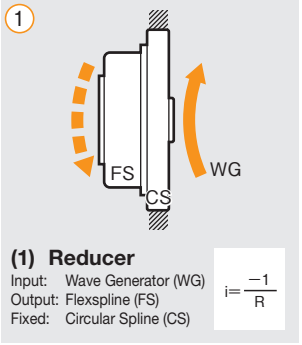
The rotational direction and reduction ratio of the cup-type HarmonicDrive® are shown below.
The cup-type HarmonicDrive® is composed of the following series.
CSG, CSF, CSD, CSF-mini, CSF-GH

■Rotational direction

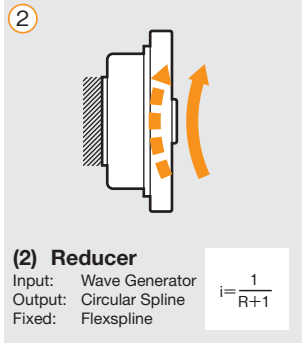
Fig. 010-1



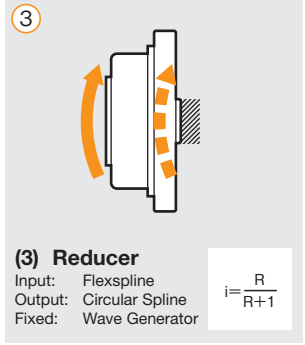
(Note) Contact us if you use the product as Accelerator (5) and (6).



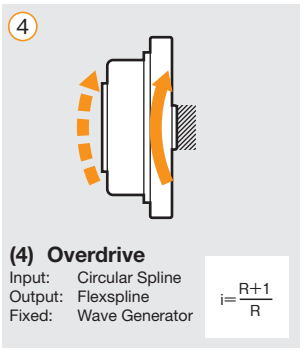
(1) Reducer
Input: Wave Generator (WG)
Output: Flexspline (FS)
Fixed: Circular Spline (CS)
$i=\frac{-1}{R}$



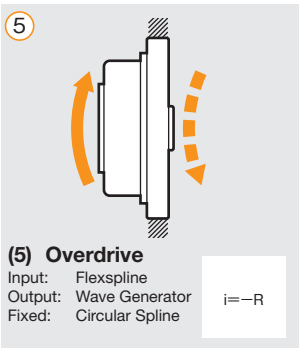
(2) Reducer
Input: Wave Generator
Output: Circular Spline
Fixed: Flexspline
$i=\frac{1}{R+1}$



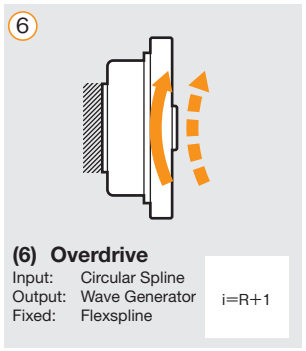
(3) Reducer
Input: Flexspline
Output: Circular Spline
Fixed: Wave Generator
$i=\frac{R}{R+1}$



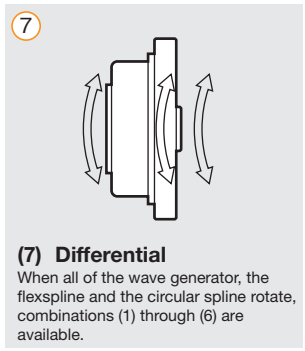
(4) Overdrive
Input: Circular Spline
Output: Flexspline
Fixed: Wave Generator
$i=\frac{R+1}{R}$



(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.

* Using as an overdrive will cause torque pulsation. Contact us for details.

■Reduction ratio

The reduction ratio of HarmonicDrive® 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.

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

Silk hat type

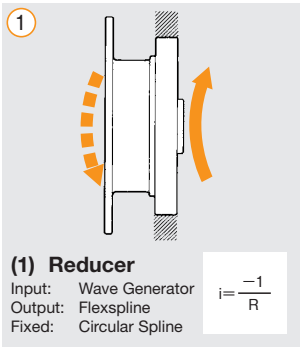
The rotational direction and reduction ratio of the silk hat type HarmonicDrive® are shown below.
The silk hat type HarmonicDrive® is composed of the following series.
SHG, SHF, SHD

■Rotational direction

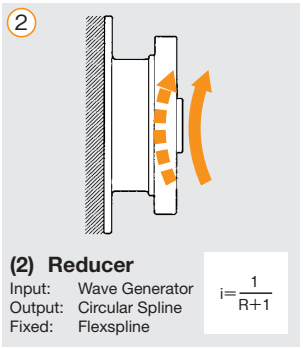
Fig. 011-1



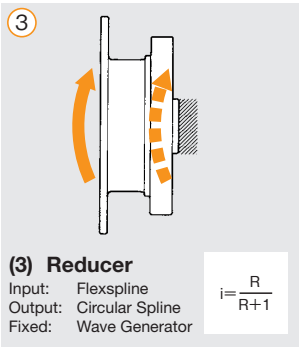
(Note) Contact us if you use the product as an overdrive of (5) or (6).



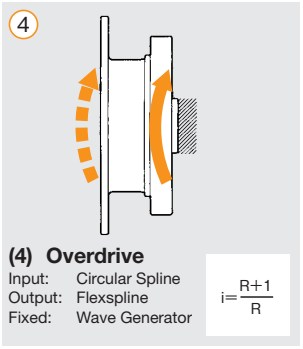
(1) Reducer
Input: Wave Generator
Output: Flexspline
Fixed: Circular Spline
$i=\frac{-1}{R}$



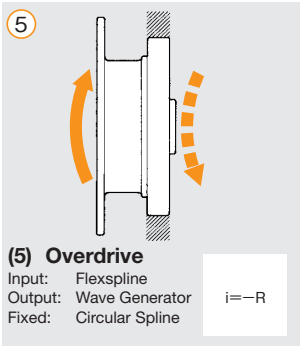
(2) Reducer
Input: Wave Generator
Output: Circular Spline
Fixed: Flexspline
$i=\frac{1}{R+1}$



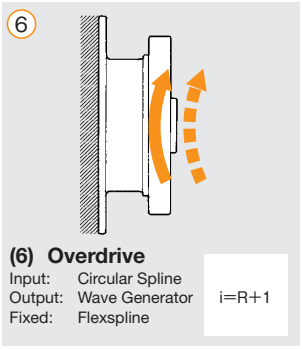
(3) Reducer
Input: Flexspline
Output: Circular Spline
Fixed: Wave Generator
$i=\frac{R}{R+1}$



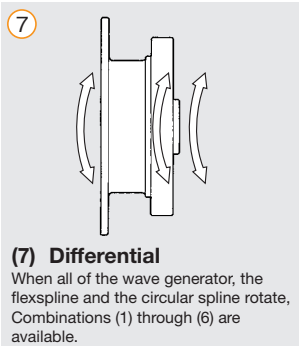
(4) Overdrive
Input: Circular Spline
Output: Flexspline
Fixed: Wave Generator
$i=\frac{R+1}{R}$



(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.

* Using as an overdrive will cause torque pulsation. Contact us for details.

■Reduction ratio

The reduction ratio of HarmonicDrive® 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.

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

Pancake type

See the corresponding pages of each series for the rotational direction and reduction ratio of the pancake type HarmonicDrive®.
The pancake type HarmonicDrive® is composed of the following series.
FB and FR

Terms on the rated table

The ratings of HarmonicDrive® consist of 6 values and inertia moment.
See the corresponding pages of each series for values from the ratings.

■Rated torque

This indicates the permissible continuous load torque when the input rotational speed is 2000 r/min.

■Permissible peak torque for start and stop (see Graph 012-1)

Load larger than the steady torque is applied to HarmonicDrive® by the load inertia moment for start and stop. Values from the ratings show the acceptable value at peak torque.

■Permissible maximum value at average load torque

When the load torque and input rotational speed change, the average value of the load torque needs to be obtained. Values from the ratings show the acceptable value at average load torque. When the average load torque (calculation formula: Page 014) exceeds the value from the ratings, generation of heat degrades the lubricant earlier and accelerates the abrasion of the teeth. Due care should be taken.

■Permissible maximum momentary torque (see Graph 012-1)

Unexpected impact torque may be applied from the exterior except regular-load torque and load torque for start and stop.
The maximum value of the impact torque must not exceed the maximum momentary torque in the rating table.
The frequency of applying the impact torque is limited. See “On intensity” and “On life” section.
Also, if there is a possibility that this torque is applied, see the “Tightening the Flexspline bolt.” page in the manual for each series.

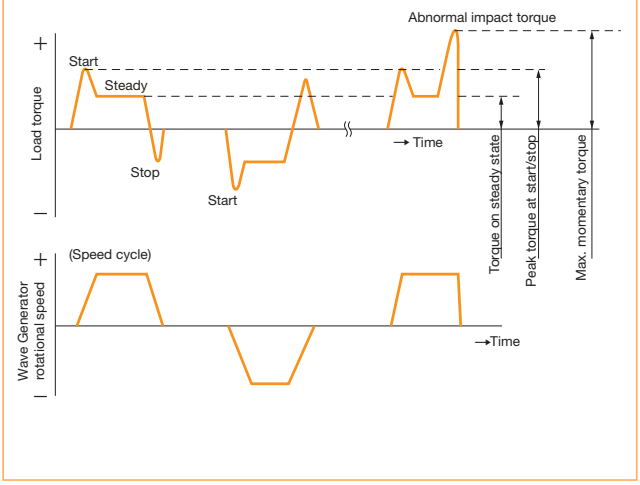
■Permissible maximum input rotational speed, permissible average input rotational speed

Use the input rotational speed within the limit of acceptable values shown from the ratings (calculation formula of the average input rotational speed: Page 014).

■Inertia moment

The inertia moment on the axles of the wave generators of each model is indicated.

Example of load torque pattern — Graph 012-1



On life

■Life of the wave generator

The life of HarmonicDrive® is determined by the life of the wave generator bearing, and you can calculate this by the rotational speed and the load torque just as with a general ball bearing.

Table 012-1

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

* Life is based on the rated rotational speed and rated torque from the ratings.

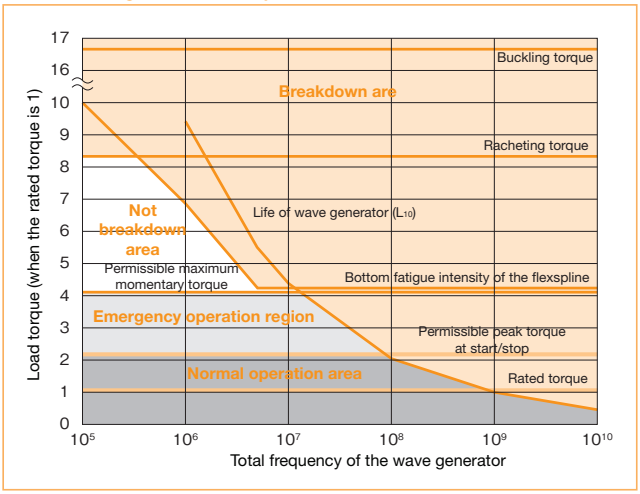
Calculation formula for life (Lh) by actual operation condition — Formula 012-1

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

Table 012-2

Ln	Life of L_{10} or L_{50}
Tr	Rated torque
Nr	Rated rotational speed
Tav	Average load torque on the output side (calculation formula: Page 014)
Nav	Average input rotational speed (calculation formula: Page 014)

Relational diagram of intensity and life of HarmonicDrive® — Graph 012-2



(Note)
Use HarmonicDrive® within the range of “Normal operation area.” Using it beyond “Emergency operation area” may result in damaging HarmonicDrive® earlier than usual.
* Lubricant life such as for abrasion on the tooth surface is not taken into consideration in the graph described above.
* Use the graph above as reference values.

On intensity

■Intensity of flexspline

As flexspline repeats elastic deformation, the transmission torque of HarmonicDrive® is calculated based on the fatigue strength of the bottom of the flexspline. Values of the rated torque and permissible peak torque for start and stop are those within the fatigue limit of the bottom of the flexspline.
If impact torque that exceeds the peak torque for start and stop is applied, it could generate fatigue fracture. Therefore, the number of applications of impact torque is limited to prevent possible fatigue fracture. However, the maximum value of the impact torque can not exceed the permissible maximum momentary torque.

Restriction on the bending frequency of the flexspline by the rotation of the wave generator while the impact torque is applied: 1.0×10^4 (frequency)

You can calculate the permissible frequency of impact torques from this restriction on the bending frequency.

Calculation formula — Formula 013-1

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

Table 013-1

Permissible frequency	N frequency
Time that impact torque is applied	t sec
Rotational speed of the wave generator	n r/min
The flexspline bends two times by one cycle of the wave generator.	

Caution	If impact torque exceeds the permissible frequency, it may cause fatigue fracture to the flexspline.

■Buckling torque

When excess torque is applied to the flexspline (output) with the wave generator fixed, the flexspline causes elastic deformation, buckles on the body before long and will be destroyed. The torque at the time is called buckling torque.
* See the corresponding pages of each series for buckling torque values.

Warning	When the flexspline buckles, HarmonicDrive® will be put out of commission. Therefore, adequate care should be exercised.

■Ratcheting torque

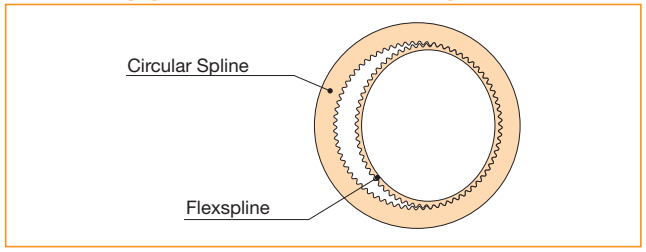
When excess impact torque is applied during operation, the engagement of the teeth between the circular spline and the flexspline may be put momentarily out of alignment instead of damaging the flexspline. This phenomenon is called “ratcheting,” and the torque is called “ratcheting torque” (see values on the corresponding page of each series). Operating the drive without fixing ratcheting will result in earlier abrasion of the teeth and shorter life of the wave generator bearing due to the effect of the grinding powder generated by ratcheting.

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

Caution	When ratcheting is caused, the teeth may not be correctly engaged and become out of alignment as shown in Figure 013-1. As operating the drive in this condition will generate vibration and damage the flexspline, adequate care should be exercised.

Caution	Once ratcheting is caused, the tips of the teeth are worn and the torque value generated by ratcheting will be lowered. Pay due attention to this point as well.

When the engagement of the teeth is out of alignment — Fig. 013-1



This condition is called “dedoi-dal”.

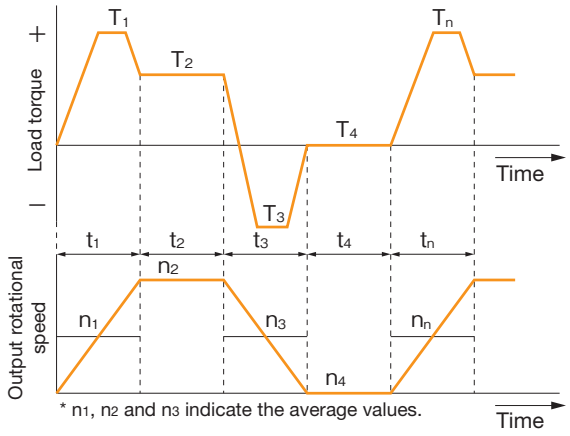
Model number selection

In general, the servo system is rarely in a continuous constant load state. 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 in selecting a model number.
As an accurate cross roller bearing is built in the direct external load support (output flange) of the unit type, the maximum moment load, life of the cross roller bearing and the static safety coefficient should also be checked (see "Checking the main roller bearing" on Page 030).

■Checking the load torque pattern

First, you need to look at the picture of the load torque pattern. Check the specifications shown in the figure below.

Graph 014-1



Obtain the value of each load torque pattern.

Load torque	T_n (N·m)
Time	t_n (sec)
Output rotational speed	n_n (r/min)

<Normal operation pattern>

Starting time	T_1, t_1, n_1
Steady operation time	T_2, t_2, n_2
Stopping (slowing) time	T_3, t_3, n_3
Break time	T_4, t_4, n_4

<Maximum rotational speed>

Max. output rotational 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 of model number selection

Select a model number according to the following flowchart.
If you find a value exceeding that from the ratings, you should review it with the upper-level model number or consider reduction of conditions including the load torque.

Review of the operation conditions and model number

Calculate the average load torque applied on the output side of HarmonicDrive® from the load torque pattern: T_{av} (N·m).

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

Select a model number temporarily with the following conditions.
T_{av} ≦ Permissible maximum value of the average load torque
(See the ratings of each series).

Calculate the average output rotational speed: no *av* (r/min)

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

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

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

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

ni *av* = no *av* · R

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

ni *max* = no *max* · R

NG — Check whether the temporarily selected model number satisfies the following condition from the ratings.
Ni *av* ≦ Permissible average input rotational speed (r/min)
Ni *max* ≦ Permissible max. input rotational speed (r/min)

OK

NG — Check whether T_1 and T_3 are equal to or less than the permissible peak torque (N·m) value at start and stop from the ratings.

OK

NG — Check whether T_s is equal to or less than the permissible maximum momentary torque (N·m) value from the ratings.

OK

NG — Calculate (Ns) the permissible number of times from output rotational speed n_s and time t_s when the impact torque is applied, and check whether it satisfies the usage conditions.

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

OK

Calculate the lifetime.

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

NG — Check whether the calculated lifetime is equal to or more than the life of the wave generator (see Page 013).

OK

The model number is determined.

■Example of model number selection

Value of each load torque pattern.

Load torque	T_n(N·m)
Time	t_n(sec)
Output rotational speed	n_n(r/min)

<Normal operation pattern>

Starting time	T_1 = 400 N·m,	t_1 = 0.3sec,	n_1 = 7r/min
Steady operation time	T_2 = 320 N·m,	t_2 = 3sec,	n_2 = 14r/min
Stopping (slowing) time	T_3 = 200 N·m,	t_3 = 0.4sec,	n_3 = 7r/min
Break time	T_4 = 0 N·m,	t_4 = 0.2sec,	n_4 = 0r/min

<Maximum rotational speed>

Max. output rotational speed	no $_{max}$ = 14 r/min
Max. input rotational speed (Restricted by motors)	ni $_{max}$ = 1800 r/min

<Impact torque>

When impact torque is applied	T_s = 500N·m, t_s = 0.15sec, n_s = 14r/min

<Required life>

L_{10} = 7000 (hours)

Calculate the average load torque applied on the output side of HarmonicDrive® from the load torque pattern: T_{av} (N·m).

$$T_{av} = \sqrt[3]{\frac{7r/min \cdot 0.3sec \cdot |400N\cdot m|^3 + 14r/min \cdot 3sec \cdot |320N\cdot m|^3 + 7r/min \cdot 0.4sec \cdot |200N\cdot m|^3}{7r/min \cdot 0.3sec + 14r/min \cdot 3sec + 7r/min \cdot 0.4sec}}$$

Select a model number temporarily with the following conditions. T_{av} = 319 N·m ≦ 451 N·m
(Permissible maximum value of the average load torque for model number CSF-40-120: See the ratings on Page 039.)
Thus, CSF-40-120-2A-GR is temporarily selected.

Calculate the average output rotational speed: no $_{av}$ (r/min)

$$no_{av} = \frac{7r/min \cdot 0.3sec + 14r/min \cdot 3sec + 7r/min \cdot 0.4sec}{0.3sec + 3sec + 0.4sec + 0.2sec} = 12r/min$$

Obtain the reduction ratio (R).

$$\frac{1800r/min}{14r/min} = 128.6 \geqq 120$$

Calculate the average input rotational speed from the average output rotational speed (no $_{av}$) and the reduction ratio (R): ni $_{av}$ (r/min)

$$ni_{av} = 12r/min \cdot 120 = 1440r/min$$

Calculate the maximum input rotational speed from the maximum output rotational speed (no $_{max}$) and the reduction ratio (R): ni $_{max}$ (r/min)

$$ni_{max} = 14r/min \cdot 120 = 1680r/min$$

Check whether the temporarily selected model number satisfies the following condition from the ratings.

Ni $_{av}$ = 1440 r/min ≦ 3600 r/min (Permissible average input rotational speed of model No. 40)
Ni $_{max}$ = 1680 r/min ≦ 5600 r/min (Permissible max. input rotational speed of model No. 40)

NG

OK

Check whether T_1 and T_3 are equal to or less than the permissible peak torque (N·m) value at start and stop from the ratings.

T_1 = 400 N·m ≦ 617 N·m (Permissible peak torque at start and stop of model number 40)
T_3 = 200 N·m ≦ 617 N·m (Permissible peak torque at start and stop of model number 40)

NG

OK

Check whether T_s is equal to or less than the permissible maximum momentary torque (N·m) value from the ratings.

T_s = 500 N·m ≦ 1180 N·m (Permissible maximum momentary torque of model number 40)

NG

OK

Calculate the permissible number of times from output rotational speed n_s and time t_s when the impact torque is applied, and check whether it satisfies the usage conditions.

$$N_S = \frac{10^4}{2 \cdot \frac{14r/min \cdot 120}{60} \cdot 0.15\ sec} = 1190 \leqq 1.0\times10^4 \text{ (times)}$$

NG

OK

Calculate the life.

$$L_{10} = 7000 \cdot \left(\frac{294N\cdot m^3}{319N\cdot m}\right) \cdot \left(\frac{2000r/min}{1440r/min}\right) \text{(hours)}$$

Check whether the calculated life is equal to or more than the life of the wave generator (see Page 012).
L_{10} =7610 hours ≧ 7000 (life of the wave generator: L_{10})

NG

OK

Model number CSF-40-120-2A-GR is determined from the result described above.

Review of the operation conditions and model number

On lubricant

Grease lubricant and oil lubricant are available for lubricating the component type. Grease lubricant is standard for lubricating the unit type and the gear head type. You do not need to apply grease during assembly as the product is lubricated and shipped.
See Page 019 for using lubricant beyond the temperature range described in the right-hand figure.

* Contact the sales division 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 range of the operating environment

Table 016-2

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

* Keep the hot section up to 40°C above the ambient temperature.

Grease lubricant

■Types of lubricant

Harmonic grease® SK-1A

This has been developed as grease exclusively for HarmonicDrive® and is excellent in durability and efficiency compared to commercial general-purpose grease.

Harmonic grease® SK-2

This has been developed exclusively for the compact HarmonicDrive® and is excellent in smoothness during wave generator rotation by liquefying extreme-pressure additive.

Harmonic grease® 4B No.2

This has been developed exclusively for the CSF and CSG series, has the fluid characteristic suited to longer operating life and is used for a wide temperature range.

(Note) 1. A seal mechanism is required for grease lubrication. Take the following actions for the rotor and the surface-contacting joints. In particular, a strong seal mechanism is required in using Harmonic grease® 4B No.2.
Rotor: Use an oil seal with a spring.
Parts-contacting joints: Use an O-ring or sealing agent paying attention to the warp and flaw on the plain surface.
2. Harmonic grease® 4B No.2 becomes soft at the portion (near the wave generator) that is subject to shear. Although the consistency varies depending on the operating conditions, it is about JIS consistency No.0 up to 00.

Table 016-3

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

■Compatible grease by model

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

Compatible grease for a reduction ratio of 30

Table 016-5

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

Compatible grease for a reduction ratio of 50 or more

Table 016-6

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

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

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

Grease specification

Table 016-4

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

Grease characteristics

Table 016-7

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

Excellent ◎
Appropriate ○
Doubtful △

■When to replace grease

Abrasion of the sliding parts of HarmonicDrive® is influenced by grease performance.
Grease performance changes by temperature and deteriorates rapidly as the temperature rises. Therefore, the grease needs to be replaced earlier than usual. Graph 017-1 below indicates the time to replace the grease from the relation between the grease temperature and the total number of rotations when the average load torque is equal to or less than the rated torque.
Obtain the time to replace the grease from the following calculation formula when the average load torque exceeds the rated torque.

Calculation formula when the average load torque exceeds the rated torque

Formula 017-1

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

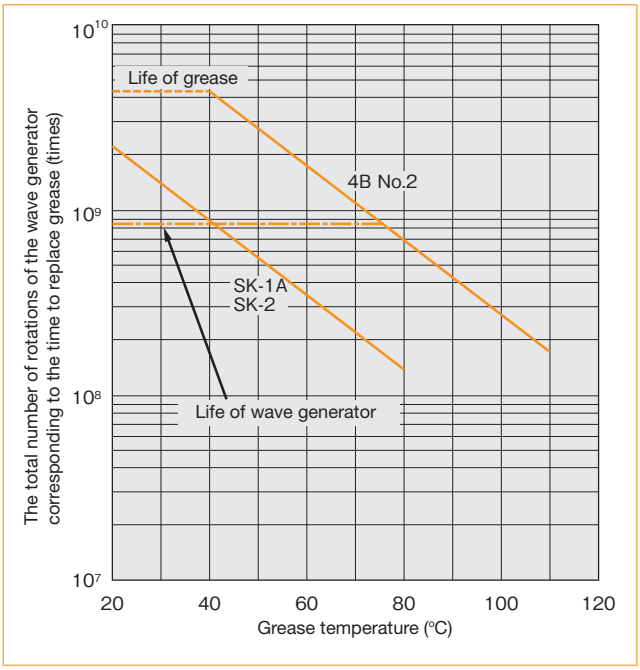
Symbols of the calculation formula

Table 017-1

L_{GT}	Replacement timing if it is equal to rated torque or more	Number of rotation	————
L_{GTn}	Replacement timing if it is equal to rated torque or less	Number of rotation	See the Graph 017-1.
Tr	Rated torque	N·m,kgf·m	See the “Ratings” of each series.
T_{av}	Average load torque on the output side		Calculation formula: See Page 014.

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

Graph 017-1



* Life of wave generator indicates the 10% of damage possibility.

■Other precautions

1. Avoid using it with other grease. HarmonicDrive® should be placed in an independent case to be built into the equipment.

2. When you use HarmonicDrive® at constant load or in one direction continuously, contact our branch office as it may cause lubrication problems.

3. Grease leakage of unit type
   Structure of the unit type is designed in view of grease leakage prevention. However, perform enhancement of seal mechanism depending on operating environment.

■See the corresponding pages of the design guide of each series for “Recommended dimensions of the inner wall of the case,” “Coating guide” and “Application quantity.”

Precautions on using Harmonic grease® 4B No.2

Harmonic grease® 4B No.2 has the fluid characteristic (softening and evenness by shearing) suited to HarmonicDrive®. The characteristic can be utilized to improve the lubricant life when performing the following procedures.

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

■Precautions on securely performing the above mechanism

(1) When greasing
When storing Harmonic grease® 4B No.2 in the container, the consistency is higher. However, please note that the consistency varies depending on the storage period.
Before greasing, agitate the grease in the container to 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 flows around each contacting joint of HarmonicDrive®.
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 is 1000r/min to 3000r/min. However, the lower rotational speed is more effective. Set the speed lower within the indicated range as possible.
- The time required for aging is 20 minutes or longer.
- Operation range for aging: Keep the output rotational angle larger as possible.

Contact our office if you have any question for handling Harmonic grease® 4B No.2.

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	Mobile Oil	ESSO	Showa Shell	COSMO Oil	Japan Energy	NIPPON Oil	Idemitsu Kosan	General Oil	NOK KLUBER
Industrial gear oil class-2 (extreme pressure) ISO VG68	Mobil gear 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	Sintesso 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 “Oil level,” “Oil groove working size of the flexspline” and “Oil quantity.”

■Other precautions

1. Avoid using it with other grease. HarmonicDrive® should be put in an independent case to be built into the equipment.

2. When you use model number 50 or upper level at around the permissible input rotational speed from the ratings, you should contact our branch office as it may cause lubrication problems.

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 taking the operating temperature range shown below into consideration.

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	Maltemp SH-KII: Kyodo Oil	–30°C to + 50°C
	Isoflex LDS-18 special A: NOK KLUBER	–25°C to + 80°C
Oil	SH-200-100CS: Toray Silicon	–40°C to + 140°C
	Sintesso D-32EP: NOK KLUBER	–25°C to + 90°C

The operating temperature range of Harmonic grease® 4B No.2 is the temperature at the lubricating section with the performance and characteristics of HarmonicDrive® 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 HarmonicDrive®. When the ambient temperature is very high or low, the materials of the parts of HarmonicDrive® need to be reviewed. Contact us in this case.

You can use Harmonic grease® 4B No.2 in the available temperature range if you consider increase in the running torque of HarmonicDrive® due to increase in viscosity at low temperature and the grease life due to oxidization and deterioration at high temperature.

On rigidity

Rigidity and backlash of the drive system greatly affects the performance of the servo system. A detailed review of these items is required before designing the equipment and selecting a model number.

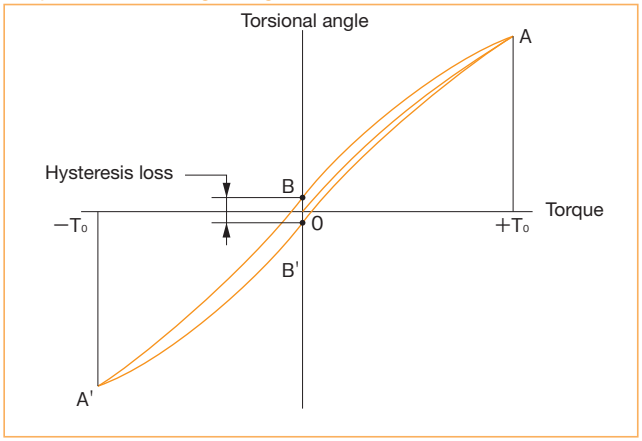
■Rigidity

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 020-1 shows the torsional angle quantity on 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 – torsional angle diagram," which normally draws a loop of 0 – A – B – A' – B' – A. The slope described in the "Torque – torsional angle diagram" is represented as the spring constant for the rigidity of HarmonicDrive® (unit: N·m/rad).
As shown in Figure 020-2, this "Torque – torsional angle diagram" is divided into 3 partitions, and the spring constants in the area are represented as K_1, K_2 and K_3.

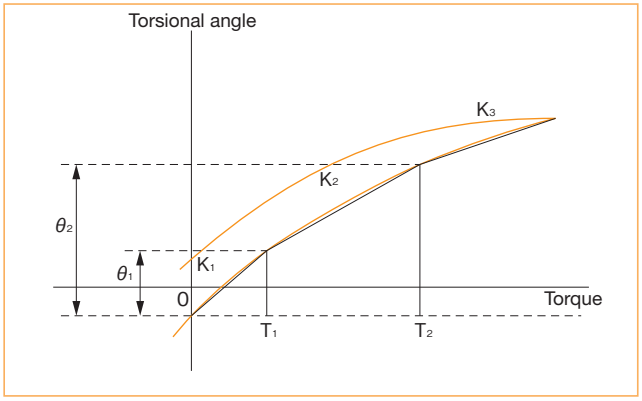
K_1 The spring constant when the torque changes from [zero] to [T_1]
K_2 The spring constant when the torque changes from [T_1] to [T_2]
K_3 The spring constant when the torque changes from [T_2] to [T_3]

■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).

Torque - torsional angle diagram Fig. 020-1



Partitioning of spring constant Fig. 020-2



■Example of calculating torsional quantity

The torsional quantity (θ) is obtained from the example of CSF-25-100-2A-GR.

When the load torque is extremely small (T_{L1}=2.9 N·m)
As the torque is T_1 or less, torsional quantity θ_{L1} is represented as follows.

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

When the load torque is T_{L2}=39 N·m)
As the torque between T_1 and T_2, torsional quantity θ_{L2} is represented as follows.

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

The total torsional quantity when the load is applied the other way round will be double the quantity obtained above plus the backlash quantity.

* The torsional quantity indicates the value of the stand-alone component. Note that the torsional quantity of the output shaft is not included.

■Hysteresis loss

As shown in Figure 020-1, when the torque is applied up to the rated value and is brought back to [zero], the torsional angle does not become absolutely [zero] and a small amount remains (B – B'). This is called hysteresis loss.

■See the corresponding pages of each series for hysteresis loss quantity.

■Backlash

As hysteresis loss is mainly generated by internal abrasion, it is hardly generated, and only a small allowance is represented in the diagram when the torque is extremely small.
As the allowance of the tooth engagement is suppressed to [zero] for HarmonicDrive®, the backlash quantity is caused by the clearance of Oldham's coupling (self-aligning mechanism) of the wave generator. The rigid type has no clearance. The value measured on the output side by fixing the input side is very small as shown on the corresponding page of each series.

* See the corresponding pages of each series for the backlash quantity.

Angle transmission accuracy

Angle transmission accuracy indicates the difference between the logical rotating angle and the actual rotating angle as the angle transmission error when any rotating angle is given as an input.

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

Example of measurement

Graph 021-1

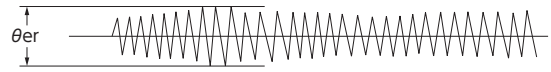


Table 021-1

θ_{er}	Angle transmission error
θ_1	Input rotating angle
θ_2	Actual output rotating angle
R	Reduction ratio of HarmonicDrive® (i =1:R)

Formula 021-1

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

On vibration

The angle transmission error elements of HarmonicDrive® may appear as rotating vibration of the load side inertia. Especially when the characteristic frequency of the vibration system including HarmonicDrive® overlaps that of the chassis or load inertia, it generates a resonant condition that amplifies angle transmission error elements of HarmonicDrive®. Observe the design guide of each series.

Two angle transmission error elements of HarmonicDrive® correspond to a cycle of the input shaft from the mechanical viewpoint of HarmonicDrive®. Therefore, the frequency is double the input frequency as it is the main element of the error.

If the characteristic frequency of the vibration system including HarmonicDrive® is F=15 Hz, the input rotating speed (N) is expressed as shown below.

Formula 021-2

$$N=\frac{15}{2}\cdot 60=450\text{r/min}$$

The resonant condition is generated in the rotating speed area (450 r/min).

How to obtain the characteristic frequency of the vibration system including HarmonicDrive®

Formula 021-3

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

Symbol of the calculation formula

Table 021-2

f	The characteristic frequency of the vibration system including HarmonicDrive®	Hz	
K	Spring constant of HarmonicDrive®	N·m/rad	See pages of each series.
J	Load inertia	kg·m^2	

On starting torque

Starting torque means the instantaneous “starting torque” with which the output side (low-speed side) starts rotation when a torque is applied on the input side (high-speed side) of HarmonicDrive® built into the case. 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.

Measuring condition: 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.

On overdrive starting torque

Overdrive starting torque means the instantaneous “starting torque” with which the input side (high-speed side) starts rotation when a torque is applied on the output side (low-speed side) of HarmonicDrive® built into the case. The values in the table of each series indicate the maximum value, and the lower-limit value indicates approximately 1/2 of the maximum value.

Measuring condition: No-load, ambient temperature: +20°C

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

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

On no-load running torque

No-load running torque means the torque on the input side (high-speed shaft side) required to put HarmonicDrive® under a no-load condition. The graph of the no-load running torque shown in this catalog depends on the measuring condition shown in Table 023-1. Add the correction values shown by each series to all reduction ratios except those of 100.

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

Measuring condition

Table 023-1

Reduction ratio 100			
Lubrication condition	Grease lubrication	Name	Harmonic grease® SK-1A
			Harmonic grease® SK-2
		Application qty.	Appropriate application qty. (See pages of each series)
The torque value is the value after a trial run for two hours or longer at an input of 2000 r/min.			

* Contact us for oil lubrication.

Efficiency characteristics

The efficiency varies depending on the following conditions.
■Reduction ratio
■Input rotational speed
■Load torque
■Temperature
■Lubrication condition (Type of lubricant and the quantity)
The efficiency characteristics of each series shown in this catalog depends depend on the measuring condition shown in Table 023-2.

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

Measuring condition

Table 023-2

Built-in	Measurement by building the recommended built-in precision into the product		
Load torque	The rated torque shown in the ratings (see the corresponding pages on each series)		
Lubricating condition	Grease lubrication	Name	Harmonic grease® SK-1A
			Harmonic grease® SK-2
		Application qty.	Appropriate application qty. (see the pages on each series)

* Contact us for oil lubrication.

■Efficiency correction coefficient

If the load torque is smaller than the rated torque, the efficiency value lowers. Obtain correction coefficient Ke from the efficiency correction coefficient graph of each series to obtain the efficiency using the following example of calculation.

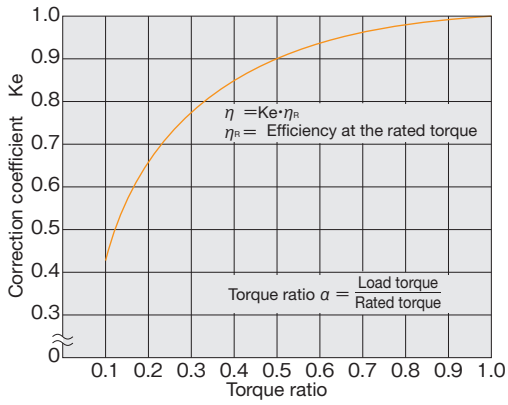
Example of calculation

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

■The efficiency correction coefficient is Ke=0.93 from Graph 023-1.
■Efficiency η at load torque 19.6 N·m: η=Ke•ηR=0.93 x 78=73%

Efficiency correction coefficient (CSF series)

Graph 023-1



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

Precaution on design

Design guideline

Pay attention to the following points to bring out the performance of HarmonicDrive®.

(1) The input shaft, the circular spline, the output shaft and the case shall be concentric.

(2) As thrust force is generated on the wave generator, input shaft should be structured to support the force. For thrust force, see Page 027.

(3) Even though HarmonicDrive® is compact, it transmits a large torque. Therefore, join the flexspline and the output shaft with a bolt and compatible tightening torque.

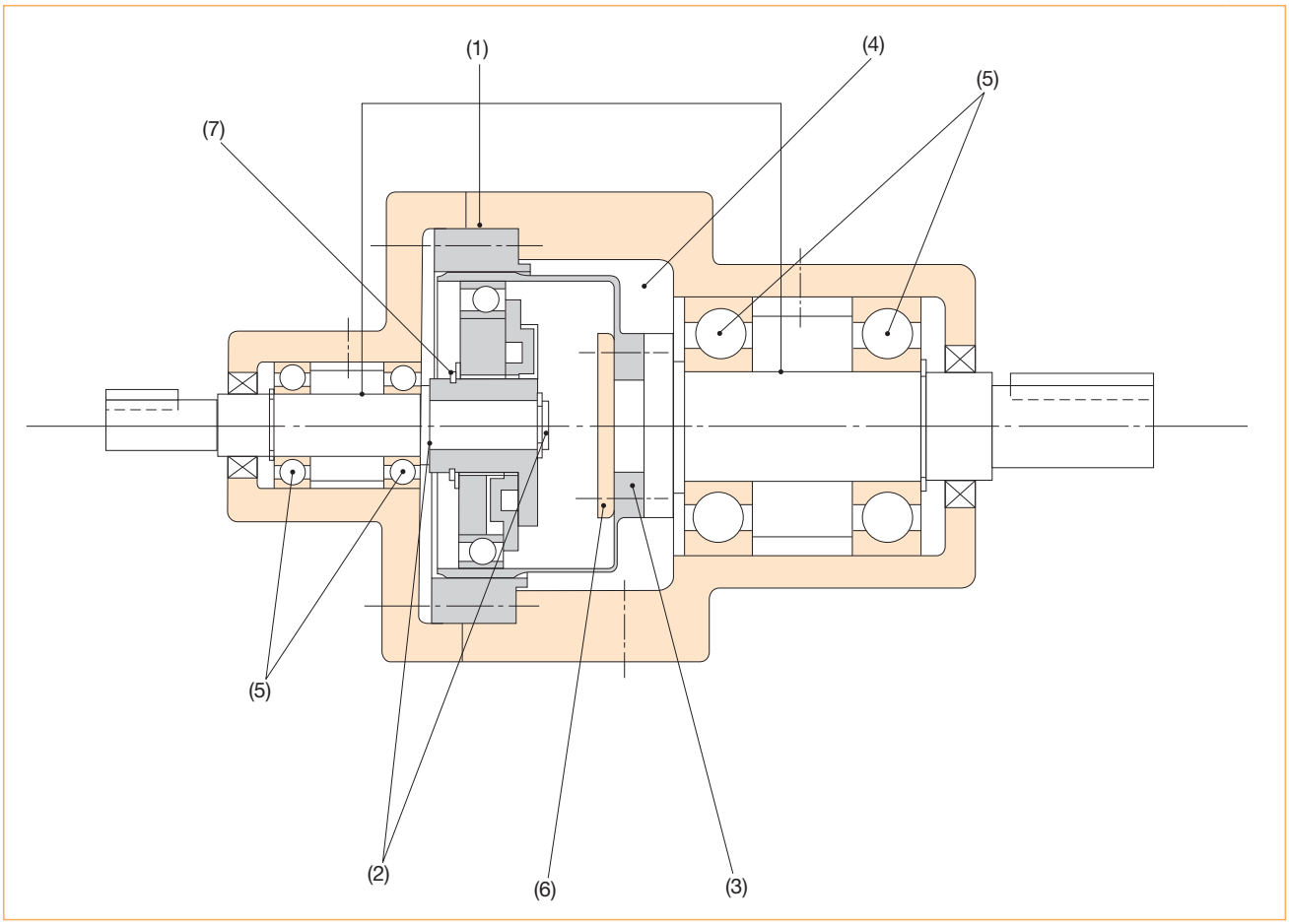
(4) As the flexspline is subject to elastic deformation, the recommended size should be applied to the inner wall of the case.

(5) The input shaft and the output shaft should be supported with two points with appropriate bearing space. It should be structured to bear all radial loads and thrust loads so that no extra force is applied to the wave generator and the flexspline.

(6) The mounting flange diameter of the flexspline shall not exceed the boss diameter of the flexspline. Attach “R” on the flange that is in contact with the diaphragm. Use the recommended size for parts.

(7) C-type retaining ring is used to hold the hub of the wave generator. The hook of the retaining ring shall not interfere with the case.

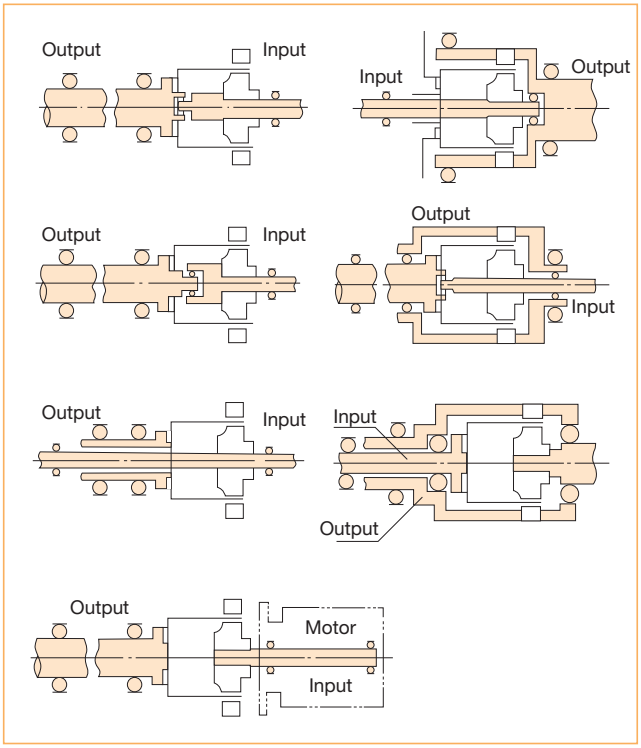
Fig. 024-1



Bearing support of the input and output shafts

As the component type endures external load, the input shaft and the output shaft should be supported with two points with appropriate bearing space. It should be structured to bear all radial loads and thrust loads so that no extra force is applied to the wave generator and the flexspline.
Use the bearing pressurized to the radial and thrust directions to remove the gap.
An example of bearing layout is shown in Figure 025-1.

Fig. 025-1

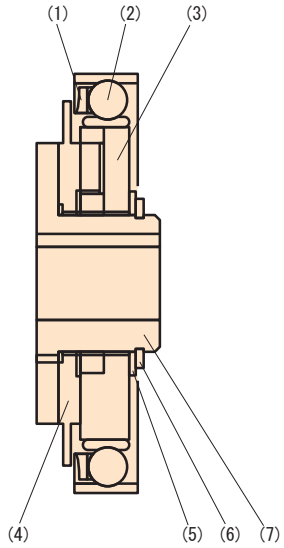


On the wave generator

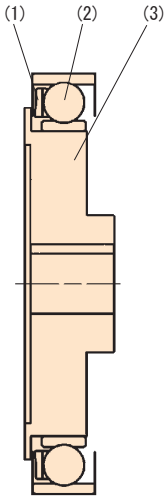
■Structure of the wave generator

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

Fig. 026-1



Oldham's coupling type

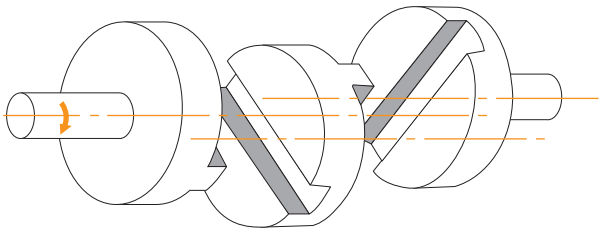


Rigid type

(1) Retainer
(2) Wave generator bearing
(3) Wave generator plug
(4) Insert
(5) Rubwasher
(6) C-type retaining ring
(7) Wave generator hub

Structure of Oldham's coupling

Fig. 026-2



■Maximum hole diameter size of the component type

The standard hole diameter of the wave generator is as shown in the dimensional outline drawing and may be changed in the range up to the maximum dimension shown in the table. The JIS standard is recommended for the key groove size. The valid length of the key shall be the value fully durable for the transmission torque.

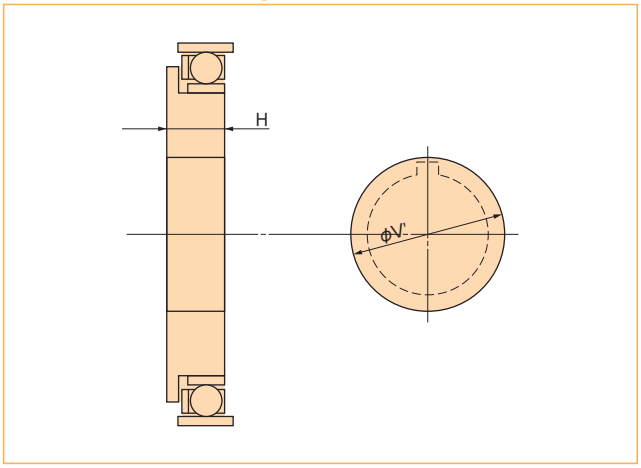
* The shape can be changed into special forms for taper holes and so on.

Oldham's coupling mechanism may be eliminated to make a hole diameter larger than the maximum size. The maximum hole diameter can be up to the value shown in the table below taking deformation of the wave generator plug by load torque into consideration.
(This is the value including the dimension of the key groove depth.)

If a hole diameter larger than this is required, please contact us.

Hole diameter of the wave generator

Fig.027 -1



Hole diameter of the wave generator hub

Table 027-1
Unit: mm

Model number	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
Prepared hole size	—	—	3	4	5	6	6	10	10	10	13	16	16	19	22
Maximum size	—	—	8	10	13	15	15	20	20	20	25	30	35	37	40

Plug maximum diameter of installing the wave generator plug directly on the input shaft

Table 027-2
Unit: mm

Model number	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. $^{0}_{-0.1}$	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

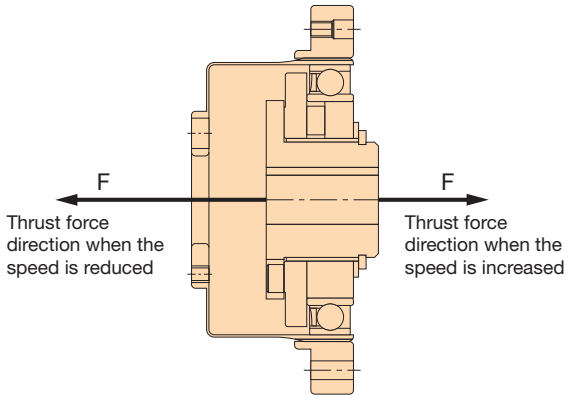
■Thrust force of the wave generator and shaft fixation

Thrust force is applied on the wave generator during operation due to elastic deformation of the flexspline of HarmonicDrive®. The thrust force used as a reducer ((1), (2) and (3) on Page 010) works in the diaphragm direction of the flexspline (Figure 027-2), while the thrust force used as an overdrive ((4), (5) and (6) on Page 010) works in the opposite direction (Figure 027-2).
You can obtain the thrust force (maximum value) of the wave generator with the following calculation formula. Thrust force varies depending on the operating condition. It tends to increase and shows almost the same value as that obtained by the calculation formula when the torque is high, when the speed is very low and when the rotation is constant and continuous. Work out a design to eliminate the thrust force of the wave generator in either case.

(Note)
Contact us when you fix the wave generator hub and the input shaft with a retaining screw.

Thrust force direction of the wave generator

Fig.027 -2



Calculation formula of thrust force

Table027 -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 of the calculation formula

Table027 -4

F	Thrust force	N	See Figure 027-2
D	(Model Number)×0.00254	m	
T	Output torque	N·m	

Example of calculation

Formula 027-1

Model name: CSF series
Model number: 32
Reduction ratio: 50
Output torque: 382 N·m
(maximum permissible momentary torque)

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

$$F=380N$$

Precautions on assembly

Sealing mechanism

The following sealing mechanism is required to prevent grease leakage and maintain the high durability of HarmonicDrive®.

- Rotating and sliding area ····· Oil seal (with a spring). Take care regarding flaws on the shaft.
- Flange mating face and mating ··· O-ring and seal agent. Take care regarding distortion on the plane and how the O-ring is engaged.
- Screw hole area ····· Use a screw lock agent (Locktite 242 is recommended) or seal tape.

(Note)
Observe the description above for the particular use of Harmonic grease® 4B No.2.

Sealing area and the recommended sealing method for the unit type

Table 028-1

Area requiring sealing		Recommended sealing method
Output side	Pass-through hole in the center of the output flange and the output flange mating face	Use O-ring (attached to our product)
	Spanner screw area	Screw lock agent with sealing effect (Locktite 242 is recommended)
Input side	Flange mating face	Use O-ring (attached to our product)
	Motor output shaft	Select one with an oil seal. Those without an oil seal should be structured so that an oil seal is attached to the motor mounting flange.

Precautions on assembly

HarmonicDrive® may generate vibration and abnormal sound due to problems during assembly. Perform assembly based on the following precautions.

■Precautions on the wave generator

1. Avoid such assembly where excessive force is applied to the wave generator bearing. You can smoothly insert the wave generator by turning it.
2. Pay attention so that the effect of misalignment and turnover is within the recommended value (see “Built-in precision” of each series) for the wave generator without Oldham’s coupling mechanism.

■Precautions on the circular spline

1. Is flatness of the mounting surface poor or distorted?
2. Is any embossment of the screw hole area, burr or trapped foreign matter found?
3. Have chamfering and relief working of the corner been conducted to prevent interference of the corner of the circular spline in the house built-in area?
4. Can the circular spline rotate built in the house? Does it interfere with or catch on any part?
5. Does any bolt inserted into the mounting bolt hole interfere with the circular spline and rotate heavily 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 may reduce the rotational precision.

■Precautions on the flexspline

1. Is flatness of the mounting surface poor or distorted?
2. Is any embossment of the screw hole area, burr or trapped foreign matter found?
3. Have chamfering and relief working of the corner been conducted to prevent the interference of the corner of the circular spline in the house built-in area?
4. Does any bolt inserted into the mounting bolt hole interfere with the circular spline and rotate heavily due to the bolt hole 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 with the specified torque. Tighten them in an even, crisscross pattern.
6. Does it engage with the circular spline in an extremely unbalanced way when it is combined? If it is unbalanced, they could be misaligned or not upright.
7. Avoid hitting the tip of the teeth on the opening and inserting the circular spline with excessive force in assembling it

■On anti-rust provision

The surface of HarmonicDrive® is not anti-rust treated. Apply anti-rust agent to the surface if required. Contact us if you would like us to provide the surface with anti-rust treatment.

*** See also “For Safe Use of HarmonicDrive® component and unit” on page 321.**

"Dedoi-dal" 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 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 "dedoi-dal". Note that the flexspline will be exhausted and damaged earlier if it continues operating without the problem being fixed.

■How to check "dedoi-dal"

By performing the following methods, check whether "dedoi-dal" is caused or not.

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

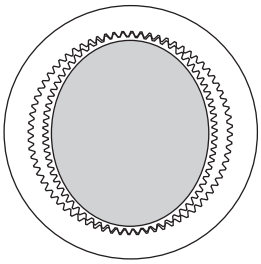
1) Lightly turn the input shaft with your hand in a no-load condition. If you can turn it with average force, it is normal. If it turns irregularly, "dedoi-dal" could have been caused.

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, "dedoi-dal" could have been caused.

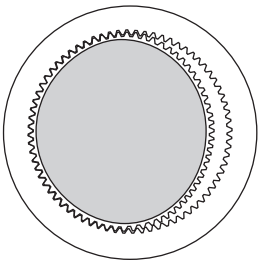
(2) Judging by measuring vibration on the body of the flexspline

The scale deflection of the dial gauge draws a sine wave as shown by the solid line in Graph 029-1 when it is normally assembled. When "dedoi-dal" is caused, the gauge draws a deflected wave shown by the dotted line as the flexspline is out of alignment.

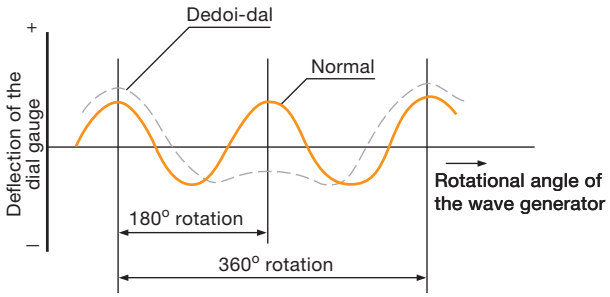
Normal engagement status — Fig. 029-1



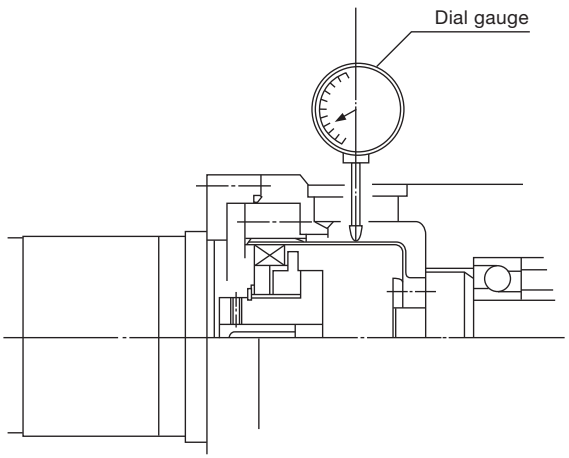
"Dedoi-dal" status — Fig. 029-2



Deflection of the dial gauge — Graph 029-1



Measuring the deflection on the body of the flexspline — Fig. 029-3



Checking main roller 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). Check the maximum load moment load, lifespan of the bearing and static safety coefficient to fully bring out the performance of the unit type.

■See the corresponding pages on each series for main shaft bearing.

Checking procedure

(1) Checking the maximum load moment load (Mmax)

Obtain the maximum load moment load (Mmax). → Maximum load moment load (Mmax) ≦ 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)

How to obtain the maximum load moment load

Maximum load moment load (M*max*) is obtained as follows.
Make sure that M*max* ≦ Mc.

Formula 030-1

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

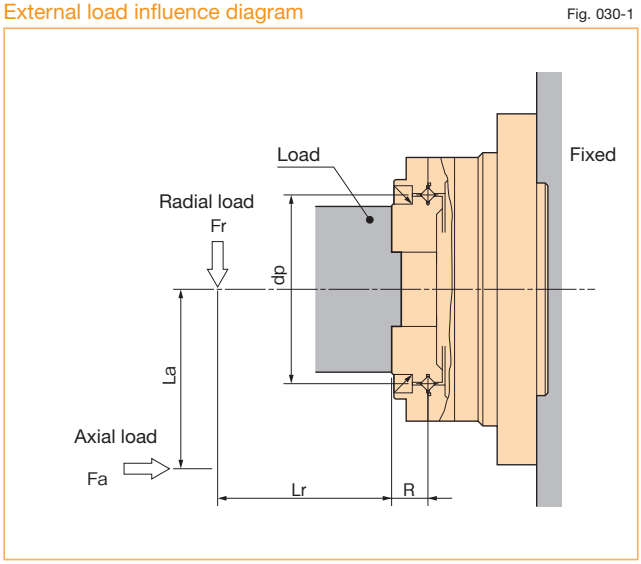
Symbol of formula 030-1

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 main roller bearing" of each series.

External load influence diagram

Fig. 030-1



How to obtain the average load

(Average radial load, average axial load, average output rotational frequency)
If the radial load and the axial load fluctuate, they should be converted into the average load to check the life of the bearing.

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

Formula 031-1

(Cross roller bearing)

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

(4-point contact ball bearing)

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

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

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

Formula 031-2

(Cross roller bearing)

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

(4-point contact ball bearing)

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

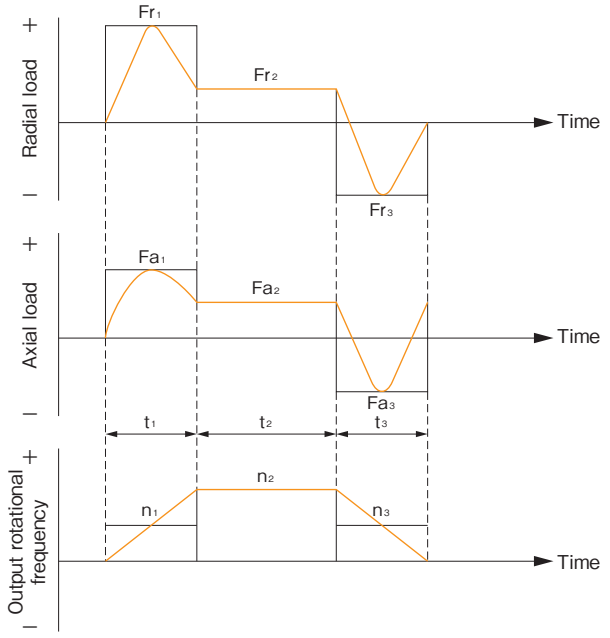
Note that the maximum axial load within the t_1 section is Fa_1 and the maximum axial load within the t_3 section is Fa_3.

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

Formula 031-3

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

Graph 031-1



How to obtain the radial load coefficient (X) and thrust load coefficient (Y)

Formula 031-4

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

Symbol of formula 031-4

Table 031-1

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

How to obtain the life

Obtain the life of the bearing by Formula 032-1.
You can obtain 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)

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

Symbols of Formula 032-1

Table 032-1

L_{10}	Life	hour	———
N_{av}	Average output rotational speed	r/min	See “How to obtain the average load.” .
C	Basic dynamic load rating	N(kgf)	See “Specification of the main roller bearing” of each series.
Pc	Dynamic equivalent radial load coefficient	N(kgf)	See Formula 032-2.
fw	Load coefficient	——	See Table 032-3.

Load coefficient

Table 032-3

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

Formula 032-2

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

Symbols of Formula 032-2

Table 032-2

Fr_{av}	Average radial load	N(kgf)	See “How to obtain the average load.” See Formula 031-1.
Fa_{av}	Average axial load	N(kgf)	See “How to obtain the average load.” See Formula 031-2.
dp	Pitch circle diameter of a roller	m	See Fig. 030-1 and “Specification of the main roller 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 amount	m	See Fig. 030-1 and “Specification of the main roller bearing” of each series.

How to obtain the life under oscillating movement

Obtain the life of the bearing under oscillating movement 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)

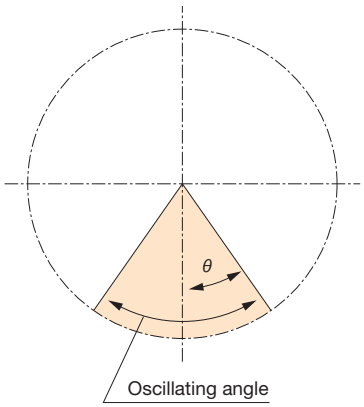
$$Loc = \frac{10^6}{60 \times n1} \times \frac{90}{\theta} \times \left(\frac{C}{fw \cdot Pc}\right)^{3}$$

Symbols of Formula 033-1

Table 033-1

Loc	Rated life under oscillating movement	hour	——
n1	No. of reciprocating oscillation per min.	cpm	——
C	Basic dynamic load rating	N(kgf)	See “Specification of the main roller bearing” of each series.
Pc	Dynamic equivalent radial load coefficient	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)
When the oscillating angle is small (less than 5°), 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.

How to obtain the static safety coefficient

In general, the basic static load rating (Co) is considered to be the permissible limit of the static equivalent load. However, obtain the limit based on the operating and required conditions.
Obtain the static safety coefficient of the roller bearing by Formula 034-1. General values under the operating condition are shown in Table 034-3. You can obtain the static equivalent radial load (Po) 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 of Formula 034-1

Table 034-1

Co	Basic static load rating	N(kgf)	See “Specification of the main roller bearing” of each series.
Po	Static equivalent radial load coefficient	N(kgf)	See Formula 034-2.

Symbols of Formula 034-2

Table 034-2

Fr_{max}	Max. radial load	N(kgf)	See “How to obtain the maximum load moment load” on Page 030.
Fa_{max}	Max. axial load	N(kgf)	
M_{max}	Max. load moment load	N·m (kgf·m)	
dp	Pitch circle diameter of a roller	m	See Fig. 030-1 and “Specification of the main roller 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