# Miniature Gearheads

Harmonic Drive® Gearheads
CSF Mini Series
CSF-2XH-F
CSF-2XH-J
CSF-1U

HARMONIC DRIVE
*Total Motion Control*

# Harmonic Drive® gear

Precision Gearing and Motion Control

## *Harmonic Drive® precision gear is the next generation in precision motion control.*

Harmonic Drive® Precision Control Speed Reducers for compact models are available in this CSF Mini Series.

## Future

### Zero-Backlash, High Positional Accuracy, High Repeatability

The innovative design of Harmonic Drive® precision gear allows consistently high performance over the life of the gear.

### Compact, Lightweight, High Torque Capacity

Harmonic Drive LLC' patented "S" gear tooth profile achieves twice the torque, life and torsional stiffness as compared to gears of the same size by allowing up to 30% of the gear teeth to be engaged at all times.

### Compact 4-Point Contact Ball Bearing Mounted In Main Shaft

A high performance 4-point contact output bearing supports the output flange/shaft. This bearing has excellent run-out characteristics and can support high radial, axial and moment loads.

### Wide Range Of Gear Ratios And Input/Output Configurations In Each Size

Gear Ratios 30:1, 50:1, and 100:1 are available in each size. This allows servomotor and gearhead combinations to operate over a wide speed range. In addition, each size has 3 input/output shaft/flange configurations allowing convenient methods for attaching loads, motors, and pulleys.

# Contents

## About Harmonic Drive® Gear



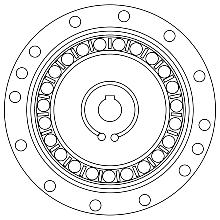
## Unit Type CSF-mini



## Engineering Data

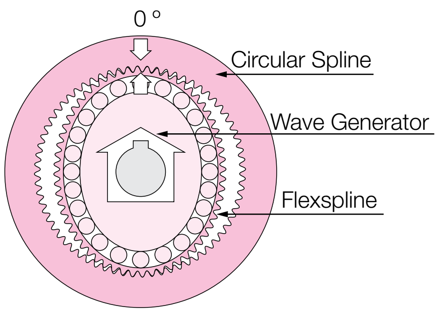


## Warranty and Safety

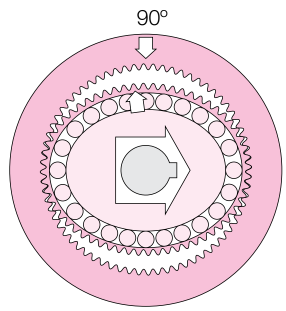




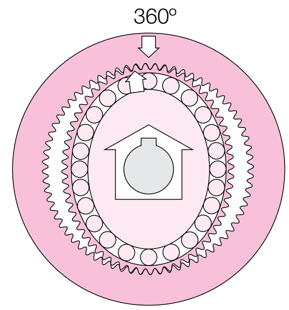
## About Harmonic Drive® strain wave gear principle and structure




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




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




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

## System Components

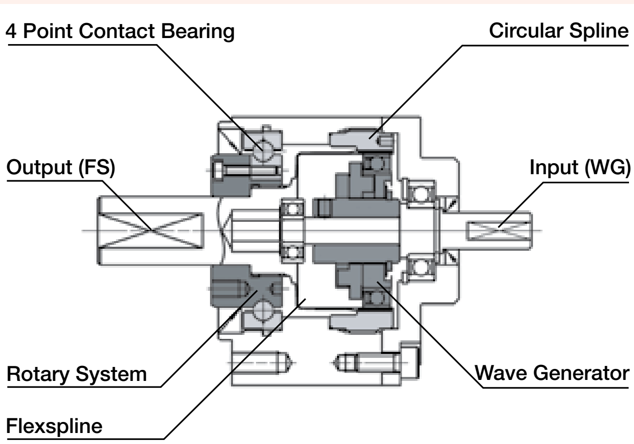
**The Wave Generator:** A thin raced ball bearing fitted onto an elliptical plug serving as a high efficiency torque converter.

**The Flexspline:** A non-rigid, thin cylindrical cup with external teeth on a slightly smaller pitch diameter than the Circular Spline. It fits over and is held in an elliptical shape by the Wave Generator.

**The Circular Spline:** A rigid ring with internal teeth, engaging the teeth of the Flexspline across the major axis of the Wave Generator.

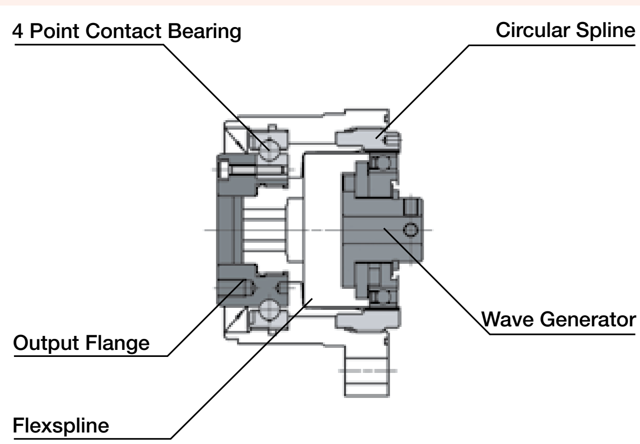
### GEARHEAD TYPE (IU)

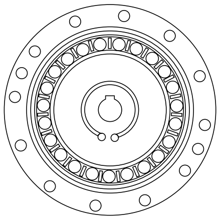
This gearhead is easy to use and has both an input and output shaft. It also allows for pulleys to be used for the input and output to the gearhead.




### GEARHEAD TYPE (2XH)

This gearhead is designed to be coupled directly to a servo-motor. It is available in 2 models. 2XH-F:Direct input coupling/ output Flange. 2XH-J: Direct input coupling/output Shaft.





# Driving Configurations

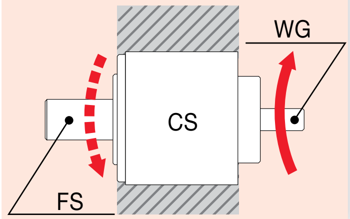
## Driving Configurations

A variety of different driving configurations are possible, as shown below. The reduction ratio given in the tables on page 10 and 11 correspond to arrangement 1, in which the Wave Generator acts as the input element, the Circular Spline is fixed and the Flexspline acts as the output element.

$$\text{Ratio} = \frac{\text{input speed}}{\text{output speed}}$$

**1**

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




1. Reduction Gearing

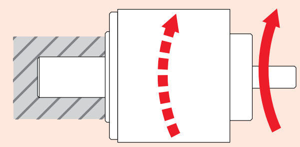
| | |
|---|---|
| CS | Fixed |
| WG | Input |
| FS | Output |

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

Input and output in opposite direction.

**2**

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



2. Reduction Gearing

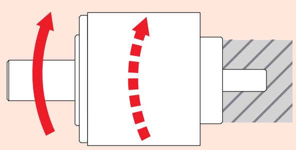
| | |
|---|---|
| FS | Fixed |
| WG | Input |
| CS | Output |

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

Input and output in same direction.

**3**

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



3. Reduction Gearing

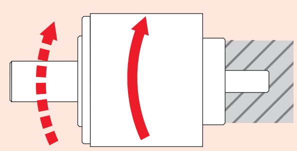
| | |
|---|---|
| WG | Fixed |
| FS | Input |
| CS | Output |

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

Input and output in same direction.

**4**

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



4. Speed Increaser Gearing

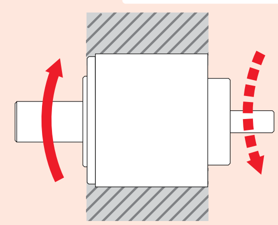
| | |
|---|---|
| WG | Fixed |
| CS | Input |
| FS | Output |

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

Input and output in same direction.

**5**

$$i = -R$$



5. Speed Increaser Gearing

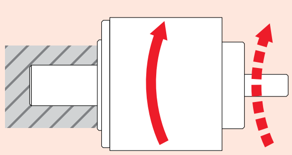
| | |
|---|---|
| CS | Fixed |
| FS | Input |
| WG | Output |

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

Input and output in opposite direction.

**6**

$$i = R+1$$



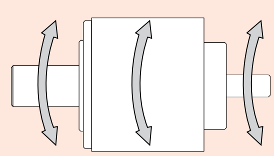
6. Speed Increaser Gearing

| | |
|---|---|
| FS | Fixed |
| CS | Input |
| WG | Output |

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

Input and output in same direction.

**7**



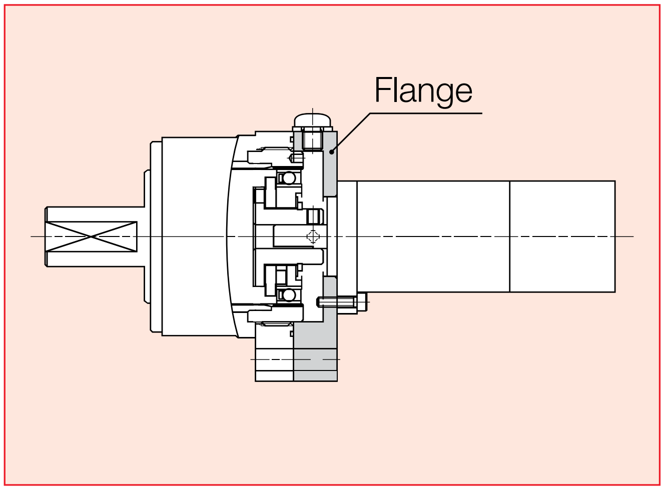
7. Differential Gearing

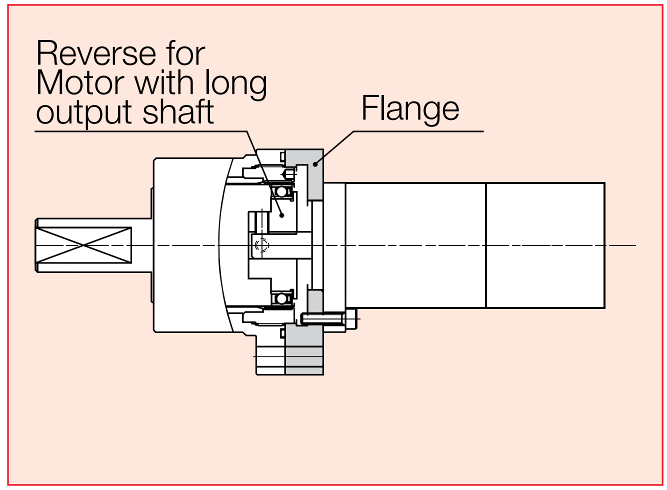
| | |
|---|---|
| WG | Control Input |
| CS | Main Drive-Input |
| FS | Main Drive-Output |

Numerous differential functions can be obtained by combinations of the speed and rotational direction of the three basic elements. [Equation 7]

# Application Example

## Application for 2XH




## Motor Matching Table

Table 1

| Manufacturer | Yaskawa / ΣMini-Series | | | | Mitsubishi / HC-AQ Series | | | Matsushita minas |
|---|---|---|---|---|---|---|---|---|
| Motor Capacity | 3W-5W | 10W | 20W | 30W | 10W | 20W | 30W | 30W |
| CSF-5-2X | • | | | | | | | |
| CSF-8-2XH | | • | | | • | | | |
| CSF-11-2XH | | | • | • | | • | • | • |
| CSF-14-2XH | | | | • | | | • | • |

# Ordering Information

| CSF | - | 14 | - | 100 | - | 2XH - F | - | SP |
|---|---|---|---|---|---|---|---|---|
| Name of Model | | Size | | Gear Ratio | | Model | | SP |

| Name | Size | Gear Ratio | Model | SP |
|---|---|---|---|---|
| CSF | 5 | 30, 50, 100 | 1U<br>2XH-F<br>2XH-J | Customized specification<br>(special)<br>shape and performance |
| | 8 | 30, 50, 100 | | |
| | 11 | 30, 50, 100 | | |
| | 14 | 30, 50, 80, 100 | | |

# Rating Table

Rating Table | Table 2

| Size | Gear Ratio | Rated Torque at 2000rpm | | Repeated peak torque | | Max. average load torque | | Max. momentary torque | | Max. Input Speed | Avg. Input Speed | Moment of Inertia(1/4 GD)$^2$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Nm | in.lb | Nm | in.lb | Nm | in.lb | Nm | in.lb | r/min | r/min | 1U kgcm$^2$ | 2XH kgcm$^2$ |
| 5 | 30 | 0.25 | 2 | 0.5 | 4 | 0.38 | 3 | 0.9 | 8 | 10,000 | 6,500 | $2.5\times10^{-4}$ | $2.5\times10^{-4}$ |
| | 50 | 0.4 | 4 | 0.9 | 8 | 0.53 | 5 | 1.8 | 16 | | | | |
| | 100 | 0.6 | 5 | 1.4 | 12 | 0.94 | 8 | 2.7 | 24 | | | | |
| 8 | 30 | 0.9 | 8 | 1.8 | 16 | 1.4 | 12 | 3.3 | 29 | 8,500 | 3,500 | $3.0\times10^{-3}$ | $3.2\times10^{-3}$ |
| | 50 | 1.8 | 16 | 3.3 | 29 | 2.3 | 20 | 6.6 | 58 | | | | |
| | 100 | 2.4 | 21 | 4.8 | 42 | 3.3 | 29 | 9.0 | 80 | | | | |
| 11 | 30 | 2.2 | 19 | 4.5 | 40 | 3.4 | 30 | 8.5 | 75 | 8,500 | 3,500 | $1.2\times10^{-2}$ | $1.4\times10^{-2}$ |
| | 50 | 3.5 | 31 | 8.3 | 73 | 5.5 | 49 | 17 | 150 | | | | |
| | 100 | 5.0 | 44 | 11 | 97 | 8.9 | 79 | 25 | 221 | | | | |
| 14 | 30 | 4.0 | 35 | 9.0 | 80 | 6.8 | 60 | 17 | 150 | 8,500 | 3,500 | $3.3\times10^{-2}$ | $3.4\times10^{-2}$ |
| | 50 | 5.4 | 48 | 18 | 159 | 6.9 | 61 | 35 | 310 | | | | |
| | 80 | 7.8 | 69 | 23 | 204 | 11 | 97 | 47 | 416 | | | | |
| | 100 | 7.8 | 69 | 28 | 248 | 11 | 97 | 54 | 478 | | | | |

# Technical Terms

## Definition of Ratings

### Rated Torque (Tr)

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

### Limit for Repeated Peak Torque ( figure 1)

During acceleration a deceleration the Harmonic Drive® gear experiences a peak torque as a result of the moment of inertia of the output load.

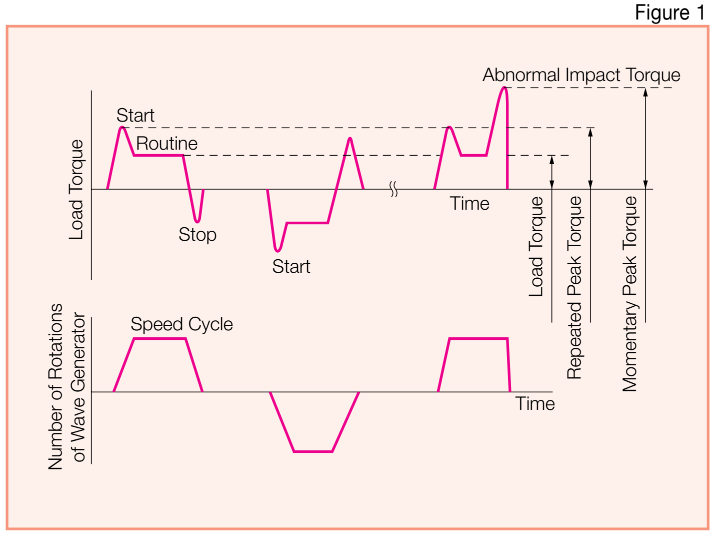
### Limit for Average Torque

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

### Limit for Momentary Peak Torque (figure 1)

The gear may be subjected to momentary peak torques in the event of a collision or emergency stop. The magnitude and frequency of occurrence of such peak torques must be kept to a minimum and they should, under no circumstance, occur during normal operating cycle. The allowable number of occurrences of the momentary peak torque may be calculated by using equation 8 on page 8.
Also see section "strength and life".

Figure 1




Maximum Input Speed, Limit for average input speed

Do not exceed the allowable rating.

Moment of Inertia

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

## Strength and Life

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

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

[Equation 8]

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

n: Input speed before collision

t: Time interval during collision

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

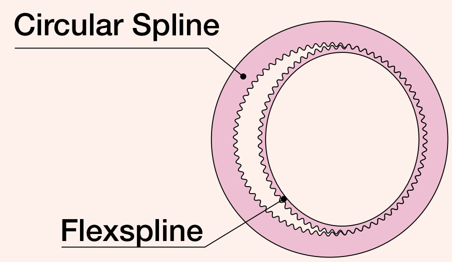
## Ratcheting phenomenon

When excessive torque is applied while the gear is in motion, the teeth between the Circular Spline and Flexspline may not engage properly. This phenomenon is called ratcheting and the torque at which this occurs is called ratcheting torque. Ratcheting may cause the Flexspline to become non-concentric with the Circular Spline. (See figure 2 and 3 on page 8) Operating in this condition may result in shortened life and a Flexspline fatigue failure.

## Note!

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

Figure 2




This condition is called “dedoidal”.

Table 3 Ratcheting Torque (Nm)

| Size | Gear Ratio 30 | 50 | 80 | 100 |
|---|---|---|---|---|
| 5 | 2.7 | 3.2 | – | 3.5 |
| 8 | 11 | 12 | – | 14 |
| 11 | 29 | 34 | – | 43 |
| 14 | 59 | 88 | 110 | 84 |

Buckling Torque (Nm)

| Size | All Ratio |
|---|---|
| 5 | 9.8 |
| 8 | 35 |
| 11 | 90 |
| 14 | 190 |

## The Life of a Wave Generator

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

## Rated Lifetime

Ln : (n = 10 or 50)

| | | |
|---|---|---|
| L10 | CSF : 7,000 | CSG: 10,000 |
| L50 | CSF : 35,000 | CSG : 50,000 |

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

[Equation 9]

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

Lh : Expected Life, hours

Ln : Rated Lifetime at L10 or L50

Tr : Rated Torque (Table 2)

Nr : Rated input speed (2000 rpm)

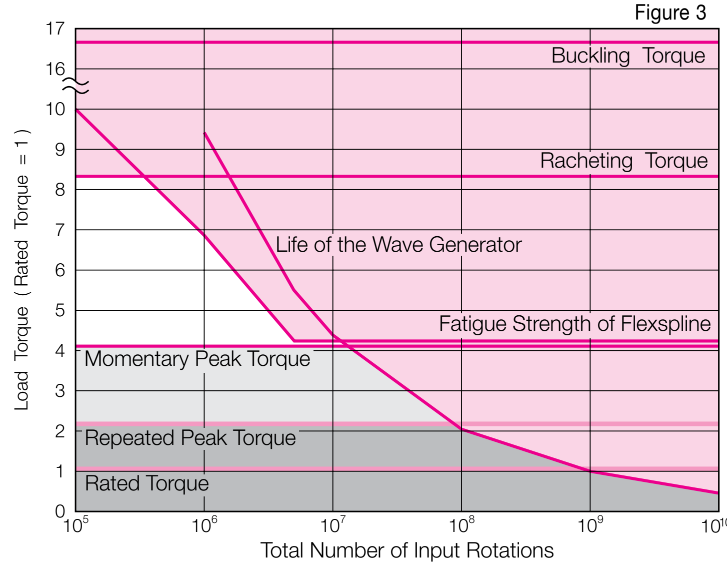
Tav : Average load torque on output side (page 9)

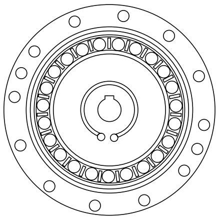
Nav : Average input speed (page 9)

## Relative Torque Rating

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

Figure 3







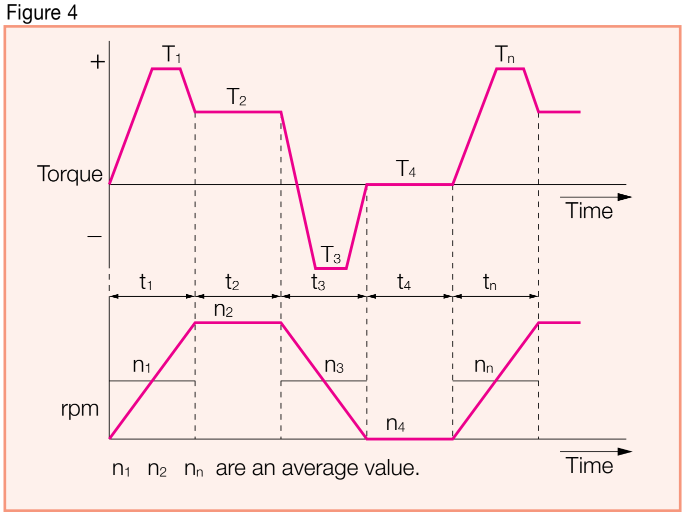
## Size Selection

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

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

This procedure does not consider the life of the output bearing for housed units. Determining the life of the output bearing for various axial, radial, and moment loads is outlined on page 12.

Figure 4




| | |
|---|---|
| Parameters | |
| Load Torque | Tn (Nm) |
| Time | tn (sec) |
| Output Speed | nn (rpm) |
| | |
| Normal Operating Pattern | |
| Acceleration | $T_1, t_1, n_1$ |
| Regular Operation | $T_2, t_2, n_2$ |
| Deceleration | $T_3, t_3, n_3$ |
| Dwell | $T_4, t_4, n_4$ |
| | |
| Maximum RPM | |
| Max output speed | no maximum |
| Max input speed | ni maximum |
| | |
| Impact Torque | $T_s, t_s, n_s$ |
| | |
| Ratings | |
| Rated Torque | Tr |
| Rated Speed | nr =2000 rpm |
| Life | $L_{10}$=L (hrs) |

## Flow Chart for Selecting a Size

Please use the flowchart shown below for selecting a size. Operating conditions must not exceed the performance ratings as described on page 7.

Calculation of the average output torque

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

Selection of tentative size under the condition shown below.

Average Output Speed

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

Determine Gear Ratio

$$\frac{ni\ max}{no\ max} \leq R$$

ni max may be limited by the motor.

Calculation of the average input speed
ni av = no av •R

Calculation of maximum input speed
ni max = no max •R

NG

ni av $\leq$ Limit for average speed
ni max $\leq$ Limit for maximum speed

OK

NG

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

OK

NG

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

OK

NG

Calculate the allowable number of rotations during impact torque.

$$Ns = \frac{10^4}{2 \cdot \frac{n_s \cdot R}{60} \cdot ts} \cdots\cdots N_s <= 1.0X10^4$$

OK

Calculate wave generator life.

$$L = 700 \cdot \left(\frac{Tr}{Tav}\right)^3 \cdot \left(\frac{nr}{niav}\right)(\text{time})$$

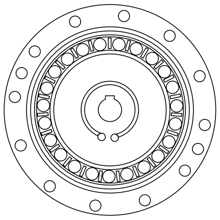
NG

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

OK

Gear is suitable for torque and speed requirements

Also consider output bearing, environment, etc.



# SELECTION EXAMPLE

<u>Values of an each Load Torque Pattern</u>

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

<u>Normal Operating Pattern</u>

| | | | |
|---|---|---|---|
| Acceleration | $T_1$ = 19 Nm, | $t_1$ = 0.4 sec, | $n_1$ = 8 rpm |
| Regular Operation Stop | $T_2$ = 2 Nm, | $t_2$ = 4 sec, | $n_2$ = 16 rpm |
| Deceleration | $T_3$ = 19 Nm, | $t_3$ = 0.4 sec, | $n_3$ = 8 rpm |
| Dwell | $T_4$ = 0 Nm, | $t_4$ = 0.2 sec, | $n_4$ = 0 rpm |

<u>Maximum Speed</u>

output max speed no max = 16 rpm

input max speed ni max = 1800 rpm

(limited by motor)

<u>Impact Torque</u>

$T_s$ = 50 Nm, ts = 0.15 sec, $n_s$ = 12 rpm

<u>Life Required</u>

$L_{10}$ = 7000 hrs.

Tav (Nm)

$$\text{Tav} = \sqrt[3]{\frac{8\text{rpm}\cdot 0.4\text{sec}\cdot|19\text{Nm}|^3+16\text{rpm}\cdot 4\text{sec}\cdot|2\text{Nm}|^3+8\text{rpm}\cdot 0.4\text{sec}\cdot|19\text{Nm}|^3}{8\text{rpm}\cdot 0.4\text{sec}+16\text{rpm}\cdot 4\text{sec}+8\text{rpm}\cdot 0.4\text{sec}}}$$

Tav =8.6Nm ≤ 11Nm (for CSF-14-100-2XH)

no av (rpm)

$$\text{no av} = \frac{8\text{rpm}\cdot 0.4\text{sec}+16\text{rpm}\cdot 4\text{sec}+8\text{rpm}\cdot 0.4\text{sec}}{0.3\text{sec} + 3\text{sec} + 0.4\text{sec} + 0.2\text{sec}} = 14\text{rpm}$$

(R)

$$\frac{1800\text{ rpm}}{14\text{ rpm}} = 129 \geq 100$$

$n_i$ av = 14 rpm •100 = 1400 rpm

$n_o$ max ni max (rpm)

$n_i$ max = 16 rpm •100 = 1600 rpm

$n_i$ av =1000rpm ≤ 3500 rpm (for CSF-14-100-2XH)

$n_i$ max=1600rpm ≤ 8500 rpm (for CSF-14-100-2XH)

Confirm that T1 and T3 are within a

OK

$T_1$ ,$T_3$ (Nm)

$T_1$ =19Nm ≤ 28Nm (for CSF-14-100-2XH)

$T_3$ =19Nm ≤ 28Nm (for CSF-14-100-2XH)

OK

$T_s$ (Nm)

$T_s$ = 500Nm ≤ 54Nm (for CSF-14-100-2XH)

OK

($N_s$ ) Calculate an allowable number of rotation(Ns) and confirm ≤ 1.0 x $10^4$

$$N_S = \frac{10^4}{2\cdot\frac{16\text{rpm}\cdot 100}{60}\cdot 0.15\text{sec}} = 1250 \leq 1.0\text{X}10^4$$

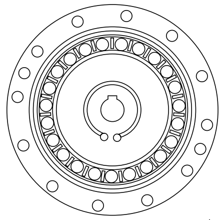
OK

$$L_{10} = 7000\cdot\left(\frac{7.8\text{ Nm}}{8.6\text{ Nm}}\right)^3\cdot\left(\frac{2000\text{ rpm}}{1400\text{ rpm}}\right)$$

$L_{10}$ =7460≥7000 ($L_{B10}$)

OK

CSF-14-100-2XH



# External Dimensions

## Compact Double Shaft Type 1U

This gearhead is easy to use and has both an input and output shaft.

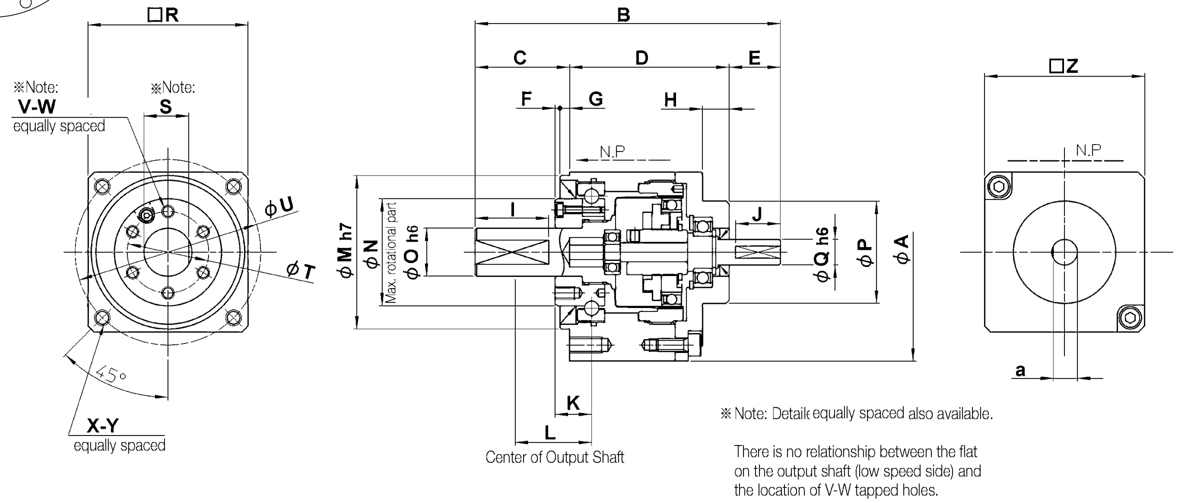



Table 4

| Symbol \ Size | 5 | 8 | 11 | 14 |
|---|---|---|---|---|
| øA | 26.5 | 40 | 54 | 68 |
| B | 37 | 65.5 | 82.5 | 95.4 |
| C | 13 | 23 | 29.5 | 29.5 |
| D | 16 | 29.5 | 37 | 49.9 |
| E | 8 | 13 | 16 | 16 |
| F | 0.5 | 0.5 | 0.5 | 1.5 |
| G | 2.5 | 2.5 | 3 | 3 |
| H | 0.8 | 2.6 | 3.9 | 8.4 |
| I | 9 | 18 | 21.5 | 23 |
| J | 7 | 11 | 14 | 14 |

Table 5

| Symbol \ Size | 5 | 8 | 11 | 14 |
|---|---|---|---|---|
| K | 4.85 | 7.3 | 9 | 11.4 |
| L | 9.85 | 17.3 | 22 | 23.9 |
| øM h7 | 19.5 | 29 | 39 | 48 |
| øN | 13 | 20 | 26.5 | 33.5 |
| øO h6 | 5 | 9 | 12 | 15 |
| øP | 9 | 16 | 24 | 32 |
| øQ h6 | 3 | 5 | 6 | 8 |
| □R | 20.4±0.42 | 30.7±0.46 | 40.9±0.50 | 51.1±0.50 |
| S | 4.6 | 8 | 10.5 | 14 |
| øT | 9.8 | 15.5 | 20.5 | 25.5 |

Table 6 m

| Symbol \ Size | 5 | 8 | 11 | 14 |
|---|---|---|---|---|
| øU | 23 | 35 | 46 | 58 |
| V | 3 | 4 | 6 | 6 |
| W | M2X3 | M3X4 | M3X5 | M4X6 |
| X | 4 | 4 | 4 | 4 |
| Y | M2X3 | M3X6 | M4X8 | M5X10 |
| □Z | 20±0.42 | 30±0.46 | 40±0.50 | 50±0.50 |
| a | 2.6 | 4.5 | 5.5 | 7.5 |
| weight(g) | 35 | 130 | 240 | 440 |

## Gearhead Type 2XH-F

This gearhead is designed to be coupled directly to a servomotor. The motor shaft is attached directly to the gearhead input element. The output of the gearhead is a flange.

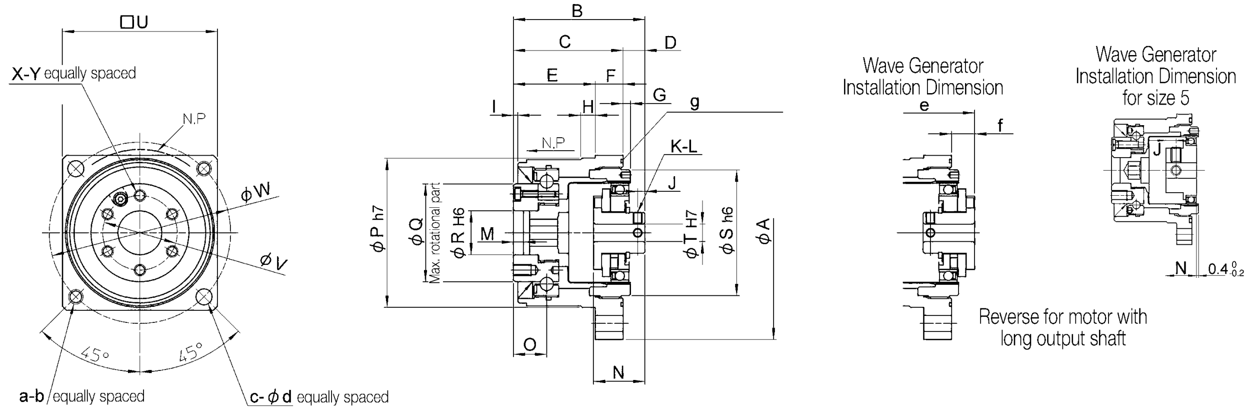



Table 7

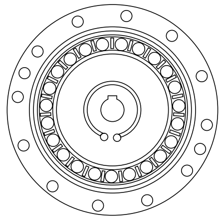
| Symbol \ Size | 5 | 8 | 11 | 14 |
|---|---|---|---|---|
| øA | 29 | 43.5 | 58 | 73 |
| B | 17 | 31 | 38.3 | 45 |
| C | 15.7 | 24.5 | 30 | 37.5 |
| D | – | $6.5^{0}_{-0.3}$ | $8.3^{0}_{-0.7}$ | $7.5^{0}_{-0.8}$ |
| E | 12.7 | 19 | 23.5 | 28 |
| F | 3 | 5.5 | 6.5 | 9.5 |
| G | 1.3 | 1.5 | 2 | 2.5 |
| H | 2 | 3 | 3 | 5 |
| I | 0.5 | 0.5 | 0.5 | 1.5 |
| J | 2 | 2 | 3 | 2.5 |
| K | 2 | 2 | 2 | 2 |

Table 8

| Symbol \ Size | 5 | 8 | 11 | 14 |
|---|---|---|---|---|
| L | M2X3 | M2X3 | M3X4 | M3X4 |
| M | 1.7 | 2.2 | 2.5 | 3.5 |
| N | 6 | 12 | 16 | 17.6 |
| O | 4.85 | 7.3 | 9 | 11.4 |
| øP h7 | 20.5 | 31 | 40.5 | 51 |
| øQ | 13 | 20 | 26.5 | 33.5 |
| øR H6 | 5 | 9 | 12 | 15 |
| øS h6 | 17 | 26 | 35 | 43 |
| øT H7 | 3 | 3 | 5 | 6 |
| □øU | 22±0.42 | 30±0.46 | 43±0.50 | 53±0.50 |
| øV | 9.8 | 15.5 | 20.5 | 25.5 |

Table 9 mm

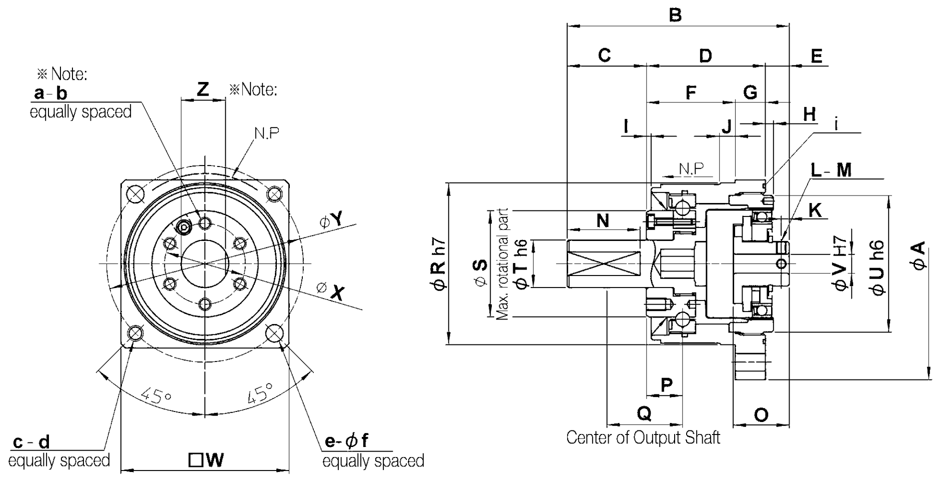
| Symbol \ Size | 5 | 8 | 11 | 14 |
|---|---|---|---|---|
| øW | 25 | 37.5 | 50 | 62 |
| X | 3 | 4 | 6 | 6 |
| Y | M2X3 | M3X4 | M3X5 | M4X6 |
| a | 2 | 2 | 2 | 2 |
| b | M2 | M3 | M4 | M5 |
| c | 2 | 2 | 2 | 2 |
| ød | 2.3 | 3.4 | 4.5 | 5.5 |
| e | – | 28.7 | 36.1 | 45.4 |
| f | – | $4.2^{0}_{-0.3}$ | $6.1^{0}_{-0.7}$ | $7.9^{0}_{-0.8}$ |
| g | 18.90±0.70 | 28.20±1.00 | 38.00±1.50 | 48±1.00 |
| weight(g) | 25 | 100 | 150 | 295 |

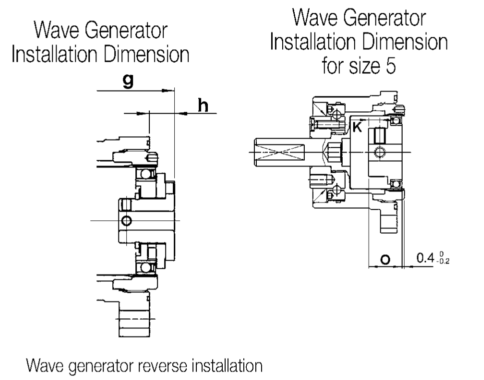


# External Dimensions & Output Bearing Ratings

## Gearhead Type 2XH-J

This gearhead is designed to be coupled directly to a servomotor. The motor shaft is attached directly to the gearhead input element. The output of the gearhead is a shaft.




※Note: Detailed drawings are also available.

Table 10

| Symbol \ Size | 5 | 8 | 11 | 14 |
|---|---|---|---|---|
| øA | 29 | 43.5 | 58 | 73 |
| B | 25.7 | 51 | 64.3 | 70 |
| C | 10 | 20 | 26 | 25 |
| D | 15.7 | 24.5 | 30 | 37.5 |
| E | – | 6.5 $^{0}_{-0.3}$ | 8.3 $^{0}_{-0.7}$ | 7.5 $^{0}_{-0.8}$ |
| F | 12.7 | 19 | 23.5 | 28 |
| G | 3 | 5.5 | 6.5 | 9.5 |
| H | 1.3 | 1.5 | 2 | 2.5 |
| I | 0.5 | 0.5 | 0.5 | 1.5 |
| J | 2 | 3 | 3 | 5 |
| K | 2 | 2 | 2 | 2.5 |
| L | 2 | 2 | 2 | 2 |

Table 11

| Symbol \ Size | 5 | 8 | 11 | 14 |
|---|---|---|---|---|
| M | M2X3 | M2X3 | M3X4 | M3X4 |
| N | 9 | 18 | 21.5 | 23 |
| O | 6 | 12 | 16 | 17.6 |
| P | 4.85 | 7.3 | 9 | 11.4 |
| Q | 9.85 | 17.3 | 22 | 23.9 |
| øR h7 | 20.5 | 31 | 40.5 | 51 |
| øS | 13 | 20 | 26.5 | 33.5 |
| øT h6 | 5 | 9 | 12 | 15 |
| øU h6 | 17 | 26 | 35 | 43 |
| øV H7 | 3 | 3 | 5 | 6 |
| □ W | 22±0.42 | 32±0.46 | 43±0.50 | 53±0.50 |
| øX | 9.8 | 15.5 | 20.5 | 25.5 |

Table 12 m

| Symbol \ Size | 5 | 8 | 11 | 14 |
|---|---|---|---|---|
| øY | 25 | 37.5 | 50 | 62 |
| Z | 4.6 | 8 | 10.5 | 14 |
| a | 3 | 4 | 6 | 6 |
| b | M2X3 | M3X4 | M3X5 | M4X6 |
| c | 2 | 2 | 2 | 2 |
| d | M2 | M3 | M4 | M5 |
| e | 2 | 2 | 2 | 2 |
| øf | 2.3 | 3.4 | 4.5 | 5.5 |
| (g) | – | 48.7 | 62.1 | 70.4 |
| h | – | 4.2 $^{0}_{-0.3}$ | 6.1 $^{0}_{-0.7}$ | 7.9 $^{0}_{-0.8}$ |
| i | 18.90X0.70 | 28.20X1.00 | 38.00X1.50 | 48.00X1.00 |
| weight(g) | 27 | 111 | 176 | 335 |

## Specification for Output Bearing

CSF-Mini Series incorporate a precise 4-point contact bearing to directly support a load. The inner race of the bearing forms the output flange. Please calculate maximum load moment, life of cross roller bearing, and static safety factor to fully maximize the performance of the CSF-Mini Series.

## Calculation Procedure

1. Maximum Load Moment (Mmax)

Calculate maximum load moment → Maximum load moment (Mmax)< Allowable moment (Mc)

2. Output Bearing Life

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

3. Static Safety Factor

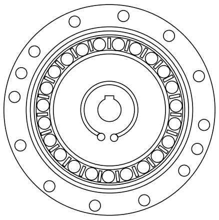
Calculate static equal radial load (Po) → Confirm static safety factor (fs)

## Specification for Output Bearing

Table 13

| Size | Pitch Circle dp mm | Offset R mm | Basic Dynamic Rated Load C $x10^2$N | Basic Dynamic Rated Load C lb | Basic Static Rated Load Co $x10^2$N | Basic Static Rated Load Co lb | Allowable Moment Load Mc Nm | Allowable Moment Load Mc in-lb | Moment Rigidity Km Nm/rad | Moment Rigidity Km in-lb arc-min | Allowable Radial Load N | Allowable Radial Load lb | Allowable Thrust Load N | Allowable Thrust Load lb |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 5 | 13.5 | 4.85 | 9.14 | 205 | 7.63 | 171 | 0.89 | 8 | $7.41X10^2$ | 1.9 | 90 | 20.2 | 270 | 60.6 |
| 8 | 20.5 | 7.3 | 21.6 | 485 | 19.0 | 427 | 3.46 | 31 | $2.76X10^3$ | 7.09 | 200 | 44.9 | 630 | 141 |
| 11 | 27.5 | 9 | 38.9 | 874 | 35.4 | 795 | 6.6 | 58 | $7.41X10^3$ | 19 | 300 | 67.4 | 1,150 | 258 |
| 14 | 35 | 11.4 | 61.2 | 1,376 | 58.5 | 1,315 | 13.2 | 117 | $1.34X10^4$ | 34.4 | 550 | 123 | 1,800 | 404 |

Allowable Radial Load is based on load acting at the middle of the output shaft 1U and gearhead type 2XH-J





## How to Calculate the Maximum Load Moment

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

Mmax = Frmax • (Lr+R) + Famax • La

| | | | |
|---|---|---|---|
| Frmax | Max. radial load | N | Figure 6 |
| Famax | Max. axial load | N | Figure 6 |
| Lr, La | Moment arm | m | Figure 5 |
| R | amount of offset | m | Table 13 |

## How to Calculate an Average Load

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

When the radial load and axial load vary, the life of cross roller bearing can be determined by converting to an average load. (see figure 6)

Equation (10) Calculate Average Radial Load

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

However Max. radial load in t1is Fr1, Max. radial load in t3 is Fr3.

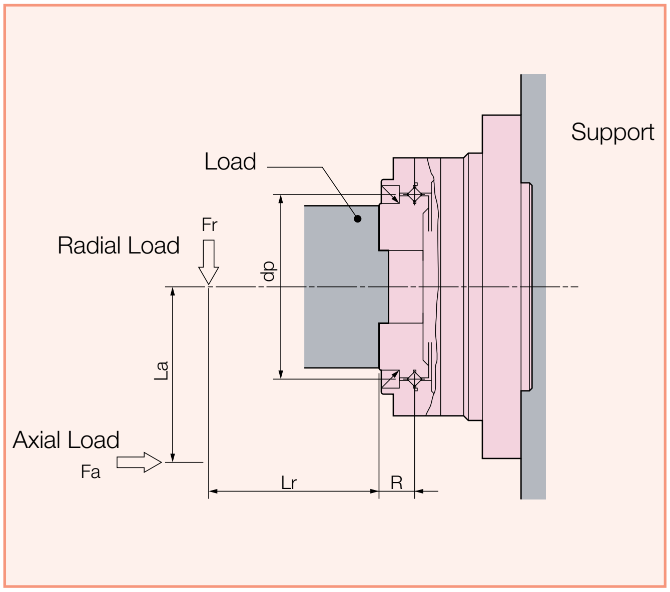
Equation (11) Calculate Average Axial Load(Faav)

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

However, an axial load in t1 is Fa1, Max. axial load in t3 is Fa3.

Equation (12) Calculate Average Output Speed

$$Nav = \frac{n_1t_1 + n_2t_2 \ldots + n_nt_n}{t_1t_2 \ldots + t_n}$$





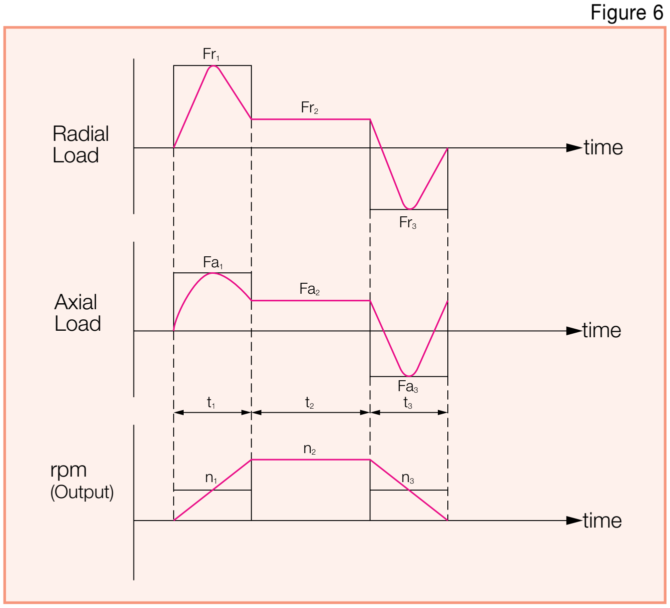
## How to calculate radial load coefficient (X) axial load (Y)

list 2

| | | X | Y |
|---|---|---|---|
| $\frac{Faav}{Frav+2 (Frav (Lr+R) + Faav.La) /dp}$ | ≤ 1.5 | 1 | 0.45 |
| $\frac{Faav}{Frav+2 (Frav (Lr+R) + Faav.La) /dp}$ | > 1.5 | 0.67 | 0.67 |

| | | | |
|---|---|---|---|
| Frmax | Max. radial load | N | Figure 6 |
| Famax | Max. axial load | N | Figure 6 |
| Lr, La | Moment arm | m | Figure 5 |
| R | amount of offset | m | Table 13 |
| dp | pitch circle | m | Table 13 |

Figure 6



## How to Calculate Life of the Output Bearing

The life of a cross roller bearing can be calculated by equation (13).

$$L_{10} = \frac{10^6}{60 \times Nav} \times \left(\frac{C}{fw.Pc}\right)^{10/3}$$ equation (13)

Equation 15

| | | | |
|---|---|---|---|
| $L_{10}$ | Life | Hour | ———— |
| Nav | Average Output Speed | rpm | equation 12 |
| C | Basic Dynamic Rated Load | N | table 13 |
| Pc | Dynamic Equivalent | N | equation 14 |
| fw | Load Coefficient | ——— | list 3 |

List 3

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

## Dynamic Equivalent Radial Load

equation (14)

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

Symbol of equation

| | | | |
|---|---|---|---|
| Frav | Average radial load | N | equation 10 |
| Faav | Average axial load | N | equation 11 |
| dp | Pitch diameter | m | table 13 |
| X | Radial load coefficient | ——— | list 2 |
| Y | Axial load coefficient | ———— | list 2 |
| Lr, La | Moment Arm | m | figure 5 |
| R | Offset | m | figure 7 and table 13 |

## How to Calculate Static Safety Coefficient

Basic static rated load is an allowable limit for static load, but its limit is determined by usage. In this case, static safety coefficient of the cross roller bearing can be calculated by equation (15). Reference values under general conditions are shown on list 4. Static equivalent radial load can be calculated by equation (15)

$$fs = \frac{Co}{Po}$$ equation (15)

| Symbols for equation (17) | | | |
|---|---|---|---|
| Co | Basic static rated load | N | table 13 |
| Po | Static equivalent radial load | N | refer to equation (17) |

list 4

| Rotating Conditions | Load Conditions | Lower Limit Value for $f_s$ |
|---|---|---|
| Normally not rotating | Slight oscillations<br>Impact loads | ≥ 2<br>≥ 3 |
| Normally rotating | Normal loads<br>Impact loads | ≥1.5<br>≥ 3 |
| Static Safety Coefficient | High Accuracy Required | ≥ 3 |
| | Oscillations, Impact Loads | ≥ 2 |
| | Normal Loads | ≥1.5 |

## How to Calculate Life for Oscillating Motion

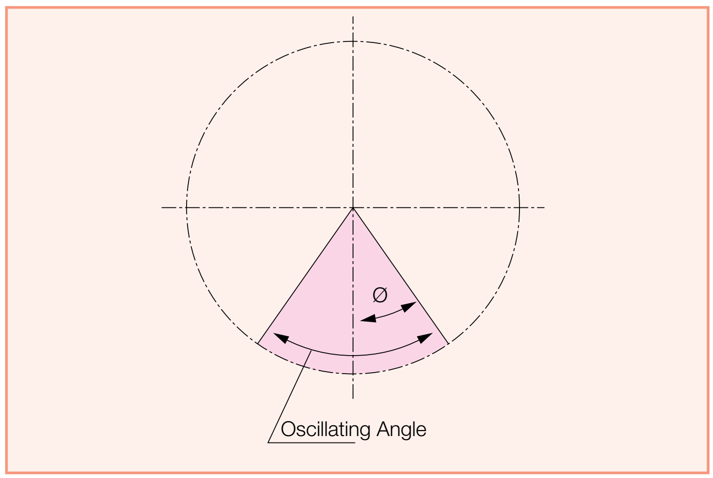
The Life of a cross roller bearing in a oscillating operation can be calculated by equation 9

equation (16)

$$Loc = \frac{106}{60 \times n1} \times \frac{90}{\varnothing} \times \left(\frac{C}{fw.Pc}\right)^{10/3}$$

Symbol of equation

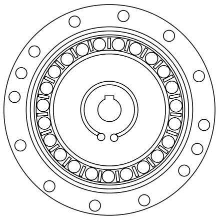
| | | | |
|---|---|---|---|
| Loc | Rated life for oscillating motion | Hour | ———— |
| n1 | Round trip oscillation each minute | rpm | ———— |
| C | Basic dynamic rated load | N | ———— |
| Pc | Dynamic equivalent radial load | N | equation 14 |
| fw | Load Coefficient | ——— | list 3 |
| Ø | Angle of oscillation/2 | | degrees refer to figure |




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

$$Po = Frmax + \frac{2Mmax}{dp} + 0.44. Famax$$ equation (17)

| Symbols for Equation (17) | | |
|---|---|---|
| Frmax | Max. radial load | N |
| Famax | Max. axial load | N |
| Mmax | Max. moment load | Nm |
| dp | Pitch diameter | m |



# EFFICIENCY

Efficiency The efficiency depends on the conditions shown below. Efficiency depends on gear ratio, input speed, load torque, temperature, quantity of lubricant and type of lubricant.
Efficiency values shown are for rated torque. If load torque is below rated torque, a compensation factor must be employed.
Load Torque≥Rated Torque: Efficiency = Efficiency from Graph
Load Torque<Rated Torque: Efficiency = Efficiency from Graph x Compensation Coefficient from figure 9.

Measurement Condition

| | |
|---|---|
| Installation : | Based on recommended tolerance |
| Load torque : | Rated torque |
| Lubricant : | Harmonic Grease SK-2 only |
| Grease quantity : | Recommended quantity |

Please contact us for details pertaining to recommended oil lubricant.

## Size 5

### 1U-2XH

**Figure 1 Ratio 30**

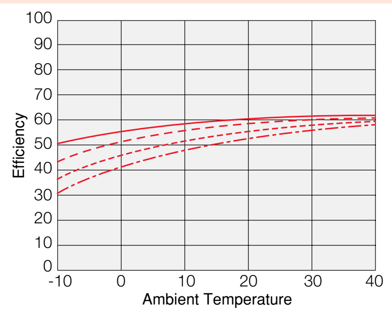



**Figure 2 Ratio 50**

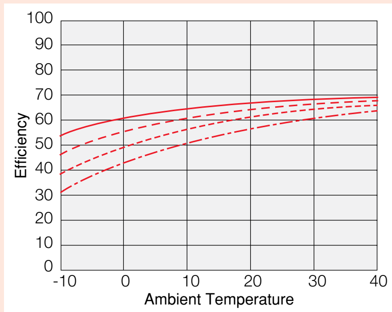
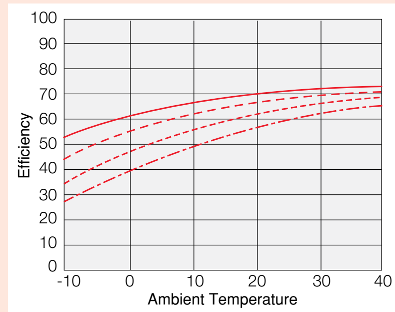



**Figure 3 Ratio 100**




Input Speed ———— 500r/min - - - - - 1000r/min ------- 2000r/min —·—·—·— 3500r/min

## Size 8

### 1U

**Figure 4 Ratio 30**

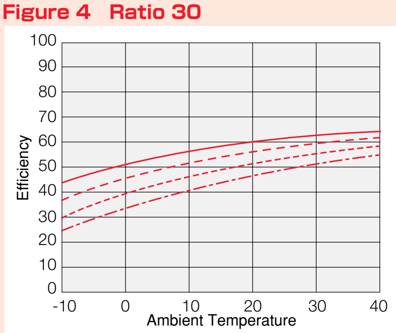



**Figure 5 Ratio 50**

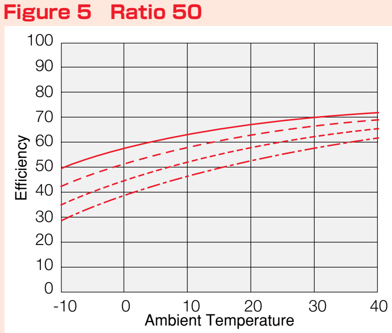
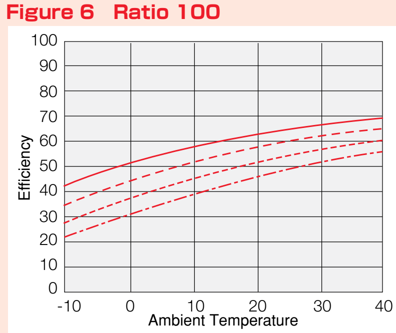



**Figure 6 Ratio 100**




### 2XH

**Figure 7 Ratio 30**

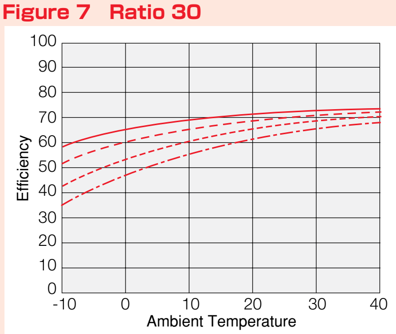



**Figure 8 Ratio 50**

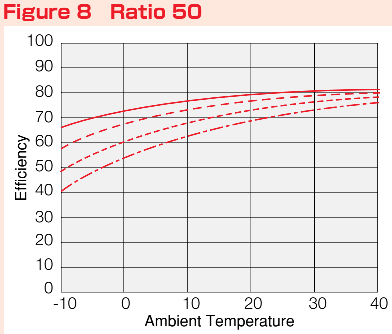
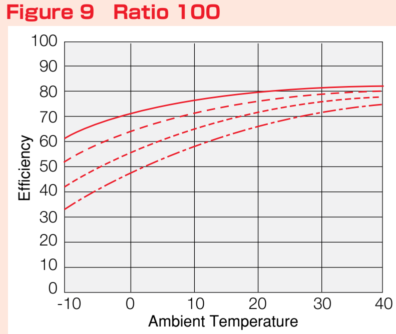



**Figure 9 Ratio 100**



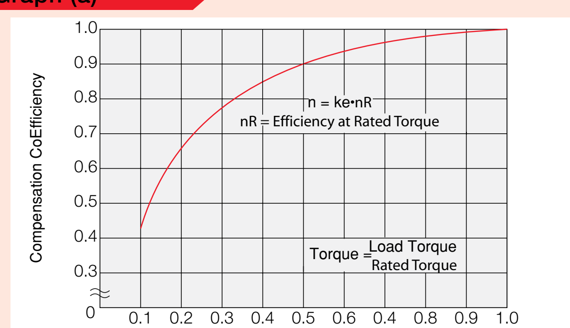

Input Speed ———— 500r/min - - - - - 1000r/min ------- 2000r/min —·—·—·— 3500r/min

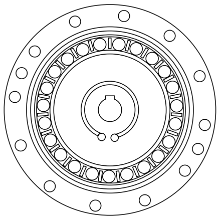
Efficiency Compensation Coefficient
Find the Compensation Coefficient (Ke) from graph (a) and calculate the Efficiency.
*For example Find the Efficiency n (%) on following condition that using model CSF-8-100-2XH

| | |
|---|---|
| Input speed | :1000 r/min |
| Load torque | : 2.0N.m |
| Type of lubricant | : grease |
| Temperature | :20°C |

Size 8—ratio 100, rated torque= 2.4N.m (see rated table, page 07)
Torque a = 2.0/2 .4≠0.83
Efficiency Compensation Coefficient Ke = 0.99
Load torque =2.0Nm
Efficiency n =Ke·NR = 0.99 x 77 = 76%
*The load torque is greater than the rated torque :The Efficiency Compensation Coefficient Ke=1

### Graph (a)





# EFFICIENCY

## Size 11

### 1U

Figure 10 Ratio 30

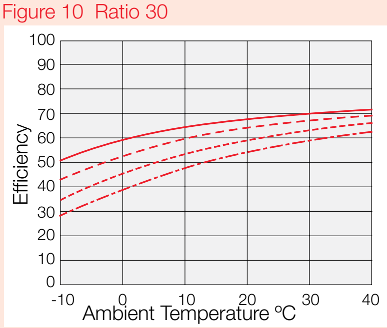



Figure 11 Ratio 50

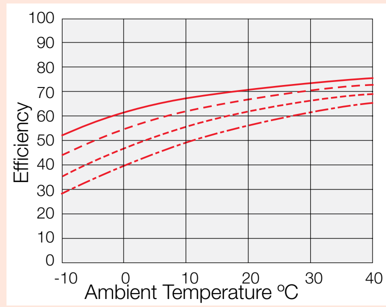
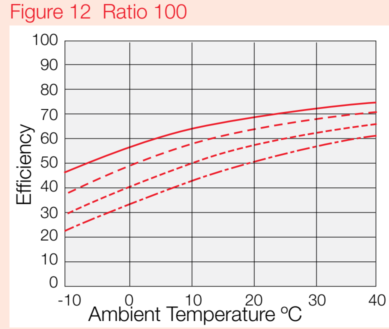



Figure 12 Ratio 100




### 2XH

Figure 13 Ratio 30

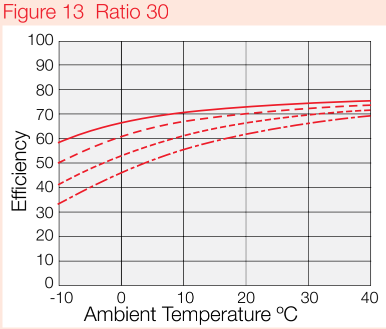



Figure 14 Ratio 50

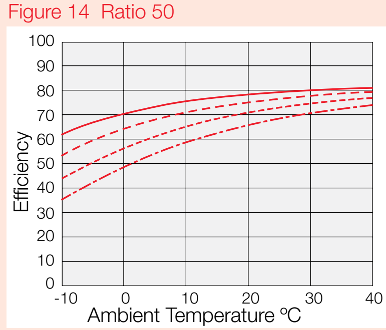
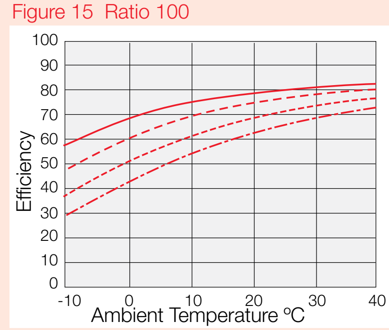



Figure 15 Ratio 100




Input 500r/min 1000r/min 2000r/min 3500r/min

## Size 14

### 1U

Figure 16 Ratio 30

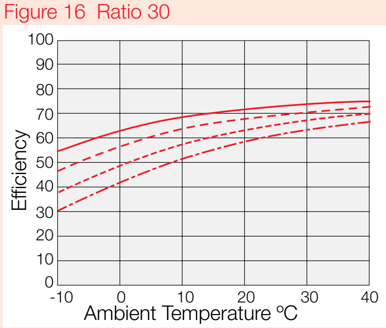



Figure 17 Ratio 50

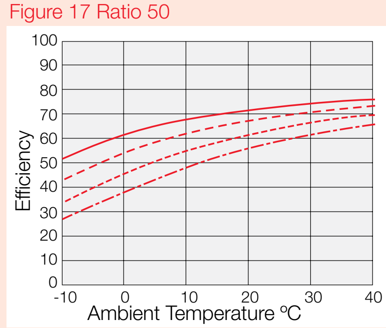
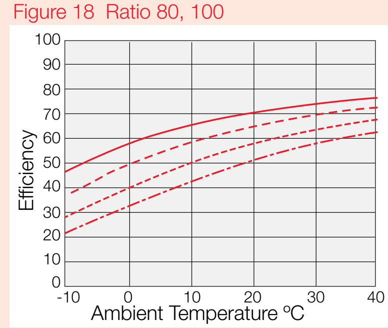



Figure 18 Ratio 80, 100




### 2XH

Figure 19 Ratio 30

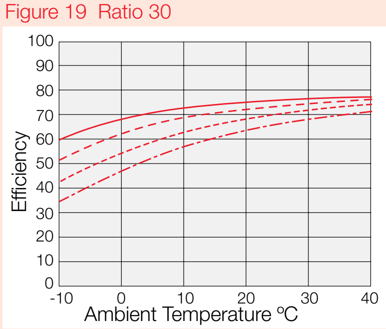



Figure 20 Ratio 50

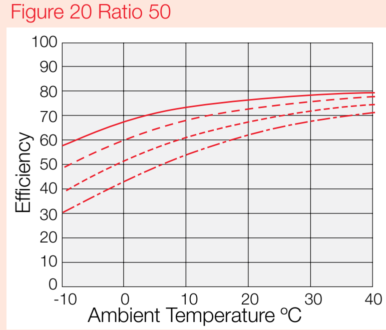
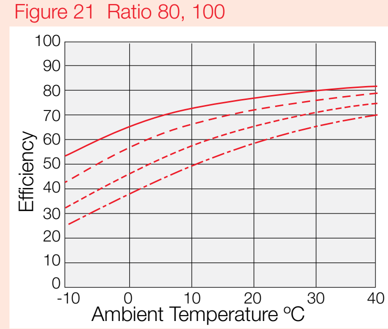
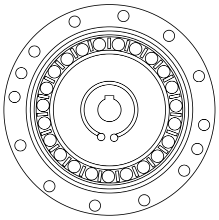



Figure 21 Ratio 80, 100




Input 500r/min 1000r/min 2000r/min 3500r/min



# NO LOAD RUNNING TORQUE

No Load Running Torque

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

Compensation Value in Each Ratio (Component Set)

No load running torque of the gear varies with ratio.The graphs indicate a value for ratio 100.
For other gear ratios, add the compensation values from table 34.

Measurement condition

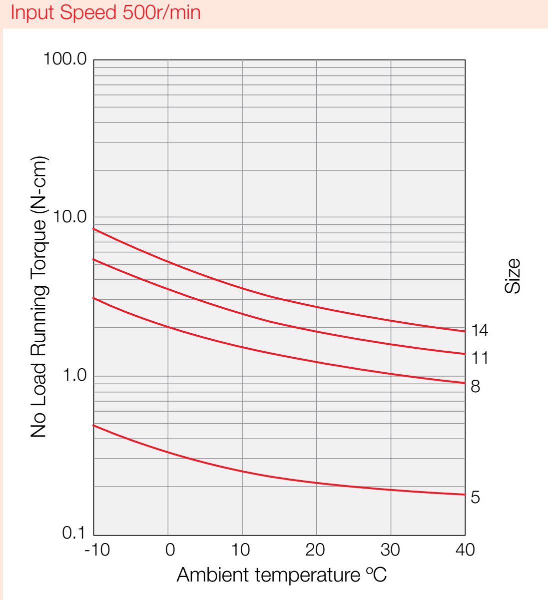
| | |
|---|---|
| Ratio | : 1/100 |
| Lubricant | : Harmonic Grease SK-2 |
| Quantity | : Recommended quantity |
| | see page 19 |

Torque value is measured after 2 hours at 2000rpm input.

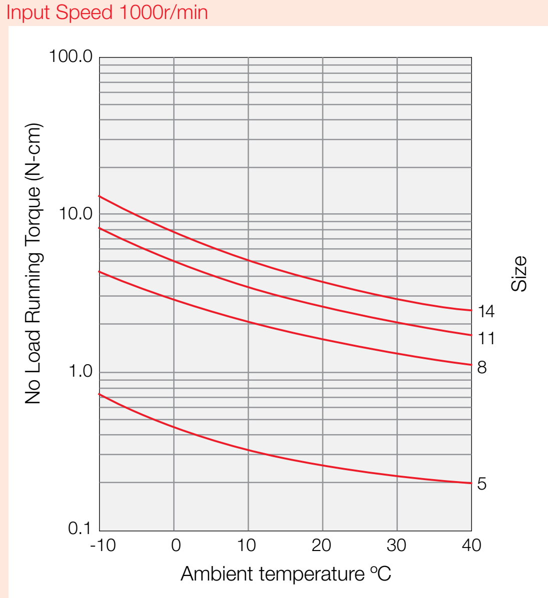
In case of oil lubricant, please contact us.

1U

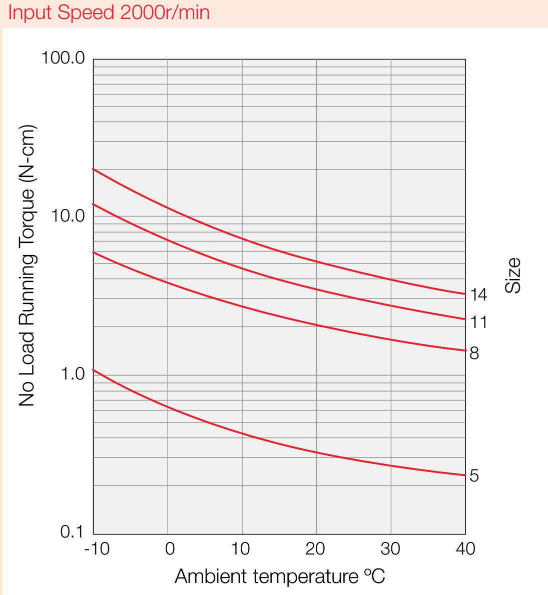
Input Speed 500r/min



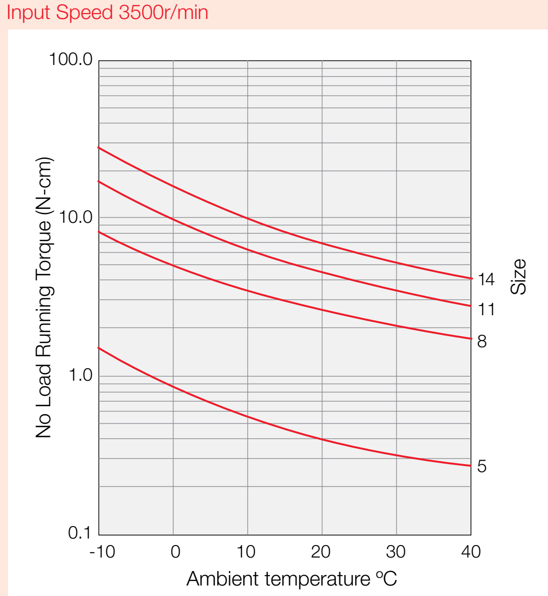

Input Speed 1000r/min

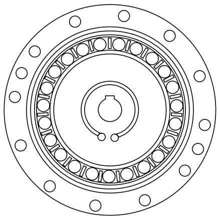



Input Speed 2000r/min




Input Speed 3500r/min





# No Load Running Torque

## Compensation Value in Each Ratio

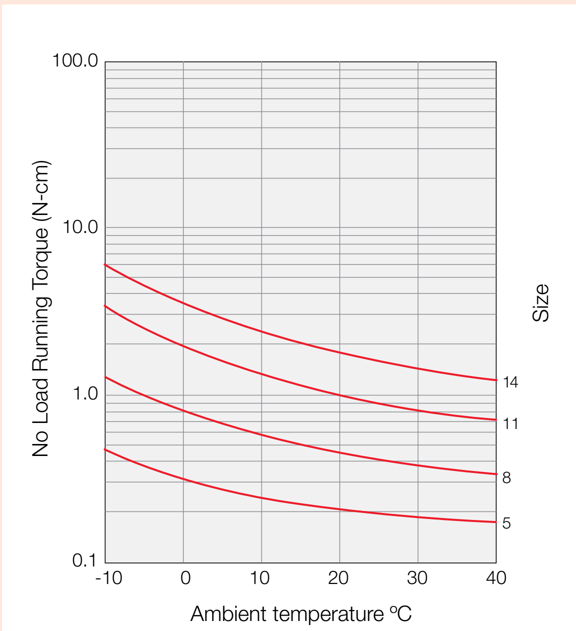
No load running torque of the gear varies with ratio. The graphs indicate a value for ratio 100. For other gear ratios, add the compensation values from table at right.

No load Running Torque Compensation Value (Ncm)

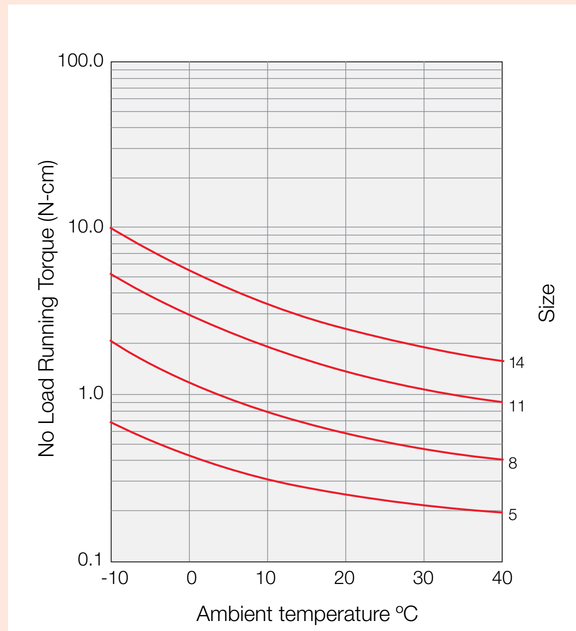
| Size | Ratio 30 | Ratio 50 | Ratio 80 |
|---|---|---|---|
| 5 | 0.26 | 0.11 | – |
| 8 | 0.44 | 0.19 | – |
| 11 | 0.81 | 0.36 | – |
| 14 | 1.33 | 0.58 | 0.1 |

### 2XH

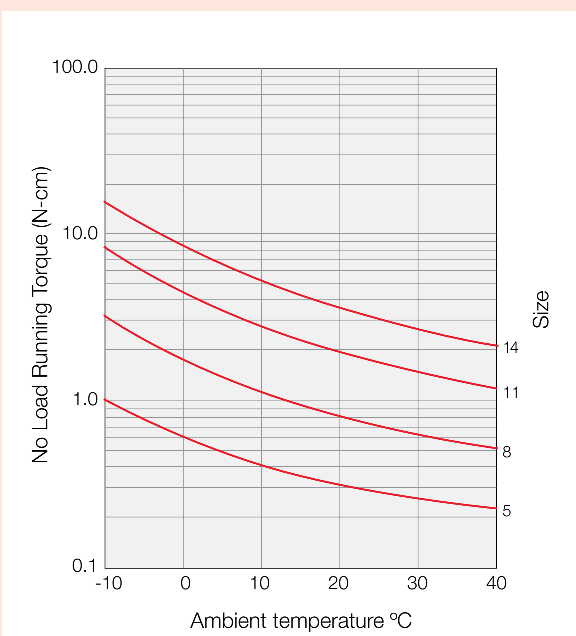
Input Speed 500r/min



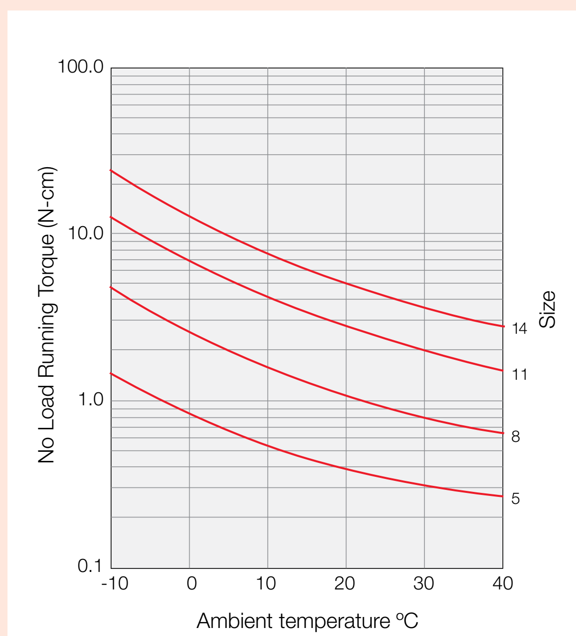

Input Speed 000r/min

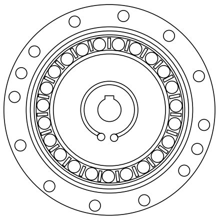



Input Speed 2000r/min




Input Speed 3500r/min







## Starting Torque

Starting torque is the torque required to commence rotation of the input element (high speed side), with no load being applied to the output. The table below indicates the maximum values. The lower values are approximately 1/2 to 1/3 of the maximum values. Temperature is at 20 degree C.

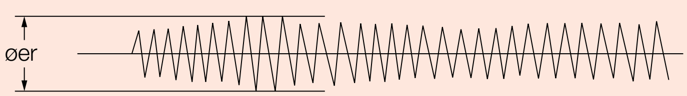
Starting Torque — Ncm

| Size | Ratio | | | |
|---|---|---|---|---|
| | 30 | 50 | 80 | 100 |
| 5 | 0.53 | 0.40 | – | 0.30 |
| 8 | 1.3 | 0.80 | – | 0.59 |
| 11 | 3.4 | 2.0 | – | 1.5 |
| 14 | 6.4 | 4.1 | 2.8 | 2.5 |

## Positioning Accuracy

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

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




Positioning Accuracy — arc-min

| Ratio | Size | | | |
|---|---|---|---|---|
| | 5 | 8 | 11 | 14 |
| 30 | 4 | 2 | 2 | 2 |
| 50+ | 3 | 2 | 1.5 | 1.5 |

## Component Type Backdriving Torque

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

Measurement condition: Ambient temperature 20°C

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

$\theta er$........................................Positioning Accuracy
$\theta_1$........................................Input Angle
$\theta_2$........................................Actual Output Angle
R........................................Gear Ratio ( i=l;R )

$$\theta er = \theta_2 - \frac{\theta_1}{R} \qquad \text{equation [18]}$$

Back Driving Torque — Nm

| Size | Ratio | | | |
|---|---|---|---|---|
| | 30 | 50 | 80 | 100 |
| 5 | 0.29 | 0.21 | – | 0.27 |
| 8 | 0.70 | 0.55 | – | 0.75 |
| 11 | 1.7 | 1.2 | – | 1.5 |
| 14 | 2.4 | 1.6 | 1.6 | 1.8 |

## Torsional Stiffness

Torsional stiffness is determined by applying a load to the output of the gear, with the input rotationally locked. The angular rotation is measured as the load is increased. The typical curve (shown in the figure 11) is non-linear. The stiffness is determined the slope of this curve. For simplicity, the curve is approximated by 3 straight lines having stiffness of K1, K2, and K3. Stiffness K1 applies for output torque of 0 to T1. Stiffness K3 applies for output torque greater than T2. Stiffness K2 applies for output torque between T1 and T2.Typical stiffness values are shown in tables 14, 15, 16.

Figure 8

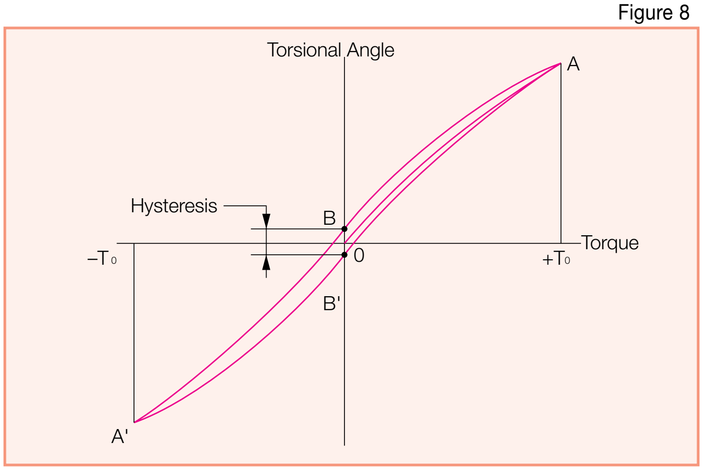
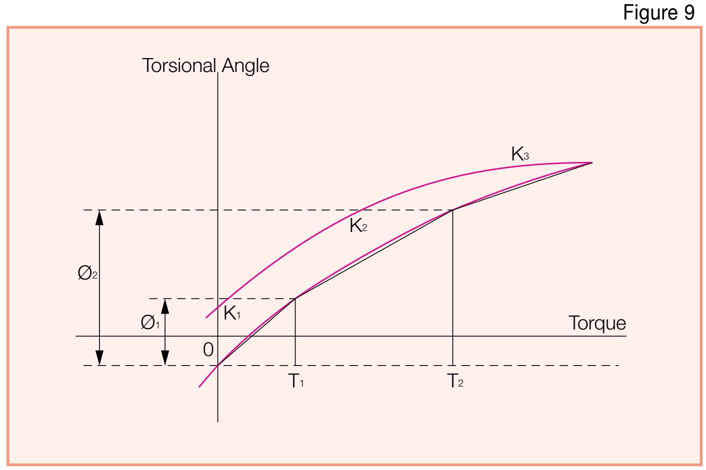



Figure 9




Torsional Stiffness for Ratio 1/30

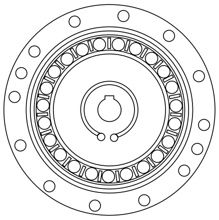
Table 14

| Size | | 5 | | | 8 | | | 11 | | | 14 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model | | 2XH-F | 2XH-J | 1U | 2XH-F | 2XH-J | 1U | 2XH-F | 2XH-J | 1U | 2XH-F | 2XH-J | 1U |
| $T_1$ | Nm | 0.075 | | | 0.29 | | | 0.80 | | | 2.0 | | |
| | In-lb | 0.66 | | | 2.57 | | | 7.08 | | | 17.70 | | |
| $K_1$ | X $10^4$Nm/rad | 0.010 | 0.009 | 0.009 | 0.034 | 0.031 | 0.031 | 0.084 | 0.077 | 0.077 | 0.188 | 0.172 | 0.172 |
| | In-lb/arc-min | 0.258 | 0.232 | 0.232 | 0.876 | 0.798 | 0.798 | 2.163 | 1.983 | 1.983 | 4.841 | 4.429 | 4.429 |
| $Q_1$ | X $10^{-4}$ rad | 7.5 | 8.7 | 8.7 | 8.6 | 9.5 | 9.5 | 9.5 | 10 | 10 | 11 | 12 | 12 |
| | arc-min | 2.6 | 3.0 | 3.0 | 3.0 | 3.2 | 3.2 | 3.3 | 3.6 | 3.6 | 3.6 | 4.0 | 4.0 |
| $T_2$ | Nm | 0.22 | | | 0.75 | | | 2.0 | | | 6.9 | | |
| | In-lb | 1.95 | | | 6.64 | | | 17.70 | | | 61.07 | | |
| $K_2$ | X $10^4$Nm/rad | 0.013 | 0.011 | 0.011 | 0.044 | 0.039 | 0.039 | 0.124 | 0.109 | 0.109 | 0.235 | 0.210 | 0.210 |
| | In-lb/arc-min | 0.335 | 0.283 | 0.283 | 1.133 | 1.004 | 1.004 | 3.193 | 2.807 | 2.807 | 6.051 | 5.408 | 5.408 |
| $Q_2$ | X $10^{-4}$ rad | 19 | 22 | 22 | 19 | 21 | 21 | 19 | 21 | 21 | 31 | 35 | 35 |
| | arc-min | 6.4 | 7.5 | 7.5 | 6.6 | 7.3 | 7.3 | 6.6 | 7.4 | 7.4 | 11 | 12 | 12 |
| $K_3$ | X $10^4$Nm/rad | 0.016 | 0.012 | 0.012 | 0.054 | 0.046 | 0.046 | 0.158 | 0.134 | 0.134 | 0.335 | 0.286 | 0.286 |
| | In-lb/arc-min | 0.412 | 0.309 | 0.309 | 1.391 | 1.185 | 1.185 | 4.069 | 3.451 | 3.451 | 8.626 | 7.365 | 7.365 |

Torsional Stiffness for Ratio 1/50

Table 15

| Size | | 5 | | | 8 | | | 11 | | | 14 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model | | 2XH-F | 2XH-J | 1U | 2XH-F | 2XH-J | 1U | 2XH-F | 2XH-J | 1U | 2XH-F | 2XH-J | 1U |
| $T_1$ | Nm | 0.075 | | | 0.29 | | | 0.80 | | | 2.0 | | |
| | In-lb | 0.66 | | | 2.57 | | | 7.08 | | | 17.70 | | |
| $K_1$ | X $10^4$Nm/rad | 0.013 | 0.011 | 0.011 | 0.044 | 0.039 | 0.039 | 0.221 | 0.177 | 0.177 | 0.335 | 0.286 | 0.286 |
| | In-lb/arc-min | 0.335 | 0.283 | 0.283 | 1.133 | 1.004 | 1.004 | 5.691 | 4.558 | 4.588 | 8.626 | 7.365 | 7.365 |
| $Q_1$ | X $10^{-4}$ rad | 5.6 | 6.9 | 6.9 | 6.6 | 7.5 | 7.5 | 3.6 | 4.5 | 4.5 | 6.0 | 7.0 | 7.0 |
| | arc-min | 2.0 | 2.4 | 2.4 | 2.3 | 2.6 | 2.6 | 1.2 | 1.6 | 1.6 | 2.0 | 2.4 | 2.4 |
| $T_2$ | Nm | 0.22 | | | 0.75 | | | 2.0 | | | 6.9 | | |
| | In-lb | 1.95 | | | 6.64 | | | 17.70 | | | 61.07 | | |
| $K_2$ | X $10^4$Nm/rad | 0.018 | 0.014 | 0.014 | 0.067 | 0.056 | 0.056 | 0.300 | 0.225 | 0.225 | 0.468 | 0.378 | 0.378 |
| | In-lb/arc-min | 0.464 | 0.361 | 0.361 | 1.725 | 1.442 | 1.442 | 7.725 | 5.794 | 5.794 | 12.051 | 9.734 | 9.734 |
| $Q_2$ | X $10^{-4}$ rad | 14 | 18 | 18 | 14 | 16 | 16 | 7.6 | 9.9 | 9.9 | 16 | 20 | 20 |
| | arc-min | 4.8 | 6.0 | 6.0 | 4.7 | 5.4 | 5.4 | 2.6 | 3.4 | 3.4 | 5.6 | 6.8 | 6.8 |
| $K_3$ | X $10^4$Nm/rad | 0.025 | 0.017 | 0.017 | 0.084 | 0.067 | 0.067 | 0.320 | 0.236 | 0.236 | 0.568 | 0.440 | 0.440 |
| | In-lb/arc-min | 0.644 | 0.438 | 0.438 | 2.163 | 1.725 | 1.725 | 8.240 | 6.077 | 6.077 | 14.626 | 11.330 | 11.330 |



# Torsional Stiffness

Torsional Stiffness for Ratio 1/80

Table 16

| Size | | 5 | | | 8 | | | 11 | | | 14 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Model | | 2XH-F | 2XH-J | 1U | 2XH-F | 2XH-J | 1U | 2XH-F | 2XH-J | 1U | 2XH-F | 2XH-J | 1U |
| $T_1$ | Nm | 0.075 | | | 0.29 | | | 0.80 | | | 2.0 | | |
| | In-lb | 0.66 | | | 2.57 | | | 7.08 | | | 17.70 | | |
| $K_1$ | X $10^4$Nm/rad | 0.020 | 0.015 | 0.015 | 0.09 | 0.072 | 0.072 | 0.267 | 0.206 | 0.206 | 0.468 | 0.378 | 0.378 |
| | In-lb/arc-min | 0.515 | 0.386 | 0.386 | 2.318 | 1.854 | 1.854 | 6.875 | 5.305 | 5.305 | 12.051 | 9.734 | 9.734 |
| $Q_1$ | X $10^{-4}$ rad | 3.7 | 5.0 | 5.0 | 3.2 | 4.1 | 4.1 | 3.0 | 3.9 | 3.9 | 4.3 | 5.3 | 5.3 |
| | arc-min | 1.3 | 1.7 | 1.7 | 1.1 | 1.4 | 1.4 | 1.0 | 1.3 | 1.3 | 1.5 | 1.8 | 1.8 |
| $T_2$ | Nm | 0.22 | | | 0.75 | | | 2 | | | 6.9 | | |
| | In-lb | 1.95 | | | 6.64 | | | 17.70 | | | 61.07 | | |
| $K_2$ | X $10^4$Nm/rad | 0.027 | 0.018 | 0.018 | 0.104 | 0.08 | 0.08 | 0.333 | 0.243 | 0.243 | 0.601 | 0.46 | 0.46 |
| | In-lb/arc-min | 0.695 | 0.464 | 0.464 | 2.678 | 2.060 | 2.060 | 8.575 | 6.257 | 6.257 | 15.476 | 11.845 | 11.845 |
| $Q_2$ | X $10^{-4}$ rad | 9.2 | 13 | 13 | 7.7 | 9.8 | 9.8 | 6.6 | 8.8 | 8.8 | 12 | 16 | 16 |
| | arc-min | 3.1 | 4.4 | 4.4 | 2.6 | 3.4 | 3.4 | 2.3 | 3.0 | 3.0 | 4.2 | 5.4 | 5.4 |
| $K_3$ | X $10^4$Nm/rad | 0.030 | 0.020 | 0.020 | 0.120 | 0.089 | 0.089 | 0.432 | 0.291 | 0.291 | 0.700 | 0.516 | 0.516 |
| | In-lb/arc-min | 0.773 | 0.515 | 0.515 | 3.090 | 2.292 | 2.292 | 11.124 | 7.493 | 7.493 | 18.025 | 13.287 | 13.287 |

## Hysteresis Loss

A typical hysteresis curve is shown in figure 8. With the input locked, a torque is applied from 0 to ± Rated Torque. Hysteresis measurement is shown in the figure.

The following table shows typical hysteresis values.

Table 17 Hysteresis Loss

| Ratio | | Size | | | |
|---|---|---|---|---|---|
| | | 5 | 8 | 11 | 14 |
| 30 | X$10^{-4}$rad | 8.7 | 8.7 | 8.7 | 8.7 |
| | arc-min | 3 | 3 | 3 | 3 |
| 50 | X$10^{-4}$rad | 8.7 | 5.8 | 5.8 | 2.9 |
| | arc-min | 3 | 2 | 2 | 1 |
| 80 and up | X$10^{-4}$rad | 8.7 | 5.8 | 5.8 | 2.9 |
| | arc-min | 3 | 2 | 2 | 1 |

## Calculate Torsion Angle

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

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

1. $T_{L1}$ =0.5Nm ($T<T_1$)

$$Q_{L1} = T_{L1}K_1$$
$$= 0.50/0.286X10^4$$
$$= 1.75X10^4 \text{ rad (0.6 arc min)}$$

2. $T_{L2}$ =4Nm ($T_1<T<T_2$)

$$Q_{L2} = Q_1 + (T_{L2}-T_1)K_2$$
$$= 7.0X10^{-4} + (4-2)/0.378X10^4$$
$$= 12.3X10^{-4} \text{ rad (4.2 arc min)}$$

*Note: Units for T, $T_1$, $T_2$, $K_3$, $K_1$, $K_2$, $K_3$, and Q must be consistent.

Table 18 Maximum Backlash

| Ratio | | Size | | |
|---|---|---|---|---|
| | | 8 | 11 | 14 |
| 30 | X$10^{-5}$rad | 28.6 | 23.8 | 29.1 |
| | arc-sec | 59 | 49 | 60 |
| 50 | X$10^{-5}$rad | 17 | 14.1 | 17.5 |
| | arc-sec | 35 | 24 | 36 |
| 80 | X$10^{-5}$rad | – | – | 11.2 |
| | arc-sec | – | – | 23 |
| 100 | X$10^{-5}$rad | 8.7 | 7.3 | 8.7 |
| | arc-sec | 18 | 15 | 18 |

## Backlash from Oldham Coupling

The gear element has zero backlash. However, an Oldham coupling is included as standard with all gearing components and gearheads. The Oldham coupling compensates for motor shaft concentricity errors. Unfortunately, the Oldham coupling does add a small amount of backlash to the system. Backlash values are shown in table 18. This amount of backlash is usually negligible. Component sets and gearheads can be supplied without an Oldham coupling. This is called a “Direct Drive” version.

## Surface Treatment

Corrosion resistant surface treatments are available for exposed areas of the gear. Additionally some components can be manufactured using corrosion resistant steels.

# Recommended Tolerances for Assembly

## Recommended Tolerances for Assembly

For peak performance of the CSF-min, Gearhead Type 2XH it is essential that the following tolerances be observed when assembly is complete.

Recommended Tolerances for Assembly Figure 10

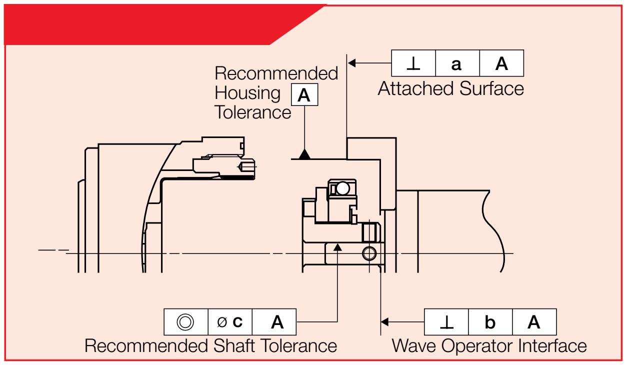



Table 19 Recommended Tolerances for Assembly Nm

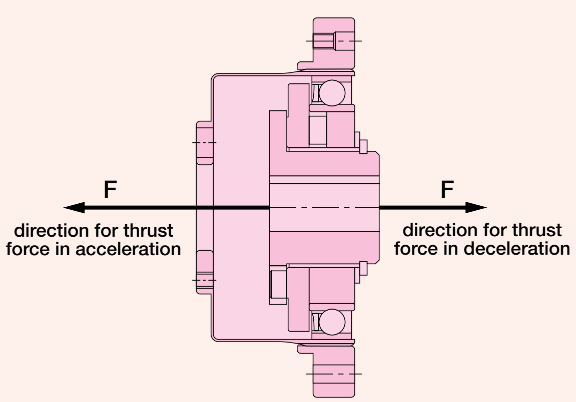
| Symbol | | Size | | | |
|---|---|---|---|---|---|
| | | 5 | 8 | 11 | 14 |
| a | Attached Surface | 0.008 | 0.010 | 0.011 | 0.011 |
| b | Wave Generator Interface | 0.005 | 0.012 (0.006) | 0.012 (0.007) | 0.017 (0.008) |
| c | Concentricity | 0.005 | 0.015 (0.006) | 0.015 (0.007) | 0.030 (0.016) |

* The values in parenthesis indicate that the wave generator does not have an Oldham coupling.

# Axial Force

Figure 11

Direction for Thrust Force of Wave Generator




Equation for axial force

| Gear Ratio | equation |
|---|---|
| i=1/30 | $F=2x\frac{T}{D}x\ 0.07\ x\ \tan 32°$ |
| i=1/50 | $F=2x\frac{T}{D}x\ 0.07\ x\ \tan 30°$ |
| i=1/80 and up | $F=2x\frac{T}{D}x\ 0.07\ x\ \tan 20°$ |

Symbols for equation

| | | |
|---|---|---|
| F | axial force | N |
| D | Gear Size x 0.00254 | m |
| T | output torque | Nm |

## Axial Force of Wave Generator

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

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

Note: Please contact us when you fix the Wave Generator hub and input shaft using bolts.

Calculation Example

| | | |
|---|---|---|
| size | : | 11 |
| Ratio | : | i=1/50 |
| Output Torque | : | 3.5 Nm |

$$F=2x\frac{3.5}{(11x0.00254)}x\ 0.07x\tan 30°$$

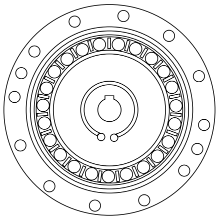
F=10N

## Sealing structure

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

## Key Points to Verify

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





## Performance Data for the Input Bearing

The Input Shaft incorporated in the CSF-1U unit is supported by two deep groove single row ball bearings.
Please calculate Input load to fully maximize the performance of CSF-1U gearhead.

Fig.12 shows the points of application of forces, which determine the maximum permissible radial and axial loads as indicated in Fig.13.

The maximum values, as given in Figures 13, are valid for an average input speed of 2000 rpm and a mean bearing life of L10=7000h.

Example: If the input shaft of a CSF-14-1U unit is subjected to an axial load (Fa) of 8N, then the maximum permissible radial face will be 20N, Fig. 13.

## Specification for Input Bearing

Table 20

| Size | Bearing A | | | | | Bearing B | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bearing A | Basic Dynamic Rated Load Cr (N) | lb | Basic Static Rated Load Cor (N) | lb | Bearing B0- | Basic Dynamic Rated Load Cr (N) | lb | Basic Statica Rated Load Cor (N) | lb | b (mm) | (mm) | (N) | lb |
| 5 | SSLF-630DD | 196 | 44 | 59 | 13 | L-520WO2 | 176 | 40 | 54 | 12 | 10.8 | 9.25 | 8 | 2 |
| 8 | MR126 | 715 | 161 | 292 | 66 | MR83 | 560 | 126 | 170 | 38 | 16.65 | 18 | 10 | 2 |
| 11 | 689 | 1330 | 299 | 665 | 149 | 624 | 1300 | 292 | 485 | 109 | 20.6 | 21.9 | 20 | 4 |
| 14 | 6900ZZ | 2700 | 607 | 1270 | 285 | 605ZZ | 1330 | 299 | 505 | 114 | 28.25 | 24.25 | 30 | 7 |

## Point of Shaft

Figure 12

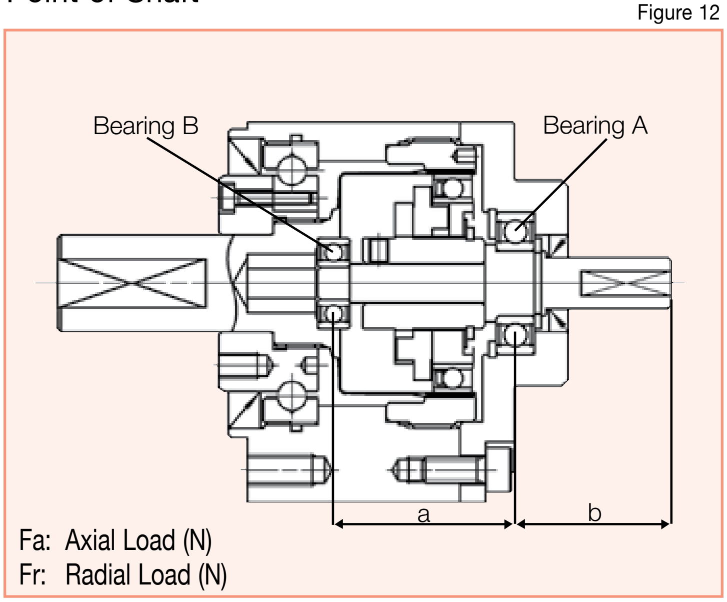
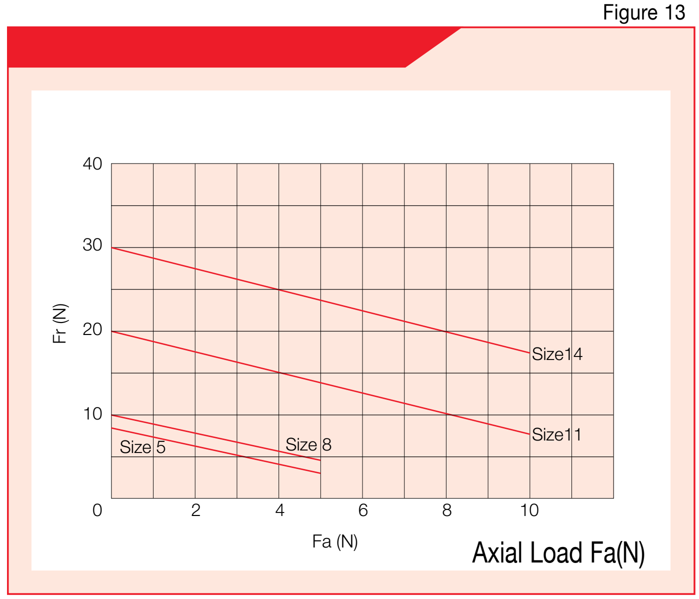
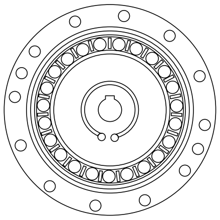



Figure 13





# INSTALLATION OF CASE SIDE

Ensure that surface used for installation is flat and does not have any burr.
Please fasten bolt with the proper torque for each size as indicated.

## 1U

Table 21

| Size | | 5 | 8 | 11 | 14 |
|---|---|---|---|---|---|
| Number of Bolts | | 4 | 4 | 4 | 4 |
| Size of Bolt | | M2 | M3 | M4 | M5 |
| Pitch Circle Diameter | mm | 23 | 35 | 46 | 58 |
| Clamp Torque | Nm | 0.25 | 0.85 | 2 | 3.96 |
| | In.lb | 0.03 | 0.09 | 17.70 | 35.05 |
| Length of Bolt | mm | 2.4 | 3.6 | 4.8 | 60 |
| Torque Transmission Capacity | Nm | 3.5 | 12 | 29 | 57 |
| | In.lb | 31 | 106 | 257 | 504 |

***Recommended Bolt: JISB1176 socket head cap, screw strength range: JISB1051 over 12.9***

## 2XH

Table 22

| Size | | 5 | 8 | 11 | 14 |
|---|---|---|---|---|---|
| Number of Bolts | | 2 | 2 | 2 | 2 |
| Size of Bolt | | M2 | M3 | M4 | M5 |
| Pitch Circle Diameter | mm | 25 | 37.5 | 50 | 62 |
| Clamp torque | Nm | 0.25 | 0.85 | 2 | 4 |
| | In.lb | 2.21 | 7.52 | 17.70 | 35.40 |
| Length of Bolt | mm | 2.4 | 3.6 | 4.8 | 6 |
| Torque Transmission Capacity | Nm | 2 | 7 | 16 | 31 |
| | In.lb | 18 | 62 | 142 | 274 |

***Recommended Bolt: JISB1176 socket head cap, screw strength range: JISB1051 over 12.9***

## Installation of Output Flange

Please refer to “Specification for a Cross Roller Bearing”. page 12-14

## 2XH (Output Flange)

Table 23

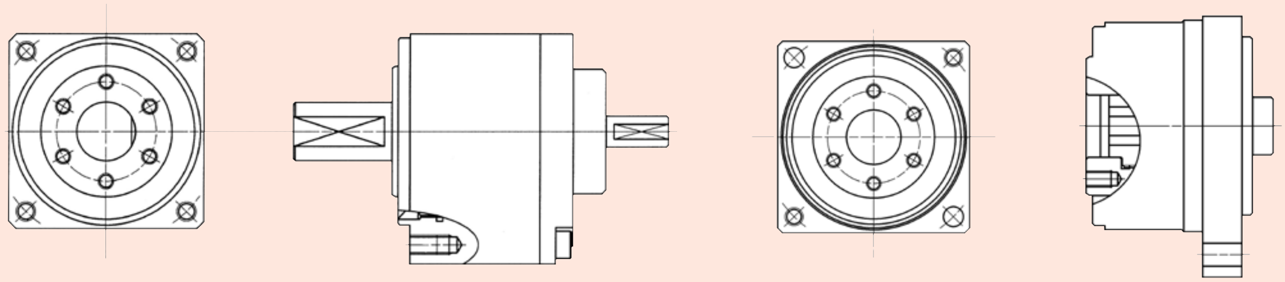
| Size | | 5 | 8 | 11 | 14 |
|---|---|---|---|---|---|
| Number of Bolts | | 3 | 4 | 6 | 6 |
| Size of Bolt | | M2 | M3 | M3 | M4 |
| Pitch Circle Diameter | mm | 9.8 | 15.5 | 20.5 | 25.5 |
| Clamp torque | Nm | 0.54 | 2 | 2 | 4.6 |
| | In.lb | 4.8 | 17.7 | 17.7 | 40.7 |
| Torque Transmission Capacity | Nm | 2 | 13 | 26 | 55 |
| | In.lb | 18 | 115 | 230 | 487 |

***Output Flange is prevented for grease leakage, re-sealing is not necessary.

## 1U, 2XH-J (Output Shaft)

Avoid impact to output shaft during assembly of pulley or pinion, loss of accuracy and speed may occur.

Figure 14

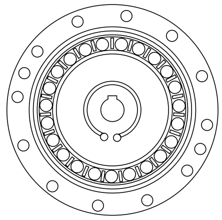


## Lubrication

Harmonic Drive® CSF-mini series are delivered ready for use. They are supplied with lifetime lubricant, which is high performance grease that meets the specific requirements of the gears. It guarantees constant accuracy of the gears over their entire service life.

Recommended Grease

| Lubricant | Speed reducers | Cross Roller Bearing |
|---|---|---|
| Name of Lubricant | Harmonic Grease SK-2 | Multemp HL-D |
| Manufacturer | Harmonic Drive Systems | Kyodo Yushi |
| Base Oil | Refined Mineral Hydrocarbon base oil | Hydrocarbon type synthetic oil and polymer |
| Thickening Agent | lithium soap thickener | Lithium soap thickener |
| Viscosity (25°) | 295 | 280 |
| Melting Point | 198°C | 210°C |
| Color | Green | White |



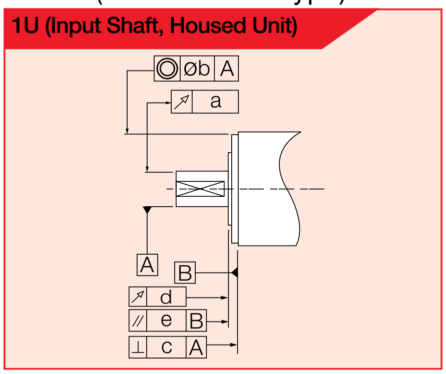


## Tolerances for Assembly

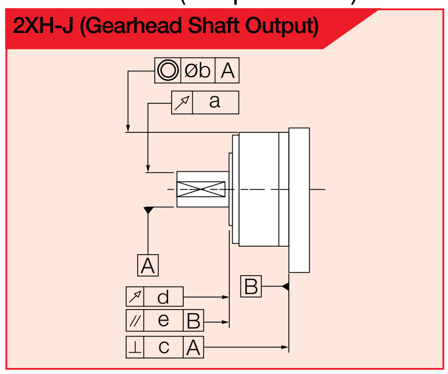
This innovative gearhead combines precision Harmonic Drive® gear and a high capacity 4-point contact bearing for output flange/shaft support.

### Recommended Tolerances for Assembly

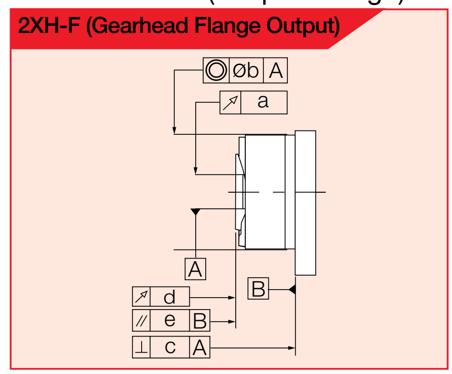
1U (Double Shaft Type)




2XH-J(Output Shaft)




2XH-F (Output Flange)




Torsional Stiffness for Ratio 1/80 — Table 24

| Size | Tolerances Item | Configuration | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 5 | | 8 | | 11 | | 14 | |
| | | 1U, 2XH-J | 2XH-F | 1U, 2XH-J | 2XH-F | 1U, 2XH-J | 2XH-F | 1U, 2XH-J | 2XH-F |
| a | 1U, 2XH-J Run Out | 0.020 | – | 0.020 | – | 0.020 | – | 0.020 | – |
| | 2XH-F Run Out | – | 0.005 | – | 0.005 | – | 0.005 | – | 0.005 |
| b | Concentricity | 0.020 | | 0.020 | | 0.030 | | 0.030 | |
| c | Perpendicularity | 0.020 | | 0.020 | | 0.025 | | 0.025 | |
| d | Run Out | 0.005 | | 0.005 | | 0.005 | | 0.005 | |
| e | Parallelism | 0.015 | | 0.020 | | 0.030 | | 0.030 | |

Note:

### Warranty Period and Terms

The Product is warranted as follows:

- Warranty period

Under the condition that the product is handled, used and maintained and conforms to each item of the documents and the manuals, the product is warranted against defects in workmanship and materials for the period of either one year after delivery or 2,000 hours of operation time, whichever is shorter.

- Warranty terms

All products are warranted against defects in workmanship and materials for the warranted period. This limited warranty does not apply to any product that has been subject to:

1. User's misapplication, improper installation, inadequate maintenance, or misuse.
2. Disassembling modification or repair by others than Harmonic Drive LLC.
3. Imperfection caused by something other than the product.
4. Disaster or other occurrences that does not belong to the responsibility of Harmonic Drive LLC.

Our liability shall be limited exclusively to repairing or replacing the product as found by Harmonic Drive LLC. to be defective. Harmonic Drive® Systems, Inc. shall not be liable for consequential damages of other equipment caused by the defective product, and shall not be liable for the incidental and consequential expenses and the labor coast associated with disassembly and installation to the driven equipment.

- Trademark

The academic and general nomenclature for Harmonic Drive® gear "Strain Wave Gearing". " Harmonic Drive" is a trademark that can be used only on products, which are manufactured and sold by Harmonic Drive LLC.

# CSF-MINI

## SAFETY GUIDE

- For actuators, motors, control units and drivers manufactured by Harmonic Drive LLC.
- Read the manual thoroughly before designing the application, installation, maintenance or inspection of the actuator.
- WARNING: Indicates a potentially hazardous situation, which, if not avoided, could result in death or serious personal injury.
- CAUTION: Indicates a potentially hazardous situation, which, if not avoided, may result in minor or moderate personal injury and/or damage to the equipment.

## LIMITATION OF APPLICATIONS:

The equipment listed in this document may not be used for the following applications:

- Space equipment
- Aircraft, aeronautic equipment
- Nuclear equipment
- Household apparatus
- Vacuum equipment
- Automobile, automotive parts
- Amusement equipment, sport equipment, game machines
- Machine or devices acting directly on the human body
- Instruments or devices to transport or carry people
- Apparatus or devices used in special environments

Please consult us, if you intend to use our products in one of the areas mentioned above.

Safety measures are essential to prevent accidents resulting in death, injury or damage of the equipment due to malfunction or faulty operation.

# Precautions When Using An Actuator and/or Driver

## CAUTIONS FOR ACTUATORS IN APPLICATION DESIGN

The product must only be used indoors, where the following conditions are provided:

- Ambient temperature: 0°C to 40°C
- Ambient humidity: 20% to 80%RH (Non-condensating)
- Vibration: Max 24.5 m/S$^2$
- No contamination by water, oil or foreign matters
- No corrosive, inflammable or explosive gas

Follow exactly the instructions in the relating manuals to install the product in the equipment.

- Ensure exact alignment of motor shaft center and corresponding center in the application.
- Failure to observe this caution may lead to vibration, resulting in damage of output elements.

## CAUTIONS FOR ACTUATORS IN OPERATIONS

Do not exceed the allowable torque of the actuator.

- Be aware, that if a load arm attached to the output hits by accident an obstacle, the output shaft may become uncontrollable.

Never connect cables directly to a power supply socket.

- An actuator must not be operated without a corresponding driver.
- Failure to observe this caution may lead to injury, fire or damage of the actuator.

Protect the actuator from impact and shocks

- Do not use a hammer to position the actuator during installation
- Failure to observe this caution could damage the encoder and may cause uncontrollable operation.
- Avoid handling of the actuator by its cables.
- Failure to observe this caution may damage the wiring, causing uncontrollable or faulty operation.

## CAUTIONS FOR DRIVERS IN APPLICATION DESIGN

Always use drivers under the following conditions:

- Mount in a vertical position keeping sufficient distance to other devices to let heat generated by the driver radiate freely.
- Ambient temperature: 0º to 50º
- Ambient humidity: less than 95% RH (Non condensation)
- No contamination by water, oil or foreign matters
- No corrosive, inflammable or explosive gas  Use sufficient noise suppressing means and safe grounding.
- Keep signal and power leads separated.
- Keep leads as short as possible.
- Ground actuator and driver at one single point, minimum ground resistance class: D (less than 100 ohms)
- Do not use a power line filter in the motor circuit. Pay attention to negative torque by inverse load.
  –Inverse load may cause damages of drivers.
- Please consult our sales office, if you intent to apply products for inverse load. Use a fast-response type ground-fault detector designed for PWM inverters.
- Do not use a time-delay-type ground-fault detector.

## CAUTIONS FOR DRIVERS IN OPERATIONS

Never change wiring while power is active:

- Make sure of power non-active before servicing the products.
- Failure to observe this caution may result in electric shock or personal injury.
  Do not touch terminals or inspect products at least 5 minutes after turning OFF power.
- Otherwise residual electric charges may result in electric shock.
- Make installation of products not easy to touch their inner electric components. Do not make a voltage resistance test.
- Failure to observe this caution may result in damage of the control unit.
- Please consult our sales office, if you intent to make a voltage resistance test.
- Do not operate control units by means of power ON/OFF switching.
- Start/stop operation should be performed via input signals.
- Failure to observe this caution may result in deterioration of electronic parts.

## DISPOSAL OF AN ACTUATOR, A MOTOR, A CONTROL UNIT AND/OR THEIR PARTS

- All products or parts have to be disposed of as industrial waste.
- Since the case or the box of drivers have a material indication, classify parts and dispose them separately.

All products are warranted to be free from design or manufacturing defects for a period of one year from the date of shipment. Such items will be repaired or replaced at the discretion of Harmonic Drive LLC. The seller makes no warranty, expressed or implied, concerning the material to be furnished other than it shall be of the quality and specifications stated. The seller's liability for any breach is limited to the purchase price of the product. All efforts have been made to assure that the information in this catalog is complete and accurate. However, Harmonic Drive LLC is not liable for any errors, omissions or inaccuracies in the reported data. Harmonic Drive LLC reserves the right to change the product specifications, for any reason, without prior notice.

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