**HarmonicDrive®**

**CSF-GH Standard Series**

### Size

<table>
<thead>
<tr>
<th>Size</th>
<th>14, 20, 32, 45, 65</th>
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**Peak torque**

18Nm to 2630Nm

**Reduction ratio**

50:1 to 160:1

**Zero backlash**

**High Accuracy**

Repeatability ±4 to ±10 arc-sec

**High Load Capacity Output Bearing**

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

**Easy mounting to a wide variety of servomotors**

Quick Connect™ coupling

### Motor Model Number

<table>
<thead>
<tr>
<th>Model Name</th>
<th>Size</th>
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<th>Model</th>
<th>Output Configuration</th>
<th>Input Configuration</th>
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<td>14</td>
<td>50, 80, 100</td>
<td>GH: Gearhead</td>
<td>F0: Flange output J2: Straight shaft (without key) J6: Straight shaft (with key and center tapped hole)</td>
<td>This code represents the motor mounting configuration. Please contact us for a unique part number based on the motor you are using.</td>
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<tr>
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<td>32</td>
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<td>GH: Gearhead</td>
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<td>80, 100, 120, 160</td>
<td>GH: Gearhead</td>
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### Gearhead Construction

- Output Shaft (flange optional)
- Grease filling port (2 locations)
- Cross roller bearing
- Mounting pilot
- Shielded bearing
- Rubber cap
- Quick Connect™ coupling
- Input rotational direction
- Oil seal
- Mounting bolt hole

(The figure indicates output shaft type.)

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### Rating Table  CSF-GH

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

### Ratcheting Torque  CSF-GH

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### Buckling Torque  CSF-GH

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## Performance Table CSF-GH

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<th>Starting torque(^{b})</th>
<th>Backdriving torque(^{b})</th>
<th>No-load running torque(^{b})</th>
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<td></td>
<td></td>
<td></td>
<td>arc min (\times 10^{-5}) rad arc sec</td>
<td>Nm kgfcm Nm kgfcm Nm kgfcm</td>
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<td>139 14 268 27</td>
<td>278 28</td>
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</table>

\(^{a}\): Accuracy values represent the difference between the theoretical angle and the actual angle of output for any given input. The values shown in the table are maximum values.

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

\(^{c}\): Starting torque is the torque value applied to the input side at which the output first starts to rotate. The values in the table are maximum values.

\(^{d}\): Backdriving torque is the torque value applied to the output side at which the input first starts to rotate. The values in the table are maximum values.

Note: Never rely on these values as a margin in a system that must hold an external load. A brake must be used where back driving is not permissible.

\(^{e}\): No-load running torque is the torque required at the input to operate the gearhead at a given speed under a no-load condition. The values in the table are average values.
## Torsional Stiffness  CSF-GH

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<td>1.8</td>
<td>1.9</td>
<td>1.8</td>
<td>—</td>
</tr>
<tr>
<td>θ₂</td>
<td>&lt;10⁻⁴rad</td>
<td>16</td>
<td>15.4</td>
<td>15.7</td>
<td>15.1</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>arc min</td>
<td>5.6</td>
<td>5.3</td>
<td>5.4</td>
<td>5.2</td>
<td>—</td>
</tr>
</tbody>
</table>

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

## Hysteresis Loss  CSF-GH

**Reduction ratio 50:** Approx. 5.8X10⁻⁴ rad (2arc min)
**Reduction ratio 80 or more:** Approx. 2.9X10⁻⁴ rad (1arc min)
### CSF-GH-14 Outline Dimensions

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

#### Flange Type I

![Flange Type I Diagram](image)

#### Flange Type II

![Flange Type II Diagram](image)

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

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

### Dimension Table

(Unit: mm)

<table>
<thead>
<tr>
<th>Flange</th>
<th>Coupling</th>
<th>A (H7)</th>
<th>B</th>
<th>C</th>
<th>F (H7)</th>
<th>G</th>
<th>H</th>
<th>Moment of Inertia</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min.</td>
<td>Max.</td>
<td>Min.</td>
<td>Max.</td>
<td>Min.</td>
<td>Max.</td>
<td>(10^-4 kgm^2)</td>
<td></td>
</tr>
<tr>
<td>Type I</td>
<td>1</td>
<td>50</td>
<td>58</td>
<td>7</td>
<td>58</td>
<td>72</td>
<td>6.0</td>
<td>7.8</td>
<td>21.5</td>
</tr>
<tr>
<td>Type II</td>
<td>1</td>
<td>30</td>
<td>45</td>
<td>6.5</td>
<td>36</td>
<td>54</td>
<td>6.0</td>
<td>7.8</td>
<td>21.5</td>
</tr>
</tbody>
</table>

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

1. May vary depending on motor interface dimensions.
2. The mass will vary slightly depending on the ratio and on the inside diameter of the input shaft coupling.
3. Tapped hole for motor mounting screw.
CSF-GH-20 Outline Dimensions

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

![Flange Type I](image1)

Flange Type I

![Flange Type II](image2)

Flange Type II

![Flange Type III](image3)

Flange Type III

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

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

### Dimension Table

<table>
<thead>
<tr>
<th>Flange</th>
<th>Coupling</th>
<th>A (H7)</th>
<th>B</th>
<th>C</th>
<th>F (H7)</th>
<th>E</th>
<th>H</th>
<th>Moment of Inertia</th>
<th>Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Max</td>
<td>Min</td>
<td>Max</td>
<td>Min</td>
<td>(kg*cm²)</td>
<td>kg</td>
</tr>
<tr>
<td>Type I</td>
<td>1</td>
<td>30</td>
<td>45</td>
<td>5</td>
<td>36</td>
<td>48</td>
<td>7.0</td>
<td>23.0</td>
<td>82.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.28</td>
<td>2.3</td>
</tr>
<tr>
<td>Type II</td>
<td>2</td>
<td>50</td>
<td>70</td>
<td>10</td>
<td>60</td>
<td>80</td>
<td>8.0</td>
<td>25.0</td>
<td>99.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.42</td>
<td>2.6</td>
</tr>
<tr>
<td>Type III</td>
<td>2</td>
<td>50</td>
<td>80</td>
<td>10</td>
<td>60</td>
<td>100</td>
<td>8.0</td>
<td>25.0</td>
<td>99.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.42</td>
<td>2.8</td>
</tr>
</tbody>
</table>

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

*1 May vary depending on motor interface dimensions.

*2 The mass will vary slightly depending on the ratio and on the inside diameter of the input shaft coupling.

*3 Tapped hole for motor mounting screw.
**CSF-GH-32 Outline Dimensions**

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

**Dimension Table**

<table>
<thead>
<tr>
<th>Flange</th>
<th>Coupling</th>
<th>A (H7)</th>
<th>B</th>
<th>C</th>
<th>F (H7)</th>
<th>G</th>
<th>H</th>
<th>Moment of Inertia</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(min)</td>
<td></td>
<td></td>
<td>(min)</td>
<td></td>
<td></td>
<td>(10⁻⁴ kgm²)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(max)</td>
<td></td>
<td></td>
<td>(max)</td>
<td></td>
<td></td>
<td>(max)</td>
<td></td>
</tr>
<tr>
<td>Type I</td>
<td>3</td>
<td>50</td>
<td>85</td>
<td>10</td>
<td>58</td>
<td>105</td>
<td>11.0</td>
<td>19.6</td>
<td>28.0</td>
</tr>
<tr>
<td>Type II</td>
<td>2</td>
<td>70</td>
<td>95</td>
<td>5</td>
<td>85</td>
<td>115</td>
<td>16.0</td>
<td>25.8</td>
<td>35.0</td>
</tr>
<tr>
<td>Type III</td>
<td>1</td>
<td>95</td>
<td>130</td>
<td>7</td>
<td>115</td>
<td>165</td>
<td>11.0</td>
<td>19.6</td>
<td>36.0</td>
</tr>
</tbody>
</table>

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

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

(Note) The dimension tolerances that are not specified vary depending on the manufacturing method. Please check the confirmation drawing or contact us for dimension tolerances not shown on the drawing above.
CSF-GH-45 Outline Dimensions

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

Dimension Table

<table>
<thead>
<tr>
<th>Flange</th>
<th>Coupling</th>
<th>A (H7)</th>
<th>B</th>
<th>C</th>
<th>F (H7)</th>
<th>C</th>
<th>H (°)</th>
<th>Moment of inertia</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min</td>
<td>Max</td>
<td>Max</td>
<td>Min</td>
<td>Max</td>
<td>Min</td>
<td>Typical</td>
<td>10°/kgf°t</td>
</tr>
<tr>
<td>Type I</td>
<td>1</td>
<td>70</td>
<td>110</td>
<td>7</td>
<td>80</td>
<td>150</td>
<td>14.0</td>
<td>29.4</td>
<td>31.5</td>
</tr>
<tr>
<td>Type I</td>
<td>2</td>
<td>70</td>
<td>110</td>
<td>7</td>
<td>80</td>
<td>150</td>
<td>19.0</td>
<td>41</td>
<td>40.5</td>
</tr>
<tr>
<td>Type II</td>
<td>1</td>
<td>110</td>
<td>130</td>
<td>6.5</td>
<td>145</td>
<td>200</td>
<td>14.0</td>
<td>29.4</td>
<td>31.5</td>
</tr>
<tr>
<td>Type II</td>
<td>2</td>
<td>110</td>
<td>130</td>
<td>6.5</td>
<td>145</td>
<td>200</td>
<td>19.0</td>
<td>41</td>
<td>40.5</td>
</tr>
</tbody>
</table>

Refer to the confirmation drawing for detailed dimensions.

**Note:** Dimensions of typical products are shown. Please contact us for other mounting options if the configurations shown above are not suitable for your particular motor.

*1 May vary depending on motor interface dimensions.
*2 The mass will vary slightly depending on the ratio and on the inside diameter of the input shaft coupling.
*3 Tapped hole for motor mounting screw.
*4 E dimension is dependent on motor selection.
CSF-GH-65 Outline Dimensions

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

<table>
<thead>
<tr>
<th>Dimension Table</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flange</strong></td>
</tr>
<tr>
<td>Type I</td>
</tr>
<tr>
<td>Type II</td>
</tr>
</tbody>
</table>

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

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

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

- **Rated torque**
  Rated torque indicates allowable continuous load torque at input speed.

- **Limit for Repeated Peak Torque** *(see Graph 086-1)*
  During acceleration and deceleration the Harmonic Drive® gear experiences a peak torque as a result of the moment of inertia of the output load. The table indicates the limit for repeated peak torque.

- **Limit for Average Torque**
  In cases where load torque and input speed vary, it is necessary to calculate an average value of load torque. The table indicates the limit for average torque. The average torque calculated must not exceed this limit. *(calculation formula: Page 91)*

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

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

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

Life

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

<table>
<thead>
<tr>
<th>Life</th>
<th>CSF-GH</th>
<th>CSG-GH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lh (average)</td>
<td>7,000 hours</td>
<td>10,000 hours</td>
</tr>
<tr>
<td>Ln (average)</td>
<td>35,000 hours</td>
<td>50,000 hours</td>
</tr>
</tbody>
</table>

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

**Calculation formula for Rated Lifetime** *(Formula 086-1)*

\[
Lh = Ln \cdot \left( \frac{Tr}{Tav} \right) \cdot \left( \frac{Nr}{Nav} \right)
\]

Table 086-2

<table>
<thead>
<tr>
<th>Ln</th>
<th>Life of Ln or Lw/c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tr</td>
<td>Rated torque</td>
</tr>
<tr>
<td>Nr</td>
<td>Rated input speed</td>
</tr>
<tr>
<td>Tav</td>
<td>Average load torque on the output side <em>(calculation formula: Page 91)</em></td>
</tr>
<tr>
<td>Nav</td>
<td>Average input speed <em>(calculation formula: Page 91)</em></td>
</tr>
</tbody>
</table>

Graph 087-1

**Relative torque rating** *(Graph 086-2)*

- Buckling torque
- Ratcheting torque
- Fatigue strength of the flexspline
- Momentary peak torque
- Repeated peak torque
- Rated torque

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

Example of load torque pattern *(Graph 086-1)*

- Abnormal impact torque
- Peak torque at startup/stops
- Peak torque at steady state
- Max. momentary torque
- Torque at steady state
- Torque at startup/stops
- Time
- (Speed cycle)
- Start
- Stop
- Time
- Life of wave generator (L10)

**Caution**

- Buckling torque
- Ratcheting torque

- **Buckling torque**
  - The torque that occurs during a collision must be below the allowable limit. (calculation formula: Page 91)

- **Ratcheting torque**
  - *Ratcheting torque is affected by the stiffness of the housing to be used when calculated.*
  - *Once ratcheting occurs, the teeth wear excessively and cause vibration and damage the flexspline.*

**Graph 087-1**

- Circular Spline
- Flexspline

**Figure 087-1**

- Harmonic Planetary® & Harmonic Drive® Gearheads
Torque Limits

■ Strength of flexspline
The Flexspline is subjected to repeated deflections, and its strength determines the torque capacity of the Harmonic Drive® gear. The values given for Rated Torque at Rated Speed and for the allowable Repeated Peak Torque are based on an infinite fatigue life for the Flexspline.
The torque that occurs during a collision must be below the momentary peak torque (impact torque). The maximum number of occurrences is given by the equation below.

Allowable limit of the bending cycles of the flexspline during rotation of the wave generator while the impact torque is applied: 1.0 x 10⁴ (cycles)

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

Calculation formula

\[
N = \frac{1.0 \times 10^4}{2 \times \frac{n \times x}{60}}
\]

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

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

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

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

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

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

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

Caution When ratcheting occurs, the teeth may not be correctly engaged and become out of alignment as shown in Figure 087-1. Operating the drive in this condition will cause vibration and damage the flexspline.

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

Figure 087-1
Torsional Stiffness

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

**Stiffness**
Fixing the input side (wave generator) and applying torque to the output side (flexspline) generates torsion almost proportional to the torque on the output side. Figure 088-1 shows the torsional angle at the output side when the torque applied on the output side starts from zero, increases up to +T0 and decreases down to −T0. This is called the “Torque – torsion angle diagram,” which normally draws a loop of 0 – A – B – A’ – B’ – A. The slope described in the “Torque – torsion angle diagram” is represented as the spring constant for the stiffness of the HarmonicDrive® gear (unit: Nm/rad).

As shown in Figure 074-2, this “Torque – torsion angle diagram” is divided into 3 regions, and the spring constants in the area are represented by K1, K2 and K3.

- K1: The spring constant when the torque changes from [zero] to [T1]
- K2: The spring constant when the torque changes from [T1] to [T2]
- K3: The spring constant when the torque changes from [T2] to [T3]

See the corresponding pages of each series for values of the spring constants (K1, K2, K3) and the torque-torsional angles (T1, T2, T3).

**Example for calculating the torsion angle**
The torsion angle (θ) is calculated here using CSG-32-100-GH as an example:

<table>
<thead>
<tr>
<th>Torque (Nm)</th>
<th>Spring Constant (Nm/rad)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 = 29 Nm</td>
<td>K1 = 6.7 x 10^4</td>
</tr>
<tr>
<td>T2 = 108 Nm</td>
<td>K2 = 6.7 x 10^4</td>
</tr>
<tr>
<td>T3 = 178 Nm</td>
<td>K3 = 6.7 x 10^4</td>
</tr>
</tbody>
</table>

When the applied torque is T1 or less, the torsion angle θ1 is calculated as follows:

θ1 = TL1/K1
θ1 = 6.0/6.7 x 10^4
θ1 = 9.0 x 10^-5 rad (0.31 arc min)

When the applied torque is between T1 and T2, the torsion angle θ2 is calculated as follows:

θ2 = TL2/K2
θ2 = 108/6.7 x 10^4
θ2 = 16.0 x 10^-5 rad (0.52 arc min)

When the applied torque is greater than T2, the torsion angle θ3 is calculated as follows:

θ3 = TL3/K3
θ3 = 178/6.7 x 10^4
θ3 = 26.7 x 10^-5 rad (0.79 arc min)

When a bidirectional load is applied, the total torsion angle will be 2 x θ plus hysteresis loss.

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

**Hysteresis loss**
As shown in Figure 088-1, when the applied torque is increased to the rated torque and is brought back to [zero], the torsional angle does not return exactly back to the zero point. This small difference (B – B’) is called hysteresis loss.

See the appropriate page for each model series for the hysteresis loss value.

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

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

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

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

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

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

Efficiency

The efficiency will vary depending on the following factors:

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

How to calculate resonant frequency of the system

Formula 089-2

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

Formula variables

| \( f \) | The resonant frequency of the system | Hz |
| K | Spring constant of the HarmonicDrive® gear | Nm/rad |
| J | Load inertia | kgm² |

Table 089-1

\( J = \frac{1}{12} \cdot \text{mass} \cdot \text{radius}^2 \)

\( K = \frac{W}{\theta} \)

where \( W \) is the load torque applied to the output, and \( \theta \) is the torsion angle at the output side when the torque applied on the output side (flexspline) generates torsion almost proportional to the input revolution of the input. Therefore, the frequency generated by the transmission error is 2x the input frequency (rev / sec).
Product Sizing & Selection

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

As an accurate cross roller bearing is built in the direct external load support (output flange), the maximum moment load, life of the cross roller bearing and the static safety coefficient should also be checked.

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

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

<table>
<thead>
<tr>
<th>Normal operation pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting</td>
</tr>
<tr>
<td>Steady operation</td>
</tr>
<tr>
<td>Stopping (slowing)</td>
</tr>
<tr>
<td>Idle</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Maximum rotational speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. output speed</td>
</tr>
<tr>
<td>Max. input rotational speed</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Impact torque</th>
</tr>
</thead>
<tbody>
<tr>
<td>When impact torque is applied</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Required life</th>
</tr>
</thead>
<tbody>
<tr>
<td>L₁₀ = L (hours)</td>
</tr>
</tbody>
</table>

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

- Calculate the average load torque applied on the output side from the load torque pattern: Tav (Nm).
  - Tav = \( \frac{\sum T_n \cdot t_n}{\sum t_n} \)

- Make a preliminary model selection with the following conditions. Tav ≤ Limit for average torque (See the ratings of each series).

- Calculate the average output speed: no av (rpm)
  - \( no \ av = \frac{n_1 \cdot t_1 + n_2 \cdot t_2 + \cdots + n_n \cdot t_n}{t_1 + t_2 + \cdots + t_n} \)

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

- Calculate the average input rotational speed from the average output rotational speed (no av) and the reduction ratio (R): ni av (rpm)
  - \( ni \ av = no \ av \cdot R \)

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

- Check whether T₁ and T₃ are equal to or less than the repeated peak torque specification.

- Check whether T₁ and T₄ are equal to or less than the maximum momentary peak torque specification.

- Calculate (Nₛ) the allowable number of rotations during impact torque.
  - \( Nₛ = \left( \frac{10^6}{2 \cdot n₃ \cdot R} \right) \cdot N₃ \leq 1.0 \times 10^6 \)

- Calculate the lifetime.
  - \( L_{10} = 7000 \cdot \left( \frac{Tav}{nₐv} \right)^2 \cdot \left( \frac{nr}{ni \ av} \right) \) (hours)

- Check whether the calculated lifetime is equal to or more than the life of the wave generator (see Page 88).

The model number is confirmed.
Example of model number selection

Value of each load torque pattern:

<table>
<thead>
<tr>
<th>Load torque (Nm)</th>
<th>Time (sec)</th>
<th>Output speed (rpm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( T_1 )</td>
<td>0.3</td>
<td>( n_1 )</td>
</tr>
<tr>
<td>( T_2 )</td>
<td>3</td>
<td>( n_2 )</td>
</tr>
<tr>
<td>( T_3 )</td>
<td>4</td>
<td>( n_3 )</td>
</tr>
<tr>
<td>( T_4 )</td>
<td>0.2</td>
<td>( n_4 )</td>
</tr>
</tbody>
</table>

\(<\text{Normal operation pattern}>\)

Starting: \( T_1 = 400 \text{ Nm}, t_1 = 0.3 \text{ sec}, n_1 = 7 \text{ rpm} \)
Steady operation: \( T_2 = 320 \text{ Nm}, t_2 = 3 \text{ sec}, n_2 = 14 \text{ rpm} \)
Stopping: \( T_3 = 200 \text{ Nm}, t_3 = 0.4 \text{ sec}, n_3 = 7 \text{ rpm} \)
Idle: \( T_4 = 0 \text{ Nm}, t_4 = 0.2 \text{ sec}, n_4 = 0 \text{ rpm} \)

\(<\text{Maximum rotational speed}>\)

Max. output speed: \( n_{\text{max}} = 14 \text{ rpm} \)
Max. input speed: \( n_{i_{\text{max}}} = 1800 \text{ rpm} \)

\(<\text{Required life}>\)

When impact torque is applied: \( T_s = 500 \text{ Nm}, t_s = 0.15 \text{ sec}, n_s = 14 \text{ rpm} \)

\(<\text{Impact torque}>\)

When impact torque is applied: \( T_s = 500 \text{ Nm}, t_s = 0.15 \text{ sec}, n_s = 14 \text{ rpm} \)

Calculate the average load torque applied on the output side of the Harmonic Drive® gear from the load torque pattern: \( T_{\text{av}} \) (Nm).

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

Make a preliminary model selection with the following conditions. \( T_{\text{av}} = 319 \text{ Nm} \leq 620 \text{ Nm} \)
(Limit for average torque for model number CSF-45-120-GH; See the ratings on Page 77.)
Thus, CSF-45-120-GH is tentatively selected.

Calculate the average output rotational speed: \( n_{\text{av}} \) (rpm)

\[
n_{\text{av}} = \frac{7 \text{ rpm} \cdot 0.3 \text{ sec} + 14 \text{ rpm} \cdot 3 \text{ sec} + 7 \text{ rpm} \cdot 0.4 \text{ sec}}{0.3 \text{ sec} + 3 \text{ sec} + 0.4 \text{ sec} + 0.2 \text{ sec}} = 12 \text{ rpm}
\]

Obtain the reduction ratio (R).

\[
1800 \text{ rpm} = 128.6 \leq 120 \text{ rpm}
\]

Calculate the average input rotational speed from the average output rotational speed (no \( n_{\text{av}} \)) and the reduction ratio (R): \( n_{i_{\text{av}}} \) (rpm)

\[
n_{i_{\text{av}}} = 12 \text{ rpm} \cdot 120 \leq 1440 \text{ rpm}
\]

Calculate the maximum input rotational speed from the maximum output rotational speed (no \( n_{\text{max}} \)) and the reduction ratio (R): \( n_{i_{\text{max}}} \) (rpm)

\[
n_{i_{\text{max}}} = 14 \text{ rpm} \cdot 120 \leq 1680 \text{ rpm}
\]

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

\( n_{i_{\text{av}}} = 1440 \text{ rpm} \leq 3000 \text{ rpm} \) (Max average input speed of size 45)
\( n_{i_{\text{max}}} = 1680 \text{ rpm} \leq 3800 \text{ rpm} \) (Max input speed of size 45)

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

\( T_1 = 400 \text{ Nm} \leq 823 \text{ Nm} \) (Limit of repeated peak torque of size 45)
\( T_3 = 200 \text{ Nm} \leq 823 \text{ Nm} \) (Limit of repeated peak torque of size 45)

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

\( T_s = 500 \text{ Nm} \leq 1760 \text{ Nm} \) (Limit for momentary torque of size 45)

Calculate the allowable number (\( N_s \)) rotation during impact torque and confirm \( \leq 1.0 \times 10^4 \)

\[
N_s = \frac{10^4}{14 \text{ rpm} \cdot 120 \div 60 \cdot 0.15 \text{ sec}} = 1190 \leq 1.0 \times 10^4
\]

Calculate the lifetime.

\[
L_{10} = 7000 \text{ (hours)} \left( \frac{402 \text{ Nm}}{319 \text{ Nm}} \right) \left( \frac{1400 \text{ rpm}}{2000 \text{ rpm}} \right) \times 10^4 \text{ (hours)}\]

Check whether the calculated life is equal to or more than the life of the wave generator (see Page 86).

\( L_{10} = 19,457 \text{ hours} \geq 7000 \) (life of the wave generator: \( L_{10} \))

The selection of model number CSF-45-120-GH is confirmed from the above calculations.
HarmonicDrive® gearing has a unique operating principle which utilizes the elastic mechanics of metals. This precision gear reducer consists of only 3 basic parts and provides high accuracy and repeatability.

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

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

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

Robust cross roller bearing is integrated with the output flange to provide high moment stiffness, high load capacity and precise positioning accuracy.

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

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

The Circular Spline is a rigid ring with internal teeth, engaging the teeth of the Flexspline across the major axis of the Wave Generator. The Circular Spline has two more teeth than the Flexspline and is generally mounted to the housing.

Quick Connect™ coupling for easy mounting of any servomotor
Output Bearing Specifications and Checking Procedure

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

**Checking procedure**

1. **Checking the maximum load moment load (M\text{max})**
   - Obtain the maximum load moment load (M\text{max}).
   - Maximum load moment load (M\text{max}) \leq \text{Permissible moment (Mo)}

2. **Checking the life**
   - Obtain the average radial load (F\text{av}) and the average axial load (F\text{av}).
   - Obtain the radial load coefficient (X) and the axial load coefficient (Y).
   - Calculate the life and check it.

3. **Checking the static safety coefficient**
   - Obtain the static equivalent radial load coefficient (Po).
   - Check the static safety coefficient (fs).

**Specification of output bearing**

<table>
<thead>
<tr>
<th>CSG-GH/CSF-GH Series</th>
<th>Table 130-1 indicates the specifications for cross roller bearing.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Size</th>
<th>Pitch circle</th>
<th>Offset amount</th>
<th>Basic load rating</th>
<th>Allowable moment load</th>
<th>Moment stiffness</th>
<th>Allowable radial load</th>
<th>Allowable axial load</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>\text{dp}</td>
<td>\text{R}</td>
<td>\text{Basic dynamic load rating Cr}^*2</td>
<td>\text{Basic static load rating Cor}^*2</td>
<td>\text{N} \text{m} / \text{rad}</td>
<td>\text{kgf/arc min}</td>
<td>\text{N}</td>
</tr>
<tr>
<td></td>
<td>\text{m}</td>
<td>\text{m}</td>
<td>\text{N}</td>
<td>\text{kgf}</td>
<td>\text{N}</td>
<td>\text{kgf}</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>0.0405</td>
<td>0.011</td>
<td>5110</td>
<td>521</td>
<td>7060</td>
<td>720</td>
<td>27</td>
</tr>
<tr>
<td>20</td>
<td>0.064</td>
<td>0.0115</td>
<td>10600</td>
<td>1082</td>
<td>17300</td>
<td>1765</td>
<td>145</td>
</tr>
<tr>
<td>32</td>
<td>0.085</td>
<td>0.014</td>
<td>20500</td>
<td>2092</td>
<td>32800</td>
<td>3347</td>
<td>258</td>
</tr>
<tr>
<td>45</td>
<td>0.123</td>
<td>0.019</td>
<td>41600</td>
<td>4245</td>
<td>76000</td>
<td>7755</td>
<td>797</td>
</tr>
<tr>
<td>65</td>
<td>0.170</td>
<td>0.0225</td>
<td>81600</td>
<td>8327</td>
<td>149000</td>
<td>15204</td>
<td>2156</td>
</tr>
</tbody>
</table>

*1 The basic dynamic load rating means a certain static radial load so that the basic dynamic rated life of the roller bearing is a million rotations.

*2 The basic static load rating means a static load that gives a certain level of contact stress (4kN/mm²) in the center of the contact area between rolling element receiving the maximum load and orbit.

*3 The allowable moment load is a maximum moment load applied to the bearing. Within the allowable range, basic performance is maintained and the bearing is operable. Check the bearing life based on the calculations shown on the next page.

*4 The value of the moment stiffness is the average value.

*5 The allowable radial load and allowable axial load are the values that satisfy the life of a speed reducer when a pure radial load or an axial load applies to the main bearing. (Lr + R = 0 mm for radial load and La = 0 mm for axial load) If a compound load applies, refer to the calculations shown on the next page.
### Technical Data

#### How to calculate the maximum load moment load

Maximum load moment load \( (M_{max}) \) is obtained as follows. Make sure that \( M_{max} \leq M_c \).

\[
M_{max} = F_r \cdot \max(Lr+R) + F_a \cdot \max(La)
\]

**Formula 131-1**

- \( F_r \): Max. radial load
- \( Lr \): Center of shaft length
- \( R \): Center of shaft length
- \( F_a \): Max. axial load
- \( La \): Center of shaft length

<table>
<thead>
<tr>
<th>Formula</th>
<th>X</th>
<th>Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>( F_{aav} )</td>
<td>( \frac{F_{rav} + 2 \cdot F_{rav} \cdot Lr + R + F_{aav} \cdot La}{dp} )</td>
<td>( \leq 1.5 )</td>
</tr>
<tr>
<td>( F_{aav} )</td>
<td>( \frac{F_{rav} + 2 \cdot F_{rav} \cdot Lr + R + F_{aav} \cdot La}{dp} )</td>
<td>&gt;1.5</td>
</tr>
</tbody>
</table>

**Formula 131-2**

- \( F_{rav} \): Average radial load
- \( F_{aav} \): Average axial load
- \( Lr \): Center of shaft length
- \( R \): Center of shaft length
- \( La \): Center of shaft length
- \( dp \): Circular pitch of roller

<table>
<thead>
<tr>
<th>Load status</th>
<th>Load coefficient</th>
<th>Average moment load ( Nm ) (kgfm)</th>
<th>Calculation Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>When impact or vibration is expected</td>
<td>( 1.2 ) to ( 1.5 )</td>
<td>See Figure 132-1.</td>
<td>See Table 133-4</td>
</tr>
<tr>
<td>When high rotation precision is required</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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

The radial load coefficient (X) and the axial load coefficient (Y) are calculated as follows.

**Formula 131-3**

\[
F_{rav} = \sqrt{n_1 \cdot (Fr_1)^{10/3} + n_2 \cdot (Fr_2)^{10/3} + \ldots + n_k \cdot (Fr_k)^{10/3}}
\]

Note that the maximum radial load within the \( t_1 \) section is \( Fr_1 \) and the maximum radial load within the \( t_i \) section is \( Fr_i \).

**Formula 131-4**

\[
F_{aav} = \sqrt{n_1 \cdot (Fa_1)^{10/3} + n_2 \cdot (Fa_2)^{10/3} + \ldots + n_k \cdot (Fa_k)^{10/3}}
\]

Note that the maximum axial load within the \( t_1 \) section is \( Fa_1 \) and the maximum axial load within the \( t_i \) section is \( Fa_i \).

**Formula 131-5**

\[
N_{av} = \frac{n_1 + n_2 + \ldots + n_k}{t_1 + t_2 + \ldots + t_k}
\]

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

\[
L_{oc} = \frac{10^6}{60 \times N_{av}} \times \left( \frac{C}{f_w \times P_c} \right)^{1/3}
\]

Where:
- \( L_{oc} \) = Rated life under oscillating movement (hour)
- \( N_{av} \) = Average output speed (rpm)
- \( C \) = Basic dynamic rated load (N·kgf)
- \( f_w \) = Load coefficient
- \( P_c \) = Dynamic equivalent radial load (N·kgf)

**Load coefficient**

<table>
<thead>
<tr>
<th>Load status</th>
<th>( f_w )</th>
</tr>
</thead>
<tbody>
<tr>
<td>During smooth operation without impact or vibration</td>
<td>1 to 1.2</td>
</tr>
<tr>
<td>During normal operation</td>
<td>1.2 to 1.5</td>
</tr>
<tr>
<td>During operation with impact or vibration</td>
<td>1.5 to 3</td>
</tr>
</tbody>
</table>

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

\[
L_{oc} = \frac{10^6}{60 \times n_1} \times 90 \times \theta \times \left( \frac{C}{f_w \times P_c} \right)^{1/3}
\]

Where:
- \( L_{oc} \) = Rated life under oscillating movement (hour)
- \( n_1 \) = No. of reciprocating oscillation per min., rpm
- \( \theta \) = Oscillating angle (°), see Figure 132-1.
- \( C \) = Basic dynamic rated load (N·kgf)
- \( P_c \) = Dynamic equivalent radial load (N·kgf)
- \( f_w \) = Load coefficient

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

In general, the basic static rated load (Co) is considered to be the permissible limit of the static equivalent load. However, obtain the limit based on the operating and required conditions. Calculate the static safety coefficient (fs) of the cross roller bearing using Formula 132-4.

\[
fs = \frac{Co}{Po}
\]

Where:
- \( Co \) = Basic static rated load (N·kgf)
- \( Po \) = Static equivalent radial load (N·kgf)

**Static safety coefficient**

<table>
<thead>
<tr>
<th>Load status</th>
<th>fs</th>
</tr>
</thead>
<tbody>
<tr>
<td>When high rotation precision is required</td>
<td>≥3</td>
</tr>
<tr>
<td>When impact or vibration is expected</td>
<td>≥2</td>
</tr>
<tr>
<td>Under normal operating condition</td>
<td>≥1.5</td>
</tr>
</tbody>
</table>

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

**How to calculate the maximum load moment load**

\[
P_C = X \left( Fr_{av} + 2(Fr_{av}L + Fr_{av}L_{av}) \right) + Y \cdot Fa_{av}
\]

Where:
- \( P_C \) = Circular pitch of roller (m)
- \( Fr_{av} \) = Average radial load (N·kgf)
- \( Fa_{av} \) = Average axial load (N·kgf)
- \( X \) = Radial load coefficient
- \( Y \) = Axial load coefficient
- \( L_{av} \) = Max. axial load

**How to calculate the average load**

1. \( Fr_{av} = \frac{Fr_{max}}{2} \)
2. \( Fa_{av} = \frac{Fa_{max}}{2} \)
3. \( Fr_{max} \) = Max. radial load (N·kgf)
4. \( Fa_{max} \) = Max. axial load (N·kgf)
5. \( M_{max} \) = Max. load moment load (Nm·kgf)
6. \( dp \) = Circular pitch of roller (m)

See Table 132-2 and Table 133-4.

**How to calculate average axial load (Fr_{av})**

1. \( Fr_{av} \) = Max. axial load
2. \( Fa_{av} \) = Average axial load
3. \( X \) = Radial load coefficient
4. \( Y \) = Axial load coefficient
5. \( L_{av} \) = Max. axial load

See Formula 132-5 and check the life.