HarmonicDrive®
CSG-GH High Torque Series

Size
14, 20, 32, 45, 65

Peak torque
23Nm to 3419Nm

Reduction ratio
50:1 to 160:1

Zero backlash

High Accuracy
Repeatability ±4 to ±10 arc-sec

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

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

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

<table>
<thead>
<tr>
<th>Model Name</th>
<th>Size</th>
<th>Reduction Ratio</th>
<th>Model</th>
<th>Output Configuration</th>
<th>Input Configuration</th>
</tr>
</thead>
<tbody>
<tr>
<td>HarmonicDrive® CSG High Torque</td>
<td>14</td>
<td>50, 80, 100</td>
<td>GH: Gearhead</td>
<td>FC: Flange output</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>
</tr>
<tr>
<td></td>
<td>20</td>
<td>50, 80, 100, 120, 160</td>
<td></td>
<td>J2: Straight shaft (without key)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>32</td>
<td>50, 80, 100, 120, 160</td>
<td></td>
<td>J6: Straight shaft (with key and center tapped hole)</td>
<td></td>
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<tr>
<td></td>
<td>45</td>
<td>80, 100, 120, 160</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>65</td>
<td>80, 100, 120, 160</td>
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</table>

Gearhead Construction

(The figure indicates output shaft type.)
### Rating Table  CSG-GH

<table>
<thead>
<tr>
<th>Size</th>
<th>Ratio</th>
<th>Rated Torque at 2000 rpm</th>
<th>Rated Torque at 3000 rpm</th>
<th>Limit for Average Torque</th>
<th>Limit for Peaked Torque</th>
<th>Limit for Momentary Torque</th>
<th>Max. Average Input Speed</th>
<th>Max. Input Speed</th>
<th>Mass</th>
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<tr>
<td></td>
<td></td>
<td>Nm</td>
<td>Nm</td>
<td>Nm</td>
<td>Nm</td>
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<td>6500</td>
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<td>3419</td>
<td>5174</td>
<td>1900</td>
<td>2800</td>
<td>32</td>
</tr>
</tbody>
</table>

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

### Ratcheting Torque  CSG-GH

<table>
<thead>
<tr>
<th>Reduction ratio</th>
<th>Size</th>
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<th>45</th>
<th>65</th>
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<tbody>
<tr>
<td>50</td>
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<td>100</td>
<td>100</td>
<td>330</td>
<td>1300</td>
<td>4000</td>
<td>12000</td>
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<tr>
<td>120</td>
<td></td>
<td>310</td>
<td>1200</td>
<td>3600</td>
<td>10000</td>
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<tr>
<td>160</td>
<td></td>
<td>260</td>
<td>1200</td>
<td>3300</td>
<td>10000</td>
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</table>

### Buckling Torque  CSG-GH

<table>
<thead>
<tr>
<th>Size</th>
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<th>20</th>
<th>32</th>
<th>45</th>
<th>65</th>
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</thead>
<tbody>
<tr>
<td>All Ratios</td>
<td>260</td>
<td>800</td>
<td>3500</td>
<td>8900</td>
<td>26600</td>
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## Performance Table  CSG-GH

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<tr>
<th>Size</th>
<th>Flange Type</th>
<th>Ratio</th>
<th>Accuracy</th>
<th>Repeatability</th>
<th>Starting torque</th>
<th>Backdriving torque</th>
<th>No-load running torque</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>x10 rad</td>
<td>arc sec</td>
<td>Ncm</td>
<td>kgfcm</td>
<td>Nm</td>
<td>kgfcm</td>
</tr>
<tr>
<td>14</td>
<td>All</td>
<td>50</td>
<td>1.5</td>
<td>±10</td>
<td>8.5</td>
<td>0.9</td>
<td>3.0</td>
</tr>
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<td></td>
<td></td>
<td>80</td>
<td></td>
<td></td>
<td>7.1</td>
<td>0.7</td>
<td>4.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td>6.8</td>
<td>0.7</td>
<td>4.5</td>
</tr>
<tr>
<td>20</td>
<td>Type I</td>
<td>50</td>
<td>1.0</td>
<td>±8</td>
<td>14</td>
<td>1.4</td>
<td>8.0</td>
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<td></td>
<td>80</td>
<td></td>
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<td>10</td>
<td>1.1</td>
<td>10.0</td>
</tr>
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<td>10</td>
<td>1.0</td>
<td>13.3</td>
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<td></td>
<td></td>
<td>120</td>
<td></td>
<td></td>
<td>9.4</td>
<td>1.0</td>
<td>14.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>160</td>
<td></td>
<td></td>
<td>8.9</td>
<td>0.9</td>
<td>18.2</td>
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<td></td>
<td>Type II</td>
<td>50</td>
<td>1.0</td>
<td>±8</td>
<td>21</td>
<td>2.1</td>
<td>12.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80</td>
<td></td>
<td></td>
<td>17</td>
<td>1.8</td>
<td>16.1</td>
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<tr>
<td></td>
<td></td>
<td>100</td>
<td></td>
<td></td>
<td>16</td>
<td>1.7</td>
<td>20.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>120</td>
<td></td>
<td></td>
<td>16</td>
<td>1.7</td>
<td>24.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>160</td>
<td></td>
<td></td>
<td>15</td>
<td>1.6</td>
<td>30.0</td>
</tr>
</tbody>
</table>

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

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

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

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

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

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

---

**Table 068-2**

<table>
<thead>
<tr>
<th>Load</th>
<th>Speed reducer surface temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25°C</td>
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**Table 068-3**

<table>
<thead>
<tr>
<th>Load</th>
<th>Speed reducer surface temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>25°C</td>
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</tbody>
</table>

**Table 068-4**

<table>
<thead>
<tr>
<th>Input speed</th>
<th>Load</th>
<th>Speed reducer surface temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000 rpm</td>
<td>No load</td>
<td>25°C</td>
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### Torsional Stiffness  CSG-GH and CSF-GH

<table>
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<tr>
<th>Symbol</th>
<th>Size</th>
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<th>20</th>
<th>32</th>
<th>45</th>
<th>65</th>
</tr>
</thead>
<tbody>
<tr>
<td>T. Net</td>
<td>Nm</td>
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<td>76</td>
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<tr>
<td>T. kgf</td>
<td>kgf</td>
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<td>0.7</td>
<td>3.0</td>
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<tr>
<td>T. kgfh</td>
<td>kgfh</td>
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<td>2.5</td>
<td>11</td>
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<td>86</td>
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</tbody>
</table>

- Reduction ratio 50: Approx. $5.8 \times 10^4$ rad (2 arc min)
- Reduction ratio 80 or more: Approx. $2.9 \times 10^4$ rad (1 arc min)

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

### Hysteresis Loss  CSG-GH

<table>
<thead>
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<th>Reduction ratio 50</th>
<th>Reduction ratio 80 or more</th>
</tr>
</thead>
<tbody>
<tr>
<td>Approx. 5.8X10^4 rad (2 arc min)</td>
<td>Approx. 2.9X10^4 rad (1 arc min)</td>
</tr>
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</table>
CSG-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]

**Flange Type II**

![Flange Type II Diagram]

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.

<table>
<thead>
<tr>
<th>Dimension Table</th>
</tr>
</thead>
</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**2</th>
<th>Moment of Inertia</th>
<th>Mass (kg)**2</th>
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<td>0.78</td>
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</tbody>
</table>

*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.

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.
**CSG-GH-20 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&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Moment of Inertia (10^-4kgm²)</th>
<th>Mass (kg)</th>
<th>Type</th>
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<tbody>
<tr>
<td>Type I</td>
<td>1</td>
<td>30</td>
<td>45</td>
<td>5</td>
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<td>7.0</td>
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<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>
<td>0.42</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>
<td>0.42</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.

---

(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.

---

**Output shaft shape:**
- J2 (Straight shaft, without key)
- J6 (Straight shaft, with key, with center tapped hole)
**CSG-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^1</th>
<th>Moment of Inertia</th>
<th>Mass (kg)</th>
<th>J1</th>
<th>J2</th>
<th>J3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type I</td>
<td>3</td>
<td>50</td>
<td>85</td>
<td>10</td>
<td>58</td>
<td>105</td>
<td>9.0</td>
<td>19.6</td>
<td>28.0</td>
<td>57</td>
<td>133</td>
<td>2.7</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>
<td>67</td>
<td>145.5</td>
<td>2.7</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>
<td>65</td>
<td>141</td>
<td>2.0</td>
</tr>
</tbody>
</table>

*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.
CSG-GH-45 Outline Dimensions

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

**Flange Type I**

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

**Flange Type II**

(Units: mm)

**Dimension Table**

<table>
<thead>
<tr>
<th>Flange</th>
<th>Coupling</th>
<th>A (H7) Min.</th>
<th>A (H7) Max.</th>
<th>B</th>
<th>C</th>
<th>F (H7) Min.</th>
<th>F (H7) Max.</th>
<th>G</th>
<th>H Max.</th>
<th>Moment of inertia</th>
<th>Mass (kg)</th>
</tr>
</thead>
<tbody>
<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>
<td>167</td>
<td>11</td>
</tr>
<tr>
<td></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>
<td>167</td>
<td>11</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>
<td>176</td>
<td>11</td>
</tr>
<tr>
<td></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>
<td>176</td>
<td>11</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.
**CSG-GH-65 Outline Dimensions**

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

---

### Dimension Table

| Flange | Coupling | A (H7) | B | C | F (H7) | G | H **| Moment of Inertia | Mass (kg) **
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></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>Max. (10^-3 kgm²)</td>
<td></td>
</tr>
<tr>
<td>Type I</td>
<td>1</td>
<td>95</td>
<td>95</td>
<td>10</td>
<td>110</td>
<td>125</td>
<td>19.0</td>
<td>39.3</td>
<td>201.5</td>
</tr>
<tr>
<td>Type II</td>
<td>1</td>
<td>110</td>
<td>200</td>
<td>6.5</td>
<td>145</td>
<td>235</td>
<td>19.0</td>
<td>39.3</td>
<td>40.5</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.
*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.
Harmonic Drive®

CSG/CSF Gearhead Series
Servomotor Matching Table

Motor flanges and input couplings have been prepared for all motors listed in the servomotor matching table. Please contact Harmonic Drive Systems’ sales office if using a motor which is not listed in the matching table.

The motor must be torque limited if using a motor capable of producing more output torque than the repeated peak torque listed in the rating table.

The gearheads listed in the servomotor matching table are selected based upon the peak torque of the motor.

Please contact Harmonic Drive Systems’ sales office if you use a motor under the conditions when a load greater than the motor maximum torque is applied to the output shaft.

The gearheads listed in the servo matching table should be used for “preliminary” selection. Be sure to check the machine operating conditions before making the “final” selection of the gear size and ratio.

Please double check the dimensions shown on the gearhead confirmation drawing with the motor drawing before ordering.
### 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.

#### Life

<table>
<thead>
<tr>
<th>Series name</th>
<th>CSF-GH</th>
<th>CSG-GH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life L&lt;sub&gt;50&lt;/sub&gt;</td>
<td>7,000 hours</td>
<td>10,000 hours</td>
</tr>
<tr>
<td>Life L&lt;sub&gt;50c&lt;/sub&gt;</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

**Table 086-1**

<table>
<thead>
<tr>
<th>L&lt;sub&gt;50&lt;/sub&gt;</th>
<th>L&lt;sub&gt;50c&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>7,000 hours</td>
<td>10,000 hours</td>
</tr>
<tr>
<td>35,000 hours</td>
<td>50,000 hours</td>
</tr>
</tbody>
</table>

**Formula 086-1**

\[ L_i = L_{50} \times \left( \frac{T_r}{T_{av}} \right) \times \left( \frac{N_r}{N_{av}} \right) \]

**Table 086-2**

- L<sub>i</sub> Life of L<sub>50</sub> or L<sub>50c</sub>
- T<sub>r</sub> Rated torque
- N<sub>r</sub> Rated input speed
- T<sub>av</sub> Average load torque on the output side (calculation formula: Page 91)
- N<sub>av</sub> Average input speed (calculation formula: Page 91)

**Graph 086-1**

Exemplary load torque pattern

**Graph 086-2**

Relative torque rating

* Lubricant life not taken into consideration in the graph described above.

* Use the graph above as reference values.
## Torque Limits

### Strength of flexspline

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

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

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

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

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

**Calculation formula**

**Formula 087-1**

<table>
<thead>
<tr>
<th>Permissible occurrences</th>
<th>N occurrences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time that impact torque is applied</td>
<td>t sec</td>
</tr>
<tr>
<td>Rotational speed of the wave generator</td>
<td>n rpm</td>
</tr>
</tbody>
</table>

* 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.

\[\text{Ratcheting torque}\]

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.

\[\text{Ratcheting torque is affected by the stiffness of the housing to be used when installing the circular spline. Contact us for details of the ratcheting torque.}\]

**Warning**

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

### Ratcheting torque

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.

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

**Figure 087-1**

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

* Ratcheting torque is affected by the stiffness of the housing to be used when installing the circular spline. Contact us for details of the ratcheting torque.
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 – torsional 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]

■ Example for calculating the torsion angle

The torsion angle (θ) is calculated here using CSG-32-100-GH as an example:

\[ T1 = 29 \text{ Nm} \]
\[ T2 = 108 \text{ Nm} \]
\[ K1 = 6.7 \times 10^4 \text{ Nm/rad} \]
\[ K2 = 6.7 \times 10^4 \text{ Nm/rad} \]
\[ K3 = 6.7 \times 10^4 \text{ Nm/rad} \]
\[ \theta1 = 4.4 \times 10^{-4} \text{ rad} \]
\[ \theta2 = 11.6 \times 10^{-4} \text{ rad} \]

When the applied torque is T1 or less, the torsion angle \( \theta_{11} \) is calculated as follows:

When the load torque \( T_{L1} = 6.0 \text{ Nm} \)

\[ \theta_{11} = \frac{T_{L1}}{K1} = \frac{6.0}{6.7 \times 10^4} = 9.0 \times 10^{-4} \text{ rad (0.31 arc min)} \]

When the applied torque is between T1 and T2, the torsion angle \( \theta_{12} \) is calculated as follows:

When the load torque \( T_{L2} = 50 \text{ Nm} \)

\[ \theta_{12} = \theta_{11} + \frac{T_{L2} - T1}{K2} = 4.4 \times 10^{-4} + \frac{(50 - 6)}{11.0 \times 10^4} = 4.4 \times 10^{-4} + 4.0 \times 10^{-5} = 8.4 \times 10^{-5} \text{ rad (2.89 arc min)} \]

When the applied torque is greater than T2, the torsion angle \( \theta_{13} \) is calculated as follows:

When the load torque \( T_{L3} = 178 \text{ Nm} \)

\[ \theta_{13} = \theta_{12} + \frac{T_{L3} - T2}{K3} = 4.4 \times 10^{-4} + 11.6 \times 10^{-4} + \frac{178 - 108}{12.0 \times 10^4} = 4.4 \times 10^{-4} + 11.6 \times 10^{-4} + 5.8 \times 10^{-4} = 2.18 \times 10^{-3} \text{ rad (7.5 arc min)} \]

When a bidirectional load is applied, the total torsion angle will be \( 2 \times \theta_{13} \) plus hysteresis loss.

■ 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.

---

* The torsion angle calculation is for the gear component set only and does not include any torsional windup of the output shaft.
### 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 2\( \times \) 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.

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

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**

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

**Formula variables**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( f )</td>
<td>The resonant frequency of the system</td>
<td>Hz</td>
</tr>
<tr>
<td>( K )</td>
<td>Spring constant of the HarmonicDrive® gear</td>
<td>Nm/rad</td>
</tr>
<tr>
<td>( J )</td>
<td>Load inertia</td>
<td>kgm²</td>
</tr>
</tbody>
</table>

See pages of each series.
**Product Sizing & Selection**

In general, a servo system rarely operates at a continuous load and speed. The input rotational speed, load torque change, and speed are applied at start and stop. Unexpected impact torque may be applied. Therefore, selecting a gearhead that can withstand these fluctuating load torques is important. As an accurate cross roller bearing is installed in the output shaft, lubrication failure may occur. In this case, please contact us for details.

(Note) If Harmonic Drive® CSG-GH series is installed in 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.

**Flowchart for selecting a size**

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

1. Calculate the average load torque applied on the output side from the load torque pattern. The average load torque (Nm):
   \[
   T_{av} = \frac{1}{n} \sum_{i=1}^{n} T_i 
   \]
2. Make a preliminary model selection with the following conditions:
   - \( T_{av} \geq \) Limit (Refer to the ratings of each series).
3. Calculate the average output speed:
   \[
   n_{av} = \frac{n_i \cdot t_i}{t_1 + t_2 + \cdots + t_i} 
   \]
4. Obtain the reduction ratio (R):
   \[
   n_{max} = \frac{n_i}{n_{av}} 
   \]
5. Calculate the maximum input rotational speed from the max. output rotational speed (no max) and the reduction ratio (R):
   \[
   n_{i max} = \frac{n_{max}}{R} 
   \]
6. Check whether the preliminary model number satisfies the following condition from the ratings:
   - \( n_{i max} \leq \) Limit for average speed (rpm)
   - \( n_{max} \leq \) Limit for maximum speed (rpm)

- If (NG), return to step 1.
- If (OK), check whether \( T_1 \) and \( T_3 \) are equal to or less than the repeated peak torque specification.

- If (NG), return to step 1.
- If (OK), check whether \( T_2 \) is equal to or less than the the momentary peak torque specification.

- If (NG), return to step 1.
- If (OK), calculate (Nm) the allowable number of rotations during impact torque:
  \[
  N_s = 10^4 \left( \frac{n_{max}}{n_{av}} \right)^2 \left( \frac{R}{n_{max}} \right) \leq 1.0 \times 10^4 
  \]

- If (NG), return to step 1.
- If (OK), calculate the lifetime:
  \[
  L_{10} = 7000 \left( \frac{T_{av}}{n_{av}} \right)^2 \left( \frac{N_{i max}}{n_{av}} \right) \text{ hours} 
  \]

- If (NG), return to step 1.
- If (OK), the model number is confirmed.

---

**Graph 090-1**

- \( n_1, n_2 \) and \( n_3 \) indicate the average values.

- \( T_1, T_2, T_3, T_4 \) indicate the load torque pattern.

- \( t_1, t_2, t_3, t_4 \) indicate the time pattern.

- \( n_1, n_2, n_3 \) indicate the output rotational speed pattern.
Example of model number selection

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

\[
T_{av} = \frac{\sum (\text{load torque} \times \text{time})}{\text{total time}}
\]

Evaluate the operation conditions and model number specifications.

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

\[
\frac{T_{1,\text{av}}}{\text{max. input speed}} \leq \frac{\text{no max}}{14 \text{ rpm}} \leq 1400 \text{ rpm}
\]

OK

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

\[
T_1 = 400 \text{ Nm} \leq 823 \text{ Nm} \quad \text{(limit of repeated peak torque of size 45)}
\]

\[
T_3 = 200 \text{ Nm} \leq 823 \text{ Nm} \quad \text{(limit of repeated peak torque of size 45)}
\]

OK

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

\[
T_s = 500 \text{ Nm} \leq 1760 \text{ Nm} \quad \text{(limit for momentary torque of size 45)}
\]

OK

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

\[
N_s = \frac{10^4}{2 \times \frac{14 \text{ rpm}}{120} \times \frac{0.4 \text{ sec}}{60} \times 0.15 \text{ sec}} = 1190 \leq 1.0 \times 10^4
\]

OK

Calculate the lifetime.

\[
L_{10} = 7000 \left( \frac{402 \text{ Nm}}{319 \text{ Nm}} \right)^{0.5} \left( \frac{2000 \text{ rpm}}{1440 \text{ rpm}} \right) \text{ (hours)}
\]

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

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

OK

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.

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
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.

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 (Mmax)**
   - Obtain the maximum load moment load (Mmax).
   - **Maximum load moment load (Mmax) ≤ Permissible moment (Mc)**

2. **Checking the life**
   - Obtain the average radial load (Favg) and the average axial load (Favg).
   - Obtain the 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 130-1

<table>
<thead>
<tr>
<th>Size</th>
<th>Pitch circle amount</th>
<th>Offset amount</th>
<th>Basic load rating</th>
<th>Allowable moment load M(max)×10^5</th>
<th>Moment stiffness K(m)</th>
<th>Allowable radial load</th>
<th>Allowable axial load</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>0.0045</td>
<td>0.011</td>
<td>Pci</td>
<td>5110</td>
<td>0.085</td>
<td>720</td>
<td>732</td>
</tr>
<tr>
<td>20</td>
<td>0.064</td>
<td>0.0115</td>
<td>R</td>
<td>10600</td>
<td>0.0153</td>
<td>760</td>
<td>1330</td>
</tr>
<tr>
<td>32</td>
<td>0.065</td>
<td>0.014</td>
<td>dp</td>
<td>20500</td>
<td>0.1115</td>
<td>3265</td>
<td>1500</td>
</tr>
<tr>
<td>45</td>
<td>0.123</td>
<td>0.019</td>
<td>R</td>
<td>41600</td>
<td>0.085</td>
<td>323</td>
<td>11693</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.
How to calculate the maximum load moment load

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

\[
M_{\text{max}} = F_r \max (L_r + R) + F_a \max L_a
\]

Where:
- $F_r \max$: Max. radial load (N (kgf))
- $F_a \max$: Max. axial load (N (kgf))
- $L_r, L_a$: — m
- $R, R$: Offset amount m
- $\sqrt{dp}$: Circular pitch of roller

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

The radial load coefficient ($X$) and the axial load coefficient ($Y$) can be calculated using the following formulas:

\[
X = \frac{F_r \text{avg}}{F_r \max}, \quad Y = \frac{F_a \text{avg}}{F_a \max}
\]

Where:
- $F_r \text{avg}$: Average radial load (N (kgf))
- $F_a \text{avg}$: Average axial load (N (kgf))
- $dp$: Circular pitch of roller m

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.

How to obtain the average radial load ($F_{r \text{avg}}$)

\[
F_{r \text{avg}} = \sqrt{\frac{n_1 \text{avg} (F_{r1})^{10/9} + n_2 \text{avg} (F_{r2})^{10/9} + \cdots + n_s \text{avg} (F_{rs})^{10/9}}{n_1 + n_2 + \cdots + n_s}}
\]

How to obtain the average axial load ($F_{a \text{avg}}$)

\[
F_{a \text{avg}} = \sqrt{\frac{n_1 \text{avg} (F_{a1})^{10/9} + n_2 \text{avg} (F_{a2})^{10/9} + \cdots + n_s \text{avg} (F_{as})^{10/9}}{n_1 + n_2 + \cdots + n_s}}
\]

How to obtain the average output rotational frequency ($N_{\text{avg}}$)

\[
N_{\text{avg}} = \frac{n_1 \text{avg} + n_2 \text{avg} + \cdots + n_s \text{avg}}{n_1 + n_2 + \cdots + n_s}
\]
How to calculate the life

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

**Formula 132-1**

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

- \( L_\text{av} \): Life (hour)
- \( N_{av} \): Ave. output speed (rpm)
- \( C \): Basic dynamic rated load (N/kgf)
- \( P_c \): Dynamic equil. radial load (N/kgf)
- \( f_w \): Load coefficient

<table>
<thead>
<tr>
<th>Load status</th>
<th>( f_w )</th>
</tr>
</thead>
<tbody>
<tr>
<td>During smooth operation</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</td>
<td>1.5 to 3</td>
</tr>
</tbody>
</table>

**Formula 132-2**

\[
P_c = \frac{X \left( \frac{F_{ar} + 2 \frac{F_{ar} (L_r + R)}{X} F_{ai} av}{dp} \right)}{Y \times F_{ai} av}
\]

- \( X \): Radial load coefficient
- \( Y \): Axial load coefficient
- \( L_r, L_a \): See Figure 131-1.
- \( R \): Offset amount (m)

**Note**

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

How to calculate the life during oscillating movement

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

**Formula 132-3**

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

- \( L_{oc} \): Rated life during oscillating movement (hour)
- \( n_1 \): No. of reciprocating oscillation per min. (rpm)
- \( C \): Basic dynamic rated load (N/kgf)
- \( P_c \): Dynamic equil. radial load (N/kgf)
- \( f_w \): Load coefficient
- \( \theta \): Oscillating angle (Deg.)

**Note**

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

How to calculate the static safety coefficient

In general, the basic static rated load \( (C_o) \) 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 \( (f_s) \) of the cross roller bearing using Formula 132-4.

**Formula 132-4**

\[
f_s = \frac{C_o}{P_o}
\]

- \( C_o \): Basic static rated load (N/kgf)
- \( P_o \): Static equivalent radial load (N/kgf)

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

**Formula 132-5**

\[
P_o = F_{r max} + \frac{2M_{max}}{dp} + 0.44F_{a max}
\]

- \( F_{r max} \): Max. radial load (N/kgf)
- \( F_{a max} \): Max. axial load (N/kgf)
- \( M_{max} \): Max. load moment load (Nm/kgf)
- \( dp \): Circular pitch of roller (m)

**Note**

Max. load moment load, see “Output Bearing Specs.” of each series.
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