**Features of HDUA/FD series**

- As the differential mechanism is put together as one, it is easily installed in the equipment.
- It consists of only four parts and is coaxially put together.
- As the backlash is very small, the unit requires no assembly adjustment at all, which helps reduce the assembly cost significantly.
- As it has very large reduction ratio between the adjusting shaft and the output, it allows highly accurate and minute position adjustment easily and requires little torque for adjusting the shaft.

---

**Structure of the HDUA/FD series**

- **Circular spline S**
  - It has two more teeth than the flexspline like the cup-type circular spline.

- **Circular spline D**
  - It has the same number of teeth as the flexspline. As it generates no relative rotation with the flexspline, it rotates at the same speed as the flexspline.

---

**Part No.** | **Part name**
---|---
① | Wave generator
② | Wave generator plug
③ | Wave generator bearing
④ | Retainer presser
⑤ | Flexspline
⑥ | Circular spline S
⑦ | Circular spline D
⑧ | Ball bearing
⑨ | Internal C-type stop ring
⑩ | Casing
⑪ | Bolt with hexagonal hole

**(Note)** How to tell circular spline D from circular spline S:
The peripheral chamfering of circular spline D is larger than that of circular spline S.
Rotational direction and reduction ratio

The rotational direction is the same as the HDUF/FB series (Page 2). This section describes how to use the unit as a differential unit. (R indicates the reduction ratio value in the ratings table.)

**Input:** Circular spline S  
**Output:** Circular spline D  
**Fixed:** Wave generator

Reduction ratio (i) is: \[ i = \frac{R+1}{R} \]

Hence, input rotation: \( N_s \)  
output speed: \( N_{D1} \)

When (1) and (2) are combined, the rotational speed of circular spline S is represented as shown on the right.

(Note) The sign (+) indicates that the wave generator is turned in the opposite direction to the circular spline S.

![Diagram](image1)

**Input:** Wave generator  
**Output:** Circular spline D  
**Fixed:** Circular spline S

Reduction ratio (i) is: \[ i = \frac{-1}{R} \]

Hence, input rotation: \( N_w \)  
output speed: \( N_{D1} \)

![Diagram](image2)

**Input:** Circular spline D  
**Output:** Circular spline S  
**Fixed:** Wave generator

Reduction ratio (i) is: \[ i = \frac{R}{R+1} \]

Hence, input rotation: \( N_s \)  
output speed: \( N_{S1} \)

When (1) and (2) are combined, the rotational speed of circular spline D is represented as shown on the right.

(Note) The sign (-) indicates that the wave generator is turned in the opposite direction to the circular spline D.

![Diagram](image3)
**Model and Symbol**

**HDUA - 20 - 80 - 0 - G**

<table>
<thead>
<tr>
<th>Model name</th>
<th>Model No.</th>
<th>Reduction ratio</th>
<th>Note 1</th>
<th>Model</th>
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<tr>
<td>HDUA FD</td>
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<td>100</td>
<td>80</td>
<td>100</td>
<td>120</td>
</tr>
</tbody>
</table>

Note 1: The reduction ratio indicates the value for the following condition.

- Input: wave generator, fixed: circular spline S, output: circular spline D
- Model names: HDUA for European markets, FD for Asia and North America

Table 3-1

**Model names:**
- HDUA: Unit type
- FD: Component type
- G: Oil lubrication type
- GP: Grease lubrication type
- G: New type
How to use

Usage example

■ Phase adjustment

Brake a unit to adjust the phase of two rolls, normally an adjusting motor, and rotate it in the system: roll (1) → C₀ → C₁ → Roll (2). When the phase of Roll (2) against Roll (1) needs to be adjusted, the adjusting motor should be rotated. Stop the motor after adjustment and return Roll (2) to the original rotation.

(Calculation formula)
When the adjusting motor is fixed, the rotational speed of Roll (2) should be N₀. Assuming that the adjusting motor rotates in Nₚ, rotational speed N of the roll is expressed as follows.

\[ N = N₀ \pm \frac{1}{R} \left( \frac{Z₂}{Z₁} \right) Nₚ \]

The sign is minus (−) when the wave generator rotates in the same direction as the circular spline. It is plus (+) when the wave generator rotates in the opposite direction.

Fig. 4-1

■ Fine adjustment

This is the method to fine-tune the speed and timing of the drive shaft by the adjusting motor without changing the rotational speed of the main motor.

(Calculation formula)
When the adjusting motor is fixed, the rotational speed of the drive shaft is expressed as follows.

\[ N = N₀ \pm \frac{1}{R+1} \left( \frac{Z₂}{Z₁} \right) Nₚ \]

The sign is plus (+) when the wave generator rotates in the same direction as the circular spline. It is minus (−) when the wave generator rotates in the opposite direction.

Fig. 4-2

■ Continuous operation adjustment

This is a unit to continuously make a slight change to the rotational speed of the roll. The rotation of the main motor has the following two routes.

1. Z₁ \rightarrow Z₁(C₀) \rightarrow Z₁(C₁) \rightarrow Z₁ \rightarrow Roll
2. Variable-speed pulley \rightarrow wave generator \rightarrow C₀(Z₁) \rightarrow Z₁ \rightarrow Roll

The speed change of the roll is given by (2).

(Calculation formula)
Assuming that the rotation of the variable-speed pulley is zero, the rotational speed of the roll rotated by the main motor is N₀. When the rotation of the wave generator, namely the variable-speed pulley, changes from N₁ to N₂, rotational speed N of the roll is expressed as follows.

\[ N = N₀ \pm \frac{1}{R+1} \left( \frac{Z₂}{Z₁} \right) (N₁ \text{ to } N₂) \]

The sign is plus (+) when the wave generator rotates in the same direction as the circular spline. It is minus (−) when the wave generator rotates in the opposite direction.

Fig. 4-3
Example of assembly

Paper-cutting machine

The right-hand figure shows an example of a general application that is used for the mechanism shown below.

Outline of operation

Rollers (1), (2) and (3) are interlocked based on the rotation of the cutter. Roller (2) feeds paper for further printing on the printed paper that is then extracted by Roller (1). Roller (2) adjusts the misaligned printing. Roller (1) adjusts the printed paper so that it will be cut in the correct position by Roller (2). Roller (3) makes further adjustment following Roller (1).

You can change the phase between the rollers by building a Harmonic differential gear in Units (1), (2) and (3) without stopping the unit.

Printer (film material)

The following process is essential for printing on elastic material.

1. A device to adjust printing misalignment by expansion and contraction
2. A device to continue tensioning film to prevent wrinkling

Outline of operation

The film material is withdrawn by 1. tensions film between 2 and 3 to prevent wrinkling, 2. tensions film between 3 and 4 to prevent slackening in the printing process 5. In the printing process 5, all rollers from 1 to 5 are used for 6-color printing. Adjustment is made to 6 based on 2, to 7 based on 3 and so on up to 5 by the Harmonic differential gear.

The harmonic differential is built in for all rollers from 1 to 5.
Difference between the differential gear and the Harmonic differential gear

<table>
<thead>
<tr>
<th>Feature</th>
<th>Differential gear</th>
<th>Harmonic differential gear</th>
</tr>
</thead>
<tbody>
<tr>
<td>As many gears are required in the differential device, the device increases in size, causing problems in design, and is difficult build it in.</td>
<td>As the Harmonic differential gear includes the differential mechanism, it can be designed to be of compact size and is easily built in.</td>
<td></td>
</tr>
<tr>
<td>A unit using a plant gear causes a lot of backlash and is disadvantageous in position and timing precision.</td>
<td>As it causes very small backlash, it is advantageous in position and timing precision.</td>
<td></td>
</tr>
<tr>
<td>It is not easy to fine tune compared to the Harmonic differential gear.</td>
<td>As it has a large reduction ratio, it can produce very fine tuning.</td>
<td></td>
</tr>
<tr>
<td>Noisy gear sound</td>
<td>Very quiet.</td>
<td></td>
</tr>
</tbody>
</table>

That shown in the right-hand figure is a differential gear used in a printer maker. It is an example of very smart, compact design using the Harmonic differential gear.
Example of design

Multicolor printer Phase adjuster

The figure is an example of a Harmonic differential gear unit (HDUA/FD-0) built in as a phase adjuster for the roll of a multicolor printer.

The adjusting motor is fixed during normal operation, and the rotation at \( Z_1 \) is transmitted to \( Z_2 \) almost at a ratio of 1:1. To adjust the phase of only Roll (2), rotate the adjusting motor to generate a small rotational difference. After adjustment, stop the motor to bring Roll (2) back to the original rotational speed.

Gear selection data

The selection data of the number of teeth, \( Z_1, Z_2, Z_3 \) and \( Z_4 \), of the gear is shown when rotational speed \( N_1 \) is equal to \( N_2 \), namely

\[
\frac{N_2}{N_1} = \frac{Z_1}{Z_2} \cdot \frac{Z_3}{Z_4} \cdot \ldots \cdot (i)
\]

Where,

- \( Z_s \): the number of teeth of circular spline S
- \( Z_D \): the number of teeth of circular spline D

Here \( i = \frac{Z_3}{Z_1} \cdot \frac{Z_4}{Z_2} \cdot \frac{R}{R+1} \) makes

\[
Z_1 = Z_s \cdot i
\]

\[
Z_2 = Z_D \cdot i
\]

\[
Z_3 = Z_1 \cdot \frac{R}{R+1}
\]

\[
Z_4 = Z_2 \cdot \frac{R}{R+1}
\]

<table>
<thead>
<tr>
<th>( i )</th>
<th>( \frac{Z_1}{Z_2} \cdot \frac{Z_3}{Z_4} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>80/81</td>
<td>18/18 16/20 18/16 27/30 15/16 27/25</td>
</tr>
<tr>
<td>120/121</td>
<td>22/22 20/24</td>
</tr>
<tr>
<td>128/129</td>
<td>15/16 43/40 33/32 43/42 43/64</td>
</tr>
<tr>
<td>160/161</td>
<td>14/23 16/20 21/23 24/24</td>
</tr>
</tbody>
</table>

**Tabl 7-3**

**Fig. 7-2**

(Note) 1. The number of teeth given above is applicable when \( Z_s \) and \( Z_D \) are arranged as shown in the figure.

2. The difference in the number of teeth is adjusted to \( Z_1 - Z_2 \leq 3 \) and \( Z_3 - Z_4 \leq 3 \).

3. It is useful to break down \( i \) to prime numbers to use a different number of teeth.

It is not possible to break down \( i \) to prime numbers for \( R=79, 96, 100, 131, 208 \) and 258.
**Example of calculation**

This is to calculate the torque required for the number of teeth of the gear, rotational speed, adjustment quantity and adjustment based on the example shown in the right-hand figure (Fig. 8-1).

**[Usage condition]**

In Figure 8-1

- Speed around the roller \( V = 60 \text{m/min} \)
- Length around the roller \( L_w = 500 \text{mm} \)
- Roller torque \( T_w = 7 \text{kg-m} \)
- Rotational speed of the drive shaft \( N_1 = 500 \text{rpm} \)
- Rotational speed of the roller \( N_r = \frac{V}{R} \times \frac{60}{0.5} = 120 \text{rpm} \)

Under these conditions, select model number 25 of differential gear with reduction ratio \( R = 80 \), review whether or not this mode number is appropriate, as well as the number of teeth and adjustment torque.

### The number of teeth of each gear (selection of \( Z_1, Z_2, Z_3 \), and \( Z_4 \))

The total reduction ratio is as follows.

\[
\frac{Z_2 \cdot Z_4}{Z_1 \cdot Z_3} = \frac{N_r \cdot C_3}{N_i \cdot C_1}
\]

From

\[
i = \frac{N_r}{N_i} = \frac{Z_2 \cdot C_3}{Z_1 \cdot C_1} \cdot \frac{Z_4}{Z_3}
\]

\[
\frac{Z_2 \cdot Z_4}{Z_1 \cdot Z_3} = \frac{N_r \cdot C_3}{N_i \cdot C_1}
\]

is obtained.

Here,

\[
\frac{N_r}{N_i} = \frac{120}{500} = 2/5\times 3/5
\]

\[
\frac{C_3}{C_1} = \frac{80}{81} = 2/5\times 3/3
\]

\[
\frac{Z_2 \cdot Z_4}{Z_1 \cdot Z_3} = \frac{2/5\times 3/5 \times 2/5\times 3/5}{2/5\times 3/3} = \frac{2/5\times 3/3}{2/5\times 3/3} = \frac{2/5}{2/5} = \frac{3/3}{3/3} = \frac{8}{9} \times \frac{4}{9} = \frac{16}{30} \times \frac{16}{36}
\]

Hence,

\( Z_1 = 30, Z_2 = 16, Z_3 = 36, Z_4 = 16 \)

### Calculation of rotational speed

The rotational speed of each gear is shown below.

- \( Z_1: \quad N_1 = 500 \text{rpm} \)
- \( Z_2: \quad N_i = \frac{Z_2}{Z_1} \times \frac{N_1}{36} = 500 \times 222.2 = 222.2 \text{rpm} \)
- \( Z_3: \quad N_i = \frac{Z_2}{Z_1} \times \frac{N_1}{36} = 500 \times 222.2 = 225 \text{rpm} \)
- \( Z_4: \quad N_r = 120 \text{rpm} \)

### Adjustment quantity

The misalignment (adjustment quantity), \( \Delta \theta \), at the roller is expressed as follows when the adjusting wave generator rotates once (360°).

\[
\Delta \theta = \frac{Z_1}{Z_2} \times \frac{1}{R} \times \frac{1}{N} \times \frac{V}{R} \times 360° = 2.4°
\]

Therefore, the adjustment quantity is expressed as follows in the circle.

\[
\Delta \theta = \frac{2.4°}{360°} \times 500 \text{mm} = 3.3 \text{mm}
\]

### Adjustment torque required

The torque required for adjustment is expressed as follows.

\[
T = T_w - \frac{Z_1}{Z_2} \times \frac{1}{R} \times \frac{1}{n} \times \frac{7 \text{kg-m} \times 16}{30} \times \frac{1}{80} \times \frac{1}{0.6}
\]

\( = 0.07 \text{kg-m} \) (\( \eta \): efficiency)
The rated torque at each rotational speed is shown below.

<table>
<thead>
<tr>
<th>Rotational speed rpm</th>
<th>3500</th>
<th>2850</th>
<th>1750</th>
<th>1450</th>
<th>1150</th>
<th>960</th>
<th>870</th>
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<td>Nm</td>
<td>kgf.m</td>
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<td>kgf.m</td>
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<td>157</td>
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</tbody>
</table>

(Note) 1. Rotational speed: This indicates the rotational speed of the wave generator if used as a reducer.
2. This indicates the relative rotational speed of the wave generator and the circular spline if used as a differential unit.
3. The torque against a rotational speed of 2,500 rpm or less is equal to the torque for 500 rpm.
4. The permissible momentary torque allows up to 200% of the torque at a rotational speed of 1,450 rpm.
**Outline drawing of unit type (HDUA/FD-0)**

![Outline drawing of unit type](image)

**Measurement table of unit type (HDUA/FD-0)**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Model</th>
<th>20</th>
<th>25</th>
<th>32</th>
<th>40</th>
<th>50</th>
<th>65</th>
<th>80</th>
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<tbody>
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<td>M6×9</td>
<td>M8×11</td>
<td>M10×13.5</td>
<td>M12×23</td>
<td>M12×23</td>
<td>M14×27</td>
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<td>#6006</td>
<td>#6008</td>
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<td>#6012</td>
<td>#6014</td>
<td>#6018</td>
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<td>8.3</td>
<td>17</td>
<td>34</td>
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</table>

*Fig. 10-1*

Unit: mm
Measurement table of component type (HDUA/FD-2)

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Model</th>
<th>20</th>
<th>25</th>
<th>32</th>
<th>40</th>
<th>50</th>
<th>65</th>
<th>80</th>
<th>100</th>
</tr>
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<tbody>
<tr>
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<td>85</td>
<td>110</td>
<td>135</td>
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<td>68</td>
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<td>87</td>
<td>106</td>
<td>130</td>
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</tr>
<tr>
<td>F</td>
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<td>59</td>
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<td>92</td>
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<td>14</td>
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</tr>
<tr>
<td>( \phi_{H_{HF}} )</td>
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<td>50</td>
<td>60</td>
<td>70</td>
<td>90</td>
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<tr>
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<td>0.2</td>
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<td>1.5</td>
<td>1.5</td>
<td>1.5</td>
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<td>2</td>
<td>2</td>
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</tr>
<tr>
<td>Q_{C}</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1.5</td>
<td>2</td>
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</tr>
<tr>
<td>S</td>
<td>42</td>
<td>53</td>
<td>69</td>
<td>84</td>
<td>105</td>
<td>138</td>
<td>169</td>
<td>211</td>
<td></td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>0.6</td>
<td>1.0</td>
<td>2.0</td>
<td>3.6</td>
<td>7.2</td>
<td>14</td>
<td>26</td>
<td>48</td>
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</tr>
</tbody>
</table>
Efficiency characteristics

The efficiency of the differential unit type (HDUA/FD-0) varies depending on the power transmission route.

(1) The efficiency when the power enters from circular spline S (or D) to transmit the rotation to circular spline D (or S)
   - For oil lubrication: About 90%
   - For grease lubrication: About 80%

(2) The efficiency for obtaining the input torque required by the wave generator for phase adjustment and to use it as a reducer is shown in graph 12-1.

\[
\begin{array}{|c|c|}
\hline
\text{Efficiency characteristics} & \text{Graph 12-1} \\
\hline
\end{array}
\]

Table 12-2

<table>
<thead>
<tr>
<th>Load torque</th>
<th>Rated torque in rating table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lubrication condition</td>
<td>Oil lubrication (approx. 40°C)</td>
</tr>
</tbody>
</table>

(Note) The efficiency decreases by about 10% for grease lubrication.

Inertia moment

The value of \(DG^2\) of each part is shown in table 12-3.

\[
\begin{array}{|c|c|c|c|c|c|c|c|c|}
\hline
\text{Model} & 20 & 25 & 32 & 40 & 50 & 60 & 80 & 100 \\
\hline
\text{I. Wave generator (except the outer race of the wave generator)} & 1.44 & 3.63 & 12.9 & 37.0 & 112 & 366 & 1020 & 3050 \\
\hline
\text{II. Circular spline S, D} & 13.7 & 33.8 & 125 & 326 & 1020 & 3440 & 9270 & 27000 \\
\text{III. I + II} & 15.2 & 37.5 & 138 & 363 & 1140 & 3810 & 10300 & 30100 \\
\text{IV. Support bearing (4)} & 2.91 & 8.98 & 23.4 & 451 & 104 & 205 & 646 & 1590 \\
\text{V. Casing (right and left casing total)} & 52.6 & 69.0 & 204 & 484 & 1660 & 6220 & 15700 & 43200 \\
\hline
\end{array}
\]

Max. permissible rotational speed

The maximum permissible rotational speed means:

1. The rotational speed of the wave generator when used as a reducer
2. The relative rotational speed of the wave generator and the circular spline when used as a differential unit

\[
\begin{array}{|c|c|c|c|c|c|c|c|c|}
\hline
\text{Model} & 20 & 25 & 32 & 40 & 50 & 60 & 80 & 100 \\
\hline
\text{Max. permissible rotational speed} & 6000 & 5000 & 4500 & 4000 & 3500 & 3000 & 2500 & 2000 \\
\hline
\end{array}
\]

(1) For oil lubrication

\[
\begin{array}{|c|c|c|c|c|c|c|c|c|}
\hline
\text{Model} & 20 & 25 & 32 & 40 & 50 & 60 & 80 & 100 \\
\hline
\text{Max. permissible rotational speed} & 3600 & 3600 & 3600 & 3300 & 3000 & 2200 & 2000 & 1700 \\
\hline
\end{array}
\]

(2) For grease lubrication
Lost motion and spring constant

Hysteresis loss and the spring constant of the differential type is the value when either the wave generator or the circular spline is fixed and a torque is applied to another circular spline.

Table 13-1

<table>
<thead>
<tr>
<th>Model</th>
<th>Lost motion (arc min)</th>
<th>Spring constant (kgm/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>± load (kgm)</td>
<td>Standard product (max.)</td>
</tr>
<tr>
<td>20</td>
<td>0.12</td>
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<tr>
<td>25</td>
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<td>0.92</td>
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<td>50</td>
<td>1.73</td>
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<td>65</td>
<td>3.9</td>
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<tr>
<td>80</td>
<td>7.4</td>
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<tr>
<td>100</td>
<td>14.4</td>
<td>24</td>
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</tbody>
</table>
**Design guide**

### Precautions on handling

The casing and the roller bearing in using a component type (HDUA/FD-2) as a differential unit should be pursuant to the unit type (HDUA/FD-0).

### Precautions on assembly

HarmonicDrive® may generate vibration and abnormal sound due to problems during assembly. Perform assembly based on the HDUF/FB series precautions (Page 6, Fig. 6-3).

### Lubrication

There are two types of lubrication: oil lubrication and grease lubrication. Although oil lubrication is common, grease lubrication is applicable to intermittent operation.

#### Oil lubrication

1. **Type of lubricant**

   Mineral oil CLP 68 (ISO VG 68) according to DIN 51517 T3.

2. **Oil quantity**

   The oil level shall be the position shown in Table 14-1.

<table>
<thead>
<tr>
<th>Model</th>
<th>20</th>
<th>25</th>
<th>32</th>
<th>40</th>
<th>50</th>
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<td>A</td>
<td>12</td>
<td>15</td>
<td>31</td>
<td>38</td>
<td>44</td>
<td>62</td>
<td>75</td>
<td>94</td>
</tr>
</tbody>
</table>

#### Grease lubrication

Different from oil lubrication, as a cooling effect is not expected from grease lubrication, it is only available for short operation.

- Operating condition: ED% < 10% or less, continuous operation for 10 minutes or less, the maximum permissible input rotational speed (see documentation for HDUR gears)
- Recommended grease: Harmonic grease SK-1A

**Note**

If you use the product over ED% or the maximum permissible rotational speed, the grease will deteriorate, will not work as a lubricating mechanism and will result in damaging the reducer earlier. Extreme care should be taken.

Please consider the unit type since unit type (HDUA/FD-0) also comes in grease sealed type (NIKON KOYU LTD. MP No. 2).