4.2 Method of measurement with Over balls or Rollers

For spur gear, putting Over balls or Rollers to Spacewidth. External gear is measured by outside dimension of Over ball or Rollers. Internal gear is measured by inner dimension of Over balls or Rollers.
Use method of Over balls or Rollers for Helical gear. Measurement for Internal gear, this method has advantages over others.

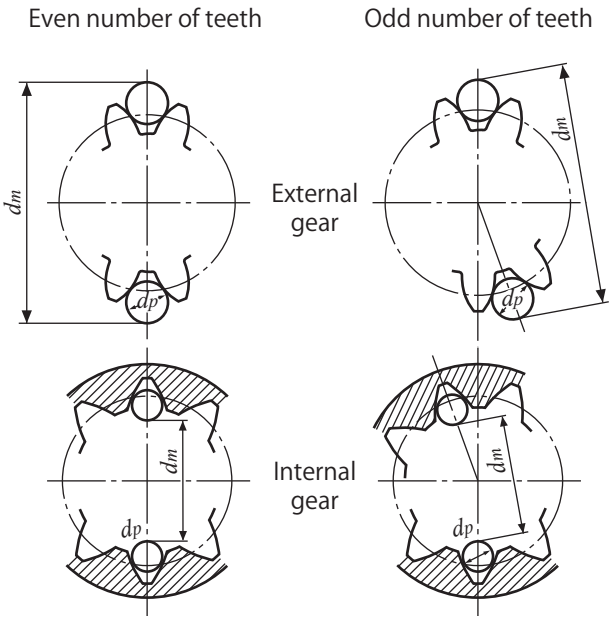

Fig. 2 Method of Over balls or Rollers

*Note for gear with small and odd number of teeth and large helix angle. We recommend using method of Over balls or Rollers due to unstable pins causing inaccurate measurement

Diameter for Over balls or Rollers

Refer to Fig. 3 to find diameter of Over balls or Rollers. Obtain the nearest available diameter from the graph as standard for Over balls or Rollers to measure the gear.

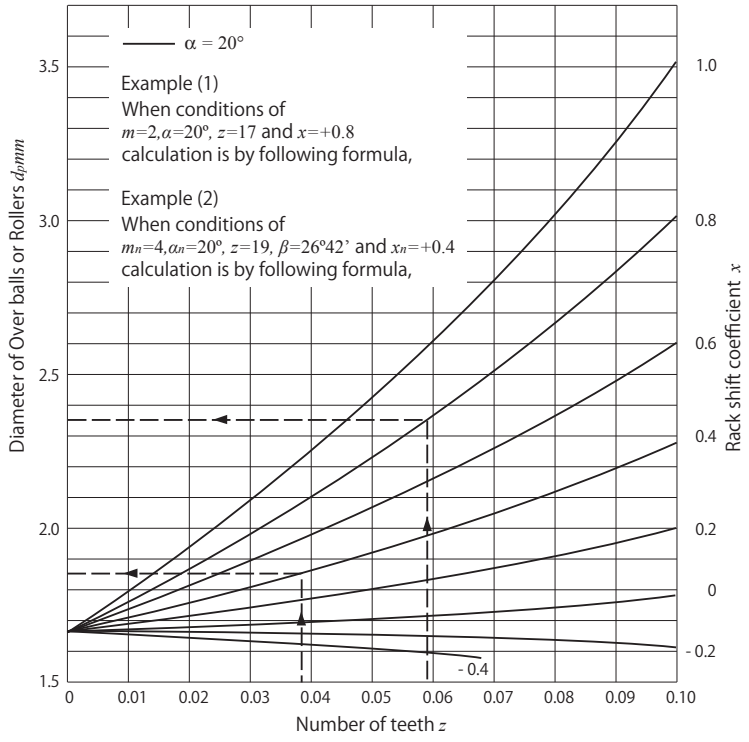

Fig. 3 Graph to find suitable diameter of Over balls or Rollers (for module m_n=1.0)

Increase proportionately by module used. Number of teeth of Helical gear is Virtual number of teeth of Spur gear.

Dimensions of Over balls or Rollers for Spur gear.

For even number of teeth, calculation is by following formula

$$d_m = \frac{zm\cos\alpha}{\cos\phi} + d_p$$

For odd number of teeth, calculation is by following formula

$$d_m = \frac{zm\cos\alpha}{\cos\phi}\cos\frac{90°}{z} + d_p$$

For invϕ, calculation is by following formula

$$\mathrm{inv}\phi = \frac{d_p}{zm\cos\alpha} - \left(\frac{\pi}{2z} - \mathrm{inv}\alpha\right) + \frac{2x\tan\alpha}{z}$$

Hereby

- d_m : Over balls or Rollers dimension(mm)
- z : Number of teeth
- x : Rack shift coefficient
- ϕ : Pressure angle (°) at pin centre
- d_p : Diameter of Practical Over balls or Rollers (mm)
- m : Module (mm)
- α : Reference pressure angle(°)

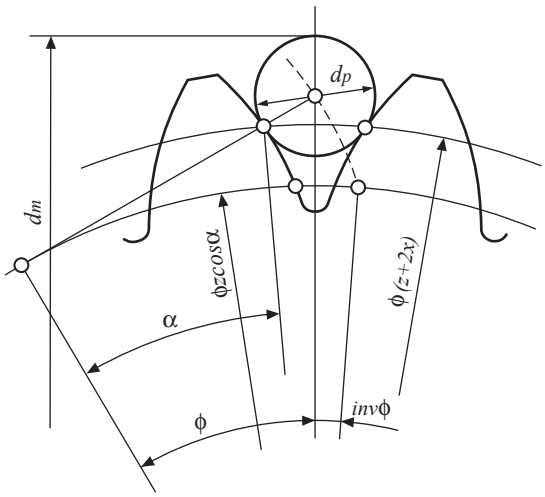

Fig. 4 Dimension of Over balls or Rollers for Spur gear

Example 1, even number of teeth

When module m=2.0, Number of teeth z=30, Reference pressure angle α=20° and Rack shift coefficient x= 0.15. Calculations of Over balls or Rollers dimensions is as follows,

① **Over balls or Rollers dimension** d_p

Refer to Fig. 3, d_p=1.73 multiply by module 2.0 = 3.46(mm)

Use nearest available pin size d_p=3.5(mm) instead of 3.46(mm)

② **Pressure angle ϕ at contact point between flank and Over balls or Rollers**

$$\mathrm{inv}\phi = \frac{3.5}{30 \cdot 2 \cdot \cos 20°} - \left(\frac{\pi}{2 \cdot 30} - \mathrm{inv}20°\right) + \frac{2 \cdot 0.15 \cdot \tan 20°}{30}$$

$$= 0.0282613 \quad (\mathrm{inv}20° = 0.0149044)$$

$\phi = 24.5388°$ (See page 164 to 167 for Involute function charts)

③ **Over balls or Rollers dimension** d_m

$$d_m = \frac{30 \cdot 2 \cdot \cos 20°}{\cos 24.5388°} + 3.5 = 65.48 \ (\mathrm{mm})$$

Example 2, odd number of teeth

Follow example 1 for calculation method, Number of teeth is changed to 29 (Other data remains the same)

① **Over balls or Rollers dimension** d_p d_p=3.5(mm)

② **Pressure angle (°) at pin centre**

$$\mathrm{inv}\phi = \frac{3.5}{29 \cdot 2 \cdot \cos 20°} - \left(\frac{\pi}{2 \cdot 29} - \mathrm{inv}20°\right) + \frac{2 \cdot 0.15 \cdot \tan 20°}{29}$$

$$= 0.0287218$$

$\phi = 24.6645°$ (24°39′52″)

③ **Over balls or Rollers dimension** d_m

$$d_m = \frac{29 \cdot 2 \cdot \cos 20°}{\cos 24.6645°} \cdot \cos\frac{90°}{29} + 3.5 = 63.39 \ (\mathrm{mm})$$

Dimension of Over balls or Rollers for Internal gear

Calculation for even number of teeth is by following formula

$$d_m = \frac{zm\cos\alpha}{\cos\phi} - d_p$$

Calculation for odd number of teeth is by following formula

$$d_m = \frac{zm\cos\alpha}{\cos\phi}\cos\frac{90^\circ}{z} - d_p$$

For invϕ, calculation is by following formula

$$\mathrm{inv}\phi = \left(\frac{\pi}{2z} + \mathrm{inv}\alpha\right) + \frac{2x\tan\alpha}{z} - \frac{d_p}{zm\cos\alpha}$$

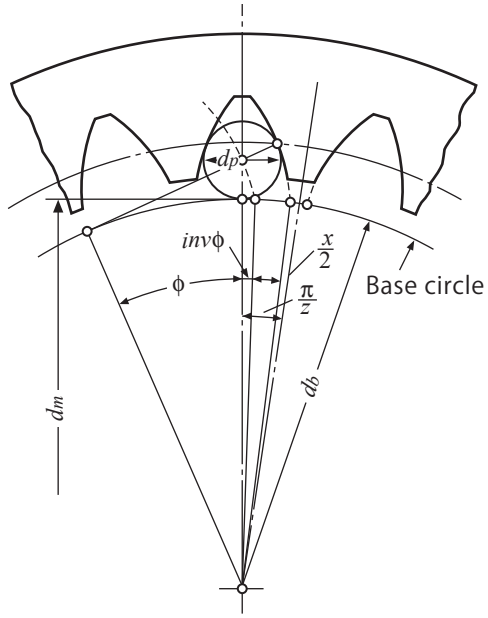

Fig. 5 Over balls or Rollers dimension for Internal gear

Example 1, even number of teeth

When module m=1.0, Number of teeth z=80, Reference pressure angleα = 20° and Rack shift coefficient x= 0.12. Calculations for dimensions of Over balls or Rollers is as follows,

① **Over balls or Rollers diameter** d_p

Refer to Fig. 3, d_p=1.68 multiply by module 1.0 = 1.68 (mm)

Use nearest available pin size d_p=1.70(mm) instead of 1.68(mm)

② **Pressure angle (°) at pin centre**

$$\mathrm{inv}\phi = \left(\frac{\pi}{2\cdot 80} + \mathrm{inv}20^\circ\right) - \frac{1.7}{80\cdot 1\cdot\cos 20^\circ} + \frac{2\cdot 0.12\cdot\tan 20^\circ}{80}$$

$$= 0.0130174$$

$$\phi = 19.145^\circ \ (19^\circ 8' 42'')$$

③ **Over balls or Rollers dimension** d_m

$$d_m = \frac{80\cdot 1\cdot\cos 20^\circ}{\cos 19.145^\circ} - 1.7 = 77.88 \ (\mathrm{mm})$$

Example 2, odd number of teeth

Number of teeth for calculation example 1 is changed to 81 (other data remains the same).

① **Over balls or Rollers dimension** d_p d_p=1.7(mm)

② **Pressure angle (°) at pin centre**

$$\mathrm{inv}\phi = \left(\frac{\pi}{2\cdot 81} + \mathrm{inv}20^\circ\right) - \frac{1.7}{80\cdot 1\cdot\cos 20^\circ} + \frac{2\cdot 0.12\cdot\tan 20^\circ}{81}$$

$$= 0.0130407$$

$$\phi = 19.156^\circ \ (19^\circ 9' 22'')$$

③ **Over balls or Rollers dimension** d_m

$$d_m = \frac{81\cdot 1\cdot\cos 20^\circ}{\cos 19.156^\circ}\cdot\cos\frac{90^\circ}{81} - 1.7 = 78.86 \ (\mathrm{mm})$$

Over balls or Rollers for Straight tooth rack

$$d_m = h'' + \frac{d_p}{2}\left(1+\frac{1}{\sin\alpha}\right) - \frac{\pi m}{4\tan\alpha}$$

Hereby

h'' : Datum line (mm) is from Rack base to Reference line [1].

Helical rack is the same as straight rack at normal section. The above formula can be used. For calculation of Pressure angleα and module m, use α_n and m_n at normal section.

Example,

When module m=3.0, Reference pressure angle α=20° and Datum line h''=32. Calculations of Over balls or Rollers dimensions is as follows,

① **Over balls or Rollers diameter** d_p

Refer to Fig. 3, d_p=1.68 multiply by module 3.0 = 5.04 (mm)

Use nearest available pin size d_p=5.0(mm) instead of 5.04(mm)

② **Over balls or Rollers dimension** d_m

$$d_m = 32 + \frac{5}{2}\bullet\left(1+\frac{1}{\sin 20°}\right) - \frac{\pi\bullet 3}{4\tan 20°}$$

$$= 35.34 \ \text{(mm)}$$

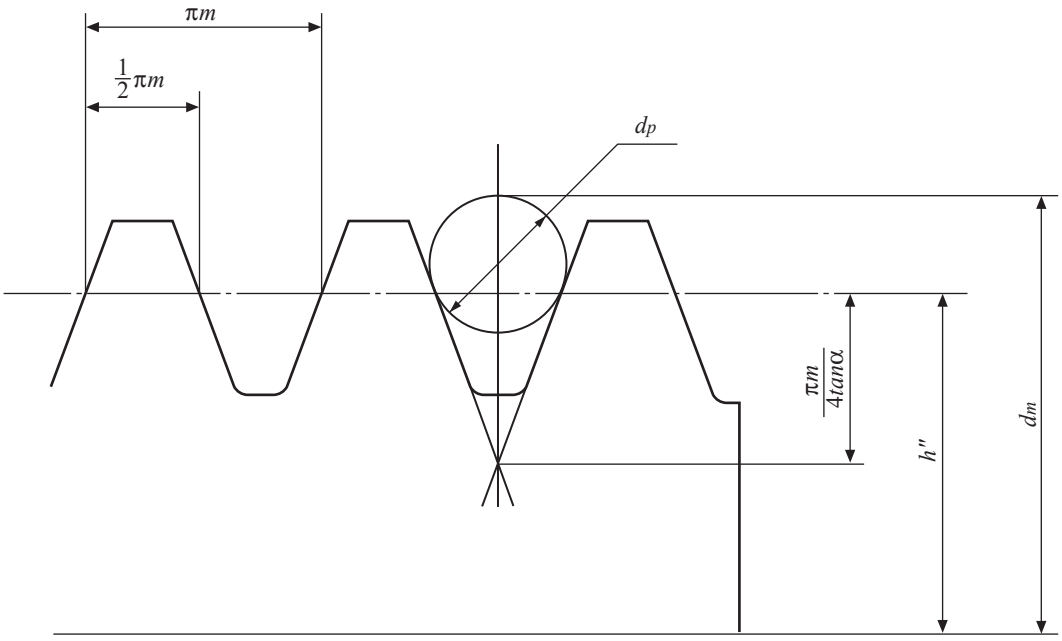

Fig. 6 Over balls or Rollers dimension for Straight rack

Note: (1) Adopted the old Standard term.

Over balls or Rollers dimension for Helical gear

Calculation for even number of teeth is by following formula

$$d_m = \frac{z\, m_t \cos\alpha_t}{\cos\phi} + d_p$$

Calculation for odd number of teeth is by following formula

$$d_m = \frac{z\, m_t \cos\alpha_t}{\cos\phi} \cos\frac{90^\circ}{z} + d_p$$

For inv ϕ, calculation is by following formula

$$\mathrm{inv}\phi = \frac{d_p}{z\, m_n \cos\alpha_n} - \left(\frac{\pi}{2z} - \mathrm{inv}\alpha_t\right) + \frac{2x_n \tan\alpha_n}{z}$$

Hereby

m_n : Normal module (mm)
α_n : Normal pressure angle(°)
x_n : Normal rack shift coefficient
m_t : Transverse module
α_t : Transverse pressure angle(°)

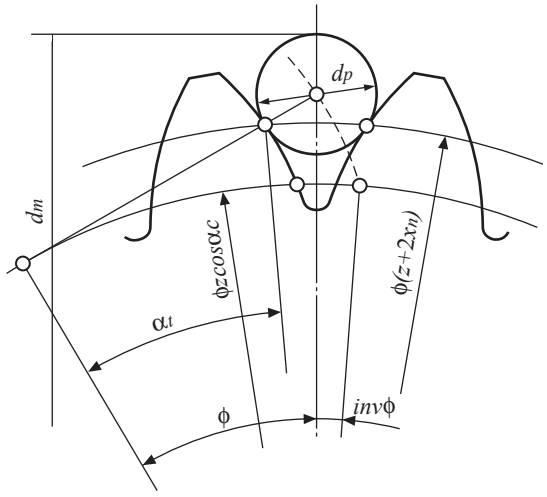

Fig. 7 Over balls or Rollers dimension for Helical gear (shown in axis section)

Example 1, even number of teeth

When module m=2.0, Number of teeth z=36, helix angle β=15°, Normal pressure angleα_n = 20° and Normal rack shift coefficient x_n= 0.05. Calculations of Over balls or Rollers dimensions is as follows,

① (1)**Virtual Number of teeth of Spur gear** z_v

$$z_v = \frac{z}{\cos^3\beta} = \frac{36}{\cos^3 15^\circ} = 39.94 \fallingdotseq 40$$

Note: (1) Adopted the old Standard term.

② **Over balls or Rollers diameter** d_p

Refer to Fig. 3, d_p=1.7 multiply by module 2.0 = 3.4 (mm)
Use nearest available pin size d_p=3.5(mm) instead of 3.4(mm)

③ **Transverse module** m_t

$$m_t = \frac{m_n}{\cos\beta} = \frac{2}{\cos 15^\circ} = 2.07055 \ \text{(mm)}$$

④ **Transverse pressure angle** α_t

$$\alpha_t = \tan^{-1}\left(\frac{\tan\alpha_n}{\cos\beta}\right) = \tan^{-1}\left(\frac{\tan 20^\circ}{\cos 15^\circ}\right)$$
$$= 20.646896^\circ \ (20^\circ 38' 48'')$$

⑤ **Pressure angle (°) at pin centre**

$$\mathrm{inv}\phi = \frac{3.5}{36 \cdot 2 \cdot \cos 20^\circ} - \left(\frac{\pi}{2 \cdot 36} - \mathrm{inv}20.646896^\circ\right) + \frac{2 \cdot 0.05 \cdot \tan 20^\circ}{36}$$
$$= 0.025562 \ (\mathrm{inv}20.646896^\circ = 0.0164533)$$
$$\phi = 23.77^\circ$$
(23°46′12″ See page 164 to 167 for Involute function charts)

⑥ **Over balls or Rollers dimension** d_m

$$d_m = \frac{36 \cdot 2.07055 \cdot 20.646896^\circ}{\cos 23.77^\circ} + 3.5 = 79.72 \ \text{(mm)}$$

Example 2, odd number of teeth

Number of teeth for calculation example 1 is changed to 35 (other data remains the same).

① (1)**Virtual Number of teeth of Spur gear** z_v

$$z_v = \frac{z}{\cos^3\beta} = \frac{35}{\cos^3 15^\circ} = 38.84 \fallingdotseq 39$$

② **Over balls or Rollers diameter** d_p

Refer to Fig. 3, d_p=1.7 multiply by module 2.0 = 3.4 (mm)
Use nearest available pin size d_p=3.5(mm) instead of 3.4(mm)

③ **Transverse module** m_t

m_t=2.07055(mm)
Calculations is the same as above in even number of teeth part ③

④ **Transverse pressure angle** α_t

α_t =20.646896° (20°38’48”)
Calculations is the same as Example 1, even number of teeth part ④

⑤ **Pressure angle at pin centre** (°)

$$\mathrm{inv}\phi = \frac{3.5}{35 \cdot 2 \cdot \cos 20^\circ} - \left(\frac{\pi}{2 \cdot 35} - \mathrm{inv}20.646896^\circ\right) + \frac{2 \cdot 0.05 \cdot \tan 20^\circ}{35}$$
$$= 0.025822 \ (\mathrm{inv}20.646896^\circ = 0.0164533)$$
$$\phi = 23.8465^\circ$$
(23°50′47″ See page 164 to 167 for Involute function charts)

⑥ **Over balls or Rollers dimension** d_m

$$d_m = \frac{35 \cdot 2.07055 \cdot \cos 20.646896}{\cos 23.8465^\circ} \cdot \cos\frac{90^\circ}{35}$$
$$+3.5 = 77.57 \ \text{(mm)}$$

Over balls or Rollers dimension for Worm gear

To obtain Over balls or Rollers dimension for Worm gear, introduce following methods,

1) Substituted three wire method from thread screw used for measurement.
2) Use same calculation method of Rack for Worm gear.
3) Use same calculation method of Helical gear for Worm gear. However, only formula 3) is introduced.

$$d_m = d(1+A) + d_p + Ae^2\mathrm{d}\left\{\frac{1}{2(1+A)} + \frac{3}{8}e^2\right\} - A^2e^4\mathrm{d}$$

$$A = \frac{1}{d\sin\gamma_b}\left(d_p - \frac{p_x}{2}\cos\gamma_b\right) \qquad e = \frac{z\,p_x}{\pi d}\cot\gamma_b$$

$$p_x = \frac{\pi m_n}{\cos\gamma} \qquad \gamma_b = \tan^{-1}\left(\frac{\tan\gamma}{\cos\alpha_t}\right)$$

$$\alpha_t = \tan^{-1}\left(\frac{\tan\alpha_n}{\sin\gamma}\right)$$

Hereby

d : Pitch diameter of Worm gear (mm)
z : Number of thread of Worm gear
p_x : Axial pitch of Worm gear (mm)
γ : Reference cylinder lead angle (°)
γ_b : Base cylinder lead angle (°)

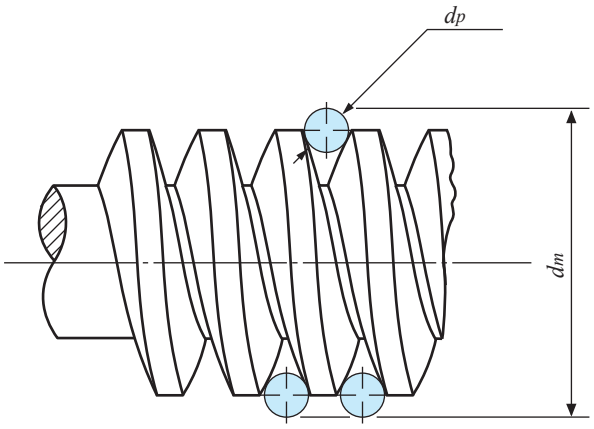

Fig. 8 Over balls or Rollers dimension of Worm gear

Example

When module m_n=2.0, Number of thread z=1, Pitch diameter of Worm gear d = 31, Normal pressure angle α_n=20° and Reference cylinder lead angle γ= 3°42′(3.7 °). Calculations of Over balls or Rollers dimensions of Worm gear is as follows.

① **Over balls or Rollers diameter** d_p

Refer to Number of teeth(10 to ∞) in Fig. 3, d_p=1.68 and multiply by module 2.0 = 3.36 (mm)
Use nearest available pin size d_p=3.4 (mm) instead of 3.36(mm)

② **Transverse pressure angle** α_t

$$\alpha_t = \tan^{-1}\left(\frac{\tan 20°}{\sin 3.7°}\right) = 79.9459°$$

③ **Base cylinder lead angle** γ_b

$$\alpha_t = \tan^{-1}\left(\frac{\tan\alpha_n}{\cos\beta}\right) = \tan^{-1}\left(\frac{\tan 20°}{\cos 15°}\right)$$

④ **Axial pitch**

$$p_x = \frac{\pi \cdot 2}{\cos 3.7°} = 6.2963$$

⑤ A

$$A = \frac{1}{31\sin 20.3256°}\left(3.4 - \frac{6.2963}{2}\cos 20.3256°\right)$$
$$= 0.04159$$

⑥ e

$$e = \frac{1 \cdot 6.2963}{\pi \cdot 31}\cot 20.3256°$$
$$= 0.17453$$

⑦ **Over balls or Rollers dimension**

$$d_m = 35.71 \text{ (mm) (Substitution method omitted)}$$