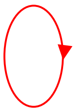
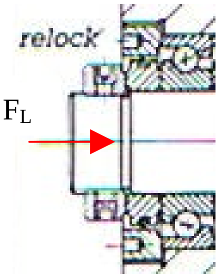
Calculation of torque

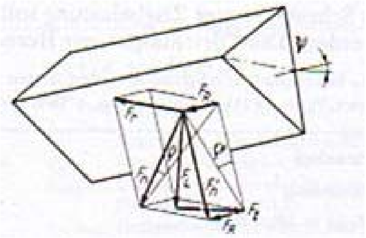


M =F r



M = torque that is exerted on the adjusting nut (Nmm)
F = Leverage (N)
r = Lever arm (mm)
F_L = Axial force (N)

Forces on metric v-thread:



F_N = Normal force (N)
F_R = Frictional force (N)
F_t = Tangential force (N)

Characteristics:
d = Nominal thread ∅ (mm)
p = Pitch (mm)
d_2 = Flank ∅ = $d - 0.64952p$ (mm) ⇒ VSM

$$\psi = \text{Pitch angle} = \arctan\left(\frac{p}{d_2\pi}\right) = \arctan\left(\frac{p}{(d-0.64952\,p)\pi}\right)\ (°)$$

β = Half flank angle = 30° ⇒ VSM
μ = Coefficient of friction of steel/ground steel~ 0.15
ρ = Friction angle on v-thread (°)

$$\rho = \arctan\left(\frac{\mu}{\cos[\arctan(\tan\beta\cos\psi)]}\right)$$

⇒ ψ is a relatively small angle

simplified: $$\rho = \arctan\left(\frac{\mu}{\cos\beta}\right) = \arctan\left(\frac{0.15}{\cos 30°}\right) = 9.826°$$

The following also applies:
$F_t = F_L \cdot \tan(\psi \pm \rho)$ ⇒ with '+' for tightening and '–' for loosening

Calculation of the torque $M_{A/L}$ and axial force F_L on the thread:

$$M_{A/L} = F\,r = F_t \cdot \frac{d_2}{2} = 0.5 \cdot d_2 \cdot F_L \cdot \tan(\psi \pm \rho)$$

M =$_A$ = tightening torque (Nmm)
M =$_L$ = loosening torque (Nmm)

Therefore:

$$\Rightarrow F_L = \frac{M_{A/L}}{0.5\cdot d_2\cdot\tan(\psi\pm\rho)} = \frac{M_{A/L}}{0.5\cdot d_2\cdot\tan\left[\arctan\left(\frac{p}{d_2\pi}\right)\pm 9.826^\circ\right]}$$

$$= \frac{M_{A/L}}{0.5(d-0.64952p)\cdot\tan\left[\arctan\left(\frac{p}{(d-0.64952p)\pi}\right)\pm 9.826^\circ\right]}$$

⇒ ψ is a relatively small angle
We assume an average value of 0.9° (please see table below)

M6x0.5	M8x0.75	M11x1	M25x1	M50x1.5	M55x2	M150x2	M155x2	M200x3
1.6°	1.82°	1.76°	0.749°	0.558°	0.679°	0.245°	0.357°	0.276°

$$F_L = \frac{M_{A/L}}{0.5(d-0.64952p)\cdot\tan[0.9^\circ\pm 9.826^\circ]}$$

⇒ for further simplification we use only d instead of (d-0.64952p)

$$F_L = \frac{M_{A/L}}{0.5\cdot d\cdot\tan(0.9^\circ\pm 9.826^\circ)}$$

Tighten:

$$F_L = \frac{M_A}{0.0947\cdot d} \qquad \Rightarrow M_A = 0.0947\cdot F_L\cdot d$$

Loosen:

$$F_L = \frac{M_L}{-0.0785\cdot d} \qquad \Rightarrow M_L = -0.0785\cdot F_L\cdot d$$

Calculation of the frictional torque adjusting nut – bearing surface M =$_R$:

$$M_R = F_L\cdot\mu\cdot\frac{d_M}{2} = F_L\cdot 0.15\cdot\frac{d_M}{2} = 0.075\cdot F_L\cdot d_M$$

Simplified with $d_M \approx d$:

$$M_R = 0.075\cdot F_L\cdot d$$

M_R = Frictional torque adjusting nut – bearing surface (Nmm)
μ = Coefficient of friction ≈ 0.15
d_M = Average surface ∅ of adjusting nut

Note:
M_R only comes into effect if the adjusting nut is pressing on the bearing surface.

Torque being exerted on the adjusting nut:
Tighten:

$$\boxed{M = M_A + M_R = 0.0947\cdot F_L\cdot d + 0.075\cdot F_L\cdot d = 0.17\cdot F_L\cdot d}$$

Loosen:

$$\boxed{M = M_L + M_R + M_G = 0.0785\cdot F_L\cdot d + 0.075\cdot F_L\cdot d + n\cdot F_R\cdot\frac{d}{2} = 0.15\cdot F_L\cdot d + n\cdot F_R\cdot\frac{d}{2}}$$

Note: Derivation of M_G please see below

Values still to be taken into account:

Surface pressure on the thread flanks ⇒ max. axial load

$$Pa = \frac{F_L}{A} = \frac{F_L}{\frac{m}{p}\cdot\pi\cdot d_2\cdot H1} \le Pa_{zul}$$

$$F_L \le Pa_{zul}\cdot\frac{m}{p}\cdot\pi\cdot(d-0.64952p)\cdot 0.54126p$$

Simplified:

$$F_L \le Pa_{zul}\cdot\frac{m}{p}\cdot\pi\cdot d\cdot 0.54126p$$

Pa_{zul} = 80-150 N/mm^2 ⇒ Gieck Z18
m/p = Number of thread pitches = thread length/pitch
d_2 = Flank ∅ = $d-0.64952p$ (mm)
F_L = Axial force (N)
H_1 = Thread load-bearing depth (VSM) = $0.54126p$ (mm)

And shear stress on thread

$$\tau = \frac{F_L}{\pi\cdot d_2\cdot m} \le \tau_{zul}$$

$$F_L \le \tau_{zul}\cdot\pi\cdot(d-0.64952p)\cdot m$$

Simplified:

$$F_L \le \tau_{zul}\cdot\pi\cdot d\cdot m$$

m = Adjusting nut height (mm)
τ_{zul} = 560 N/mm^2 ⇒ Mechanical engineering p.39

Braking effect of gib MRR/MRR-A (radial)

$$F_R = F_G\cdot\cos 60°\cdot\mu$$

With ψ = 3.23° ⇒ average value of thread M4-M12

M_{AI} = Tightening torque of grub screw (Nmm)
F_G = Axial force of grub screw (N)
F_R = Frictional force of gib on adjusting nut thread. (N)
μ = Coefficient of friction grub screw – adjusting nut~0.2
d_{St} = ∅ of grub screw (mm)

And $\rho = \arctan\left(\frac{\mu}{\cos\beta}\right) = \arctan\left(\frac{0.2}{\cos 30°}\right) = 13°$

$$\Rightarrow \quad F_G = \frac{M_{AI}}{0.5\cdot d_{St}\cdot\tan(\psi+\rho)} = \frac{M_{AI}}{0.5\cdot d_{St}\cdot\tan(3.23°+13°)}$$ with the simplification $d2_{St}\approx d_{St}$

Tighten:

$$F_G = \frac{M_{AI}}{0.5\cdot d_{St}\cdot\tan(3.23°+13°)} = \frac{M_{AI}}{0.1455\cdot d_{St}}$$

Therefore:

$$F_R = \cos 60°\cdot 0.2\cdot F_G = 0.687\cdot\frac{M_{AI}}{d_{St}}$$

Tightening torque M_{AI} (Nmm) of the grub screw as per Bossard T.037 for M4-M16:

M4	M5	M6	M8	M10	M12	M14	M16
1000	3000	5000	10000	20000	45000	45000	90000

Therefore for F_R (N) for one gib:

M4	M5	M6	M8	M10	M12	M14	M16
171.75	412.2	572.5	858.75	1374	2576.25	2208.2	3864.37

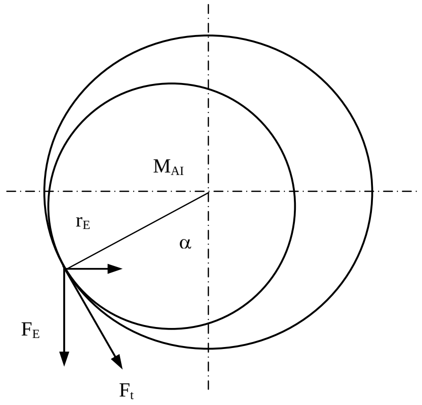
Therefore the result for frictional torque M_G:

$$M_G = n\cdot F_R\cdot\frac{d}{2} = n\cdot 0.687\cdot\frac{M_{AI}}{d_{St}}\cdot\frac{d}{2}$$

$$M_G = 0.343\cdot n\cdot\frac{M_{AI}}{d_{St}}\cdot d$$

M_G = Braking torque of gib on adjusting nut thread (Nmm)
d = ∅ of adjusting nut thread (mm)
d_{St} = ∅ of grub screw (mm)
n = Number of gibs
M_{AI} = Tightening torque of grub screw (Nmm)

Braking effect of gib MRA/MRA-A (axial)



F_E = Force of eccentric on gib (N)
F_t = Tangential force on eccentric (N)
r_E = Radius on outer surface of eccentric (mm)
M_{AI} = Tightening torque on eccentric (Nmm)
α = Angle of eccentric to gib (°)
F_R = Frictional force of gib on adjusting nut thread. (N)
μ = Coefficient of friction gib – adjusting nut ≈ 0.2

$$F_E = \sin\alpha \cdot F_t \qquad \text{with } F_t = \frac{M_{AI}}{r_E}$$

$$F_E = \sin\alpha \cdot \frac{M_{AI}}{r_E}$$

Therefore:

$F_R = F_E \cdot \cos 60° \cdot \mu$ (please see above)

$$F_R = F_E \cdot \cos 60° \cdot \mu = \sin\alpha \cdot \frac{M_{AI}}{r_E} \cdot 0.5 \cdot 0.2 = \sin\alpha \cdot \frac{M_{AI}}{r_E} \cdot 0.1$$

Therefore the result for frictional torque M_G:

$$M_G = n \cdot F_R \cdot \frac{d}{2}$$

$$M_G = 0.05 \cdot n \cdot \sin\alpha \cdot \frac{M_{AI}}{r_E} \cdot d$$

M_G = Braking torque of gib on adjusting nut thread (Nmm)
d = ∅ of adjusting nut thread (mm)
n = Number of gibs

Note:
The angle α is dependent on which position the gib has been ground. The tolerances when manufacturing the eccentric, as well as the gib, also have a great influence on the angle α.

Sample calculation:

Assuming: An adjusting nut MRR 50x1.5 (2 gibs with M6) is used to clamp a spindle bearing.
The maximum axial load on the bearing must not exceed 10,000 N.
What are the tightening and loosening torques?

Tightening and loosening torque of the adjusting nut:
Tighten:

$$M = M_A + M_R = 0.17 \cdot F_L \cdot d = 0.17 \cdot 10000 \cdot 50 = 85000 Nmm$$

Loosen:

$$M = M_L + M_R + M_G = 0.0785 \cdot F_L \cdot d + 0.075 \cdot F_L \cdot d + n \cdot F_R \cdot \frac{d}{2} = 0.15 \cdot F_L \cdot d + n \cdot F_R \cdot \frac{d}{2}$$

$$M = 0.15 \cdot 10000 \cdot 50 + 2 \cdot 572.5 \cdot 25 = 103625 Nmm$$

Check surface pressure/shear stress ⇒ max. axial load:

$$F_L \le Pa_{zul} \cdot \frac{m}{p} \cdot \pi \cdot d \cdot 0.54 p = 150 \cdot \frac{14}{1.5} \cdot \pi \cdot 50 \cdot 0.54 \cdot 1.5 = 178128 N \qquad \Rightarrow \text{OK}$$

$$F_L \le \tau_{zul} \cdot \pi \cdot d \cdot m = 560 \cdot \pi \cdot 50 \cdot 14 = 1231504 N \qquad \Rightarrow \text{OK}$$

Assuming: An adjusting nut MRR 100x2 (2 gibs with M8) is used to clamp a spindle bearing.
The maximum axial load on the bearing must not exceed 25,000 N.
What are the tightening and loosening torques?

Tightening and loosening torque of the adjusting nut:

Tighten:

$$M = M_A + M_R = 0.17 \cdot F_L \cdot d = 0.17 \cdot 25000 \cdot 100 = 425000 Nmm$$

Loosen:

$$M = M_L + M_R + M_G = 0.0785 \cdot F_L \cdot d + 0.075 \cdot F_L \cdot d + n \cdot F_R \cdot \frac{d}{2} = 0.15 \cdot F_L \cdot d + n \cdot F_R \cdot \frac{d}{2}$$

$$M = 0.15 \cdot 25000 \cdot 100 + 2 \cdot 858.75 \cdot 50 = 460875 Nmm$$

Check surface pressure/shear stress ⇒ max. axial load:

$$F_L \le Pa_{zul} \cdot \frac{m}{p} \cdot \pi \cdot d \cdot 0.54 p = 150 \cdot \frac{20}{2} \cdot \pi \cdot 100 \cdot 0.54 \cdot 2 = 508938 N \qquad \Rightarrow \text{OK}$$

$$F_L \le \tau_{zul} \cdot \pi \cdot d \cdot m = 560 \cdot \pi \cdot 100 \cdot 20 = 3518583 N \qquad \Rightarrow \text{OK}$$