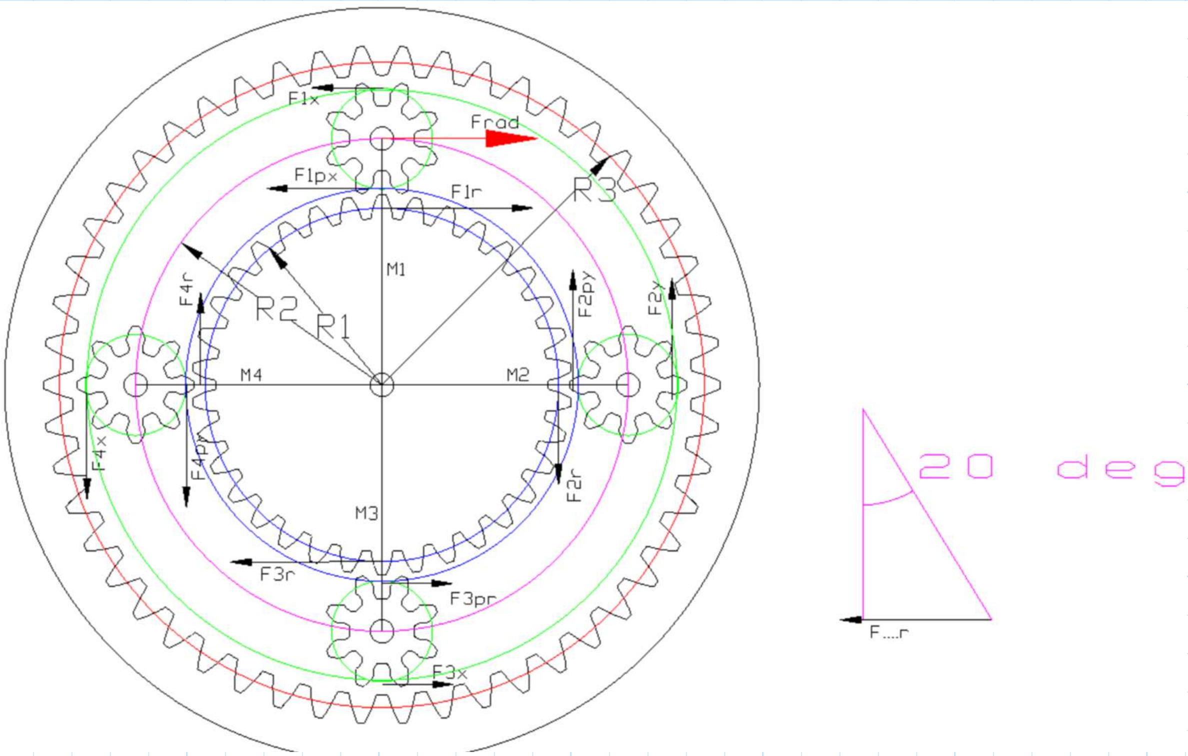
Gear ring forces

The purpose of this spreadsheet is to calculate the forces between the sunwheel and the planet gears. The geometry of the tooth profile is not considered. The problem here is that we have 3 equations and 4 unknowns. Often, these equations are solved by addressing the geometry issue.



Gear propperties

Pitch diameter of the gear ring	$D_{gearring} := 1.2\ m$	$R_{gearring} := \frac{D_{gearring}}{2}$
Pitch diameter of the sun gear(yellow)	$D_{sunw} := 300\ mm$	$R_{sunw} := \frac{D_{sunw}}{2}$
Pitch diameter of carrier (pink)	$D_{carrier} := 800\ mm$	$R_{carrier} := \frac{D_{carrier}}{2}$
Pitch diameter planet gear	$D_{planetw} := 600\ mm$	$R_{planetw} := \frac{D_{planetw}}{2}$
Moment planet carrier	$M_{planet} := 2500\ kN \cdot m$	
Pressure angle	$\alpha_1 := 20\ deg$	
Number of planet wheels	$n_1 := 4$	

$R_{gearring} - R_{planetw} = 300\ mm$

Averge tooth load

Force of on the planet carrier divided over 4 planet wheels. Assuming that all the forces are devided equal over each planet wheel

$$F_{gearring} := \frac{M_{planet} \cdot \frac{1}{n_1}}{\left(R_{gearring}\right)} \qquad F_{gearring} = 1041.667\ kN$$

The avarge radial load on the tooth of the planet wheel

$$F_{planet} := \frac{M_{planet} \cdot \frac{1}{n_1}}{\left(R_{gearring} - R_{planetw}\right)} \qquad F_{planet} = 2083.333\ kN$$

Radial load on the planet carrier $F_{rad} := 290\ kN$

Even vragen aan waar deze vandaan komen

Add. load on planet 1 $F_{1add} := 122\ kN$ Add. load on planet 3 $F_{3add} := -134\ kN$

Add. load on planet 2 $F_{2add} := -40\ kN$ Add. load on planet 4 $F_{4add} := 53\ kN$

Force with added load 1 $F_{1py} := F_{1add} + F_{planet}$ $F_{1py} = \left(2.205 \cdot 10^3\right)\ kN$

Force with added load 2 $F_{2py} := F_{2add} + F_{planet}$ $F_{2py} = \left(2.043 \cdot 10^3\right)\ kN$

Force with added load 3 $F_{3py} := F_{3add} + F_{planet}$ $F_{3py} = \left(1.949 \cdot 10^3\right)\ kN$

Force with added load 4 $F_{4py} := F_{4add} + F_{planet}$ $F_{4py} = \left(2.136 \cdot 10^3\right)\ kN$

$$F_{avx} := \frac{\left(F_{1py} + F_{2py} + F_{3py} + F_{4py}\right)}{4} \qquad F_{avx} = 2083.583\ kN$$

Force with added load 1 in % $F_{1p} := \frac{F_{planet}}{F_{1py}}$ $F_{1p} = 94.468\%$

Force with added load 2 in % $F_{2p} := \frac{F_{planet}}{F_{2py}}$ $F_{2p} = 101.958\%$

Force with added load 3 in % $F_{3p} := \frac{F_{planet}}{F_{3py}}$ $F_{3p} = 106.874\%$

Force with added load 4 in % $F_{4p} := \frac{F_{planet}}{F_{4py}}$ $F_{4p} = 97.519\%$

The three equations

Moment balance around the axis of the planetary carrier:
The moment balance around the axis of the planetary carrier tells us that the sum of all moments around this axis must be equal to the total moment on the planetary carrier. So:

$M_{pl} = (F_1 + F_2 + F_3 + F_4) \times (2/3)$

Here:

M_{pl} = 2500 kNm, the moment on the planetary carrier.
D = 1.2 m, the diameter of the gear ring.
F_1, F_2, F_3, F_4 are the unknown forces on the teeth of the gear system.

Force balance in the x-direction:

$F_1 - F_2 \times \tan(\alpha) - F_3 + F_4 \times \tan(\alpha) = Frad$

Here, Frad = 290 kN is the radial load on the planetary carrier. See the freebody diamgram

Force balance in the y-direction:

$- F_1 \times \tan(\alpha) - F_2 + F_3 \times \tan(\alpha) + F_4 = 0$

Setup first equations of motion

We now have three equations: the moment balance and force balances in the x and y directions. To solve this system, we need four equations. However, the moment balance provides only one additional equation.

To obtain the fourth equation, we can leverage the geometric symmetry of the gear system. We can assume that the forces are evenly distributed across the planetary gears, and that the radial load is equal on each tooth. With this geometric assumption, we can derive a fourth equation.

Step 1: Adding extra geometric symmetry for uniform force distribution
Consideration of radial distances: We can consider the radial distances between the axis of each gear and the axis of the planet carrier. These radial distances can help us establish additional equations based on geometric ratios.

The geometric relationships of the system, particularly the radial distances between the axes of the gears and the planet carrier. These radial distances can assist us in establishing additional equations.

Assuming that:

- The radial distance between the axis of each gear and the axis of the planet carrier is known**.**
- that the arm are equal long and the tolerances and geometric shape of the wheels are the same.

With this information, we can formulate 4 moment equations based on the radial forces acting on the gears and the moment arms between the axes of the gears and the planet carrier.

The moment equations might look as follows:

Moment balance around the planetary carrier arm 1:

$$M_{1t} = F_{1py} \cdot R_{sunw} - F_{rad} \cdot R_{gearring} - F_{1r} \cdot R_{sunw}$$

Moment balance around the planetary carrier arm 2:

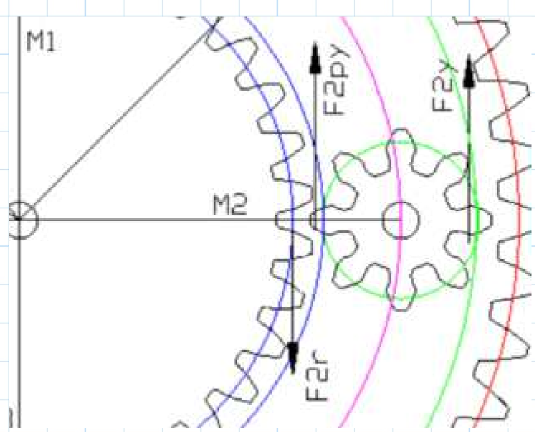
$$M_{2t} = F_{2py} \cdot R_{sunw} - F_{rad} \cdot R_{gearring} - F_{2r} \cdot R_{sunw}$$

Moment balance around the planetary carrier arm 3:

$$M_{3t} = F_{3py} \cdot R_{sunw} - F_{rad} \cdot R_{gearring} - F_{3r} \cdot R_{sunw}$$

Moment balance around the planetary carrier arm 4:

$$M_{4t} = F_{4py} \cdot R_{sunw} - F_{rad} \cdot R_{gearring} - F_{4r} \cdot R_{sunw}$$



Moment balance around the planetary carrier arm 4:

Convert the moment equations into matrix form. We have four moment equations:

$$M1 = F_{1py} \cdot R_{sunw} - F_{rad} \cdot R_{gearring} - F_{1r} \cdot R_{sunw}$$

$$M2 = F_{2py} \cdot R_{sunw} - F_{rad} \cdot R_{gearring} - F_{2r} \cdot R_{sunw}$$

$$M3 = F_{3py} \cdot R_{sunw} - F_{rad} \cdot R_{gearring} - F_{3r} \cdot R_{sunw}$$

$$M4 = F_{4py} \cdot R_{sunw} - F_{rad} \cdot R_{gearring} - F_{4r} \cdot R_{sunw}$$

coefficient matrix A $$A := \begin{bmatrix} R_{sunw} & 0 & 0 & 0 \\ 0 & R_{sunw} & 0 & 0 \\ 0 & 0 & R_{sunw} & 0 \\ 0 & 0 & 0 & R_{sunw} \end{bmatrix}$$

vector matrix $$b1 := \begin{bmatrix} -F_{1py} \cdot R_{sunw} + F_{rad} \cdot R_{gearring} \\ -F_{2py} \cdot R_{sunw} + F_{rad} \cdot R_{gearring} \\ -F_{3py} \cdot R_{sunw} + F_{rad} \cdot R_{gearring} \\ -F_{4py} \cdot R_{sunw} + F_{rad} \cdot R_{gearring} \end{bmatrix}$$

Radiaal krachten $$F_{radt} := A^{-1} \cdot b1 \qquad F_{radt} = \begin{bmatrix} -1.045 \cdot 10^{3} \\ -883.333 \\ -789.333 \\ -976.333 \end{bmatrix} kN$$

Horizontaal krachten $$F_{radh} := F_{radt} \cdot \frac{1}{\tan(\alpha_1)} \qquad F_{radh} = \begin{bmatrix} -2.872 \cdot 10^{3} \\ -2.427 \cdot 10^{3} \\ -2.169 \cdot 10^{3} \\ -2.682 \cdot 10^{3} \end{bmatrix} kN$$

Pressure angle force $$P_{force} := F_{radh} \cdot \frac{1}{\cos(\alpha_1)} \qquad P_{force} = \begin{bmatrix} -3.056 \cdot 10^{3} \\ -2.583 \cdot 10^{3} \\ -2.308 \cdot 10^{3} \\ -2.855 \cdot 10^{3} \end{bmatrix} kN$$