Break-Away Torque Calculation for 2 Gear Rotor Shafts

Below is an example calculation method for the "initial torque" which must be used by the driving machine to achieve dynamic rotation from a static condition. This is based on the gear rotor set coupled to the rotor of the driven machine. Both the "direction of rotation" and the "break-away torque of the driven rotor (compressor/generator)" must be known since the final friction strengths are dependent on the calculation for the gearing.

**Calculation for 2 rotor shafts**

\[ M_L = \text{Combined Break Away Torque of Driven Machine(s)} \ (\text{Nm}) \]
\[ F_U = \text{Force at point of rotation @ pitch line} \ (\text{N}) \]
\[ G = \text{rotor weight (pinion or wheel)} \ (\text{N}) \]
\[ L = \text{Breaking Strength of Bearings from } F_U \text{ and } G \ (\text{Nm}) \]
\[ F = \text{force on the pitch circle to overcome friction} \ (\text{N}) \]
\[ R = \text{pitch circle radius (pinion or wheel)} \ (\text{mm}) \]
\[ r = \text{bearing journal radius} \ (\text{mm}) \]
\[ \mu = \text{friction factor - journal sleeve type bearing} \ (0.26) \]
\[ \mu = \text{friction factor - roller bearing} \ (0.01) \]
\[ \mu = \text{friction factor – roller/axial bearing} \ (0.03) \]
\[ M_R = \text{friction moment} \ (\text{Nm}) \]
\[ \uparrow\downarrow = \text{working rotor movement (up force or down force)} \]

*note: if rotor weight "G" values are not given then approximate weights can be calculated as follows: \( G_2 \) or \( G_p = (0.2215 \times \text{FW} \times d)^*1.1 \) where: FW = gear tooth face width; d = rotor diameter; 1.1 (10%) is added for rotor shafts

Shaft 2 – Driven Rotor

Rotational force required for taking into account the driven machines break-away torque

\[ F_{U_2} = 1000 \cdot \frac{M_{L2}}{R_2} \]

Net breaking force for driven rotor bearings derived from \( F_{U_2} \) and \( G_2 \)

\[ L_2 = F_{U_2} \pm G_2 \]

\( G_2 \) is negative if force direction on driven rotor mesh is up \( \uparrow \) (up mesh)

\( G_2 \) is positive if force direction on driven rotor mesh is down \( \downarrow \) (down mesh)

Net Rotational Force to overcome bearing friction on driven rotor
\[ F_2 = \frac{L_2 \cdot \mu}{R_2} \pm \mu \]  
\footnote{[3]}  
\( \mu \) is positive if force direction on driven rotor mesh is up \( \uparrow \) (up mesh)  
\( \mu \) is negative if force direction on driven rotor mesh is down \( \downarrow \) (down mesh)

Total driven rotor force

\[ F_{U_2} = F_{U_2} + F_2 \]  
\footnote{[4]}

**Shaft 1 – Driving Rotor**

Force on driving rotor derived from \( F_u \) and \( G_1 \)

\[ L_1 = F_{U_2} \pm G_1 \]  
\footnote{[5]}

\( G_1 \) is positive if force direction on driving rotor mesh is down \( \downarrow \) (up mesh)  
\( G_1 \) is negative if force direction on driving rotor mesh is up \( \uparrow \) (down mesh)

Total combined moment due to friction from both driving/driven Rotors

\[ M_R = \frac{L_1 \cdot \mu \cdot R_1}{1000} \]  
\footnote{[6]}

Total Break-Away Torque for this rotor set

\[ M_{L_{2u}} = \frac{F_{U_2} \cdot R_1}{1000} + M_R \left( + M_{L_{1}} \right) \]  
\footnote{[7]}

- including the coupled machine

The driver is like a shaft rope coupled to the drive. Unlike the driven break-away torque, the driver break-away torque \( M_{L_{1}} \) does not have any influence on the gearing. This is added to the total break-away torque of the gearing at the drive flange.
EXAMPLE:

\[ M_{L_1} = 400 \text{ Nm} - \text{assumed break-away torque of driven machine} \]
\[ G_2 = 5000 \text{ N} - \text{wheel rotor weight} \]
\[ R_2 = 200 \text{ mm} - \text{wheel pitch line radius} \]
\[ r_2 = 65 \text{ mm} - \text{wheel journal radius} \]
\[ G_1 = 2000 \text{ N} - \text{pinion rotor weight} \]
\[ R_1 = 140 \text{ mm} - \text{pinion pitch line radius} \]
\[ r_1 = 45 \text{ mm} - \text{pinion journal radius} \]
\[ \mu = 0.26 - \text{friction factor} \]

Shaft 2: Shaft 1:

\[ F_{c_1} = \frac{1000 \cdot 400}{200} = 2000 \text{ Nm} \]
\[ L_1 = 2234 + 2000 = 4234 \text{ N} \]
\[ L_2 = 2000 - 5000 = 3000 \text{ N} \]
\[ M_R = \frac{4234 \cdot 0.26 \cdot 45}{1000} = 49.5 \text{ N} \]
\[ F_2 = \frac{3000 \cdot 0.26}{200 + 0.26} = 234 \text{ N} \]
\[ M_{L_{12}} = \frac{2234 \cdot 140}{1000} + 49.5 = 362.3 \text{ Nm} \]
\[ F_{c_{12}} = 2000 + 234 = 2234 \text{ N} \]

\[ \text{note: add } M_{L_1} \text{ to obtain the total drive train break away torque.} \]