10 Calculation Example: Chain Conveyor with Frequency Inverter

**Input data**

A chain conveyor is to transport wooden boxes up a slope of $\alpha = 5^\circ$ at a speed of 0.5 m/s. There is a maximum of four boxes each weighing 500 kg on the conveyor. The chain itself has a weight of 300 kg. The friction factor between chain and base is specified at $\mu = 0.2$. A mechanical stop is mounted at the end of the chain conveyor which aligns the boxes before they are pushed onto a second conveyor belt. During this process, the box slides on the chain with a friction factor of $\mu = 0.7$.

The application calls for a helical-worm gear unit that is frequency-controlled up to approximately 50 Hz.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Velocity</td>
<td>$v = 0.5$ m/s</td>
</tr>
<tr>
<td>Incline</td>
<td>$\alpha = 5^\circ$</td>
</tr>
<tr>
<td>Weight of transported material</td>
<td>$m_L = 2,000$ kg</td>
</tr>
<tr>
<td>Weight of chain</td>
<td>$m_D = 300$ kg</td>
</tr>
<tr>
<td>Friction factor between chain and base</td>
<td>$\mu_1 = 0.2$</td>
</tr>
<tr>
<td>Friction factor between box and chain</td>
<td>$\mu_2 = 0.7$</td>
</tr>
<tr>
<td>Desired acceleration</td>
<td>$a = 0.25$ m/s$^2$</td>
</tr>
<tr>
<td>Sprocket diameter</td>
<td>$D = 250$ mm</td>
</tr>
<tr>
<td>Starting frequency</td>
<td>10 cycles/hour and 16 hours/day</td>
</tr>
</tbody>
</table>

Figure 37: Chain conveyor
10.1 Motor calculation

Resistance forces
Description
Slope with friction, direction of force upwards! The weight contains the weight of the four boxes and half of the weight of the chain.

\[ F_s = F_a \cdot \frac{\sin(\alpha + \rho)}{\cos \rho} \]
\[ \mu = \tan \rho / \rho = \arctan 0.2 \]
\[ F_s = (2000 + 150) \text{ kg} \cdot 9.81 \frac{m}{s^2} \cdot \frac{\sin(5^\circ + 11.3^\circ)}{\cos 11.3^\circ} = 6040 \text{ N} \]

Aligning
Sliding friction (box-chain) on the slope, direction of force downwards!

\[ F_s = F_a \cdot \frac{\sin(\rho - \alpha)}{\cos \rho} = 4900 \text{ N} \cdot \frac{\sin(35^\circ - 5^\circ)}{\cos 35^\circ} = 2990 \text{ N} \]
\[ \rho = \arctan 0.7 \]

Efficiency of helical-worm gear unit
The efficiency of a helical-worm gear unit has a large degree of variation depending on the reduction gear ratio. For this reason, we recommend calculating with a temporarily assumed efficiency of 70 %, since the required torque and gear ratio have not been calculated yet. This situation requires a subsequent check calculation.

The efficiency of the chain is to be calculated with 0.9 according to the table.

Static power
\[ P_s = \frac{F \cdot v}{\eta} = \frac{9030 \text{ N} \cdot 0.5 \frac{m}{s}}{0.7 \cdot 0.9 \cdot 1000} = 7.17 \text{ kW} \]

As the chain conveyor is operated continuously without a break, we select a motor with a rated power that is greater than the maximum static power. A smaller motor can often be used for short-term operation but requires an exact thermal check calculation by SEW.

Motor selection
The following motor was selected based on these conditions:

DV 132M 4 BM
\[ P_N = 7.5 \text{ kW} \]
\[ n_M = 1430 \text{ min}^{-1} \]
\[ J_M = 0.03237 \text{ kgm}^2 \]
\[ M_B = 100 \text{ Nm} \]
Calculation Example: Chain Conveyor with Frequency Inverter

The starting time $t_A = 2 \text{ s}$ at an assumed acceleration of $0.25 \text{ m/s}^2$.

\[
J_X = 91.2 \cdot m \left( \frac{\nu}{n_M} \right)^2 = 91.2 \cdot (2000 + 300) \text{ kg} \cdot \left( \frac{0.5 \text{ m/s}}{1430 \text{ min}^{-1}} \right)^2 = 0.026 \text{ kgm}^2
\]

Load torque

\[
M_L = \frac{F \cdot \nu \cdot 9550}{n_M} = \frac{9030 \text{ N} \cdot 0.5 \cdot 9.55}{1430 \text{ min}^{-1}} = 30.2 \text{ Nm}
\]

Acceleration torque

\[
M_H = \left( \frac{J_M + J_X}{\eta} \right) \cdot \frac{n_M}{9.55 \cdot t_A} + \frac{M_L}{\eta}
\]

The starting torque is based on the "worst case" scenario, i.e. four boxes are on the chain and one of these is at the stop.

\[
M_H = \left( \frac{0.03237 + 0.026}{0.63} \right) \text{kgm}^2 \cdot 1430 \text{ min}^{-1} = \frac{30.2 \text{ Nm}}{0.9 \cdot 0.7} = 53.4 \text{ Nm}
\]

Rated torque

We have already mentioned that the starting torque must be less than 130% of the rated torque calculated from the rated power provided by the inverter.

\[
M_N = \frac{P_N \cdot 9550}{n_M} = \frac{7.5 \text{ kW} \cdot 9550}{1430 \text{ min}^{-1}} = 50.1 \text{ Nm}
\]

\[
\frac{M_H}{M_N} = \frac{53.4 \text{ Nm}}{50.1 \text{ Nm}} = 107\% < 130\%
\]

Selected frequency inverter, e.g. MOVIDRIVE® MDF 0075.
10.2 Gear unit selection

Output speed

\[ n_a = 19.1 \cdot 10^3 \cdot \frac{V}{D} \cdot \frac{250\ mm}{s} \cdot 1 = 38.2\ min^{-1} \]

Gear unit ratio

\[ i = \frac{n_M}{n_a} = \frac{1430\ min^{-1}}{38.2\ min^{-1}} = 37.4 \]

Service factor

The following service factor is determined (see the chapter on "Gear Units," required service factor \( f_B \)) for operation with 16 hours of operation/day and 10 cycles/hour:

\[ f_M = \frac{J_X}{J_M} = \frac{0.026\ kgm^2}{0.032\ kgm^2} = 0.8 \]

Using a mass acceleration factor \( f_M = 0.8 \) results in load classification II and service factor \( f_B = 1.2 \).

Gear unit selection

You can select an S97 gear unit with \( n_a = 39\ min^{-1} \), \( M_{\text{amax}} = 3,300\ Nm \) and \( f_B = 2.0 \).

Checking the efficiency

An efficiency of 86% is listed for this gear unit in the geared motors catalog. Since an efficiency of 70% was assumed at the beginning, it is now possible to check whether a smaller drive would be sufficient.

\[ P_s = \frac{9030\ N \cdot \frac{0.5\ m}{s}}{0.86 \cdot 0.9 \cdot 1000} = 5.83\ kW \]

The next smaller motor with a rated power of 5.5 kW is too small.

Selected drive

The selected drive system is: S97 DV132M 4 BMG.