5 The Technical Dimensioning of the Conveyor Chain

5.1 Calculation Parameters

Designation	Symbol	Unit	Designation	Symbol	Unit
Total tensile force of chain	F	N	Filling ratio	φ	----
Circumferential tensile force of chain, total	F_g	N	Coefficient of friction between bush and roller	μ_3	----
Circumferential tensile force of chain, per chain strand	F_i	N	Sagging of slack strand	f	m
Supporting tensile force of chain(depending on sagging)	F_s	N	Coefficient of friction (conveyed material to steel)	μ_4	----
Centrifugal tensile force of chain	F_f	N	Distance of unit load	l_s	m
Pretension force of chain	F_v	N	Coefficient of rolling resistance	μ_2	----
Breaking load of chain	F_b	N	Chain velocity	v	m/s
Number of chain strands	i	----	Coefficient of sliding friction	μ_1	----
Conveying height	H	m	Articulation surface of chain	A_K	cm^2
Conveying length, horizontal	B	m	Slack distance	a_d	m
Distance between axes	a	m	Safety factor	k	----
Angle of inclination of conveyor	α	° (degrees)	Chain length of slack strand	l_d	m
Mass of chain per m of chain	M_K	kg/m	Articulation surface pressure, effective	P_{eff}	N/mm^2
Mass of materials to be conveyed per m of chain	M_F	kg/m	Articulation surface pressure, admissible	P_{zul}	N/mm^2
Conveyor capacity (pieces)	Q_S	St/h	Chain pitch	p	m
Conveyor capacity (mass)	Q_M	t/h	Angular velocity	ω	s^{-1}
Trough width of conveyer	b	m	Number of teeth	z	----
Trough height of conveyor	h	m	Pitch diameter	d_0	m
Cross-sectional area of conveyor	A_M	m^2	Motor output of drive	P	kW
Mass of bulk material to be conveyed	γ	t/m^3	Efficiency of drive	η	----

5.2 Types of Conveyor

The conveyors are subdivided in two main categories:

- Sliding conveyor chains
- Rolling conveyor chains

They are furthermore classified according to the following arrangement criteria:

- Horizontal conveyance
- Oblique conveyance
- Vertical conveyance
- Combined conveyance

5.3 Total Mass of the Material to be conveyed

This is the total mass of the material to be conveyed, which is resting and is to be moved on the conveyor chains or on possibly existing supporting elements (plates, transverse bars, cross-rails, slat bands, etc.).

According to the load distribution on the conveyor chain, a difference is to be made between point, individual and linear loading. If the load is concentrated on a reduced area, the chain pins and rollers have to be recalculated concerning deflexion and pressure, respectively, when dimensioning the conveyor chain.

5.4 Load Carrying Capacity of the Rollers

The load carrying capacity of the rollers depends on the roller material, the type of bearing, the chain velocity, the temperature, and the lubrication. For surface-hardened steel rollers, with a low chain velocity (< 0,25m/s) and a sufficient surface pressure, up to 800 N/cm² are admissible.

If rollers are made of quenched and tempered or of unhardened steel, of grey cast iron or of synthetic material, lower bearing contact pressures are admissible (compare the following tables).

Advantages of synthetic rollers are:

- No maintenance
- Lightweight construction
- Silent run
- High chemical resistance

It is furthermore possible to improve the sliding properties of the rollers by means of bearing bushes. A suitable bearing material is lead tin bronze (surface pressures up to 300 N/cm²), but also special bearing materials are appropriate for a low-maintenance operation.

The following tables 3a and b show admissible roller loads for conveyor chains according to DIN 8165 and DIN 8167, which have to be multiplied by the corresponding correction factors from tables 4 to 8, using the formulae indicated:

$$\text{Admissible load of the roller} = \text{table value} \cdot f_1 \cdot f_2 \cdot f_3 \cdot f_4 \cdot f_5$$

Chain according to DIN 8165	Mating of material Bush / Roller C15E / C15E C15E / 9SMn28E	Chain according to DIN 8167	Mating of material Bush / Roller C15E / C15E C15E / 9SMn28E
FVT 40	2000	MT 20	1050
FVT 63	3000	MT 28	1350
FVT 90	3800	MT 40	1900
FVT 112	5100	MT 56	2750
FVT 140	7050	MT 80	3850
FVT 180	10550	MT 112	5200
FVT 250	15550	MT 160	7200
FVT 315	21500	MT 224	10050
FVT 400	23900	MT 315	13500
FVT 500	31200	MT 450	18450
FVT 630	39400	MT 630	26000
		MT 900	36450

Tab. 3: Loadability of rollers (N/Roller) for carrying roller chains according to DIN 8165 and DIN 8167

Roller type	f_1
Roller	1,0
Flanged roller	0,9

Tab. 4: Factor f_1 : Roller type

Roller material (bush of case-hardened steel, hardened)	f_2
Case-hardened steel, hardened	1,00
Stainless steel, hardened	0,60
Stainless steel, unhardened	0,30
Standard steel, unhardened	0,20
Grey cast iron	0,12

Tab 5: Factor f_2 : Roller material

Lubricating conditions	f_3
Sufficient lubrication, no dirt or rough operating conditions	1,0
Insufficient lubrication, no dirt or rough operating conditions	0,4 - 0,6
Without lubrication, with much dirt and rough operating conditions	0,2 - 0,35

Tab. 6: Factor f_3 : Lubrication

Chain velocity in m/s	f_4
0,10	1,15
0,25	1,00
0,50	0,85
1,00	0,50

Tab. 7: Factor f_4 : Chain velocity

Temperature in °C	f_5
20 - 200	1,00
200 - 260	0,50
260 - 285	0,25
285 - 300	0,15

Tab 8: Factor f_5 : Temperature

Mating of material		Max. specific bearing contact pressure in N/cm²
Roller	Bush	
Case-hardened steel, hardened	Case-hardened steel, hardened	800
Quenched and tempered steel	" "	300
Unhardened steel	" "	160
Grey cast iron	" "	100
Bronze	" "	300
Polyamide 6	" "	50

Tab. 9: Admissible maximum values of specific pressing

5.5 Coefficients of Friction

5.5.1 Sliding Friction of Chains on a Base in Continuous Operation

Material of slide rail	μ_1	
	Insufficient lubrication	Good lubrication
Steel	0,35	0,25
Synthetic material	0,20	0,15
Hardwood	0,30	0,25

Tab. 10: Coefficient of sliding friction μ_1

5.5.2 Rolling Friction of Chains on Steel Guides

Coefficient of rolling resistance $\mu_2 = \frac{2 \cdot c + \mu_3 \cdot d_3}{d_5}$ $\mu_2 = 0{,}08 \ldots \underline{0{,}12} \ldots 0{,}18$

d_3 = bush diameter [mm]
d_5 = roller diameter [mm]
c = experimental coefficient,
depending on material and the surface roughness of the areas of contact

Conditions of guide c
0,5 Steel roller on steel guide with smooth surface
0,6 Mean value
1,0 Steel roller on steel guide with rough surface

Tab. 11: Coefficient c in dependence on material and contact surface

Mating of material Roller / bush	μ_3	
	Insufficient lubrication	Good lubrication
Steel roller on steel bush	0,30	0,20
Roller with bronze bush on steel bush	-	0,15
PA6 roller on steel bush	0,15	0,10
Roller with rolling bearing on steel bush	0,03	0,015 ... 0,005

Tab. 12: Coefficient of friction between roller and bush μ_3

5.5.3 Coefficient of Friction between Material to be conveyed and Steel μ_4, Bulk Weight γ and Filling Ratio φ

Type of material to be conveyed	Coefficient of friction μ_4	Bulk weight γ in t/m³	Filling ratio φ
Ash	0,85	0,50	0,70
Ore	1,20	2,25	0,60
Cereals	0,50	0,65	0,80
Wood chips	0,80	0,25	0,75
Gravel	1,00	1,75	0,65
Coal	0,90	0,80	0,50
Coke	1,00	0,45	0,60
Loam	0,75	1,25	0,70
Flour	0,50	0,60	0,70
Sand	0,80	1,55	0,60
Broken stone	0,65	1,80	0,65
Peat	0,70	0,40	0,80
Cement	0,65	1,20	0,70

Tab. 13: Coefficient of friction - material to be conveyed / steel, bulk weight and filling ratio

5.6 Calculation of the Total Tensile Force of Chain F

The total tensile force of a chain F results from the sum of the total circumferential tensile force F_g, the supporting tensile force of chain F_s, and the centrifugal tensile force of chain F_f.

$$F = F_g + F_s + F_f$$

5.6.1 Chain Supporting Tensile Force F_s

The supporting tensile force of the chain is produced when the chain is freely sagging and depends on the dead weight of the chain and the chain length of the sagging slack strand.

$$F_s = \frac{M_K \cdot 9{,}81 \cdot a_d^{\,2}}{8 \cdot f} \cdot \sqrt{1 + 16 \cdot \frac{f^2}{a_d^{\,2}}}$$

Sag f results from the following equation:

$$f = \sqrt{0{,}375 \cdot a_d \cdot (l_d - a_d)} \qquad (f \text{ selected should be} \approx 10\% \text{ of } a_d)$$

5.6.2 Chain Centrifugal Tensile Force F_f

The centrifugal tensile force of the chain is a tensile force depending on the chain velocity v and the chain wheel diameter, which, as a component of the total tensile force of the chain, is to be considered above all in the case of higher chain velocities.

$$F_f = M_K \cdot v^2$$

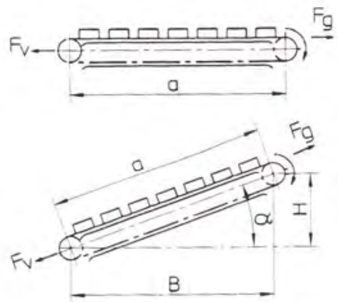
where $v = \omega \cdot \frac{d_0}{2}$; $\omega = 2 \cdot p \cdot n$ (n = number of revolutions of the chain wheel in s^{-1})

5.6.3 Chain Circumferential Tensile Force F_g

The circumferential tensile force (effective power) results from the operating load dependent torque of the chain drive to be transmitted. In the following you will find some formulae for the calculation of the total circumferential tensile force F_g in dependence of the conveyor type. If the conveyor includes various chain strands, the chain circumferential tensile force per strand F_i results from the relation:

$$F_i = \frac{F_g}{i}$$

Sliding Friction



$$F_g = 1{,}1 \cdot a \cdot \mu_1 \cdot 9{,}81 \cdot (2 \cdot M_K + M_F) \qquad Q_S = \frac{3600 \cdot v}{l_s}$$

$$F_v = 2{,}2 \cdot (F_s + a \cdot \mu_1 \cdot 9{,}81 \cdot M_K)$$

$$F_g = 1{,}1 \cdot a \cdot 9{,}81 \cdot [(M_K + M_F) \cdot (\mu_1 \cdot \cos\alpha + \sin\alpha) + M_K \cdot (\mu_1 \cdot \cos\alpha - \sin\alpha)]$$

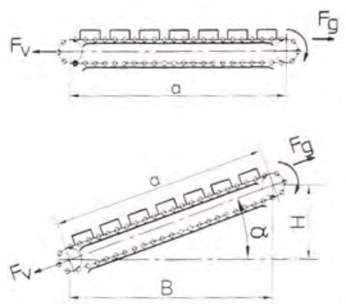
if $(\mu_1 \cdot \cos\alpha - \sin\alpha) < 0$:

$$F_g = 1{,}1 \cdot a \cdot 9{,}81 \cdot (M_K + M_F) \cdot (\mu_1 \cdot \cos\alpha + \sin\alpha)$$

$F_v = 2{,}2 \cdot F_s$ ... if $H/B > \mu_1$

$F_v = 2{,}2 \cdot [F_s + 9{,}81 \cdot M_K \cdot (B \cdot \mu_1 - H)]$ ... if $H/B < \mu_1$

Rolling Friction



$$F_g = 1{,}1 \cdot a \cdot \mu_2 \cdot 9{,}81 \cdot (2 \cdot M_K + M_F) \qquad Q_S = \frac{3600 \cdot v}{l_s}$$

$$F_v = 2{,}2 \cdot (F_s + a \cdot \mu_2 \cdot 9{,}81 \cdot M_K)$$

$$F_g = 1{,}1 \cdot a \cdot 9{,}81 \cdot [(M_K + M_F) \cdot (\mu_2 \cdot \cos\alpha + \sin\alpha) + M_K \cdot (\mu_2 \cdot \cos\alpha - \sin\alpha)]$$

if $(\mu_2 \cdot \cos\alpha - \sin\alpha) < 0$:

$$F_g = 1{,}1 \cdot a \cdot 9{,}81 \cdot (M_K + M_F) \cdot (\mu_2 \cdot \cos\alpha + \sin\alpha)$$

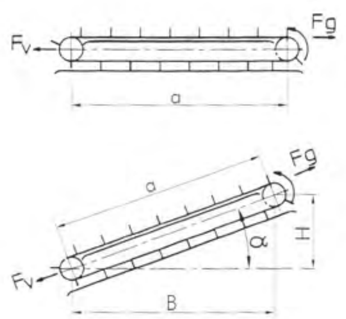
$F_v = 2{,}2 \cdot F_s$ ... if $H/B > \mu_2$

$F_v = 2{,}2 \cdot [F_s + 9{,}81 \cdot M_K \cdot (B \cdot \mu_2 - H)]$ ... if $H/B < \mu_2$

Trough Chain Conveyor

$$F_g = 1{,}1 \cdot a \cdot 9{,}81 \cdot \left(2 \cdot M_K \cdot \mu_1 + \frac{Q_M}{3{,}6 \cdot v} \cdot \mu_4\right)$$

$$F_v = 2{,}2 \cdot (F_s + a \cdot \mu_1 \cdot 9{,}81 \cdot M_K)$$



$$F_g = 1{,}1 \cdot a \cdot 9{,}81 \cdot \left[M_K \cdot (\mu_1 \cdot \cos\alpha + \sin\alpha) + \frac{Q_M}{3{,}6 \cdot v} \cdot (\mu_4 \cdot \cos\alpha + \sin\alpha) + M_K \cdot (\mu_2 \cdot \cos\alpha - \sin\alpha) \right]$$

if $(\mu_1 \cdot \cos\alpha - \sin\alpha) < 0$:

$$F_g = 1{,}1 \cdot a \cdot 9{,}81 \cdot \left[M_K \cdot (\mu_1 \cdot \cos\alpha + \sin\alpha) + \frac{Q_M}{3{,}6 \cdot v} \cdot (\mu_4 \cdot \cos\alpha + \sin\alpha) \right]$$

$F_v = 2{,}2 \cdot F_s$ ... if $H/B > \mu_1$

$F_v = 2{,}2 \cdot [F_s + 9{,}81 \cdot M_K \cdot (B \cdot \mu_1 - H)]$ ... if $H/B < \mu_1$

5.7 Calculation of the Chain Breaking Load F_b required

$$F_b = k \cdot F_i$$

Safety factor k $k = 5 \ldots \underline{7} \ldots 12$

The safety factor k depends mainly on the operational conditions and the number of teeth of the chain wheel. Generally, k is about 6 to 7.

5.8 Calculation of the Driving Power P

$$P = \frac{F \cdot v}{1000 \cdot \eta} \quad ; \quad \text{where } \eta = 0{,}75 \ldots \underline{0{,}8} \ldots 0{,}9$$

5.9 Calculation of the Articulation Surface Pressure P_{eff}

$$P_{eff} = \frac{F}{A_K}$$

Diagram for P_{zul}

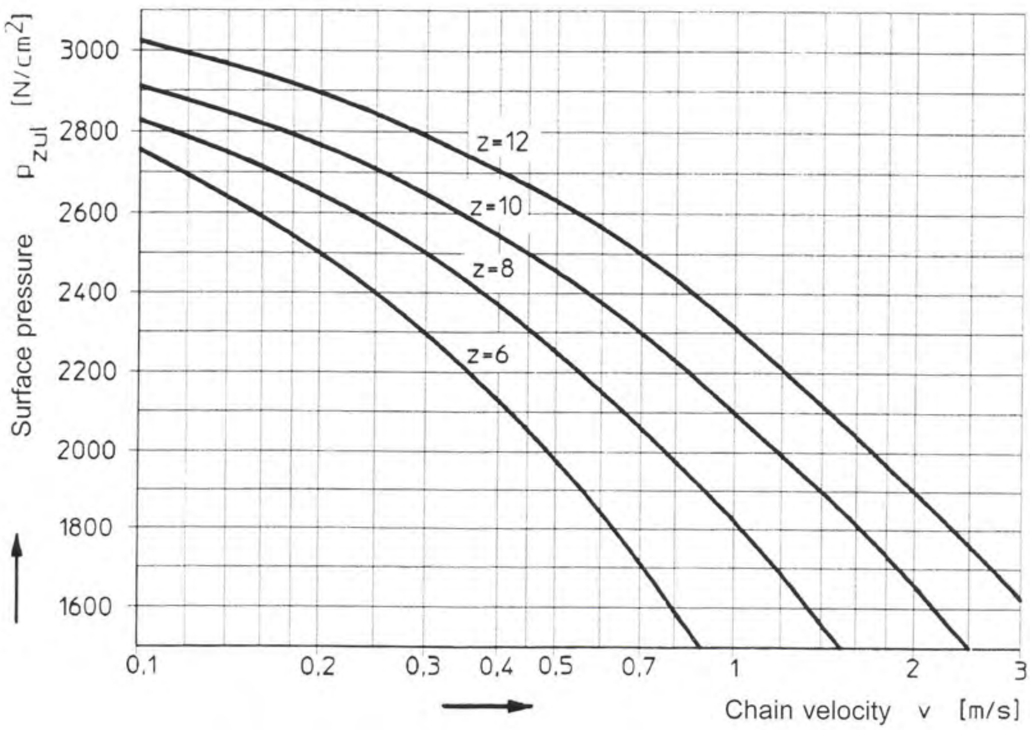


Fig. 7: Articulation surface pressure

5.10 Examples of Calculation

Example 1: Trough conveyor, horizontal

Material to be conveyed	: Wood chips
Conveying length	: 40 m
Conveyor capacity	: 25 t/h
Trough width of conveyor	: 400 mm
Trough height of conveyor	: 300 mm
Number of chain strands	: 1
Number of teeth of chain wheel	: 8

a) Calculation of the chain velocity

$$Q_M = 3600 \cdot v \cdot A_M \cdot \gamma$$

$$v = \frac{Q_M}{3600 \cdot A_M \cdot \gamma}$$

$$v = \frac{25}{3600 \cdot 0{,}09 \cdot 0{,}25} = \underline{\underline{0{,}31\ m/s}}$$

$$A_M = b \cdot h \cdot \varphi$$
$$A_M = 0{,}4 \cdot 0{,}3 \cdot 0{,}75$$
$$A_M = 0{,}09\ m^2$$

$Q_M = 25\ t/h$
$\gamma = 0{,}25$ (see section 4.5.3)
$\varphi = 0{,}75$ (see section 4.5.3)
$b = 0{,}4\,m$
$h = 0{,}3\,m$

b) Calculation of the chain tensile force

$$F_g = 1{,}1 \cdot a \cdot 9{,}81 \cdot \left(2 \cdot M_K \cdot \mu_1 + \frac{Q_M}{3{,}6 \cdot v} \cdot \mu_4 \right)$$

$$F_g = 1{,}1 \cdot 40 \cdot 9{,}81 \cdot \left(2 \cdot 8 \cdot 0{,}35 + \frac{25}{3{,}6 \cdot 0{,}31} \cdot 0{,}8 \right)$$

$$F_g = \underline{\underline{10150\,N}}$$

$a = 40\ m$
$M_K = 8\ kg/m$
$\mu_1 = 0{,}35$ (see section 4.5.1)
$\mu_4 = 0{,}8$ (see section 4.5.3)
$i = 1$
$k = 7$

$$F_i = \frac{F_g}{i} = \frac{10150}{1} = F \quad (F_s \text{ and } F_f \text{ negligible})$$

$$F_b = k \cdot F = 7 \cdot 10150 = \underline{\underline{71050\ N}}$$

⇒ 1. assumption: Selection of the trough conveyor chain TF 90 according to table on page 50
Standard pitch: p = 125 mm

c) Recalculation of chain considering articulation surface pressure

$$P_{eff} = \frac{F}{A_K} \le P_{zul}$$

$$P_{eff} = \frac{10150}{5} = \underline{\underline{2030\ N/cm^2}} < 2500\ N/cm^2$$

$F = 10150\ N$
$A_K = 5\ cm^2$ (see table on page 50)
$P_{zul} = 2500\ N/cm^2$ (see section 4.9)

Chain size TF90 selected correctly!

Example 1: Trough conveyor, horizontal - continuation

d) Calculation of chain pretensioning force

$$F_v = 2{,}2 \cdot (F_s + a \cdot \mu_1 \cdot 9{,}81 \cdot M_K)$$

$$F_v = 2{,}2 \cdot (0 + 40 \cdot 0{,}35 \cdot 9{,}81 \cdot 8)$$

$$F_v = \underline{\underline{2420\ N}}$$

$F_s = 0$ (as slack strand is supported)
$a = 40$ m
$M_K = 8\ ^{kg}/_{m}$
$\mu_1 = 0{,}35$ (see section 4.5.1)

e) Driving power required

$$P = \frac{F \cdot v}{1000 \cdot \eta}$$

$$P = \frac{10150 \cdot 0{,}31}{1000 \cdot 0{,}8} = \underline{\underline{3{,}9\ kW}}$$

$F = 10150$ N
$v = 0{,}31\ ^{m}/_{s}$
$\eta = 0{,}8$

Example 2: Conveyance of pallets

Material to be conveyed	:	Pallets
Conveying length	:	30 m
Pallet size	:	Length: 1200 mm, width: 800 mm
Total mass per pallet	:	600 kg
Number of chain strands	:	2
Chain velocity	:	0,2 m/s
Number of teeth of chain wheel	:	10
Max. number of pallets	:	20
Chain type selected	:	Carrying roller chain according to DIN 8165

a) Calculation of the chain tensile force

$$F_g = 1{,}1 \cdot a \cdot \mu_2 \cdot 9{,}81 \cdot (2 \cdot M_K + M_F)$$

$$F_g = 1{,}1 \cdot 30 \cdot 0{,}12 \cdot 9{,}81 \cdot (2 \cdot 11 + 400)$$

$$F_g = \underline{\underline{16400\ N}}$$

$$F_i = \frac{F_g}{i} = \frac{16400}{2} = \underline{\underline{8200\ N}}$$

$$F_b = k \cdot F_i$$

$$F_b = 7 \cdot 8200 = \underline{\underline{57400\ N}}$$

$a = 30$ m
$\mu_2 = 0{,}12$ (estimated, see section 4.5.2)

$$M_K = 2 \cdot 5{,}5\ ^{kg}/_{m} = \underline{\underline{11\ ^{kg}/_{m}}}$$

$$M_F = \frac{20\ St \cdot 600\ ^{kg}/_{piece}}{30\ m}$$

$$M_F = \underline{\underline{400\ ^{kg}/_{m}}}$$

$k = 7$

⇒ Selection of the chain type FVT 63, with a minimum breaking load of 63 kN (see table on page 44)

Example 2: Conveyance of pallets - continuation

b) Recalculation of chain considering articulation surface pressure

$$P_{eff} = \frac{F_i}{A_K} \le P_{zul}$$

$F_i = 8200$ N

$A_K = 3{,}7\ cm^2$ (see tables on pages 44 and 45)

$P_{zul} = 2780\ N/cm^2$ (see section 4.9)

$$P_{eff} = \frac{8200}{3{,}7} = \underline{\underline{2220\ N/cm^2}} \le 2780\ N/cm^2$$

c) Recalculation of roller load

Number of carrying rollers	:	4
Chain pitch	:	100 mm
Pallet mass	:	600 kg

Existing roller load $= \frac{600 \cdot 9{,}81}{4} = \underline{\underline{1472\ N/roller}} \approx \underline{\underline{1500\ N/roller}}$

Admissible roller load : see section 4.4

Carrying roller chain FVT 63 : $3000\ N/roller \cdot f_1 \cdot f_2 \cdot f_3 \cdot f_4 \cdot f_5$

- Roller	f_1 : 1,0
- Case-hardened steel, hardened	f_2 : 1,0
- Insufficient lubrication, no dirt or rough operating conditions	f_3 : 0,4...0,6
- Chain velocity = 0,2 m/s	f_4 : 1,0
- Ambient temperature 10 - 25 °C	f_5 : 1,0

⇒ Admissible roller load $= 3000\ N/roller \cdot 1{,}0 \cdot 1{,}0 \cdot 0{,}4 \cdot 1{,}0 \cdot 1{,}0 = \underline{\underline{1200\ N/roller}}$

⇒ Existing roller load $= 1500\ N/roller > \underline{\underline{1200\ N/roller}}$

In dependence of the chain lubrication (factor f3), the admissible roller load may be exceeded. It is therefore more reasonable to select the next chain in size. ⇒ FVT 90

d) Driving power required

$$P = \frac{F_g \cdot v}{1000 \cdot \eta}$$

$$P = \frac{16400 \cdot 0{,}2}{1000 \cdot 0{,}8} = \underline{\underline{4{,}1\ kW}}$$

$F_g = 16400$ N

$v = 0{,}2\ m/s$

$\eta = 0{,}8$