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05/2003

Calculation Guidelines

Ammeraal Beltech

Innovation & Service in Belting

1. Symbols and Units

Symbol	Description	Unit
A	Cross-sectional area of bulk flow	[m^2]
A_{sc}	Area of contact of belt scraper	[mm^2]
d_{min}	Minimum diameter of drive drum	[mm]
e	2.72	[-]
f_D	Coefficient of friction between belt and drive drum; see tables	[-]
f_r	Coefficient of friction of support rollers; see tables	[-]
f_s	Coefficient of friction between slider support and belt; see tables	[-]
f_{sc}	Coefficient of friction between belt and scraper	[-]
f_{sw}	Coefficient of friction between bulk materials and sidewalls	[-]
F_1	Frictional force caused by the support in the upper part	[N]
F_2	Frictional force caused by the support in the return part	[N]
F_3	Force needed for inclined conveying	[N]
F_4	Frictional force caused by the contact between bulk material and sidewalls	[N]
F_5	Frictional force caused by the belt scraper	[N]
F_6	Total of resistances of bearings in snub pulleys	[N]
F_B`	$F_1 + F_2 + F_3 + F_4 + F_5$	[N]
F_B	Required driving force	[N]
F_p	Initial tensile force	[N]
F_{tot}	Total belt force	[N]
g	Gravitational accelleration: $g = 9.81$	[m/s^2]
k	Capacity reduction factor; see tables	[-]
L	Conveyor length	[m]
L_p	Pitch of products in piece goods transport	[m]
L_{Rr}	Pitch of support rollers return part	[m]
L_{Rt}	Pitch of support rollers upper part	[m]
L_{sw}	Length per sidewall (one side only)	[m]
m_B	Mass per m of the belt	[kg/m]
m_B	Mass per m^2 of the belt; see data sheet of the belt concerned	[kg/m^2]
m_L	Mass per m of the load	[kg/m]
m_{Rr}	Mass per m of support rollers in return part	[kg/m]
m_{Rt}	Mass per m of support rollers in upper part	[kg/m]
M_p	Weight of one product in piece goods transport	[kg]
M_{Rr}	Mass of one or of a set of support rollers in the return part; see tables	[kg]
M_{Rt}	Mass of one or of a set of support rollers in the upper part; see tables	[kg]
N	Number of drums and rollers with an arc of contact $= 90^0$	[-]
p_a	Average surface pressure between belt and drum; $p_a = 60{,}000$	[N/m^2]
p_{sc}	Surface pressure of belt scraper	[N/mm^2]
P_M	Power of the drive motor	[W]
Q_h	Capacity of flow of bulk materials; see tables	[m^3/h]
Q_H	Capacity of flow of bulk materials; corrected to angle of inclination	[m^3/h]
Q_p	Capacity of flow of piece goods	[nr/s]
Q_M	Capacity of flow of bulk materials	[kg/s]
Q_V	Capacity of flow of bulk materials	[m^3/s]
v	Belt speed	[m/s]
v_{max}	Maximum admissible belt speed; see tables	[m/s]
W	Belt width	[m]
W_h	Width horizontal part of 3-part trough or slider support	[m]
W_L	Effective belt width	[m]
W_{sw}	Widht between the sidewalls	[m]
	Arc of contact drive drum	[^{0}]
	Dynamical loading angle, see tables	[^{0}]
	Angle of inclination (negative for declined conveying)	[^{0}]
$_{max}$	Maximum angle of inclination; see tables	[^{0}]
	Efficiency, transmission motor to drive drum; see tables	[-]
	Trough angle	[^{0}]
	3.14	[-]
	Specific mass bulk materials; see tables	[kg/m^3]
$_a$	Maximum admissible belt tension; see data sheet of the belt concerned	[N/mm]
$_{tot}$	Total belt tension	[N/mm]

2. Calculations

2.1 Conveying capacity

2.1.1 For bulk materials

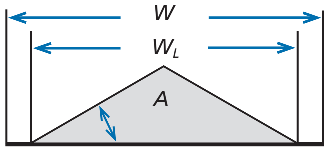
For an indication refer to table: Q_h
This table applies for a belt speed of 1 m/s. Depending on the angle of inclination Q_h needs to be corrected:

$Q_H = k \cdot Q_h$ . . . . [m^3/h]

Exact calculation

- Calculation of the cross-sectional area of the flow of goods:

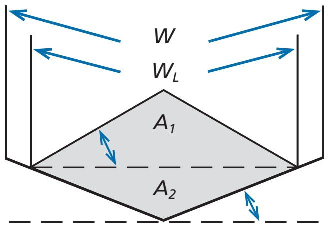
Flat



$W_L = 0.9 \cdot W - 0.05$ . . . . [m]

$A \;= 0.25 \cdot W_L^2 \cdot \tan$ . . . . [m^3]

V-trough



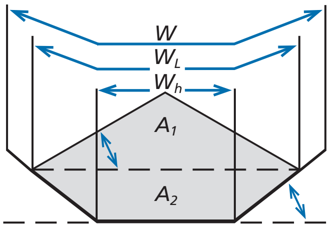
$W_L = 0.9 \cdot W - 0.05$ . . . . [m]

$A_1 = 0.25 \cdot (W_L \cdot \cos \quad)^2 \cdot \tan$ . . . . [m^2]

$A_2 = 0.25 \cdot W_L^2 \cdot \cos \quad \cdot \sin$ . . . . [m^2]

$A \;= A_1 + A_2$ . . . . [m^2]

Three-part trough



$W_L = 0.9 \cdot W - 0.05$ . . . . [m]

$A_1 = 0.25 \cdot [W_h + (W_L - W_h) \cdot \cos \quad]^2 \cdot \tan$ . . . . [m^2]

$A_2 = [W_h + 0.5 \cdot (W_L - W_h) \cdot \cos \quad] \cdot$
$0.5 \cdot (W_L - W_h) \cdot \sin$ . . . . [m^2]

$A \;= A_1 + A_2$ . . . . [m^2]

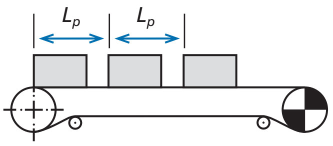
- Calculation capacity:

In volume: $Q_V = k \cdot A \cdot v$ . . . . [m^3/s]

In mass: $Q_M = k \cdot A \cdot v \cdot$ . . . . [kg/s]

Condition: $v < \; v_{max}$

2.1.2 For piece goods



$Q_p = \frac{v}{L_p}$ . . . . [nr/s]

2.2 Required driving force and initial tensile force

2.2.1 Load/mass per m

Load per m

Bulk materials: $m_L = k \cdot A \cdot$ . . . . [kg/m]

or: $m_L = Q_H \cdot \quad \cdot \frac{1}{v} \cdot \frac{1}{3600}$ . . . . [kg/m]

Piece goods: $m_L = \frac{M_p}{L_p}$ . . . . [kg/m]

Mass per m

Belt: $m_B = W \cdot m_B`$ . . . . [kg/m]

Roller support upper part: $m_{Rt} = \frac{M_{Rt}}{L_{Rt}}$ . . . . [kg/m]

Roller support return part: $m_{Rr} = \frac{M_{Rr}}{L_{Rr}}$ . . . . [kg/m]

2.2.2 Frictional force and force needed for inclined transport

$F_1 = L \cdot f_r \cdot g \cdot [m_{Rt} + (m_B + m_L) \cdot \cos \quad]$ . . . . [N]
(roller support)

$F_1 = L \cdot f_s \cdot g \cdot (m_B + m_L) \cdot \cos$ . . . . [N]
(slider support)

$F_2 = L \cdot f_r \cdot g \cdot (m_B \cdot \cos \quad + m_{Rr})$ . . . . [N]

$F_3 = L \cdot m_L \cdot g \cdot \sin$ . . . . [N]

$F_4 = \frac{f_{sw} \cdot \quad \cdot L_{sw} \cdot Q_v^2 \cdot g}{v^2 \cdot W_{sw}^2} \cdot \tan^2 (45 - \frac{}{2})$ . . . . [N]

$f_{sw} = 0.5$ for dry material . . . . [-]
$f_{sw} = 0.7$ for wet material . . . . [-]

$F_5 = f_{sc} \cdot p_{sc} \cdot A_{sc}$ . . . . [N]

$f_{sc} = 0.6 - 0.7$ . . . . [-]
$p_{sc} = 0.03$ at low pressure . . . . [N/mm^2]
$p_{sc} = 0.1$ at high pressure . . . . [N/mm^2]

$F_B` = F_1 + F_2 + F_3 + F_4 + F_5$ . . . . [N]

Initial tensile force

For fixed tensioning device:

$F_p = 0.25 \cdot \frac{F_B' \cdot (e^{f_D \cdot \quad \cdot \frac{}{180}} + 3)}{e^{f_D \cdot \quad \cdot \frac{}{180}} - 1}$ . . . . [N]

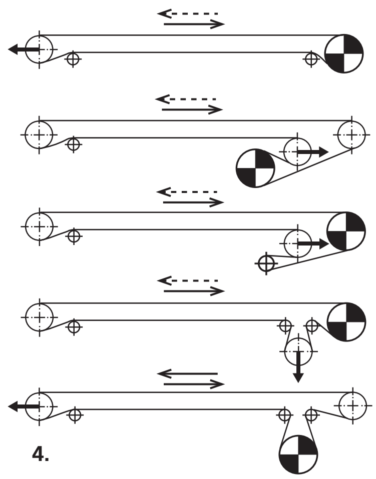
For the calculation of this initial tensile force the belt is considered to be equally loaded.

For automatic tensioning device:

$F_p = F_B' \cdot \frac{1}{e^{f_D \cdot \quad \cdot \frac{}{180}} - 1}$ . . . . [N]

$F_6 = 2 \cdot (F_B` + F_p + 2000 \cdot W) \cdot 0.0075 \cdot 0.3 \cdot N$ . . . . [N]

2000 · W = extra factor to calculate practical situations
0.0075 = coefficient of friction bearings
0.3 = max. value diameter ratio: shaft diameter/drum diameter
N = number of drums and rollers with an arc of contact ≧ 90⁰ (see drawing 4)



4.

Remark: F_6 is a safe calculated frictional force.

2.2.3 Required driving force

$F_B = F_B` + F_6$ . . . . [N]

2.3 Total belt tension

$F_{tot} = F_B + F_p$ . . . . [N]

$_{tot} = \frac{1}{1000} \cdot \frac{F_{tot}}{W}$ . . . . [N/mm]

Condition: $_{tot} < \ _a$

2.4 Power of the drive motor

$P_M = \frac{1}{\ } \cdot F_B \cdot v$ . . . . [W]

2.5 Minimum diameter of drive drum

A good estimation of the minimum drive drum diameter will be obtained from the following formula:

$d_{min} = \frac{F_B \cdot 360}{W \cdot f_D \cdot \ \cdot \ \cdot p_a} \cdot 1000$ . . . . [mm]

Remarks:
- The diameter must not be less than the drummer diameter mentioned in the data sheet of the belt concerned.
- Application of smaller diameters can cause the belt to have a shorter life.
- For rubber belts there is a standard for the calculation of the minimum diameter: DIN 22101.

2.6 Amount of tensioning required

For the determination of the tensioning length, you have to take into account:
- force-elongation ratio of the belt: see the data sheet of the belt concerned.
- assembly length.

In practise a tensioning length equal to 1% of the belt length is generally sufficient.

Q_h Theoretical conveying capacity bulk materials

Issue: loading angle = 15⁰,
belt speed v = 1m/s
Dimensions trough assemblies according DIN 22107

Belt width [mm]	Flat [m³/h]	V-trough = 20⁰ [m³/h]	V-trough = 25⁰ [m³/h]	3-part trough = 30⁰ [m³/h]
300	11	24	26	25
400	23	48	52	50
500	38	80	86	85
650	69	143	155	153
800	108	225	243	242
1000	174	362	392	391
1200	255	532	575	576
1400	353	735	794	796

M_{Rr} - M_{Rt} Dimensions and mass of support rollers

This table is to be used as guide line, and is valid for steel rollers. For exact mass contact your supplier.
Execution according DIN 15207 part 1 and DIN 22107.
This concerns support rollers for bulk materials.

Belt width [mm]	Dia. roller [mm]	Mass rolling part rollers M_{Rr} and M_{Rt} [kg] Flat	V-trough	3-part trough
300	63.5	1.7	1.8	
	89.	3.1	3.6	
400	63.5	1.9	2.2	1.8
	89	3.8	4.2	3.9
	108	4.8	5.4	5.1
500	63.5	2.3	2.8	2.7
	89	6.1	7.4	8.7
	108	7.2	8.6	9.9
650	63.5	2.8	3.4	3.3
	89	7.5	8.8	9.9
	108	8.6	10.8	11.4
	133	11.0	12.6	13.8
800	89	9.1	10.0	11.1
	108	10.3	12.4	12.9
	133	13.6	14.6	16.2
1000	89	10.8	12.4	12.9
	108	13.1	14.8	15.3
	133	16.1	18.0	18.6
	159	21.4	24.0	24.6
1200	108	15.8	16.8	18.0
	133	19.4	20.6	22.2
	159	25.4	26.6	28.2
1400	108	17.9	19.0	20.4
	133	21.9	23.2	24.9
	159	28.8	30.2	31.8

k Capacity reduction factor for inclined transport of bulk materials

Angle of inclination [°]	Factor *k*
0- 5	0.99
5-10	0.95
10-15	0.89
15-20	0.80
20-25	0.68

f_r Coefficient of friction for support rollers with ball bearings

• Normal circumstances (clean, dry)	0.02
• Unfavourable circumstances (dust, dirt)	0.03
• Inferior circumstances (aggressive/corrosive influences)	0.04

f_s Coefficient of friction slider supports

Support	Bottomside belt Fabric	Fine Square profile
Hard wood, hard plastic, uncovered steel		
• Theoretical (clean circumstances)	0.25	0.60
• Practical (working conditions)	0.30	0.55

f_D Coefficient of friction between belt and drive drum

Drum surface		Bottomside belt Polyester fabric	PVC smooth	PVC Fine Square profile	Rubber smooth
Lagged with PVC non-slip material	dry	0.40	0.40	0.40	0.40
	moist	0.30	0.35	0.35	0.35
Lagged with rubber	dry	0.30	0.35	0.35	0.40
	moist	0.20	0.30	0.30	0.35
Uncovered steel	dry	0.20	0.40	0.30	0.35
	moist	0.20	0.30	0.20	0.20

Efficiency transmission motor - drive drum

See documentation of the supplier for drive systems not mentioned.

Straight gear wheel reduction and chain transmission	0.90
Bevel gear wheel reduction	0.90
Worm wheel reduction, depending on transmission	0.60-0.80
Drum motor	0.94

- V_{max} - $_{max}$ - Specific mass and theoretical values for maximum belt speed, maximum angle of inclination and loading angle of bulk materials

Always check the values of v_{max} and $_{max}$ in practise! $_{max}$ is valid for non-profiled belts.

This table you will find on the next page »

- v_{max} - $_{max}$ -

Specific mass and theoretical values for maximum belt speed, maximum angle of inclination and loading angle of bulk materials

Type bulk material	[kg/m³] X10³	v_{max} [m/s]	$_{max}$ [°]	[°]
Anthracite coal	0.90	3	17	15
Apples	0.35	1	10-12	15
Ashes dry	0.55-0.65	2	15	10
Ashes wet	0.70-0.90	2	20	15
Asphalt	1.00-1.30	2		
Barley	0.80-0.90	4	15	5
Basalt	1.60-2.30	1.8	20	15
Bauxite broken	1.20-1.40	2	20	15
Bauxite raw	2.55	3	20	15
Blast furnace slag granulated	1.30-1.60	2	15-20	15
Borax	0.80-1.15	2.5	15	10
Bricks broken	1.50-1.70	1.8	20	15
Brown coal briquettes	0.65-0.85	1	15	20
Brown coal dry	0.65-0.80	3	20	15
Cement dry	1.20	3	20	10
Cement mortar	2.00	2	8	10
Chalk broken	1.35-1.45		17	15
Chalk powdery	1.10-1.20		15-18	15
Charcoal	0.18-0.40	1.8	18-20	12
Clay dry	1.60-1.80	4	18	15
Clay wet	1.80-2.00	4	15-18	15
Cocoa powder	0.45-0.56	1	20	5
Coffee beans roasted	0.30-0.45	2	12	5
Coffee beans raw	0.45-0.65	2	12	
Coke	0.40-0.60	2	18	15
Cole seed	0.65	1.2	15	5
Compost	0.80	3	15	15
Concrete with gravel	1.80	2	18	10
Cork fine	0.20-0.25	1.2	15	10
Cork broken	0.10-0.20	1.5	15	15
Corn grain	0.70-0.75	2	10-12	5
Corn flour	0.60-0.65	1.5	15	5
Earth dry	1.60	4	15	10
Earth wet	2.00	4	20	15
Fertilizer	0.90-1.20	4	20	15
Glass broken	1.30-1.60	1.5	18-20	15
Graphite powder.	0.45	1	15	5
Gravel dry	1.40-1.50	1.8	17	10
Gravel wet	1.80-1.90	1.8	20	12
Hay pressed	0.13	1.6	15-18	
Hay loose	0.08	1	15-18	
Lead ore	3.20-4.70	1.8	17	15
Lime mortar	1.70	2	8	10
Lime powdery	1.00-1.20	1.5	20	5
Limestone broken	1.40-1.50	3	18	15
Limestone dust	1.30-1.40	1	15	5
Loam dry	1.60	2	15	15
Loam wet	2.00	1.5	20	15
Magnesium	3.00	1.8	17	15
Milk powder	0.57	1.8	15	5
Mushrooms	0.40	0.8	15	10
Oats	0.55	4	10	5
Peanuts pealed	0.35	1.6	12	10
Peanuts unpealed	0.30	1.6	16	
Pears	0.35	1	10-15	10
Peas dried	0.70-0.80	1.6	10	5
Peat dry	0.32-0.80	2	15	15
Peat wet	0.65-1.00	3	12	15
Plaster mortar	1.20	2	8	10
Plaster powdery	0.95-1.50	1.6	20	10
Potash	1.35	1.2	10	10
Potatoes	0.75	1.2	10-12	15
Quartz	1.60-1.75	3	17	15
Quartz sand	1.70-1.90	3	15	15
Rice	0.70-0.80	4	8	
Rye	0.70-0.80	4	15	5
Rubble	1.50-1.70	1.8	20	15
Salt coarse	0.70-0.80	4	15	10
Salt fine	1.20-1.30	4	20	10
Sand dry	1.30-1.60	4	18	10
Sand wet	1.60-2.00	4	20	15
Sawdust	0.20-0.30	0.8	18	20
Shell lime	2.60	2	18	
Soda	0.90-1.20	4	20	
Soy beans	0.80	2	15	10
Sugar	0.80-0.90	4	17	5
Sugar powder	0.60-0.80	1.5	12-15	2
Tomatoes	0.90	0.6	10-12	10
Wood chips dry	0.20-0.30	2	20	10
Zinc ore	2.40	3	15	15

General rules for the design of a belt conveyor

Belt support upper part

Slider support

- Construction
  - Steel (contact surface not painted), stainless steel, hard wood or hard plastic
  - Width support = belt width + 50 mm

Roller support

- *Flat carrying idlers*
- Pitch
  - Transport of bulk: 1 x belt width with a maximum of 1 m
  - Transport of piece goods: maximum 0.5 x product length
- Length of the carrying idlers
  - Belt width + 50 mm

- *Trough assemblies*
- Pitch
  - 1 x belt width with a maximum of 1 m
  - At loading point: adjust the pitch as a function of the loading height, product size and method of loading
- Maximum trough angle
  - V-trough assembly: 25^0
  - Three part trough assembly: 40^0
- Transition length
  - Light belts: 1 x belt width
  - Heavy belts: 1.5 x belt width
- Position of end drums with regard to trough assemblies
  - Top face of drums at an equal height or higher with the bottomside of the belt in the trough (see drawing 1)

Belt support return part

- Pitch of return idlers
  - 2 - 3 m

Knife edge transfer

- Arc of contact
  - As small as possible, preferably < 135^0
- Friction fixed knife
  - As low as possible, e.g. polished

Process/conveyor belt

- Belt width
  - For bulk: 1.1 x the width of the flow of goods + 50 mm
  - For piece goods: width of item + 100 mm
- Running direction
  - One running direction: always try to achieve a pulling arrangement
  - Two running directions: try to achieve a pulling arrangement for the most important running direction

Drive drum

- Position
  - Preferably at the `head´ of the belt conveyor = at the discharge point, resulting in a pulling arrangement
- Arc of contact
  - As large as possible: > 180^0
- Use of lagging
  - Yes, for belts with a fabric or a fine square profiled bottomside, namely:
    - for PVC/PU/SIR belts: PVC non-slip tape
    - for rubber belts: smooth or profiled rubber

Tensioning device

- Method
  - Tail drum or
  - Tensioning drum in return part
- Position of tensioning drum in return part
  - For pulling arrangement directly after drive drum
  - For pushing arrangement directly after tail drum
- Amount of tensioning
  - See calculations: item 2.6

Tracking facilities

- Execution/sequence of tracking facilities
  - 1. crown the drums
  - 2. mount tracking idlers
  - 3. adjusting trough assemblies
  - 4. other tracking facilities

1. Crown the drums

- Which
  - 1. Drive drum
  - 2. Drive drum and tail drum when conveyor is longer than 8 x belt width
- Amount of crowning
  - Diameter difference $D_1 - D_2$ = 1% of D_1 up to a maximum of 4 mm (see drawing 2)
  - Proportion drum length A-B-A (see drawing 2)
    - < 400 mm: 1/3 - 1/3 - 1/3
    - 400- 800 mm: 1/4 - 2/4 - 1/4
    - 800-1200 mm: 1/5 - 3/5 - 1/5
    - 1200-1600 mm: 1/6 - 4/6 - 1/6
    - > 1600 mm: both conical parts 300 mm

2. Mount tracking idlers

- Position of tracking idler
  - For pulling arrangement: last return idler before the tail drum
  - For pushing arrangement: last return idler before the drive drum
  - Centre distance with respect to drum: 100 - 400 mm (see drawing 3)
- Arc of contact tracking idler
  - 15 - 30^0 (see drawing 3)
- Adjustment of tracking idler
  - 10% of the belt width (5% to both sides, see drawing 3)
- Lagging tracking idler
  - Fabric bottomside: necessary
  - PVC or rubber bottomside: not necessary

3. Adjusting trough assemblies

- Which trough assemblies adjustable
  - All assemblies when 1^0 toe-in
  - 1 out of 5 when 3 - 5^0 toe-in

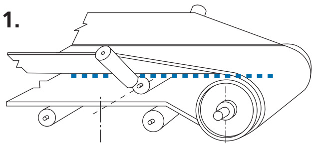
4. Other tracking facilities

- Ask our experts

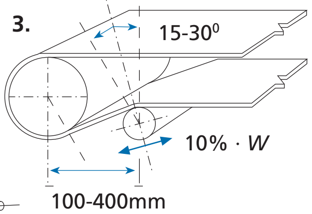
Belt cleaner

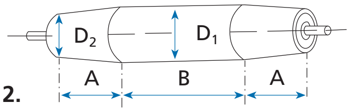
- Mount facilities for cleaning belt and conveyor (scrapers,etc.)

1.



3.





2.