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DESIGN OF HORIZONTAL AND SLIGHTLY INCLINED SCREW CONVEYORS – A CASE STUDY

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Abstract

Screw conveyors are widely used in the transportation of various bulk materials in the industry because of their simple structure and low cost. The paper will present the calculation of screw conveyors, including an analysis of all relevant coefficients, as well as the selection of bulk material types and classes. The case study examines several instances of conveyor use, analyzing capacities, motor powers, and shaft loads.

Key words: *screw conveyors, types, design, comparison.*

1 INTRODUCTION

Screw conveyors are widely used devices for transporting bulk materials, and play an irreplaceable role in the modern industrial system.

Book [1] outlines a detailed procedure for calculating screw conveyors, including all divisions, coefficients, and factors. It also provides original tables with recommended speeds and specific volumetric capacities (cubic meters at 1 rpm) for various classes of materials and a wide range of screw conveyor's dimensions. Paper [2] addresses the challenge of designing screw conveyors with a focus on determining their operational characteristics. It validates theoretical design methods and the results from a numerical discrete element method model using actual values of mass efficiency and power demand obtained through laboratory experiments.

Articles [3, 4] work aims to compare the design standards of screw conveyors in China, Germany, and the USA. By analyzing the relevant standards from prominent associations in these three countries, the similarities and differences in their design guidelines are highlighted. By performing the geometric and operational designs for the horizontal and slightly inclined transport of three representative bulk solids (barley, lignite, and sand), the advantages and disadvantages are examined, as well as the potential impact of empirical coefficients.

Papers [5, 6, 7] offer a complete study of screw conveyors, detailing the process for determining various coefficients required for dimensioning, selection, and calculation. These papers emphasize procedures for enhancing performance, particularly in terms of increasing capacities.

Paper [8] focuses primarily on screw conveyors with fully enclosed tubular casings. The throughput, torque, and power are significantly influenced by the vortex motion of the bulk solid being conveyed. This vortex motion, along with the degree of fill, determines the volumetric efficiency, which in turn governs the throughput.

A comprehensive review [9] presents the theoretical flow rate formulas for both U-shaped and enclosed screw conveyors, while work [10] reviews recent research on the performance evaluation of screw conveyors during the handling process, particularly in the context of agricultural grains and bulk materials. Paper [11] gives velocity distribution, forces distribution and structure optimization for screw conveyors.

Paper [12] introduces the design of a flexible screw sectional working body, aimed at enhancing the functional and operational performance of screw conveyors used for transporting bulk agricultural materials. The braking process for screw conveyors has also been analyzed, along with the dynamic loads that could potentially exceed the electric motor's maximum critical torque and the screw shaft's rated load torque. The paper [13] presents a new design method and an analysis of the torque on the shafts. References [14, 15, 16, 17] offer comprehensive information on screw conveyors, bulk materials, and the speed limitations associated with the different classes.

2 SCREW CONVEYORS DESIGN

There are six basic steps for screw conveyor design. They are:

- establish characteristics of the bulk material to be conveyed,
- specity conveyors capacity,
- resolve conveyor size and speed based on capacity,
- calculate electric motor power requirements,
- verify torque rating,
- select all conveyor components.

2.1 Screw conveyors bulk material characteristics

The size and design of screw conveyors, along with the number of revolutions and required motor power, are directly influenced by the characteristics of the bulk materials being conveyed. The key characteristics of bulk materials that determine the design of screw conveyors include: lump or particle density (ρ_m in t/m³), bulk density (ρ in t/m³), lump size (L_s - in millimeters), material class, special material properties, material factor (f_m), capacity (Q_v in m³/h or Q_m in t/h) and the degree of loading of the screw conveyor (ξ in %).

Due to the internal friction between the particles of the bulk material, the material, when placed freely, assumes an approximately conical shape. The angle formed by the slope of this cone with the horizontal is referred to as the angle of repose (φ_0), or the angle of internal friction of the material at rest. This angle is greater than the angle of the bulk material when in motion (φ_k), where φ_k is typically around $\varphi_k \approx (0.7 \div 0.8)\cdot\varphi_0$.
In bulk materials, two types of density are distinguished: lump or particle density (ρ_m - kg/m³) and the bulk density (ρ - kg/m³). The bulk density is always less than the particle density because the material is porous, containing air spaces between the particles. Porosity (ε) is defined as the ratio of the volume of air between the particles to the total volume of the material ($0 < \varepsilon < 1$). The relationship between the bulk density and lump density is given by the equation:

$$\rho = \rho_m \cdot (1 - \varepsilon) \quad (1)$$

All bulk materials can be divided into four types: powdery (consisting of particles up to 1 mm in size), granular (particles from 1 to 12.5 mm), lumpy (particles larger than 12.5 mm) and bulk materials with irregularly shaped particles. Bulk materials are classified according to the proportion of granulation (lumps, particles) in the mixture of bulk materials (Fig. 1).

Class 1 *Class 2* *Class 3*

Fig. 1 *Layout of Belt Sorter*

Class 1 bulk materials consist of a mixture of lumps and fines, with no more than 10% of the material being lumps ranging from the maximum size to half of the maximum size, and 90% being smaller lumps with a size less than half of the maximum size.
Class 2 bulk materials are a mixture of lumps and fines, where no more than 25% of the material consists of lumps ranging from the maximum size to half of the maximum size, and 75% consists of lumps smaller than half of the maximum size.
Class 3 bulk materials are a mixture of lumps and fines, where no more than 95% of the material consists of lumps ranging from the maximum size to half of the maximum size, with the remaining 5% being lumps smaller than half of the maximum size.
Lump size ratio (R_G) is a function of screw conveyor radial clearance (R_r) and lump size (Ls). The ratio (R_G) is used to determine the correct screw conveyor design based on maximum bulk material lump size.

$$R_G = R_r / Ls \quad (2)$$

where radial clearance is: $R_r \approx 0.5\cdot(D - d) + z$; (see Fig. 2).
Data for radial clearance (R_r) and lump size (Ls) of the bulk materials for different sizes of screw conveyors is shown in Table 1.

Table 1 Clearance and Lump Size of Bulk Materials for Diifferent Screw Conveyors

Screw diameter	Shaft diameter	Radial clearance	*Class 1* $R_G \approx 1.75$	*Class 2* $R_G \approx 2.5$	*Class 3* $R_G \approx 4.5$
D	***d***	R_r	***L*s**	***L*s**	***L*s**
[mm]	[mm]	[mm]	[mm]	[mm]	[mm]
50	25	14	6	4	2.5
75	30	24	13	7	5
100	40	33	18	13	7
150	60	49	31	19	11
250	75	92	57	39	20
300	80	115	70	50	25
350	100	130	82	61	31
400	120	145	95	69	38
500	155	176	108	77	45
550	180	190	120	89	50
600	220	195	140	95	60

General material properties of bulk materials for screw conveyors are shown in Table 2, and provide informations on the relative abrasiveness, corrosiveness, and flowability of the listed bulk materials.

Table 2 General Properties of Bulk Materials

	Designation of bulk materials			
	I	**II**	**III**	**IV**
Description	Mildly Abrasive	Moderate Abrasive	Very Abrasive	Extremely Abrasive
Abrasive-ness	Not Corrosive	Mildly Corrosive	Highly Corrosive	Especially Corrosive
Corrosoive-ness	Very Free Flowing	Free Flowing	Average Flowability	Sluggish
Flowability	To 30°	30° – 45°	30° – 45°	Beyond 45°
Angle of repose	Mildly Abrasive	Moderate Abrasive	Very Abrasive	Extremely Abrasive

Special characteristics of bulk materials are listed in the Table 3.

Table 3. Special Characteristics of Bulk Materials

A	Builds Up and Hardens
B	Generates Static Electricity
C	Decomposes—Deteriorates in Storage
D	Flammability
E	Becomes Plastic or Tends to Soften
F	Very Dusty
G	Aerates and Becomes Fluid
H	Explosiveness
I	Stickiness—Adhesion
J	Contaminable, Affecting Use
K	Degradable, Affecting Use
L	Gives Off Harmful or Toxic Gas or Fumes
M	Hygroscopic
N	Interlocks, Mats, or Agglomerates
O	Oils Present
P	Packs Under Pressure
Q	Very Light and Fluffy—May Be Windswept
R	Elevated Temperature
V	May Be Conveyed In a Vertical Screw Conveyor
W	Acidic (pH < 7) or alkaline (pH > 7)

2.2 Screw conveyors trough loading

A screw conveyor can be made of a tubular or U-shaped trough in which a shaft with a spiral screw rotates. The screw shaft is supported by bearings. The rotation of the screw pushes the bulk material along the trough.

Trough loading refers to the volume of bulk material contained within the trough of a screw conveyor, expressed as a percentage relative to the total trough capacity, with a full trough defined as 100% capacity. Recommended nominal trough loadings of 15%, 30%, and 45% (Fig. 2) have been established based on the physical properties of bulk materials. The optimal trough loading for a screw conveyor is influenced by factors such as the material's density, abrasiveness, and flowability. For a specific material capacity, the size and rotational speed of the screw conveyor are determined by the desired trough loading percentage.

45% Trough Loading - loading class A (class A nominal loading coefficient is $\xi_A = 0.45$)

This includes materials with a bulk density range of 80 to 650 [kg/m^3] that are non-abrasive and exhibit very free-flowing properties, such as flour, cereals, rice, granulated sugar or baking soda,). The trough loading can be increased to the level of the center pipe without causing excessive wear on the conveyor components, including the screws, hanger bearings, coupling shafts, and troughs. The loading level for bulk materials with similar characteristics is in range 40 – 50% or more, the recommended translational velocities are 0.3 to 0.5 [m/s].

30% Trough Loading - filling class B (class B nominal loading coefficient is $\xi_B = 0.30$)

The recommended trough loading for these bulk materials of loading class B is typically 21 – 40%, a recommended trough loading of 30% is advised. The usual translational speeds for these materials are generally from 0.2 to 0.3 [m/s]. The trough loading can be increased to a level just below the center pipe without causing excessive wear on the conveyor components, including the screws, hanger bearings, coupling shafts, and troughs.

Bulk materials of filling class B can be divided into two subclasses, with the same nominal loading coefficient of the screw trough loading of 30%, but with slightly different properties of the materials themselves:

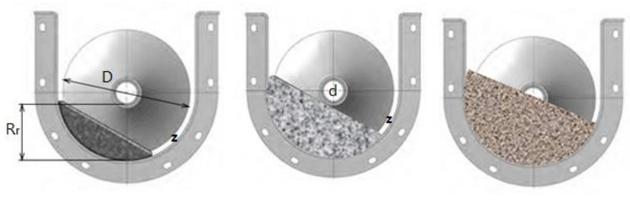
- filling subclass Bα – 30% α,
- filling subclass Bγ – 30% γ.

Subclass Bα materials have a bulk density range of 240 to 1000 [kg/m^3], are slightly abrasive materials and free-flowing such as carbon black or spent brewers grain. Subclass Bγ of powdery, granular or lumpy materials have bulk densities of 450 to 1300 [kg/m^3], they are very abrasive materials and have an average to slow flow, such as cement clinker, crushed bauxite, flue dust or coarse salt.

Due to the different properties of the materials of the B filling class, the recommended speed of the screw conveyors is lower for granular materials classified in sub-class Bγ (30% γ) compared to bulk materials of subclass Bα (30% α). Some materials have properties at the transition from one subclass to another and can be treated depending on the operating conditions in subclass Bα or Bγ.

15% Trough Loading - filling class C (class C nominal loading coefficient is $\xi_C = 0.15$)

Class C bulk materials have a bulk density in range of 800 to 2000 [kg/m^3], are highly abrasive, tough, fibrous or coarse-grained materials, with poor flowability, such as sand, aluminum, crushed stone or broken glass. The recommended loading level for bulk materials of group C is generally in the range of 13 – 20% and a nominal trough loading of 15% is given. The recommended translational velocities of these bulk materials are around 0.1 [m/s]. To minimize excessive wear on key conveyor components, including the screws, hanger bearings, coupling shafts, and troughs, it is crucial to maintain trough loading at a level significantly below the center pipe.



15% TL (class **C**) 30% TL (class **B**) 45% TL (class **A**)

Fig. 2 *Screw conveyors trough loadings (TL) types of bulk materials*

There are also bulk materials that have properties at the transition from class A to class B (Bα) or from class B (Bγ) to class C, which will be indicated in the Table 4 (together with a material factor).

2.3 Screw conveyors material factor (f_m)

The material factor (f_m) indicates the shifting resistance of material and is influenced by the friction coefficient (material/screw flight), the screw's angle of inclination, rotational speed (number of revolutions per minute), and the operating conditions. This factor varies depending on the bulk material, considering all the properties mentioned above. Material factors (f_m) and classes of some bulk materials are given in Table 4.

Table 4 Material factors (f_m) and classes of bulk materials

Bulk material	Class	Factor f_m
Almonds, grain	Bα	2.0
Asbestos, rock ore	C	4.5
Asbestos, shredded	Bγ – C	4.0
Barley, grain	A	2.3
Buckwheat, grain	A – Bα	2.3
Cement (Portland)	Bγ – C	3.0
Coal, Anthracite	A – Bα	3.5
Coal, Lignite	Bα	3.0
Coffee, beans	A	2.3
Coffee, ground	A – Bα	2.0
Corn meal	Bα	2.0
Corn seed	A	1.9
Cotton seed	A	2.0
Fertilizer	Bα	2.8
Flaxseed	A – Bα	1.8
Gravel	C	5.0
Hops, dry	Bα	2.3
Iron, ore	C	5.0
Malt ground	Bα	2.0
Oat flakes	Bα	2.3
Potassium salt (KCl)	C	3.6
Rye flakes	Bα	2.4

Bulk material	Class	Factor f_m
Rye grain	A	2.0
Salt (NaCl)	Bγ	3.0
Sand	C	5.0
Semolina	A	2.3
Sodium acetate / acetic acid salt	Bα – Bγ	3.2
Soil	Bγ	3.3
Soybean flakes	Bα	2.4
Soybean whole	A	2.2
Strach, powder	A	2.8
Sugar, refined / powdered	Bα	3.2 / 2.5
Sulfur, granular	Bγ – C	3.5
Sunflower seed	A	2.3
Table salt (NaCl)	Bγ	3.0
Tobacco, fine cut	A – Bα	2.8
Wheat flakes	Bα	2.4
Wheat seed	A	2.0

Detailed list of material's factors can be found in book [1].

2.4 Types of single line screw conveyors

There are different shapes of the screw spiral. The main parameters of the spiral are screw pitch (s) and screw diameter (D) – see Fig.3 left.

Screw conveyors can have a short pitch ($\psi = s / D < 1$), which is typically used for larger screw diameters. For medium and smaller screw diameters, standard pitch screws are preferred ($\psi = s / D = 1$), or long pitch screws are recommended ($\psi = s / D > 1$). Short pitch screw conveyors ($s = 0.5 \cdot D$ to $0.8 \cdot D$) generally provide higher efficiency compared to both standard and long pitch screws.

Single flight screw (Fig. 3 left) or single full flight is the most commonly used screw type in horizontal screw conveyors and inclines up to 10 degrees. In some cases screw conveyors can be made with variable pitch.

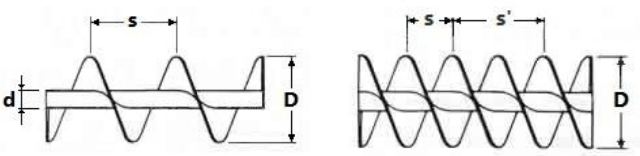


Fig. 3. *Single screw flight (left) and double flight (right)*

Double flight screw pitch (Fig. 3 right) have a second set of flights is added 180-degrees apart from the first set of flights to provide a more even discharge of bulk materials. For double flight screws there is single flight pitch (s'), but for conveyors capacity calculation is relevant aggregated pitch (s), which is half size.

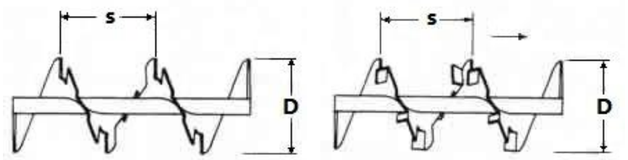


Fig. 4. *Single cut flight (left) and single cut and folded flight (right)*

Single cut flight screws (Fig.4 left) are notched at regular intervals on the outer edge to promote mixing and agitation of bulk materials. Single cut and folded flight screws (Fig.4 right) are notched at regular intervals on the outer edge and have lifting paddles to promote aggressive mixing and agitation of bulk materials.

Single ribbon flight screws (Fig.5 left) have a space within the flight and around the center pipe to minimize the collection and buildup of viscous and sticky bulk materials. Paddle screws (Fig.5 right) have adjustable paddles located in a helix around the diameter of the center pipe. Up to four paddles per pitch can be used for aggressive mixing and controlled flow of bulk materials. Paddles can be wider and capture a larger amount of material. There are also single flight screws that have paddles added to the empty spaces between the flights.

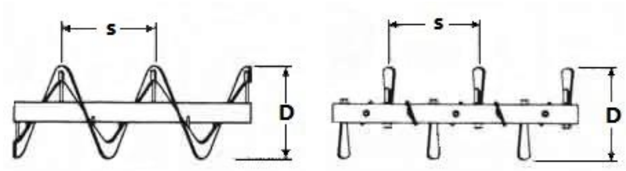


Fig. 5. *Single ribbon flight (left) and flights with paddles (right)*

Combined single flight (Fig.6) is a hybrid screw flight design that gradually transitions from a full flight to a ribbon flight, or vice versa, continuously changing between the two configurations. This screw flight combines the properties of both flights. Single tapered flight screws (Fig.7) feature a tapered outside diameter that increases from half diameter ($D' = 0.5 \cdot D$) or from two thirds of diameter ($D' = 0.667 \cdot D$) to the full diameter (D). They are used in screw feeders to ensure the uniform withdrawal of free-flowing bulk materials from hoppers, bins, or silos. Mass flow screws use a combination of an internal cone and variable pitch to increase the volume with each flight. They are commonly used in screw feeders to ensure the uniform withdrawal of bulk materials from hoppers, bins, or silos.

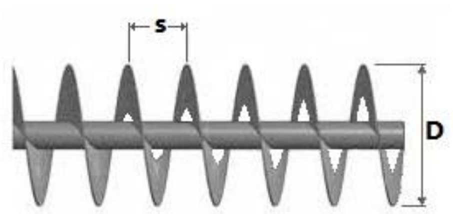


Fig. 6. *Combined single flight*

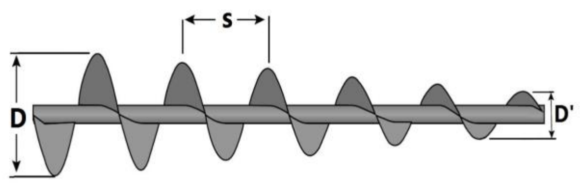


Fig. 7. *Tapered single flight*

2.5 Screw conveyors working conditions

Operating conditions, such as temperature, humidity, dust, vibration, and to some extent noise, can significantly impact the capacity and design of screw conveyors. However, this paper does not address these working conditions.

3 BASIC DESIGN OF HORIZONTAL AND SLIGHTLY INCLINED SCREW CONVEYORS

3.1 Screw conveyors data

For different classes of bulk materials, based on empirical indicators and characteristics of the materials themselves, Table 5 gives recommended values for the maximum speed n_{max} [rpm] and the maximal specific volumetric capacity of screw conveyors Q_v^*(max) in [m^3/h at 1 rpm], for theoretical 100% loading. In certain cases, higher values than those listed may be selected depending on the condition of the bulk material, the quality of the screw, operating conditions or other factors. The original data table below was created by the author [1].

Table 5. Maximal screw conveyors capacity and recommended RPM's for different material classes

Screw diameter	Max. capacity at 1 RPM	Maximal recommended revolutions per minute n_{max} [RPM]						
D	Q_v^* (max) for 100% loading	45% loading $\xi_{nom} = 0.45$	95% loading $\xi^* = 0.95$	30% loading $\xi_{nom} = 0.30$	95% loading $\xi^* = 0.95$	30% loading $\xi_{nom} = 0.30$	15% loading $\xi_{nom} = 0.15$	95% loading $\xi^* = 0.95$
[mm]	[m^3/h at 1 RPM]	[class **A**]		[class **B**α]	[class **B**]	[class **B**γ]	[class **C**]	
100	0.047124	**140 – 190**	96	**112 – 140**	80 – 89	**90 – 112**	**71 – 90**	69
125	0.092039	**130 – 175**	90	**100 – 130**	76 – 83	**80 – 100**	**68 – 80**	65
160	0.193019	**120 – 160**	85	**90 – 120**	69 – 76	**71 – 90**	**65 – 71**	60
200	0.376991	**112 – 150**	77	**80 – 112**	63 – 72	**65 – 80**	**60 – 65**	56
250	0.736311	**100 – 145**	70	**71 – 100**	58 – 65	**60 – 71**	**55 – 60**	52
320	1.544156	**90 – 140**	60	**65 – 90**	49 – 55	**55 – 65**	**50 – 55**	45
400	3.015929	**80 – 130**	50	**60 – 80**	40 – 45	**50 – 60**	**45 – 50**	38
500	5.890486	**71 – 120**	40	**55 – 71**	31 – 33	**45 – 55**	**40 – 45**	30
630	11.783187	**65 – 112**	35	**50 – 65**	25 – 27	**40 – 50**	**35 – 40**	23
800	24.127432	**60 – 100**	30	**45 – 60**	22 – 23	**35 – 45**	**30 – 35**	20
1000	47.123890	**50 – 80**	25	**40 – 50**	19 – 20	**30 – 40**	**25 – 30**	18

Conveyor loadings can exceed the recommended nominal loading percentages. By installing enhanced and more durable screw components and bearings, some bulk materials may allow up to 95% loading for tubular or shrouded conveyors (U shaped). Table 5 also provides the maximum recommended speeds for 95% loading (where feasible) for each class of bulk materials. In general, lighter-duty construction for screw conveyors is suitable for free-flowing and non-abrasive bulk materials, while heavier-duty construction is recommended for sluggish and abrasive materials.

The maximal specific capacity of screw conveyors Q_v (max) in [m^3/h at 1 rpm], for real conveyor trough loading and speed can be calculated as:

$$Q_V(\max) = Q_V^*(\max) \cdot n \cdot \xi \ \left[m^3/h\right] \quad (3)$$

where: Q_v^*(max) [m3/h at 1 rpm] – maximal recomended capacity at 1 rpm for 100% trough loading (Tab.5),
n [rpm] – real screw conveyors speed,
ξ – real screw truogh loading coefficient.

Conveyors bulk material velocity is:

$$v = \frac{s \cdot n}{60} \ \left[m/s\right] \quad (4)$$

Real screw conveyors volumetric flow rate is than:

$$Q_V = A \cdot v \cdot \xi \cdot k_\delta \cdot c_z = 15 \cdot \psi \cdot D^3 \cdot \pi \cdot n \cdot \xi \cdot k_\delta \cdot c_z \le Q_V(\max) \ \left[m^3/h\right] \quad (5)$$

where: A [m^2] – screw cross section,
v [m/s] – transportation velocity,
$\psi = s / D$ – ratio of screw pitch and diameter,
n [RPM] – screw's revolution per minute,
ξ – screw loading coefficient (filling level),
k_δ – screw coveyor inclination factor (Tab. 6),
c_z – screw flight parameter or coefficient of velocity (Tab. 7).

Screw coveyor inclination factor (Tab. 6) takes into account the reduction in real screw conveyor capacity due to angle of inclination.

Table 6. Screw inclination factor (k_δ)

Angle of inclination δ [°]	0	5	10	15	20	25
Screw inclination factor k_δ	1	0.9	0.8	0.7	0.6	0.5

Screw flight parameter (Tab. 7) or coefficient of velocity and it takes into consideration the leaving behind of the conveyed material for different screw flights.

Table 7. Screw flight parameter (c_z)

Flight type	full	comb-ined	ribbon	cut (folded)	with paddles
Parameter c_z	1	0.9	0.8	0.6 – 0.75	~ 0.5

The bulk material mass flow rate (mass capacity) for screw conveyors is than:

$$Q_m = \rho \cdot Q_v \ [t/h] \quad (6)$$

and the required power of the electric drive motor can be determined:

$$P_M = \frac{Q_v \cdot \rho \cdot g}{3600 \cdot c_z \cdot \eta}(f_m \cdot L + H) \ [kW] \quad (7)$$

where: f_m – material factor for particulare bulk material (T.4),
Q_v [m^3/h] – real capacity (Eq. 5),
ρ [t/m^3] – bulk material density,
L [m] – screw conveyor length,
H [m] – conveying height,
η – drive efficiency.

Torque moment at screw's shaft can be calculated as:

$$T = 9549 \cdot \frac{P_M \cdot \eta}{n} \ [Nm] \quad (8)$$

3.2 Screw conveyor case study

Let assume that the length of screw conveyor is L = 3 m, and here will be calculated screw coneyor with standard screw pitch ($\psi = s / D = 1$) for 4 different screw diameters (D = 0.2 m, D = 0.25 m, D = 0.32 m, and D = 0.4 m) and with single screw full flights (Fig. 3 left), than is screw flight parameter (c_z = 1).

There will be analyzed 3 different angle of inclination:

a) horizontal screw conveyor (δ = 0°) with inclination factor ($k_{\delta=0}$ = 1) – see Table 6, no lifting height H_a = 0,
b) slightly inclined screw conveyor (δ = 10°), with inclination factor ($k_{\delta=10}$= 0.8), and lifting height H_b = 0.521 m,
c) more inclined screw conveyor (δ = 20°), with inclination factor ($k_{\delta=20}$= 0.6), and lifting height H_c = 1.026 m.

If we take bulk materials from different classes (from Tab. 5), we can calculate basic parameters for screw conveyor. Chosen bulk materials for this case study are shown in Table 7, with all their characteristics, that will be implied in later calculations in this case study.

Table 7. Bulk materials and theirs characteristics for case study

	Bulk material	material class	nominal loading (%)	nominal truogh loading coefficient (ξ_{nom})	material factor (f_m)	bulk density ρ [t/m^3]
1.	Roasted coffee beans (coffee b.)	A	45%	0.45	2.3	0.4
2.	Rye grain (rye)	A	45%	0.45	2.0	0.7
3.	Starch powder (strach p.)	A	45%	0.45	2.8	0.67
4.	Corn seed (corn)	A	45%	0.45	1.9	0.72
5.	Flax seed (flax)	A - Bα	30% - 45%	0.375	1.8	0.7
6.	Fine cut tobacco (tobacco)	A - Bα	30% - 45%	0.375	2.8	0.25
7.	Wheat flakes (wheat f.)	Bα	30%	0.30	2.4	0.42
8.	Lignite	Bα	30%	0.30	3.0	0.8
9.	Soil	Bγ	30%	0.30	3.3	1.3
10.	Table salt – NaCl (table salt)	Bγ	30%	0.30	3.0	1.2
11.	Granular sulfur (sulfur)	Bγ - C	15% - 30%	0.225	3.5	1.1
12.	Cement Portland (cement)	Bγ - C	15% - 30%	0.225	3.0	1.5
13.	Potassium salt – KCl (potas. salt)	C	15%	0.15	3.6	1.1
14.	Sand	C	15%	0.15	5.0	1.6

For the recommended screw speeds (n_{max} from Table 5), this analysis adopts the highest recommended values for each bulk material and the corresponding conveyor dimensions in the case study. For materials that fall between classes (e.g., A - Bα or Bγ - C), the minimum speed for the higher class is considered. By calculating data for all bulk materials using the specified conveyor parameters, across four different diameters and three angles of inclination. The twelve tables shown in Apendix (Table 11 – Table 22) were generated for the given case study parameters and inclination angles of screw conveyors.

The best performance of screw conveyors for various classes of materials is for horizontal conveyor (a). Logically, conveyors with larger diameters have better performance.

When comparing bulk materials with distinctly different characteristics, such as roasted coffee beans (Class A) and sand (Class C), and applying their respective nominal trough loading (45% for coffee beans and 15% for sand), it is observed that for the same conveyor, the volumetric capacity for sand is approximately 6.9 to 7.6 times smaller than for coffee beans, with the difference being more pronounced at greater angles of inclination. However, the required electric motor power is greater for sand than for coffee beans. Additionally, the torque on the screw conveyor shaft is more than three times higher for sand than for coffee beans, which places significant strain on the conveyor's components and bearings during operation. This disparity can be attributed to the material characteristics, with two key factors contributing: the material factor (f_m) for sand is twice that of coffee beans, and the bulk density of sand is approximately 4.6 times greater than that of roasted coffee beans.

This analysis highlights the significant differences in the selection of components and bearings for a screw conveyor when transporting two entirely different material classes, even if the conveyor dimensions remain the same. While capacities and torques can vary greatly due to differences in trough loading and material properties, required engine powers do not necessarily differ significantly. Therefore, designing a single screw conveyor to handle different bulk materials with unrelated required capacities is a complex task.

4 COMPARISON OF ANALIZED CONVEYORS

The speed ratio values (n_{max} / n_{min}) are higher at nominal loading, ranging from 2.3 for the smallest conveyor diameter to 2.6 for the largest diameter. In contrast, the difference in recommended speeds for 95% trough loading (where feasible) is much smaller, with the ratio being approximately 1.34.

The evaluation of the screw conveyors data (from Table 8 to Table 19) will be shown in in tabelar form. Values for maximal and minimal volumetric capacity, as well as their ratio (Q_v(max) / Q_v(min)) is shown in Table 8.

Table 8. Screw conveyor's volumetric capacity values for nominal loading (data from Tab. 11 to Tab. 22)

nominal loading	D = 0.2 m		D = 0.25 m	
(ξ_{nom})	Q_v (min) [m³/h]	Q_v (max) [m³/h]	Q_v (min) [m³/h]	Q_v (min) [m³/h]
δ = 0°	3.68 (C)	25.45 (A)	6.63 (C)	48.04 (A)
δ = 10°	2.94 (C)	20.36 (A)	5.30 (C)	38.44 (A)
δ = 20°	2.21 (C)	15.27 (A)	3.98 (C)	28.83 (A)
Q_v (max)/Q_v (min)	~ 6.91		~ 7.24	
nominal loading	D = 0.32 m		D = 0.4 m	
(ξ_{nom})	Q_v (min) [m³/h]	Q_v (max) [m³/h]	Q_v (min) [m³/h]	Q_v (min) [m³/h]
δ = 0°	12.74 (C)	97.28 (A)	22.62 (C)	176.43 (A)
δ = 10°	10.19 (C)	77.83 (A)	18.10 (C)	141.15 (A)
δ = 20°	7.64 (C)	58.37 (A)	13.57 (C)	105.86 (A)
Q_v (max)/Q_v (min)	~ 7.64		~ 7.80	

As expected, the highest volumetric capacities are achieved by Class A bulk materials, which exhibit the highest recommended speeds and a nominal loading of 45%. In contrast, the lowest volumetric capacities are observed for conveyors transporting Class C bulk materials, characterized by the lowest speeds and a nominal loading of 15%. These relationships remain consistent at a maximum loading of 95% (where feasible), with the capacity values being higher.

The mass flow rate (capacities) varies due to the differing bulk densities of the transported materials. Accordingly, the maximum values are observed for Class A materials (rye, starch, and corn, which are very close), while fine-cut tobacco (material number 6, Class A-Bα) exhibits the lowest mass flow rate, attributed to its lowest bulk density.

Values for maximal and minimal required electric motor power, as well as their ratio (P_M(max) / P_M(min)) is shown in Table 21. Power ratio is in the range of 4.2 for smallest to 5.2 for biggest conveyors.

Table 9. Screw conveyor's requiered electric motor power values for nominal loading (data from Tab. 11 to Tab. 22)

nominal loading	D = 0.2 m		D = 0.25 m	
(ξ_{nom})	P_M (min) [kW]	P_M (max) [kW]	P_M (min) [kW]	P_M (max) [kW]
δ = 0°	0.10 (*6*)	0.43 (*3*)	0.18 (*6*)	0.82 (*3*)
δ = 10°	0.09 (*6*)	0.37 (*3*)	0.15 (*6*)	0.70 (*3*)
δ = 20°	0.07 (*6*)	0.29 (*3*)	0.12 (*6*)	0.55 (*3*)
P_M (max)/P_M (min)	~ 4.2		~ 4.6	
nominal loading	D = 0.32 m		D = 0.4 m	
(ξ_{nom})	P_M (min) [kW]	P_M (max) [kW]	P_M (min) [kW]	P_M (max) [kW]
δ = 0°	0.33 (*6*)	1.66 (*3*)	0.58 (*6*)	3.01 (*3*)
δ = 10°	0.28 (*6*)	1.41 (*3*)	0.49 (*6*)	2.55 (*3*)
δ = 20°	0.22 (*6*)	1.12 (*3*)	0.39 (*6*)	2.02 (*3*)
P_M (max)/P_M (min)	~ 5.05		~ 5.2	

The lowest required engine power is observed when transporting tobacco (material number 6, Class A-Bα), while the highest is for starch (material number 3, Class A). The minimum shaft torque also occurs for tobacco (material number 6, Class A-Bα), but the maximum torque values shift toward lower-class materials. The highest torque is recorded for transporting soil (material number 9, Class Bγ), although sand (material number 12, Class C) closely follows. The values for maximum and minimum torque on the screw conveyor shaft, as well as their ratio (T_{max} / T_{min}), are presented in Table 22. The torque ratio ranges from 4.8 to 4.9 for all case studies.

Table 10. Screw conveyor's shaft torque values for nominal loading (data from Tab. 11 to Tab. 22)

nominal loading	D = 0.2 m		D = 0.25 m	
(ξ_{nom})	T_{min} [Nm]	T_{max} [Nm]	T_{min} [Nm]	T_{max} [Nm]
δ = 0°	7.73 (*6*)	37.88 (*9*)	15.09 (*6*)	73.98 (*9*)
δ = 10°	6.56 (*6*)	31.89 (*9*)	12.82 (*6*)	62.79 (*9*)
δ = 20°	5.20 (*6*)	25.08 (*9*)	10.16 (*6*)	48.99 (*9*)
T_{max} / T_{min}	4.8 – 4.9		4.8 – 4.9	
nominal loading	D = 0.32 m		D = 0.4 m	
(ξ_{nom})	T_{min} [Nm]	T_{max} [Nm]	T_{min} [Nm]	T_{max} [Nm]
δ = 0°	31.64 (*6*)	155.14	61.8 (*6*)	303.0 (*9*)
δ = 10°	26.88 (*6*)	130.64	52.5 (*6*)	255.2 (*9*)
δ = 20°	21.30 (*6*)	102.73	41.60 (*6*)	200.6 (*9*)
T_{max} / T_{min}	4.8 – 4.9		4.8 – 4.9	

This paper presents a calculation of the conveyor's maximum loading capacity at 95% (where feasible) for all bulk materials, aiming to determine the conditions under which a single electric motor can be used for shorter durations while maintaining higher capacity demands. By examining the maximum achievable loading at 95% (where feasible) for all materials, it is found that the minimum required engine power and torque values align with those at nominal loading, as observed for tobacco (material number

6, Class A-Bα). However, the maximum required engine power and torque values are reached when transporting sand (material number 14, Class C). In this case, the engine power ratio is considerably less favorable than under nominal loading, ranging from 8.5 to 9, making it impractical to use a single conveyor configuration across such a broad spectrum of bulk materials. The complexity increases further when evaluating the torque at maximum loading, where the torque ratio exceeds 11.

The ratio of the highest torque at 95% maximum loading to the highest torque at nominal loading for all analyzed materials ranges from 5.7 to 5.9 under varying conditions. In contrast, the ratio for the conveyor's engine power is more favorable, with the highest calculated engine power at 95% maximum loading relative to the highest engine power at nominal loading ranging from 2.5 to 3.4.

5 CONCLUSION

This analysis provides a detailed calculation of horizontal and slightly inclined screw conveyors, including the selection of parameters and coefficients for the calculations. It provides tables with parameters for conveyor selection and presents an extensive range of calculated data for four different diameters and three conveyor inclination angles.

The conveyor comparison demonstrated the conditions under which identical screw conveyors can be used for different bilk materials, as well as the scenarios where stronger components or a more powerful electric motor are required.

The results for all bulk materials are presented with both nominal and maximum (where feasible) trough loadings.

The ratios of the maximum and minimum values of volumetric capacity, mass flow, required motor power, and torque on the screw conveyor shaft are presented for all the cases analyzed in the case study.

Based on the previous calculation and the given screw conveyors analysis, for three different angles of inclination and four screw diameters, with different material classes and variable trough loadings, some directions for further research would be:

- expand analysis with an even larger screw diameters,
- analyze non-standard screw pitch ($\psi = s / D \neq 1$),
- include other flights types (ribbon, combined, cut and folded) in the study,
- include the cost of the conveyor in the evaluation,
- include in further calculation only bulk materials that can be transported by the same conveyor (for example only food, or only chemical bulk materials),
- include in the analysis operating conditions (temperature, humidity, dust...),
- create a new screw conveyors model that would give an optimal proposal for choosing a multi-purpose screw conveyor for different bulk materials and operating conditions.

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REFERENCES

[1] S. Marković, Technical logistic with solved examples, Faculty of Mechanical Engineering Univers. of Niš, 2023.

[2] B. Karwat, P. Rubacha, E. Stanczyk, Optimization of a screw conveyor's exploitation parameters, Maintenance and Reliability 2021, 23 (2): 285–293, http://doi.org/10.17531/ein.2021.2.8.

[3] Yuan Tan, Michael Rackl, Weijie Yang, Johannes Fottner, Wenjun Meng, Stephan Kessler, A comparative study on design standards of screw conveyors in China,Germany and the USA – Part I: Theoretical calculation andquantitative analysis, Particuology 69 (2022) 61–76, https://doi.org/10.1016/j.partic.2021.11.011.

[4] Yuan Tan, Michael Rackl, Weijie Yang, Johannes Fottner, Wenjun Meng, Stephan Kessler, A comparative study on design standards of screw conveyors in China,Germany and the USA – Part II: Discrete element method, Particuology 92 (2024) 113–125, https://doi.org/10.1016/j.partic.2024.04.014.

[5] W.A. Günthner, O. Rong, Empirische Entwicklung von Kenngrößen zur Auslegung von Hochleistungs-Schneckenförderern für Schüttgut, Schüttgut 8 (2002) 5.

[6] W.A. Günthner, S. Rakitsch, Ermittlung von Dimensionierungs- und Auslegungsvorschriften für stark geneigte Schneckenförderer, 15. Fachtagung Schüttgutfördertechnik, 2010, Proceedings, III, 1 - 23.

[7] W.A. Günthner, N. Blomeyer, Verification von Auslegungsverfahren für Hochleistungs-Schneckenförderer, Logistic Journal, 2007, https://doi.org/10.2195/LJ_Not_Ref_Blomeyer_042007.

[8] A. W. Roberts, Design considerations and performance evaluation of screw conveyors, Beltcon Proceedings 2001.

[9] P. Chongchitpaisan, S. Sudsawat, A Review on Screw Conveyors for Bulk Materials in Various Applications, Engineering and Technology Horizons, 2022, 39 (2), 1-12.

[10] H. Zareiforoush, M.H. Komarizadeh, M.R. Alizadeh, A review on screw conveyors performance evaluation during handling process, Journal of Scientific Review, 2010, Vol. 2 (1), 55-63.

[11] E. Dai, H. Wan, B. Jian, G. Hu, Selection and Optimization of Structures of Double Screw Conveyors, ACAAI Conference, 2018, Vol. 155, 1-4.

[12] V. Bulgakakov, O. Trokhaniak, V. Adamchuk, M. Chernovol, M. Korenko, I. Dukulis, S. Ivanovs, A study of dynamic loads of a flexible sectional screw conveyor, Acta Technologica Agriculturae 3, 2022, 131–136, https://doi.org/10.2478/ata-2022-0020.

[13] F. Alberti, D. D'Andrea, A. Macor, G. Risitano, A. Rosseti, A. Sedmak, Novel smart design of rear half shaft of large urban transport vehicle, Facta Universitatis, Series Mechanical Enginering, Vol. 22, No 4 (2024), https://doi.org/10.22190/FUME240203027A.

[14] MOLLET GMBH, https://www.mollet.de/.

[15] KASE, www.kaseconveyors.com/screw-conveying

[16] Schnekenflügel GMBH, https://schneckenfluegel.de/

[17] KWS, www.kwsmfg.com/engineering-guides/

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APENDIX

The following tables were generated for the given case study parameters and inclination angles of screw conveyors.

Table 11. Horizontal screw conveyors data for standard pitch ($D = s = 0.2$ m) with nominal trough loading for every bulk material (ξ_{nom}) and for maximal loading of 95% ($\xi^* = 0.95$) for all bulk materials (if possible)

Bulk material	material class	nominal loading (ξ_{nom})						maximal loading ($\xi^* = 0.95$)					
		n_{max} [rpm]	v [m/s]	Q_v [m³/h]	Q_m [t/h]	P_M [kW]	T [Nm]	n^*_{max} [rpm]	v^* [m/s]	Q^*_v [m³/h]	Q^*_m [t/h]	P^*_M [kW]	T^* [Nm]
Coffee b.	A	150	0.5	25.45	10.18	0.21	12.18	77	0.257	27.58	11.03	0.23	25.72
Rye	A	150	0.5	25.45	17.81	0.32	18.54	77	0.257	27.58	19.30	0.35	39.14
Starch p.	A	150	0.5	25.45	17.05	0.43	24.84	77	0.257	27.58	18.48	0.47	52.45
Corn	A	150	0.5	25.45	18.32	0.32	18.12	77	0.257	27.58	19.86	0.34	38.25
Flax	A - Bα	112	0.373	15.83	11.08	0.18	13.91	75	0.25	26.86	18.80	0.31	35.23
Tobacco	A - Bα	112	0.373	15.83	3.96	0.10	7.73	75	0.25	26.86	6.72	0.17	19.57
Wheat f.	Bα	112	0.373	12.67	5.32	0.12	8.90	72	0.24	25.79	10.83	0.24	28.18
Lignite	Bα	112	0.373	12.67	10.13	0.28	21.19	72	0.24	25.79	20.63	0.56	67.10
Soil	Bγ	80	0.267	9.05	11.76	0.35	37.88	63	0.21	22.56	29.33	0.88	119.94
Table salt	Bγ	80	0.267	9.05	10.86	0.30	31.78	63	0.21	22.56	27.08	0.74	100.65
Sulfur	Bγ - C	65	0.217	5.51	6.06	0.19	25.49	60	0.2	21.49	23.64	0.75	107.64
Cement	Bγ - C	65	0.217	5.51	8.27	0.23	29.80	60	0.2	21.49	32.23	0.88	125.81
Potas.salt	C	65	0.217	3.68	4.04	0.13	17.48	56	0.187	20.06	22.06	0.72	110.71
Sand	C	65	0.217	3.68	5.88	0.27	35.31	56	0.187	20.06	32.09	1.46	223.66

Table 12. Horizontal screw conveyors data for standard pitch ($D = s = 0.25$ m) with nominal trough loading for every bulk material (ξ_{nom}) and for maximal loading of 95% ($\xi^* = 0.95$) for all bulk materials (if possible)

Bulk material	material class	nominal loading (ξ_{nom})						maximal loading ($\xi^* = 0.95$)					
		n_{max} [rpm]	v [m/s]	Q_v [m³/h]	Q_m [t/h]	P_M [kW]	T [Nm]	n^*_{max} [rpm]	v^* [m/s]	Q^*_v [m³/h]	Q^*_m [t/h]	P^*_M [kW]	T^* [Nm]
Coffee b.	A	145	0.604	48.04	19.22	0.40	23.80	70	0.292	48.96	19.59	0.41	50.24
Rye	A	145	0.604	48.04	33.63	0.61	36.21	70	0.292	48.96	34.28	0.62	76.45
Starch p.	A	145	0.604	48.04	32.19	0.82	48.52	70	0.292	48.96	32.81	0.83	102.44
Corn	A	145	0.604	48.04	34.59	0.60	35.38	70	0.292	48.96	35.25	0.61	74.70
Flax	A - Bα	100	0.417	27.61	19.33	0.32	27.16	68	0.283	47.57	33.30	0.54	68.80
Tobacco	A - Bα	100	0.417	27.61	6.90	0.18	15.09	68	0.283	47.57	11.89	0.30	38.22
Wheat f.	Bα	100	0.417	22.09	9.28	0.20	17.38	65	0.271	45.47	19.10	0.42	55.04
Lignite	Bα	100	0.417	22.09	17.67	0.48	41.38	65	0.271	45.47	36.37	0.99	131.05
Soil	Bγ	71	0.296	15.68	20.39	0.61	73.98	58	0.242	40.57	52.74	1.58	234.25
Table salt	Bγ	71	0.296	15.68	18.82	0.51	62.08	58	0.242	40.57	48.68	1.33	196.58
Sulfur	Bγ - C	60	0.250	9.94	10.93	0.35	49.79	55	0.229	38.47	42.32	1.35	210.23
Cement	Bγ - C	60	0.250	9.94	14.91	0.41	58.20	55	0.229	38.47	57.71	1.57	245.72
Potas.salt	C	60	0.250	6.63	7.29	0.24	34.14	52	0.217	36.37	40.01	1.31	216.23
Sand	C	60	0.250	6.63	10.60	0.48	68.97	52	0.217	36.37	58.20	2.64	436.84

Table 13. Horizontal screw conveyors data for standard pitch ($D = s = 0.32$ m) with nominal trough loading for every bulk material (ξ_{nom}) and for maximal loading of 95% ($\xi^* = 0.95$) for all bulk materials (if possible)

Bulk material	material class	nominal loading (ξ_{nom})						maximal loading ($\xi^* = 0.95$)					
		n_{max} [rpm]	v [m/s]	Q_v [m³/h]	Q_m [t/h]	P_M [kW]	T [Nm]	n^*_{max} [rpm]	v^* [m/s]	Q^*_v [m³/h]	Q^*_m [t/h]	P^*_M [kW]	T^* [Nm]
Coffee b.	A	140	0.747	97.28	38.91	0.81	49.90	60	0.320	88.02	35.21	0.74	105.35
Rye	A	140	0.747	97.28	68.10	1.24	75.94	60	0.320	88.02	61.61	1.12	160.32
Starch p.	A	140	0.747	97.28	65.18	1.66	101.76	60	0.320	88.02	58.97	1.50	214.83
Corn	A	140	0.747	97.28	70.04	1.21	74.21	60	0.320	88.02	63.37	1.09	156.66
Flax	A - Bα	90	0.480	52.12	36.48	0.60	56.96	58	0.309	85.08	59.56	0.97	144.29
Tobacco	A - Bα	90	0.480	52.12	13.03	0.33	31.64	58	0.309	85.08	21.27	0.54	80.16
Wheat f.	Bα	90	0.480	41.69	17.51	0.38	36.45	55	0.293	80.68	33.89	0.74	115.43
Lignite	Bα	90	0.480	41.69	33.35	0.91	86.79	55	0.293	80.68	64.55	1.76	274.83
Soil	Bγ	65	0.347	30.11	39.14	1.17	155.14	49	0.261	71.88	93.44	2.80	491.27
Table salt	Bγ	65	0.347	30.11	36.13	0.98	130.18	49	0.261	71.88	86.26	2.35	412.25
Sulfur	Bγ - C	55	0.293	19.11	21.02	0.67	104.42	47	0.251	68.95	75.84	2.41	440.88
Cement	Bγ - C	55	0.293	19.11	28.66	0.78	122.05	47	0.251	68.95	103.42	2.82	515.32
Potas.salt	C	55	0.293	12.74	14.01	0.46	71.60	45	0.240	66.01	72.61	2.37	453.48
Sand	C	55	0.293	12.74	20.38	0.93	144.65	45	0.240	66.01	105.62	4.80	916.12

Table 14. Horizontal screw conveyors data for standard pitch ($D = s = 0.4$ m) with nominal trough loading for every bulk material (ξ_{nom}) and for maximal loading of 95% ($\xi^* = 0.95$) for all bulk materials (if possible)

Bulk material	material class	nominal loading (ξ_{nom})						maximal loading ($\xi^* = 0.95$)					
		n_{max} [rpm]	v [m/s]	Q_v [m^3/h]	Q_m [t/h]	P_M [kW]	T [Nm]	n^*_{max} [rpm]	v^* [m/s]	Q^*_v [m^3/h]	Q^*_m [t/h]	P^*_M [kW]	T^* [Nm]
Coffee b.	A	130	0.867	176.43	70.57	1.47	97.47	50	0.333	143.26	57.30	1.20	205.77
Rye	A	130	0.867	176.43	123.50	2.24	148.32	50	0.333	143.26	100.28	1.82	313.13
Starch p.	A	130	0.867	176.43	118.21	3.01	198.75	50	0.333	143.26	95.98	2.44	419.59
Corn	A	130	0.867	176.43	127.03	2.19	144.93	50	0.333	143.26	103.14	1.78	305.97
Flax	A - Bα	80	0.533	90.48	63.33	1.04	111.24	48	0.320	137.53	96.27	1.57	281.81
Tobacco	A - Bα	80	0.533	90.48	22.62	0.58	61.80	48	0.320	137.53	34.38	0.87	156.56
Wheat f.	Bα	80	0.533	72.38	30.40	0.66	71.19	45	0.300	128.93	54.15	1.18	225.45
Lignite	Bα	80	0.533	72.38	57.91	1.58	169.51	45	0.300	128.93	103.14	2.81	536.79
Soil	Bγ	60	0.400	54.29	70.57	2.12	303.00	40	0.267	114.61	148.99	4.47	959.51
Table salt	Bγ	60	0.400	54.29	65.14	1.78	254.27	40	0.267	114.61	137.53	3.75	805.18
Sulfur	Bγ - C	50	0.333	33.93	37.32	1.19	203.94	39	0.260	111.74	122.91	3.91	861.10
Cement	Bγ - C	50	0.333	33.93	50.89	1.39	238.38	39	0.260	111.74	167.61	4.57	1006.47
Potas.salt	C	50	0.333	22.62	24.88	0.81	139.85	38	0.253	108.88	119.76	3.92	885.70
Sand	C	50	0.333	22.62	36.19	1.64	282.52	38	0.253	108.88	174.20	7.91	1789.29

Table 15. Inclined screw conveyors data ($\delta = 10°$) for standard pitch ($D = s = 0.2$ m) with nominal trough loading for every bulk material (ξ_{nom}) and for maximal loading of 95% ($\xi^* = 0.95$) for all bulk materials (if possible)

Bulk material	material class	nominal loading (ξ_{nom})						maximal loading ($\xi^* = 0.95$)					
		n_{max} [rpm]	v [m/s]	Q_v [m^3/h]	Q_m [t/h]	P_M [kW]	T [Nm]	n^*_{max} [rpm]	v^* [m/s]	Q^*_v [m^3/h]	Q^*_m [t/h]	P^*_M [kW]	T^* [Nm]
Coffee b.	A	150	0.500	20.36	8.14	0.18	10.48	77	0.257	22.06	8.82	0.20	22.13
Rye	A	150	0.500	20.36	14.25	0.28	16.12	77	0.257	22.06	15.44	0.30	34.03
Starch p.	A	150	0.500	20.36	13.64	0.37	21.11	77	0.257	22.06	14.78	0.40	44.56
Corn	A	150	0.500	20.36	14.66	0.28	15.82	77	0.257	22.06	15.88	0.30	33.39
Flax	A - Bα	112	0.373	12.67	8.87	0.16	12.20	75	0.250	21.49	15.04	0.27	30.90
Tobacco	A - Bα	112	0.373	12.67	3.17	0.09	6.56	75	0.250	21.49	5.37	0.15	16.63
Wheat f.	Bα	112	0.373	10.13	4.26	0.10	7.63	72	0.240	20.63	8.66	0.20	24.18
Lignite	Bα	112	0.373	10.13	8.11	0.23	17.93	72	0.240	20.63	16.50	0.48	56.79
Soil	Bγ	80	0.267	7.24	9.41	0.30	31.89	63	0.210	18.05	23.47	0.74	101.00
Table salt	Bγ	80	0.267	7.24	8.69	0.25	26.90	63	0.210	18.05	21.66	0.62	85.18
Sulfur	Bγ - C	65	0.217	4.41	4.85	0.16	21.41	60	0.200	17.19	18.91	0.63	90.38
Cement	Bγ - C	65	0.217	4.41	6.62	0.19	25.22	60	0.200	17.19	25.79	0.74	106.47
Potas.salt	C	65	0.217	2.94	3.23	0.11	14.66	56	0.187	16.04	17.65	0.60	92.84
Sand	C	65	0.217	2.94	4.70	0.22	29.23	56	0.187	16.04	25.67	1.21	185.14

Table 16. Inclined screw conveyors data ($\delta = 10°$) for standard pitch ($D = s = 0.25$ m) with nominal trough loading for every bulk material (ξ_{nom}) and for maximal loading of 95% ($\xi^* = 0.95$) for all bulk materials (if possible)

Bulk material	material class	nominal loading (ξ_{nom})						maximal loading ($\xi^* = 0.95$)					
		n_{max} [rpm]	v [m/s]	Q_v [m^3/h]	Q_m [t/h]	P_M [kW]	T [Nm]	n^*_{max} [rpm]	v^* [m/s]	Q^*_v [m^3/h]	Q^*_m [t/h]	P^*_M [kW]	T^* [Nm]
Coffee b.	A	145	0.604	38.44	15.37	0.35	20.47	70	0.292	39.17	15.67	0.35	43.22
Rye	A	145	0.604	38.44	26.90	0.53	31.48	70	0.292	39.17	27.42	0.54	66.47
Starch p.	A	145	0.604	38.44	25.75	0.70	41.23	70	0.292	39.17	26.25	0.71	87.03
Corn	A	145	0.604	38.44	27.67	0.52	30.89	70	0.292	39.17	28.20	0.53	65.22
Flax	A - Bα	100	0.417	22.09	15.46	0.28	23.82	68	0.283	38.05	26.64	0.48	60.35
Tobacco	A - Bα	100	0.417	22.09	5.52	0.15	12.82	68	0.283	38.05	9.51	0.26	32.48
Wheat f.	Bα	100	0.417	17.67	7.42	0.17	14.91	65	0.271	36.37	15.28	0.36	47.22
Lignite	Bα	100	0.417	17.67	14.14	0.41	35.02	65	0.271	36.37	29.10	0.84	110.91
Soil	Bγ	71	0.296	12.55	16.31	0.51	62.29	58	0.242	32.46	42.19	1.33	197.26
Table salt	Bγ	71	0.296	12.55	15.06	0.43	52.54	58	0.242	32.46	38.95	1.12	166.36
Sulfur	Bγ - C	60	0.250	7.95	8.75	0.29	41.81	55	0.229	30.78	33.86	1.13	176.53
Cement	Bγ - C	60	0.250	7.95	11.93	0.34	49.25	55	0.229	30.78	46.17	1.33	207.96
Potas.salt	C	60	0.250	5.30	5.83	0.20	28.63	52	0.217	29.10	32.01	1.10	181.33
Sand	C	60	0.250	5.30	8.48	0.40	57.10	52	0.217	29.10	46.56	2.19	361.61

Table 17. Inclined screw conveyors data ($\delta = 10°$) for standard pitch ($D = s = 0.32$ m) with nominal trough loading for every bulk material (ξ_{nom}) and for maximal loading of 95% ($\xi^* = 0.95$) for all bulk materials (if possible)

Bulk material	material class	nominal loading (ξ_{nom})						maximal loading ($\xi^* = 0.95$)					
		n_{max} [rpm]	v [m/s]	Q_v [m^3/h]	Q_m [t/h]	P_M [kW]	T [Nm]	n^*_{max} [rpm]	v^* [m/s]	Q^*_v [m^3/h]	Q^*_m [t/h]	P^*_M [kW]	T^* [Nm]
Coffee b.	A	140	0.747	77.83	31.13	0.70	42.94	60	0.320	70.41	28.17	0.63	90.65
Rye	A	140	0.747	77.83	54.48	1.08	66.03	60	0.320	70.41	49.29	0.97	139.39
Starch p.	A	140	0.747	77.83	52.14	1.41	86.46	60	0.320	70.41	47.18	1.27	182.52
Corn	A	140	0.747	77.83	56.03	1.06	64.79	60	0.320	70.41	50.70	0.95	136.78
Flax	A - Bα	90	0.480	41.69	29.18	0.52	49.96	58	0.309	68.07	47.65	0.85	126.57
Tobacco	A - Bα	90	0.480	41.69	10.42	0.28	26.88	58	0.309	68.07	17.02	0.46	68.11
Wheat f.	Bα	90	0.480	33.35	14.01	0.33	31.27	55	0.293	64.55	27.11	0.63	99.03
Lignite	Bα	90	0.480	33.35	26.68	0.77	73.45	55	0.293	64.55	51.64	1.49	232.59
Soil	Bγ	65	0.347	24.09	31.32	0.99	130.64	49	0.261	57.50	74.76	2.36	413.69
Table salt	Bγ	65	0.347	24.09	28.91	0.83	110.18	49	0.261	57.50	69.01	1.99	348.89
Sulfur	Bγ - C	55	0.293	15.29	16.82	0.56	87.68	47	0.251	55.16	60.67	2.02	370.20
Cement	Bγ - C	55	0.293	15.29	22.93	0.66	103.29	47	0.251	55.16	82.74	2.39	436.11
Potas.salt	C	55	0.293	10.19	11.21	0.38	60.04	45	0.240	52.81	58.09	1.99	380.28
Sand	C	55	0.293	10.19	16.31	0.77	119.74	45	0.240	52.81	84.50	3.97	758.35

Table 18. Inclined screw conveyors data ($\delta = 10°$) for standard pitch ($D = s = 0.4$ m) with nominal trough loading for every bulk material (ξ_{nom}) and for maximal loading of 95% ($\xi^* = 0.95$) for all bulk materials (if possible)

Bulk material	material class	nominal loading (ξ_{nom})						maximal loading ($\xi^* = 0.95$)					
		n_{max} [rpm]	v [m/s]	Q_v [m^3/h]	Q_m [t/h]	P_M [kW]	T [Nm]	n^*_{max} [rpm]	v^* [m/s]	Q^*_v [m^3/h]	Q^*_m [t/h]	P^*_M [kW]	T^* [Nm]
Coffee b.	A	130	0.867	141.15	56.46	1.27	83.86	50	0.333	114.61	45.84	1.03	177.04
Rye	A	130	0.867	141.15	98.80	1.95	128.96	50	0.333	114.61	80.22	1.58	272.25
Starch p.	A	130	0.867	141.15	94.57	2.55	168.86	50	0.333	114.61	76.79	2.07	356.49
Corn	A	130	0.867	141.15	101.62	1.91	126.54	50	0.333	114.61	82.52	1.55	267.15
Flax	A - Bα	80	0.533	72.38	50.67	0.91	97.58	48	0.320	110.02	77.01	1.38	247.20
Tobacco	A - Bα	80	0.533	72.38	18.10	0.49	52.51	48	0.320	110.02	27.51	0.74	133.02
Wheat f.	Bα	80	0.533	57.91	24.32	0.57	61.08	45	0.300	103.14	43.32	1.01	193.41
Lignite	Bα	80	0.533	57.91	46.32	1.34	143.46	45	0.300	103.14	82.52	2.38	454.29
Soil	Bγ	60	0.400	43.43	56.46	1.78	255.16	40	0.267	91.68	119.19	3.76	808.00
Table salt	Bγ	60	0.400	43.43	52.12	1.50	215.19	40	0.267	91.68	110.02	3.17	681.43
Sulfur	Bγ - C	50	0.333	27.14	29.86	1.00	171.25	39	0.260	89.39	98.33	3.28	723.05
Cement	Bγ - C	50	0.333	27.14	40.72	1.17	201.74	39	0.260	89.39	134.09	3.87	851.79
Potas.salt	C	50	0.333	18.10	19.91	0.68	117.27	38	0.253	87.10	95.81	3.28	742.74
Sand	C	50	0.333	18.10	28.95	1.36	233.86	38	0.253	87.10	139.36	6.55	1481.14

Table 19. Inclined screw conveyors data ($\delta = 20°$) for standard pitch ($D = s = 0.2$ m) with nominal trough loading for every bulk material (ξ_{nom}) and for maximal loading of 95% ($\xi^* = 0.95$) for all bulk materials (if possible)

Bulk material	material class	nominal loading (ξ_{nom})						maximal loading ($\xi^* = 0.95$)					
		n_{max} [rpm]	v [m/s]	Q_v [m^3/h]	Q_m [t/h]	P_M [kW]	T [Nm]	n^*_{max} [rpm]	v^* [m/s]	Q^*_v [m^3/h]	Q^*_m [t/h]	P^*_M [kW]	T^* [Nm]
Coffee b.	A	150	0.500	15.27	6.11	0.15	8.40	77	0.257	16.55	6.62	0.16	17.73
Rye	A	150	0.500	15.27	10.69	0.23	13.03	77	0.257	16.55	11.58	0.25	27.50
Starch p.	A	150	0.500	15.27	10.23	0.29	16.73	77	0.257	16.55	11.09	0.32	35.31
Corn	A	150	0.500	15.27	10.99	0.22	12.83	77	0.257	16.55	11.91	0.24	27.08
Flax	A - Bα	112	0.373	9.50	6.65	0.13	9.93	75	0.250	16.12	11.28	0.22	25.15
Tobacco	A - Bα	112	0.373	9.50	2.38	0.07	5.20	75	0.250	16.12	4.03	0.11	13.18
Wheat f.	Bα	112	0.373	7.60	3.19	0.08	6.10	72	0.240	15.47	6.50	0.16	19.32
Lignite	Bα	112	0.373	7.60	6.08	0.18	14.16	72	0.240	15.47	12.38	0.38	44.85
Soil	Bγ	80	0.267	5.43	7.06	0.23	25.08	63	0.210	13.54	17.60	0.58	79.42
Table salt	Bγ	80	0.267	5.43	6.51	0.20	21.24	63	0.210	13.54	16.25	0.49	67.27
Sulfur	Bγ - C	65	0.217	3.31	3.64	0.13	16.79	60	0.200	12.89	14.18	0.49	70.89
Cement	Bγ - C	65	0.217	3.31	4.96	0.15	19.92	60	0.200	12.89	19.34	0.59	84.09
Potas.salt	C	65	0.217	2.21	2.43	0.09	11.48	56	0.187	12.03	13.24	0.47	72.74
Sand	C	65	0.217	2.21	3.53	0.17	22.64	56	0.187	12.03	19.25	0.93	143.38

Table 20. Inclined screw conveyors data ($\delta = 20°$) for standard pitch ($D = s = 0.25$ m) with nominal trough loading for every bulk material (ξ_{nom}) and for maximal loading of 95% ($\xi^* = 0.95$) for all bulk materials (if possible)

Bulk material	material class	nominal loading (ξ_{nom})						maximal loading ($\xi^* = 0.95$)					
		n_{max} [rpm]	v [m/s]	Q_v [m^3/h]	Q_m [t/h]	P_M [kW]	T [Nm]	n^*_{max} [rpm]	v^* [m/s]	Q^*_v [m^3/h]	Q^*_m [t/h]	P^*_M [kW]	T^* [Nm]
Coffee b.	A	145	0.604	28.83	11.53	0.28	16.40	70	0.292	29.38	11.75	0.28	34.62
Rye	A	145	0.604	28.83	20.18	0.43	25.44	70	0.292	29.38	20.57	0.44	53.71
Starch p.	A	145	0.604	28.83	19.31	0.55	32.67	70	0.292	29.38	19.68	0.56	68.97
Corn	A	145	0.604	28.83	20.76	0.42	25.05	70	0.292	29.38	21.15	0.43	52.89
Flax	A - Bα	100	0.417	16.57	11.60	0.23	19.39	68	0.283	28.54	19.98	0.39	49.13
Tobacco	A - Bα	100	0.417	16.57	4.14	0.12	10.16	68	0.283	28.54	7.13	0.20	25.74
Wheat f.	Bα	100	0.417	13.25	5.57	0.14	11.92	65	0.271	27.28	11.46	0.29	37.73
Lignite	Bα	100	0.417	13.25	10.60	0.32	27.66	65	0.271	27.28	21.82	0.66	87.60
Soil	Bγ	71	0.296	9.41	12.23	0.40	48.99	58	0.242	24.34	31.65	1.05	155.12
Table salt	Bγ	71	0.296	9.41	11.29	0.34	41.49	58	0.242	24.34	29.21	0.89	131.39
Sulfur	Bγ - C	60	0.250	5.96	6.56	0.23	32.79	55	0.229	23.08	25.39	0.89	138.46
Cement	Bγ - C	60	0.250	5.96	8.95	0.27	38.90	55	0.229	23.08	34.63	1.05	164.24
Potas.salt	C	60	0.250	3.98	4.37	0.16	22.43	52	0.217	21.82	24.01	0.86	142.07
Sand	C	60	0.250	3.98	6.36	0.31	44.22	52	0.217	21.82	34.92	1.69	280.03

Table 21. Inclined screw conveyors data ($\delta = 20°$) for standard pitch ($D = s = 0.32$ m) with nominal trough loading for every bulk material (ξ_{nom}) and for maximal loading of 95% ($\xi^* = 0.95$) for all bulk materials (if possible)

Bulk material	material class	nominal loading (ξ_{nom})						maximal loading ($\xi^* = 0.95$)					
		n_{max} [rpm]	v [m/s]	Q_v [m^3/h]	Q_m [t/h]	P_M [kW]	T [Nm]	n^*_{max} [rpm]	v^* [m/s]	Q^*_v [m^3/h]	Q^*_m [t/h]	P^*_M [kW]	T^* [Nm]
Coffee b.	A	140	0.747	58.37	23.35	0.56	34.40	60	0.320	52.81	21.12	0.51	72.61
Rye	A	140	0.747	58.37	40.86	0.87	53.36	60	0.320	52.81	36.97	0.79	112.64
Starch p.	A	140	0.747	58.37	39.11	1.12	68.51	60	0.320	52.81	35.38	1.01	144.64
Corn	A	140	0.747	58.37	42.03	0.86	52.54	60	0.320	52.81	38.02	0.77	110.91
Flax	A - Bα	90	0.480	31.27	21.89	0.43	40.67	58	0.309	51.05	35.73	0.70	103.02
Tobacco	A - Bα	90	0.480	31.27	7.82	0.22	21.30	58	0.309	51.05	12.76	0.36	53.97
Wheat f.	Bα	90	0.480	25.02	10.51	0.26	24.99	55	0.293	48.41	20.33	0.51	79.13
Lignite	Bα	90	0.480	25.02	20.01	0.61	58.01	55	0.293	48.41	38.73	1.18	183.70
Soil	Bγ	65	0.347	18.07	23.49	0.78	102.73	49	0.261	43.13	56.07	1.85	325.31
Table salt	Bγ	65	0.347	18.07	21.68	0.66	87.02	49	0.261	43.13	51.75	1.57	275.55
Sulfur	Bγ - C	55	0.293	11.47	12.61	0.44	68.77	47	0.251	41.37	45.50	1.59	290.38
Cement	Bγ - C	55	0.293	11.47	17.20	0.52	81.58	47	0.251	41.37	62.05	1.88	344.44
Potas.salt	C	55	0.293	7.64	8.41	0.30	47.04	45	0.240	39.61	43.57	1.56	297.94
Sand	C	55	0.293	7.64	12.23	0.59	92.73	45	0.240	39.61	63.37	3.08	587.27

Table 22. Inclined screw conveyors data ($\delta = 20°$) for standard pitch ($D = s = 0.4$ m) with nominal trough loading for every bulk material (ξ_{nom}) and for maximal loading of 95% ($\xi^* = 0.95$) for all bulk materials (if possible)

Bulk material	material class	nominal loading (ξ_{nom})						maximal loading ($\xi^* = 0.95$)					
		n_{max} [rpm]	v [m/s]	Q_v [m^3/h]	Q_m [t/h]	P_M [kW]	T [Nm]	n^*_{max} [rpm]	v^* [m/s]	Q^*_v [m^3/h]	Q^*_m [t/h]	P^*_M [kW]	T^* [Nm]
Coffee b.	A	130	0.867	105.86	42.34	1.02	67.18	50	0.333	85.95	34.38	0.83	141.82
Rye	A	130	0.867	105.86	74.10	1.58	104.21	50	0.333	85.95	60.17	1.28	220.00
Starch p.	A	130	0.867	105.86	70.93	2.02	133.82	50	0.333	85.95	57.59	1.64	282.50
Corn	A	130	0.867	105.86	76.22	1.55	102.61	50	0.333	85.95	61.89	1.26	216.63
Flax	A - Bα	80	0.533	54.29	38.00	0.74	79.43	48	0.320	82.52	57.76	1.12	201.22
Tobacco	A - Bα	80	0.533	54.29	13.57	0.39	41.61	48	0.320	82.52	20.63	0.59	105.41
Wheat f.	Bα	80	0.533	43.43	18.24	0.45	48.80	45	0.300	77.36	32.49	0.81	154.55
Lignite	Bα	80	0.533	43.43	34.74	1.05	113.30	45	0.300	77.36	61.89	1.88	358.79
Soil	Bγ	60	0.400	32.57	42.34	1.40	200.64	40	0.267	68.76	89.39	2.96	635.37
Table salt	Bγ	60	0.400	32.57	39.09	1.19	169.95	40	0.267	68.76	82.52	2.50	538.19
Sulfur	Bγ - C	50	0.333	20.36	22.39	0.78	134.32	39	0.260	67.04	73.75	2.57	567.14
Cement	Bγ - C	50	0.333	20.36	30.54	0.93	159.33	39	0.260	67.04	100.57	3.05	672.73
Potas.salt	C	50	0.333	13.57	14.93	0.53	91.88	38	0.253	65.33	71.86	2.57	581.91
Sand	C	50	0.333	13.57	21.71	1.05	181.11	38	0.253	65.33	104.52	5.07	1147.01