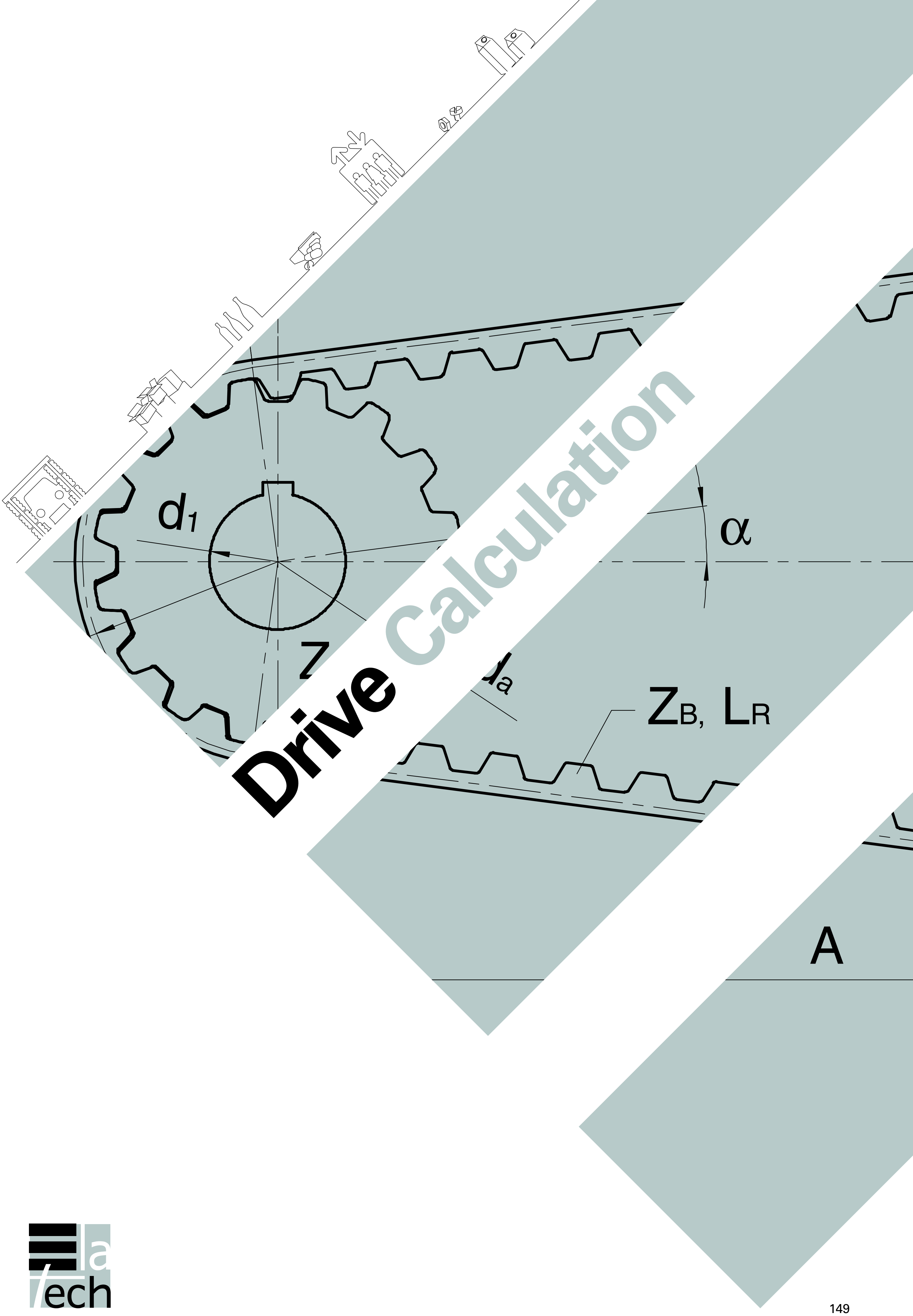
Drive Calculation



Drive calculation

GUIDELINES

Pulleys
It is recommended to use pulleys with the maximum diameter allowed by the application in order to maximise the number of teeth in mesh and increase the belt peripheral speed. For applications where high positioning precision is required, it might be useful to use zero backlash pulleys.
In order to guarantee a reliable drive, it is recommended to use superior quality pulleys.

Minimum pulley diameter
Minimum pulley diameter depends on belt construction but also on the load and the configuration of the drive. The values reported in the catalogue have been calculated and proven for drives with maximum allowable load and standard configurations. For drives where smaller pulleys are needed, please apply to ELATECH® technical department.

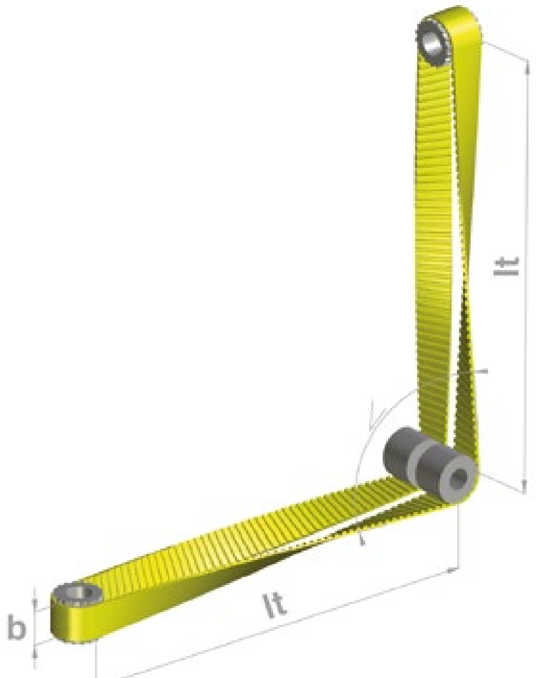
Clamping plates
In case of use of clamping plates, they must have the belt profile, be rigid and guarantee a uniform clamping force on all the surface. It is recommended to have a minimum of 7 teeth in clamp to guarantee catalogue performances. In case of belts with HPL cords, the recommended number of teeth in clamp
is 12.

Machine structure
For a trouble free drive, it is recommended that the structure of application of the timing belt drive is as rigid as possible. That will guarantee high work repeatability.

Angular drives
Elatech belts can be used in angular drives as a “Twisted” drive. In such an application, it is recommended to keep a span length
“lt” > 20 • b (belt width) for 90° twist.

Omega drive
In case of omega drive application it is recommended to keep a span length between driver pulleys and idlers > 3 • b (belt width)

Belt life
Due to the wide application range and considering the fact that belts are one component of complex equipment, the loads in the belt itself are very seldom precisely predictable. This fact makes it impossible to confirm a precise belt service life. In order to optimize belt life of the belts, it is important to follow the catalogue technical specifications related to pulley geometry and belt storage and installation. When all catalogues specifications are followed, a belt life of 3 million reverse bending cycles occurring over 10 years can be expected. This value was measured in tests under laboratory conditions.



BELT INSTALLATION

Drive installation
When installing belts on pulleys, before tensioning the drive, check that the belt teeth and pulley grooves correctly match.

Breaking load
Belt breaking load is highly dependent on several factors including pulley alignment, clamping system and others. The data given in the catalogue are average values tested in our laboratory. It is recommended to use adequate safety factors and ask the ELATECH® technical department for minimum guaranteed breaking load in applications where it is needed.

Belt drive tension
Correct belt drive tension and alignment are very important to optimize belt life and minimize noise level. In fact, improper tension in the belt drive will affect belt fit in the pulley grooves while correct tension minimizes belt pulley interference reducing the noise in the drive.

Drive Alignment
Pulley misalignment will result in an unequal tension, edge wear and reduction of belt life. Also, misaligned drives are much noisier than correctly aligned drives due to the amount of interference that is created between the belt teeth and the pulley grooves.
Proper pulley alignement should be checked with a straight edge or by using a laser alignment tool.

Belt width b [mm]	10	16	32 over
Allowable pulley misalignment [°]	0,28	0,16	0,10

Idlers
Idlers are often a means to apply tension to the drive when the centre distance is fixed but also to increase the number of teeth in mesh of the small pulley. A toothed idler on the inside of the belt on the slack side is recommended with respect to a back side idler. Drives with inside flat idlers are not recommended as noise and abnormal belt wear may occur.

- Idler location is on the slack side span of the belt drive
- Diameter for inside toothed idler must be ≥ of the diameter of the small pulley in the drive
- Idler must be mounted on a rigid support
- Idlers both flat and toothed, should be uncrowned with a minimum arc of contact.
- Idler should be positioned respecting: $2 \bullet (d_{wk} + d_{wg}) < A$
- Idler width should be ≥ of pulley width b

Backside idlers, however, increase the teeth in mesh on both pulleys in the drive and force a counter flexure of the belt and thus contributes to premature belt failure.
In case an idler is needed, It is recommended to keep a span length between driver pulleys and idlers >3 • b (belt width) in order to maximise the number of teeth in mesh of the small pulley.

BELT HANDLING AND STORAGE

Proper storage is important in order to avoid damaging the belts which may cause premature belt failure. Do not store belts on the floor unless in a protective container to avoid damages which may be accidentally caused by people or machine traffic. Belts should be stored in order to prevent direct sunlight and in a dry and cool environment without presence of chemicals in the atmosphere.
Avoid belt storage near windows (to avoid sunlight and moisture), near electric motors or devices which generate ozone, near direct airflow of heating/cooling systems.
Do not crimp belts while handling or when stored to avoid damage to tensile cords. Belts must not be hung on small pins to avoid bending to a small diameter. Handle belts with care while moving and installing. On installation, never force the belt over the pulley flange.

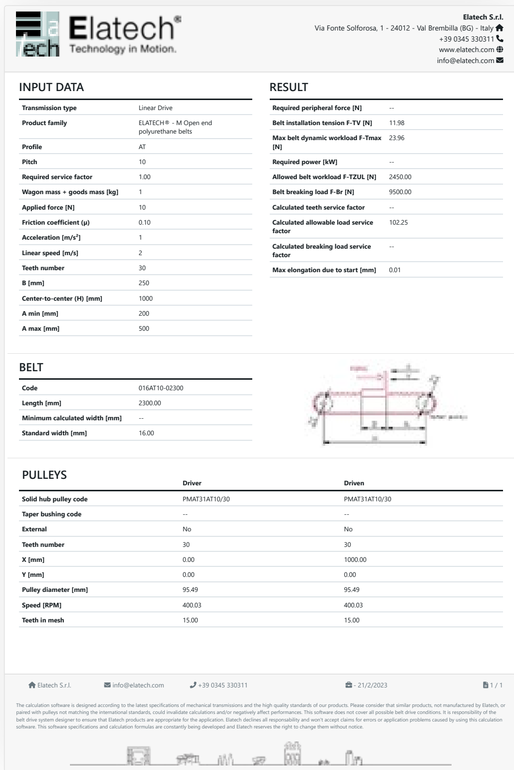
ELADRIVE

online calculation software for quick and reliable drive calculation

Elatech online drive calculation support at ↓

elatech.com

ELATECH's ELADRIVE is a drive calculation program allowing efficient and time saving drive calculation with improved performances.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INPUT DATA

Transmission type	Linear Drive
Product family	ELATECH® - M Open end polyurethane belts
Profile	AT
Pitch	10
Required service factor	1.00
Wagon mass + goods mass [kg]	1
Applied force [N]	10
Friction coefficient (μ)	0.10
Acceleration [m/s²]	1
Linear speed [m/s]	2
Teeth number	30
B [mm]	250
Center-to-center (H) [mm]	1000
A min [mm]	200
A max [mm]	500

RESULT

Required peripheral force [N]	--
Belt installation tension F-TV [N]	11.98
Max belt dynamic workload F-Tmax [N]	23.96
Required power [kW]	--
Allowed belt workload F-TZUL [N]	2450.00
Belt breaking load F-Br [N]	9500.00
Calculated teeth service factor	--
Calculated allowable load service factor	102.25
Calculated breaking load service factor	--
Max elongation due to start [mm]	0.01

BELT

Code	016AT10-02300
Length [mm]	2300.00
Minimum calculated width [mm]	--
Standard width [mm]	16.00

PULLEYS

	Driver	Driven
Solid hub pulley code	PMAT31AT10/30	PMAT31AT10/30
Taper bushing code	--	--
External	No	No
Teeth number	30	30
X [mm]	0.00	1000.00
Y [mm]	0.00	0.00
Pulley diameter [mm]	95.49	95.49
Speed [RPM]	400.03	400.03
Teeth in mesh	15.00	15.00

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The calculation software is designed according to the latest specifications of mechanical transmissions and the high quality standards of our products. Please consider that similar products, not manufactured by Elatech, or paired with pulleys not matching the international standards, could invalidate calculations and/or negatively affect performances. This software does not cover all possible belt drive conditions. It is responsibility of the belt drive system designer to ensure that Elatech products are appropriate for the application. Elatech declines all responsability and won't accept claims for errors or application problems caused by using this calculation software. This software specifications and calculation formulas are constantly being developed and Elatech reserves the right to change them without notice.

ALWAYS UP TO DATE

ELADRIVE online version is always up to date.

› RELIABLE SOLUTIONS!

FAST AND EASY

ELADRIVE offers a step by step drive calculation by an easy to follow menu with improved screen layouts for quicker navigation.

› SAVE YOUR TIME!

COMPREHENSIVE APPLICATION RANGE

ELADRIVE offers a drive calculation for all application technology fields: power transmission, linear, transport. Two pulley drives are calculated and multiple drive design solutions are generated.

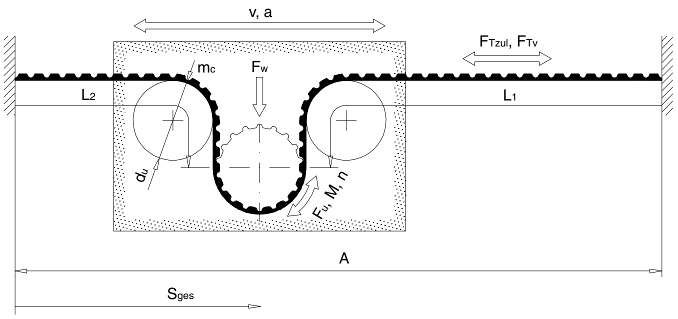
› IMPROVE EFFICIENCY!

LINEAR drives calculation

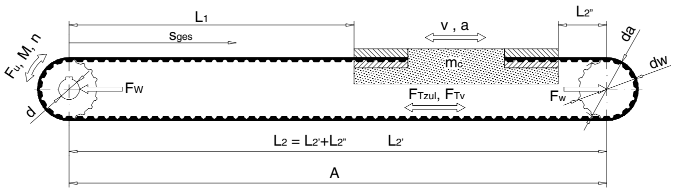
Definitions and transmission cycle

In most cases linear drives may be taken back to one of the two layouts shown, where a specific system of forces acts.

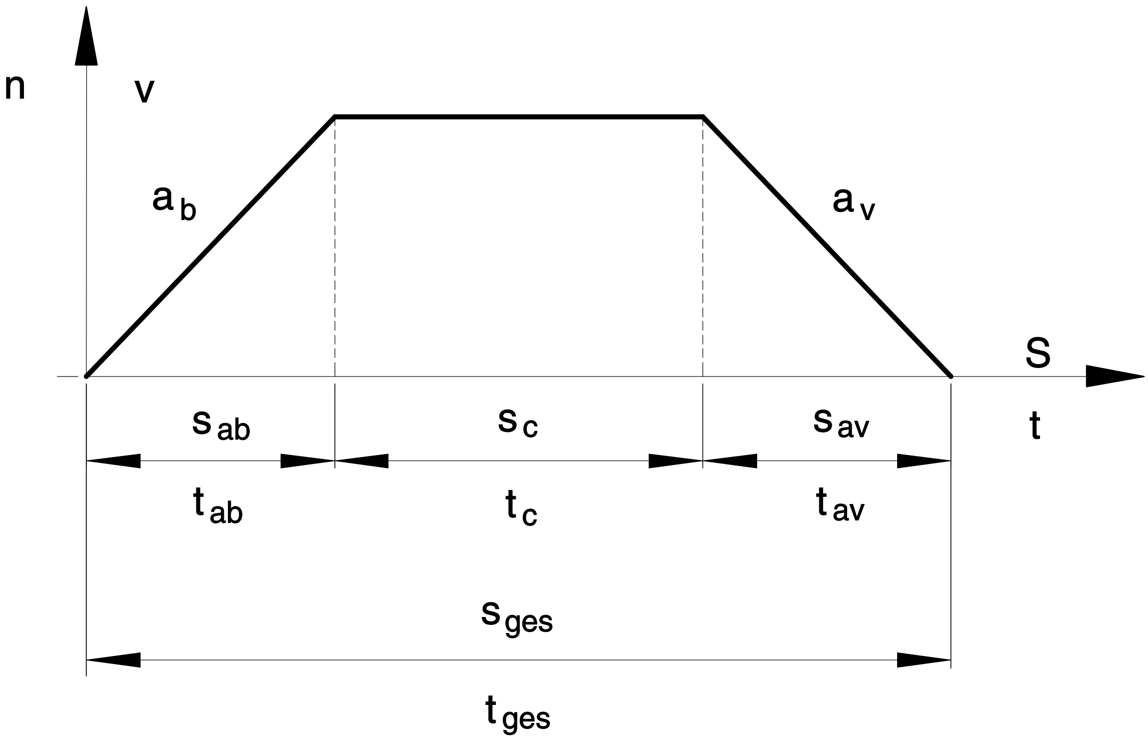
"OMEGA" drive



Linear drive



Transmission cycle (rpm/time)



Definitions and abbreviations

a_b	[m/s²]	Acceleration	M_{av}	[Nm]	Braking torque
a_v	[m/s²]	Deceleration	ρ	[kg/dm³]	Specific weight
B	[mm]	Pulley width	m	[kg]	Total mass
b	[cm]	Belt width	m_R	[kg]	Mass of belt
t	[mm]	Belt pitch	m_c	[kg]	Mass of carriage / slide
C	[N/mm]	Belt modulus / spring rate	m_S	[kg]	Pulley mass
C_{spez}	[N]	Specific spring rate	m_{Sred}	[kg]	Pulley reduced mass
A	[mm]	Centre distance	m_U	[kg]	Idler mass
A_{eff}	[mm]	Effective centre distance	m_{Ured}	[kg]	Idler reduced mass
d	[mm]	Bore diameter	n	[min⁻¹]	Rpm
d_a	[mm]	Outside pulley diameter	n_1	[min⁻¹]	Rpm driver pulley
d_w	[mm]	Pitch circle diameter	Δ_n	[min⁻¹]	Rpm variation
d_U	[mm]	Idler pulley diameter	c_1	-	Service factor
F_{wdyn}	[N]	Dynamic shaft load	P	[kW]	Power
F_{wsta}	[N]	Static shaft load	s_{ges}	[mm]	Total travel
$F_{T_{max}}$	[N]	Maximum span force	s_{ab}	[mm]	Travel during acceleration
F_R	[N]	Resisting force of friction	s_{av}	[mm]	Travel during deceleration / braking
F_{Uspez}	[N/cm]	Specific tooth shear strength	s_c	[mm]	Travel at constant speed
F_{Tv}	[N]	Pretension force for belt side	t_{ges}	[sec]	Total time of travel
F_{Tzul}	[N]	Allowable tensile load	t_{ab}	[sec]	Acceleration time
F_U	[N]	Peripheral force	t_{av}	[sec]	Deceleration time / braking time
F_H	[N]	Vertical lifting force	t_c	[sec]	Time at constant speed
F_{ab}	[N]	Acceleration force	v	[m/s]	Peripheral speed
F_{av}	[N]	Deceleration force	z	-	No. of teeth of pulley
g	[m/s²]	Acceleration due to gravity (= 9,81 m/s²)	z_k	-	No. of teeth of small pulley
Δl	[mm]	Elongation	z_g	-	No. of teeth of big pulley
Δs	[mm]	Difference of position due to force	z_R	-	No. of teeth of belt
L_1,L_2	[mm]	Length of tight and slack side	z_e	-	No. of teeth in mesh
L_R	[mm]	Belt length	i	-	Drive ratio
M	[Nm]	Torque	ω	[s⁻¹]	Angular velocity
M_{ab}	[Nm]	Torque during acceleration	μ	-	Coefficient of friction

Calculation formula

Torque

$$M = \frac{F_U \cdot d_W}{2000} = \frac{P \cdot 9550}{n}$$

Power

$$P = \frac{M \cdot n}{9550} = \frac{F_U \cdot v}{1000}$$

Peripheral force

$$F_U = \frac{2000 \cdot M}{d_W} = \frac{P \cdot 1000}{v}$$

Linear speed

$$v = \frac{d_W \cdot n}{19100} = \frac{n \cdot z \cdot t}{60000}$$

Angular velocity

$$\omega = \frac{\pi \cdot n}{30}$$

Rpm

$$n = \frac{19100 \cdot v}{d_W} = \frac{60000 \cdot v}{z \cdot t}$$

Acceleration time

$$t_{ab} = \frac{v}{a_b} = \sqrt{\frac{2 \cdot s_{ab}}{a_b \cdot 1000}}$$

Acceleration travel

$$s_{ab} = \frac{a_b \cdot t_{ab}^2 \cdot 1000}{2} = \frac{v^2 \cdot 1000}{2 \cdot a_b}$$

Braking time

$$t_{av} = \frac{v}{a_v} = \sqrt{\frac{2 \cdot s_{av}}{a_v \cdot 1000}}$$

Braking travel

$$s_{av} = \frac{a_v \cdot t_{av}^2 \cdot 1000}{2} = \frac{v^2 \cdot 1000}{2 \cdot a_v}$$

Total time

$$t_{ges} = t_{ab} + t_c + t_{av}$$

Total travel

$$s_{ges} = s_{ab} + s_c + s_{av}$$

Time at constant speed

$$t_c = \frac{s_c}{v \cdot 1000}$$

Travel at constant speed

$$s_c = v \cdot t_c \cdot 1000$$

Safety factor
ELATECH® belts do not need any safety factor. However if there are unknown peaks or shock loads or swings in the peripheral force unknown at design time, which therefore can not be included in the calculation parameters, a suitable safety factor should be considered by the designer.

Steady load $c_1 = 1,0$

Peak or fluctuating loads:

Light	$c_1 = 1,4$
Medium	$c_1 = 1,7$
Heavy	$c_1 = 2,0$

Calculation

Linear drives are correctly dimensioned when the total peripheral force, necessary for the requested work, satisfies the 3 technical parameters of the selected belt:

- **tooth shear strength**
- **allowable tensile load**
- **flexibility**

The necessary data for the calculation are: the mass to be moved, the transmission cycle, the drive layout with the related forces, the resisting force of friction.
Friction force is generally determined by the linear bearing manufacturer.
In case of conveying applications, it is resulting from the weight of the conveyed goods and the coefficient of friction between slider bed and belt surface. In case of accumulating conveyors the friction between the conveyed goods and the backside of the belt must be considered additionally.

Select belts and pulleys
For the choice of the pulleys it is recommended to use pulleys with the largest possible diameter.
That will reduce the belt width and optimise drive performances.

Calculate total mass in motion (m)

$$m = m_c + m_R + m_{Sred} + m_{Ured}$$

With:

$$m_{Sred} = \frac{m_S}{2} \cdot \left(1 + \frac{d^2}{d_a^{\,2}}\right)$$ *inertia of the idler timing pulley*

$$m_{Ured} = \frac{m_U}{2} \cdot \left(1 + \frac{d^2}{d_u^{\,2}}\right)$$ *inertia of the idler tensioning pulley*

Calculate the necessary total peripheral force F_U and torque M

$$F_U = F_{ab} + F_H + F_R$$

$$F_U = m \cdot a_b + m \cdot g \cdot \sin\propto + m \cdot g \cdot \mu \cdot \cos\propto$$

Where $\propto$ is the angle of incline of the drive (0° = horizontal ; 90° = vertical).

$$M = \frac{F_U \cdot d_w}{2000}$$

Determine the belt width

$$b = \frac{F_U \cdot C_1}{F_{Uspez} \cdot z_e}$$

with F_{Uspez} depending on the rpm of the small pulley (see technical data on tooth shear strength for the selected belt type).

Note: z_{emax} = 12 for belts ELATECH® M
z_{emax} = 6 for belts ELATECH® V

Determine installation pretension F_{TV}
Linear motion drives are correctly tensioned when in the slack side a minimum tension is guaranteed in all working conditions and for every value of F_{Tmax} (acceleration, deceleration).
It is recommended a pretension of:

$$F_{TV} \geq F_U$$

Verify of allowable tensile load
The maximum load on the belt will appear when both the pretension F_{TV} and the working load F_U will act at the same time:

$$F_{Tmax} = F_{TV} + F_U \cdot C_1$$

The maximum allowable tensile load of the belt F_{tzul} (see technical tables of corresponding selected belt) must be greater than the maximum work load:

$$F_{Tzul} > F_{Tmax}$$

Verify flexibility
The diameter of the chosen pulleys, must be greater or equal to the minimum recommended diameter for the specific belt profile chosen (see technical data).

Calculate shaft load

The shaft load under static conditions is:

$$F_{Wsta} = 2 \cdot F_{TV}$$

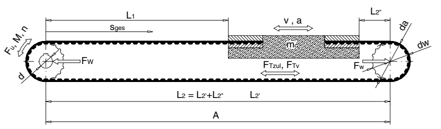
The shaft load under dynamic conditions is:

$$F_{Wdyn} = 2 \cdot F_{TV} + F_U$$

Calculate necessary static elongation

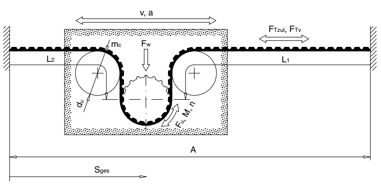
Installation tension generates a belt elongation "Δl" between the shafts (for linear drives) or the clamping plates (for "Omega" drives).

Linear drive



$$\Delta l = \frac{F_{TV} \cdot L_R}{2 \cdot C_{spez}}$$

Omega" drive



$$\Delta l = \frac{F_{TV} \cdot L_R}{C_{spez}}$$

If the resulting elongation is not acceptable for the application, it is possible to reduce it by increasing the belt width or by increasing belt rigidity (HPL cords).

Determine the positioning accuracy

The stiffness coefficient of linear drives depends on the length of slack and tight side in the drive. Every position of the system has its own stiffness coefficient calculated with the formula:

$$C = \frac{L_R}{L_1 \cdot L_2} \cdot C_{spez} \qquad L_R = L_1 + L_2$$

For C_{spez} value see technical data of selected belt type.

Stiffness coefficient will be minimum when slack and tight side will have the same length during the working cycle.

$$C_{min} = \frac{4 \cdot C_{spez}}{L_R}$$

With L_R equal to the belt length free to elongate (excluding contact length on timing pulleys).

Being F_U the resulting force on the slide, the positioning deviation generated by belt elongation is:

$$\Delta_S = \frac{F_U}{C}$$

The positioning accuracy is also depending on other parameters and therefore for an accurate calculation, please consult our technical department. When positioning is reached from both directions the actual position is affected by an error caused by backlash between belt and pulley. The use of zero backlash pulleys helps reduce the positioning error.

Installation and drive pre-tensioning:

In order to pretension a drive it is possible to use one of the following methods:

1. Measuring elongation

ELATECH® timing belts with steel cords have a constant elongation to the maximum allowable load F_{Tzul}. Therefore the correct pretension can be set by measuring the belt elongation with a gauge and using as a reference the graph load/elongation of the selected belt type. This is a simple method but requires good accessibility of the drive.

2. Using span deflection

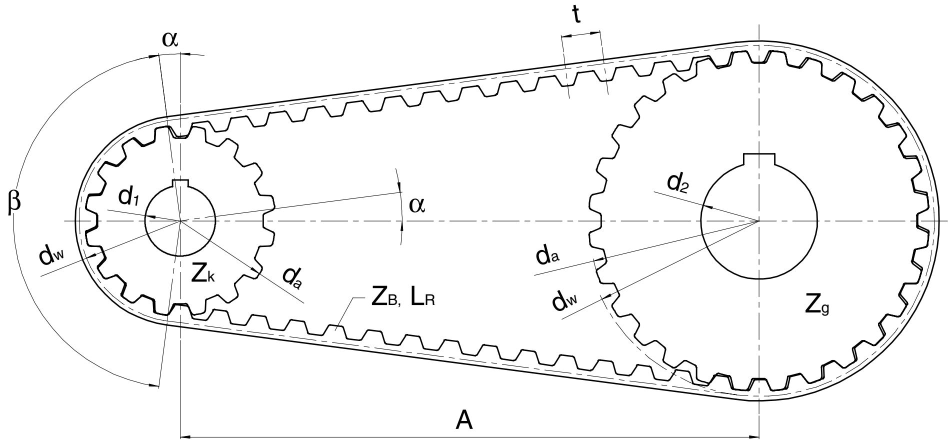
The pretension is checked by applying a force in the centre of the span length and measuring the span deflection

3. Measuring frequency

The tension of the belt is calculated from the natural frequency of vibration of the belt span which is measured by means of a special belt tension meter. This is the most accurate and easiest method.

A suitable belt tension meter is available from ELATECH®

Power transmission drives ELA-flex SD® and iSync®



Definitions

b	[cm]	Belt width	M_{spez}	[Nm]	Specific Torque
L_R	[mm]	Belt length	P	[kW]	Power
z_R	-	Number of teeth of the belt	P_{spez}	[kW]	Specific Power
B	[mm]	Pulley width	t_{ab}	[s]	Acceleration time
A	[mm]	Center distance	t_{av}	[s]	Deceleration time
A_{eff}	[mm]	Effective center distance	v	[m/s]	Peripheral speed
d	[mm]	Pulley bore diameter	z_e	-	N. of teeth in mesh
d_a	[mm]	Pulley outside diameter	z_k	-	Number of teeth of the small pulley
d_{ak}	[mm]	Small pulley outside diameter	z_g	-	Number of teeth of the large pulley
d_{ag}	[mm]	Large pulley outside diameter	i	-	Drive ratio [n1 : n2]
d_w	[mm]	Pulley pitch diameter	ρ	[kg/dm³]	Specific weight
d_{wk}	[mm]	Small pulley pitch circle diameter	J	[kgm²]	Moment of inertia
d_{wg}	[mm]	Large pulley pitch circle diameter	t	[mm]	Pitch
F_{Wsta}	[N]	Static shafts load	n	[min⁻¹]	Rpm
F_{TV}	[N]	Pretension force per belt side	n_1	[min⁻¹]	Rpm of driver pulley
F_{Tzul}	[N]	Allowable tensile load	ω	[s⁻¹]	Angular speed
F_U	[N]	Peripheral force	β	[°]	Wrap angle
M	[Nm]	Torque			

Calculation formula

Torque

$$P = \frac{M \cdot n}{9550}$$

$$P = \frac{F_t \cdot d_w \cdot n}{19100 \cdot 10^3}$$

Peripheral force

$$F_u = \frac{19100 \cdot P \cdot 10^3}{n \cdot d_w}$$

$$F_u = \frac{2000 \cdot M}{d_w}$$

Torque

$$M = \frac{F_U \cdot d_w}{2000}$$

$$M = \frac{9550 \cdot P}{n}$$

Moment of inertia

$$J = 98{,}2 \cdot 10^{-15} \cdot B \cdot \rho \cdot \left(d_a^4 - d^4\right)$$

Angular speed

$$\omega = \frac{\pi \cdot n}{30}$$

Peripheral speed

$$v = \frac{d_w \cdot n}{19100}$$

Acceleration torque

$$M_{ab} = \frac{J \cdot \Delta n}{9{,}55 \cdot t_{ab}}$$

rpm

$$n = \frac{19100 \cdot v}{d_w}$$

Torque
Belt selection is made according to a constant working load. For start up torque and in case of peak loads and vibrations a safety factor c_1 must be considered.

Transmission with steady load $c_1 = 1{,}0$

Transmission with peak or fluctuating loads:

Light	$c_1 = 1{,}4$
Medium	$c_1 = 1{,}7$
Heavy	$c_1 = 2{,}0$

For speed up driver factor c_2 must be considered:

i = from 0,66 to 1	$c_2 = 1{,}1$
i = from 0,40 to 0,66	$c_2 = 1{,}2$
i < 0,40	$c_2 = 1{,}3$

The resulting total safety factor is:

$c_0 = c_1 \cdot c_2$

Drive calculation

The necessary data for drive calculation are:

· Power to be transmitted	P	[kW]
· Driver rpm	n_1	[min^{-1}]
· Motor starting torque	M_{ab}	[Nm]
· Required center distance	A	[mm]
· Maximum driver pulley diameter	d_{w1}	[mm]

Select type of belt
For the initial drive selection, use the selection graphs illustrated in the relative ELA-flex SD® catalog section. For initial pulley choice, it is recommended to use the driver pulley with maximum diameter allowable in the application.

Calculate drive ratio

$$i = \frac{n_{driver}}{n_{driven}}$$

Calculate belt length
Belt length for drive with ratio i ≠1

$$L_R \approx \frac{t}{2} \cdot (z_g + z_k) + 2A + \frac{1}{4A} \cdot \left[\frac{(z_g - z_k) \cdot t}{\pi}\right]^2$$

and more precisely:

$$L_R = 2A \cdot \sin \cdot \frac{\beta}{2} + \frac{t}{2} \cdot \left[z_g + z_k + \left(1 - \frac{\beta}{180}\right) \cdot (z_g - z_k)\right]$$

Belt length for drive with ratio i = 1

$$L_R = 2 \cdot A + \pi \cdot d_w = 2 \cdot A + z \cdot t$$

Calculate teeth in mesh

$$z_e = \frac{\beta}{360} \cdot z_k$$

with β [°]= wrap angle

$$\beta = 2 \cdot \arccos \cdot \left[\frac{t \cdot (z_g - z_k)}{2 \cdot \pi \cdot A}\right]$$

Determine belt width

$$b = \frac{P \cdot 1000 \cdot c_0}{z_k \cdot z_e \cdot P_{spez}} \qquad b = \frac{100 \cdot M \cdot c_0}{z_k \cdot z_e \cdot M_{spez}}$$

Note: z_{emax} = 12 for belts ELA-Flex SD® or iSync®
z_{emax} = 6 for belts ELATECH® V

Determine installation pretension
The drive is correctly tensioned when the belt slack side is tensioned in all working conditions. It is also important to use the minimum necessary tension to minimize shaft loads. Belt tension is dependent also on belt length L_R and its number of teeth Z_R. According to belt number of teeth, following tension is suggested:

2 shafts drive

$Z_R < 75$	$F_{TV} = 1/3\ F_U$
$75 < Z_R < 150$	$F_{TV} = 1/2\ F_U$
$Z_R > 150$	$F_{TV} = 2/3\ F_U$

More than 2 shafts drive

$F_{TV} > F_U$

Verify of allowable tensile load
The allowable tensile load of the belt must be higher than the total corrected peripheral force.

$$F_{Tzul} \geq F_{TV} + \frac{1}{2} \cdot F_U \cdot C_0 \quad \text{with} \quad F_u = \frac{2000 \cdot M}{d_w}$$

Calculate shaft load

$$F_{Wsta} = 2 \cdot F_{Tv} \cdot \sin(\beta/2)$$
$$F_{Wsta} = 2 \cdot F_{Tv} \ (\text{for } i = 1)$$

In order to ensure the correct drive installation tension, it is recommended to use the special belt tension meter available from ELATECH®.