

1.1 Ball screw jacks description

Screw jacks transform a rotary motion of an electric, hydraulic or pneumatic motor or even a manual operation into a vertical linear lifting motion (push or pull) or into a horizontal positioning motion.

Screw jacks can be installed as a single unit or in lifting systems with different layouts connected by transmission shafts, couplings and bevel gearboxes. Screw jacks enable the synchronized constant movement of lifting systems even with a not uniformly distributed load.

Ball screw jacks combine the gear unit with a linear drive performed by a ball screw that, in comparison with the traditional acme screw, offers following advantages:

- higher total efficiency
- longer life of the whole linear drive system

The following two comparative examples give an idea of the higher efficiency that can be obtained with this system:

- considering a screw jack consisting of a worm gear with linear drive performed by an acme screw, the total efficiency of the screw jack is between 10 % and 40 %
- considering a screw jack consisting of a worm gear with linear drive performed by a ball screw, the total efficiency of the screw jack is between 30 % and 70 %

With same performance requirements in both systems (speed and applied load), the second solution allows a 45 - 50 % reduction of the installed power.

SERVOMECH screw jacks are able to work under either push or pull load and can be mounted vertically upward and downward or horizontally.

SERVOMECH ball screw jacks are available in two different models:

- travelling screw (Model A)
- travelling nut (Model B)

SERVOMECH ball screw jacks range offers three main families: MA BS, SJ BS and HS. Each family is designed and developed to represent a series of sizes with an adequate reciprocal gauge, to allow an easier selection of the most suitable size in terms of performances and costs for each application.

MA BS Series (high performance and duty cycle)

Linear drive with travelling ball screw (Mod.A) or with travelling ball nut (Mod.B), worm gear with ratio from 1 : 4 to 1 : 32, input speed up to 3 000 rpm, oil lubricated, duty cycle up to 100 % at 25°C ambient temperature.

SJ BS Series (standard performance and duty cycle)

Linear drive with travelling ball nut (Mod.B), worm gear with ratio from 1 : 4 to 1 : 36, input speed up to 1 500 rpm, grease lubricated, duty cycle up to 70 % at 25°C ambient temperature.

HS Series (high speed, performance and duty cycle)

Linear drive with travelling ball nut (Mod.B), bevel gear with ratio from 1 : 1 to 1 : 4, input speed up to 3 000 rpm, oil lubricated, duty cycle up to 100% at 25°C ambient temperature.

Ball screw jacks

1.2 Manufacturing features

SERVOMECH screw jacks are designed and manufactured using high technology and CNC machine tools. All working processes inside SERVOMECH comply to its Quality Management System, developed according to ISO 9001:2008 and certified by TÜV Italia. Check tests are carried out in-line during all manufacturing processes to monitor and adjust possible errors, obtaining a constant quality of the production without reject. Final control and functional checks are carried out to ensure high quality and reliability of the final product.

MA BS and SJ BS Series screw jacks

- Input drive: precision worm gearbox, high efficiency design, ZI involute profile, reduced angular backlash; bronze wormwheel; hardened and ground steel wormshaft, with true involute worm thread and shaft ground.
- Housing: monobloc housing designed for a more compact and robust shape, able to carry heavy loads and ensure a high precision level of machining.

HS Series screw jacks

- Input drive: bevel gear, gears made in high quality alloy steel, cut according to GLEASON spiral toothing system, case-hardened, tempered and lapped in pairs; the accurate and consolidated manufacturing technology allows to produce bevel gears able to work quietly and with high efficiency. The angular backlash on the output shaft is max. 10' arcmin (on request controlled and reduced backlash, max. 5...6' arcmin).
- Housing: cubic design, compact and robust.

Ball screws

- Nuts: made in case-hardened alloy steel, with ball tracks hardness within the range (58 ... 61) HRc; with flange DIN 69051 (for Mod.B only) or with cylindrical flange designed by SERVOMECH; standard with backlash or preloaded on request; radial or frontal recirculation system; with ball nut end seals and grease nipple.
- Threaded shafts in alloy steel, with rolled (accuracy grade IT 7) or whirled thread (accuracy grade IT 5 or IT 3 on request); the ball track hardness (58 ... 61) HRc.
- Grease lubricated.
- Wide range of diameter - thread helix lead combinations: the nominal diameter range is (16 ... 120) mm, the nominal lead range is (5 ... 40) mm.
- Geometrical checks according to ISO 3408 and DIN 69051.
- Threaded shafts with machined ends and nuts to customer's drawing available on request.

1.3 Materials and Components

Ball screws used in screw jacks

- Threaded shafts: quenched and tempered alloy steel 42 CrMo 4 or 50 CrMo 4 (UNI EN 10083)

Threaded bars available on stock (nominal diameter × nominal lead, in mm):

ROLLED, accuracy grade IT 7				
BS 16×5	BS 20×5	BS 25×5	BS 32×5	BS 40×5
BS 16×10	BS 20×10	BS 25×10	BS 32×10	BS 40×10
BS 16×16	BS 20×20	BS 25×25	BS 32×20	BS 40×20
			BS 32×32	BS 40×40

MACHINED, accuracy grade IT 5 (IT 3)									
BS 16×5	BS 20×5	BS 25×5	BS 32×5	BS 40×5	BS 50×10	BS 63×10	BS 80×10	BS 100×16	BS 120×20
BS 16×10	BS 20×10	BS 25×10	BS 32×10	BS 40×10	BS 50×20	BS 63×20	BS 80×16	BS 100×20	
	BS 20×20		BS 32×20	BS 40×20			BS 80×20		
			BS 32×32	BS 40×40					

- Nuts: case-hardened alloy steel 18 NiCrMo 5 (UNI EN 10084)

MA Series and SJ Series screw jacks

- Housing:
 - casting in hardened and tempered aluminium alloy EN 1706 - AC-ALSi10Mg T6
 - casting in grey cast iron EN-GJL-250 (UNI EN 1561)
 - casting in spheroidal graphite iron EN-GJS-500-7 (UNI EN 1563)
 - welded steel S355J2 (UNI EN 10025)
- Wormwheel: bronze EN 1982 – CuSn12-C
- Worm shaft: case-hardened steel 20 MnCr 5 (UNI EN 10084) , ground involute profile ZI

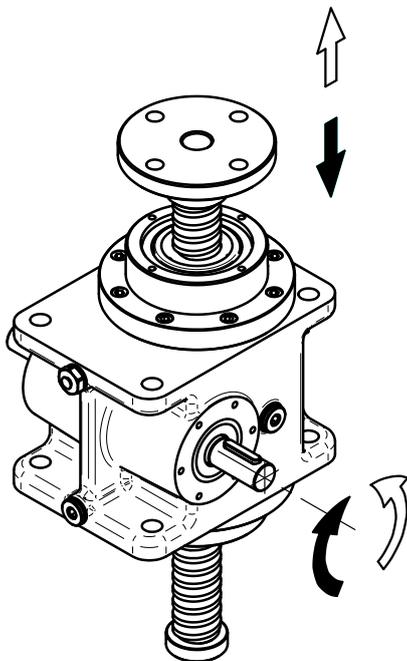
HS Series screw jacks

- Housing: casting in grey cast iron EN-GJL-250 (UNI EN 1561)
- Solid shafts: quenched and tempered carbon steel C45E +H +QT (UNI EN 10083-2)
- Input hollow shaft: case-hardened steel 20 MnCr 5 (UNI EN 10084)
- Output hollow shaft: quenched and tempered steel 39 NiCrMo 3 (UNI EN 10083-3)
- Bevel gears: case-hardened steel 20 MnCr 5 (UNI EN 10084)

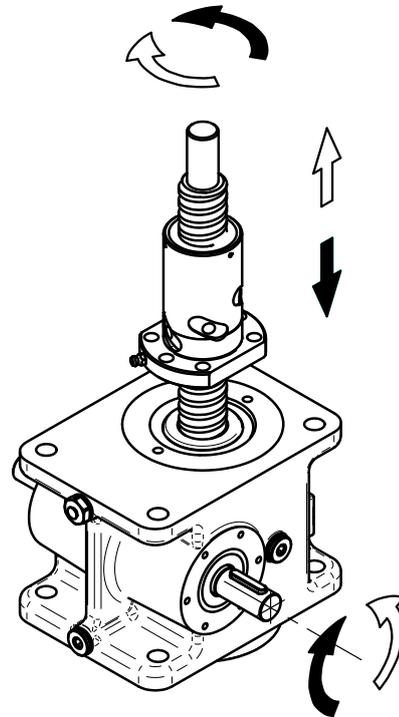
1.5 Models

Ball screw jacks are available in two different models:

- travelling screw (Model A)
- travelling nut (Model B)



Model A - travelling screw



Model B - travelling nut

The ball nut is integral with the worm wheel.

The linear motion is performed by the ball screw being driven by the nut through the screw jack housing, therefore there must be enough space on both screw jack sides. In operation, the screw does not rotate and its translation is possible only if the reacting torque is applied.

Accessories:

- protective tube
- protective bellows
- safety nut
- various screw end attachments
- limit switches
- anti-turn device
- stop nut
- trunnion mount
- bronze guides

The ball screw is fixed to the worm wheel. In operation the screw rotates with the worm wheel at the same speed, driving the bronze nut up and down along the ball screw. The linear motion of the nut is possible only if the reacting torque is applied, avoiding the integral rotation with the ball screw.

Accessories:

- protective bellows
- safety nut
- nut support with pivoting pins
- nut at customer's drawing
- trunnion mount

Ball screw jacks

1.5 Models

MA BS Series screw jacks are available in both models, while SJ BS and HS Series are available only with travelling nut.

The choice of the model depends on the selected screw jack type or on the specific requirements of the application, but in case it can be chosen between the two models (only for MA BS Series), it should be considered that, with same ball screw diameter and lead, the performances of the screw jack MA BS Series Mod. A are higher than those obtained with Mod.B. This is due to the fact that the travelling screw model has an integrated structure between the gear parts and the ball screw that allows higher performances in terms of:

- Efficiency
- Load capacity
- Life
- Stiffness

Considering the several advantages obtained, SERVOMECH has registered an industrial patent right for this screw jack model.

SERVOMECH screw jacks can operate in vertical, horizontal or inclined plane. Different input options are available, such as:

- MA BS Series and SJ BS Series: single or double shaft, motor flange or motor flange with second input shaft.
- HS Series: single solid shaft or flange as motor attachment and second solid output shaft.

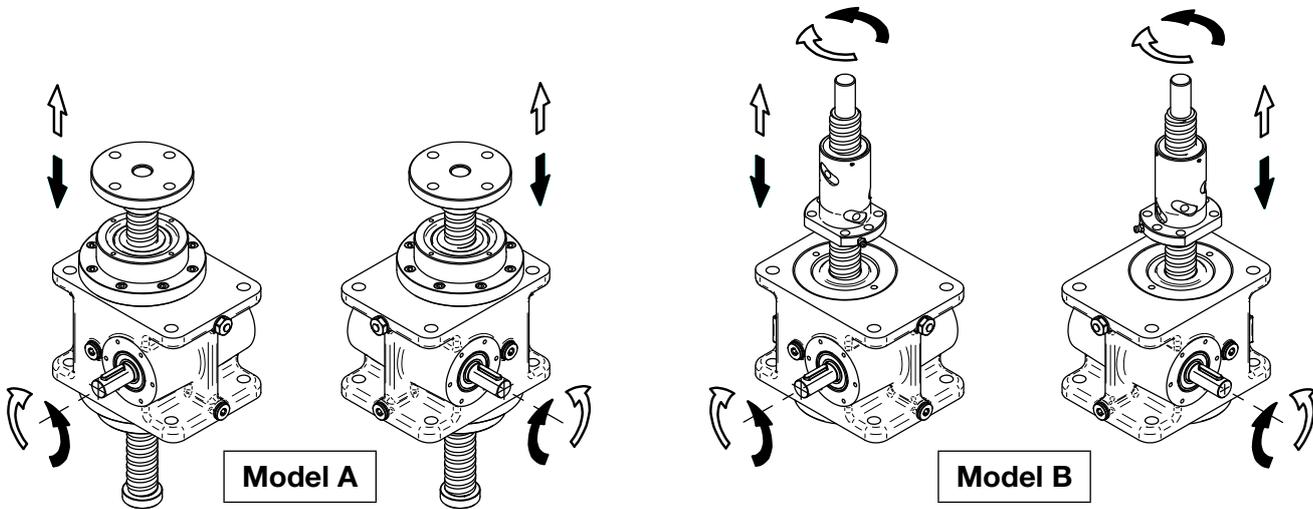
All screw jacks are available with flange or bell housing + coupling for:

- AC 3-phase electric motors with IEC UNEL-MEC flange
- servomotors
- hydraulic motors

Ball screw jacks

1.6 Design – screw jacks MA BS Series and SJ BS Series

INPUT SHAFT ROTATION – SCREW OR NUT LIFTING DIRECTION

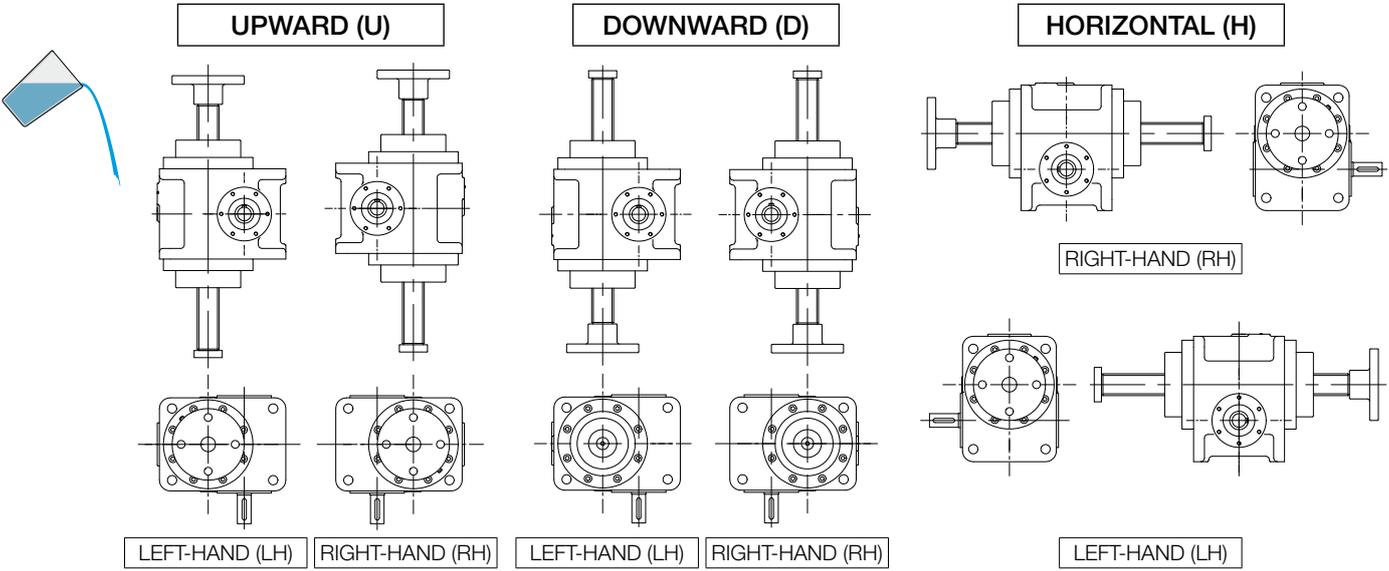


INPUT VERSIONS

Vers.1	Vers.2	Vers.3	Vers.4	Vers.5	Vers.6

- Vers.1: single input shaft
- Vers.2: double input shaft
- Vers.3: flange and hollow shaft for IEC/servo motor
- Vers.4: flange and hollow shaft for IEC/servo motor + second input shaft
- Vers.5: Vers.1 + bell housing and coupling for IEC/servo motor
- Vers.6: Vers.2 + bell housing and coupling for IEC/servo motor

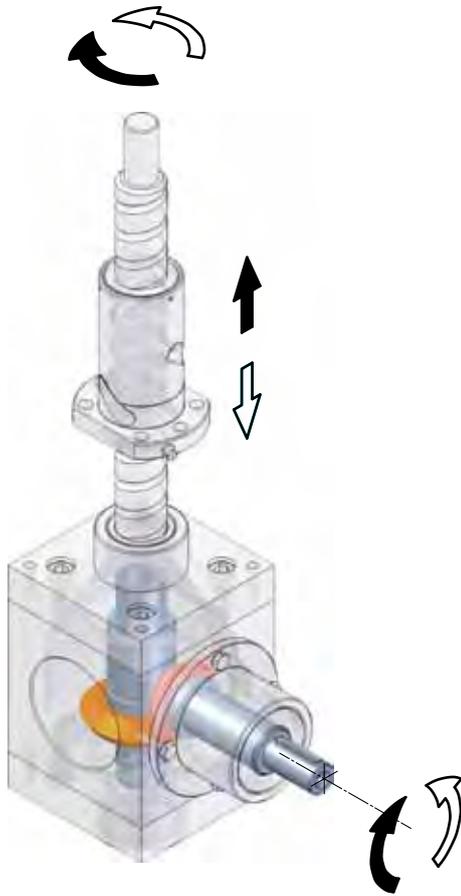
SCREW JACK MOUNTING POSITIONS



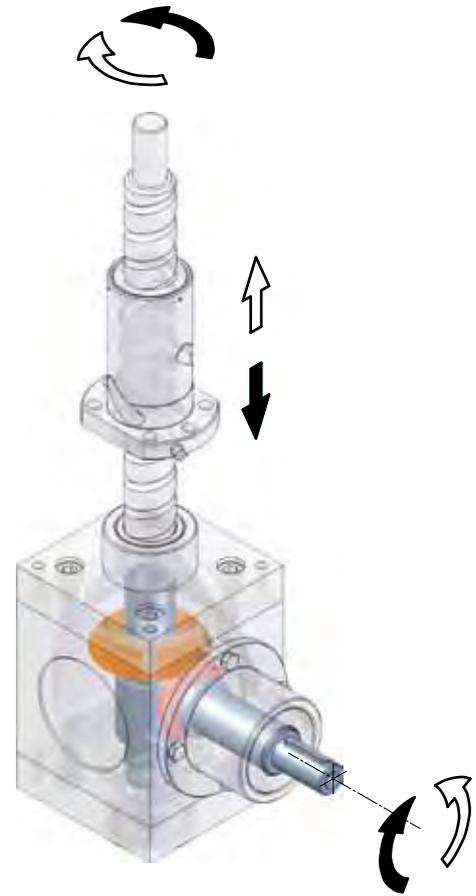
Ball screw jacks

1.7 Design – screw jacks HS Series

KINEMATICS SCHEME



Scheme 10
Bevel gear wheel
on side opposite to nut



Scheme 20
Bevel gear wheel
on nut side

INPUT SHAFT

S	R	MF / MA

- Designation S: solid shaft with key, standard diameter
- Designation R: solid shaft with key, larger diameter
- Designation MF: flange and hollow shaft for IEC/servo motor
- Designation MA: special flange for servo or hydraulic motor

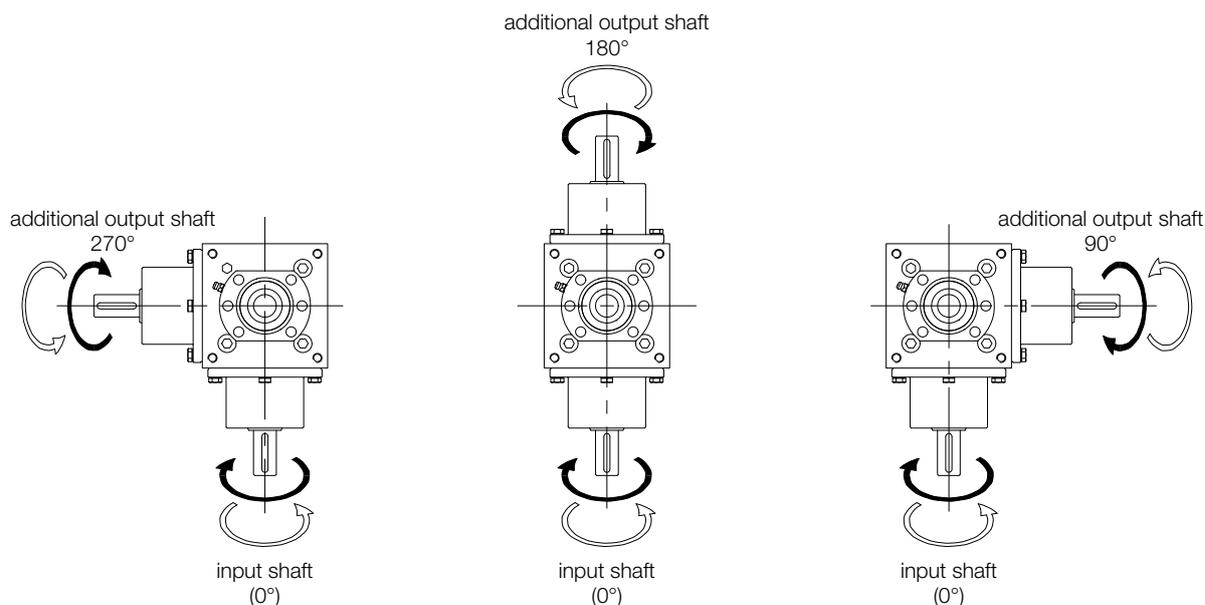
1.7 Design – screw jacks HS Series

ADDITIONAL OUTPUT SHAFT

Screw jacks HS Series can be equipped with one or more additional output shafts. Available versions are:

- S: solid shaft with key, standard diameter
- R: solid shaft with key, larger diameter

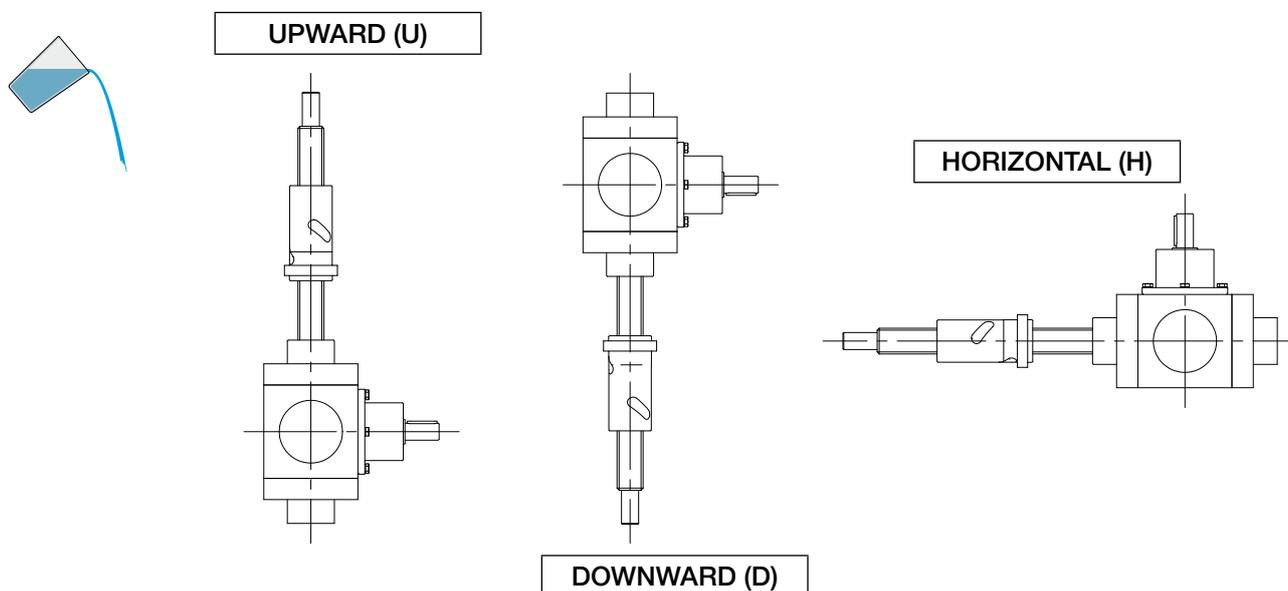
The shafts position refers to the main input shaft and is expressed by an angle with counter-clockwise positive direction and screw jack top view (ball nut side).



WARNING! The rotating speed of the additional output shaft is always the same as the input shaft rotating speed, independently from the screw jack ratio.

SCREW JACK MOUNTING POSITION

The mounting position refers to the output axis with ball screw.

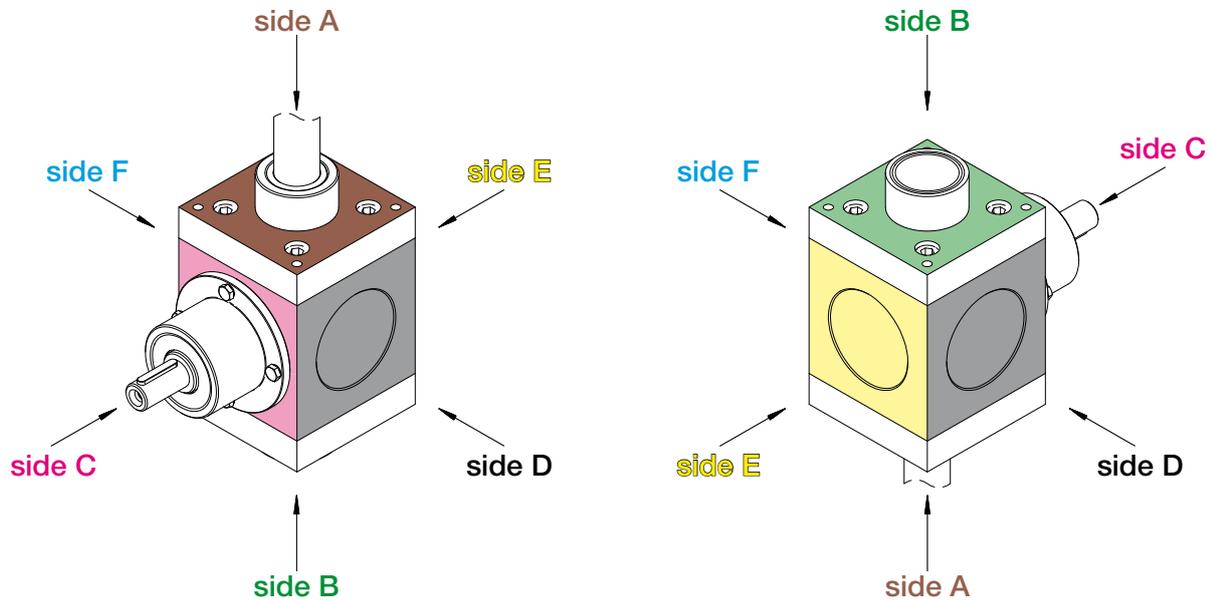


Ball screw jacks

1.7 Design – screw jacks HS Series

SCREW JACK MOUNTING SIDE

The screw jack is fixed on a surface of the supporting structure by means of proper threaded holes. It is essential to precisely define the fixing surface of the screw jack since this determines a specific position of the fixing holes.



Side C is the side of the **main input** (solid shaft or IEC motor coupling).

Side A and **side B** correspond to the **ball screw** axis, on ball nut side and opposite side respectively.

Side D, **side E** and **side F** are the sides where it is possible to mount an **additional output** shaft, in version 90°, 180° or 270° respectively.

1.8 Self-locking conditions

A ball screw jack is in self-locking condition when:

- a push or pull load applied on a not working screw jack does not cause the linear motion (static self-locking condition);
- by interrupting the motor power supply of a working screw jack with push or pull load, the motion stops (dynamic self-locking condition).

Due to the high efficiency of ball screw jacks, it is not possible to ensure the static or dynamic self-locking condition without using a brake motor.

According to the total direct efficiency value of the screw jack the following conditions are possible:

- 1) **Uncertain Self-locking**: with total direct efficiency values between 0.30 and 0.50, the screw jacks are in an uncertain condition. The self-locking condition depends on the load and the inertia of the system. In this case we recommend to use a brake motor to guarantee the self-locking condition or to contact SERVOMECH to evaluate the application.
- 2) **Back-driving**: with total direct efficiency values higher than 0.50 the screw jacks are always not self-locking.

UNCERTAIN SELF-LOCKING				BACK-DRIVING						
0.3			0.5							1

Direct efficiency values and calculation formulas to determine the required braking torque to ensure a self-locking condition are stated for each screw jack in the specific chapters.

1.9 Ball screw buckling

One of the most important screw jack selection criteria is the buckling resistance of the ball screw. Buckling limits are relevant for push load only.

Three cases are considered:

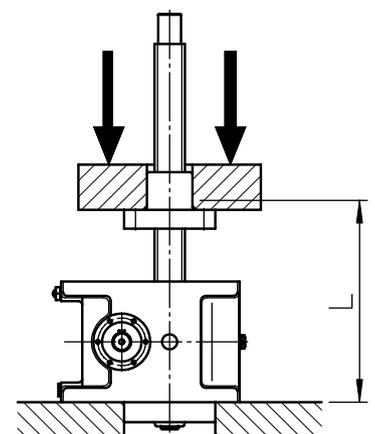
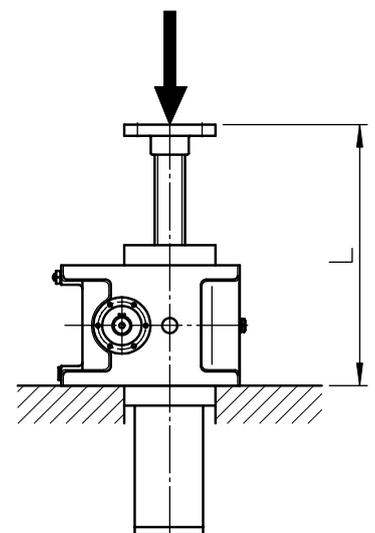
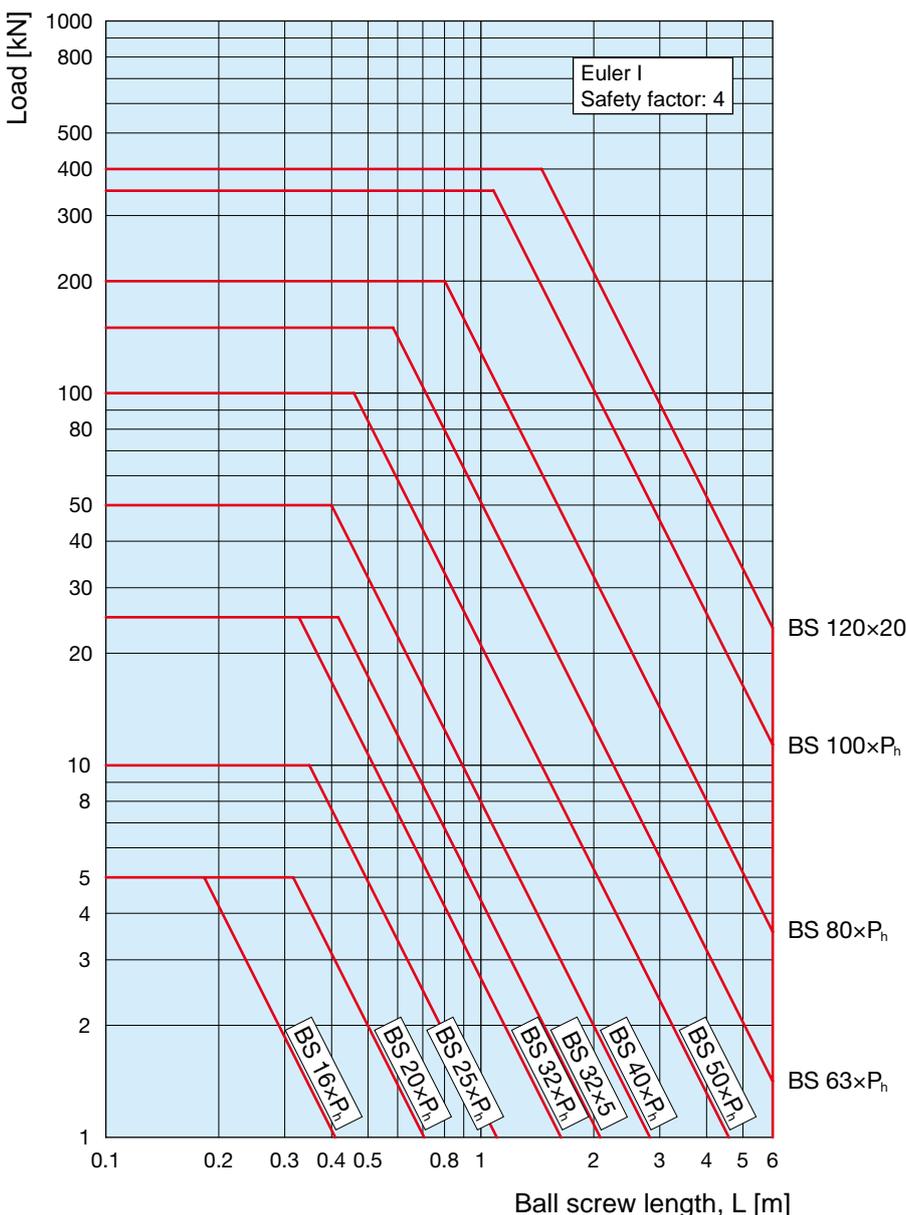
- Euler I: screw jack housing firmly fixed to the base – free travelling screw end
screw jack housing firmly fixed to the base – free travelling nut
- Euler II: screw jack housing and travelling screw end fixed to pivoting supports
screw jack housing and travelling nut fixed to pivoting supports
- Euler III: screw jack housing firmly fixed to the base – guided travelling screw end
screw jack housing firmly fixed to the base – guided travelling nut

Following diagrams (known as Euler curves) show the max. push load allowed on the ball screw, considering a buckling safety factor equals 4.

For particular or critical applications in terms of safety (e.g. theatre lifts), please contact SERVOMECH.

Euler I: screw jack housing firmly fixed to the base - free screw end screw jack housing firmly fixed to the base - free travelling nut

Example: with a push load of 7 kN applied on a screw length of 1 000 mm, the right selection is a screw with nominal diameter 40 mm, mounted on a screw jack MA 50 BS or SJ 50 BS or HS 50.

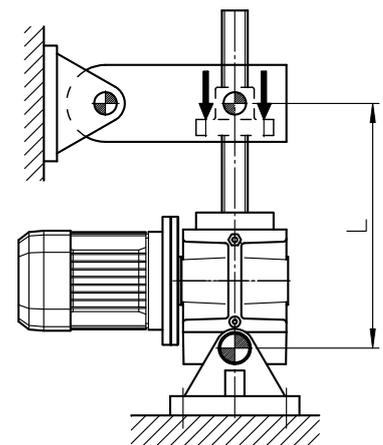
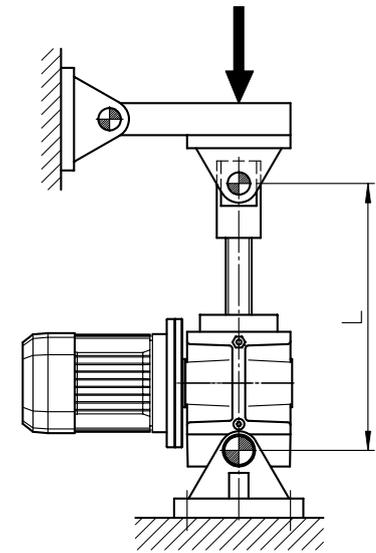
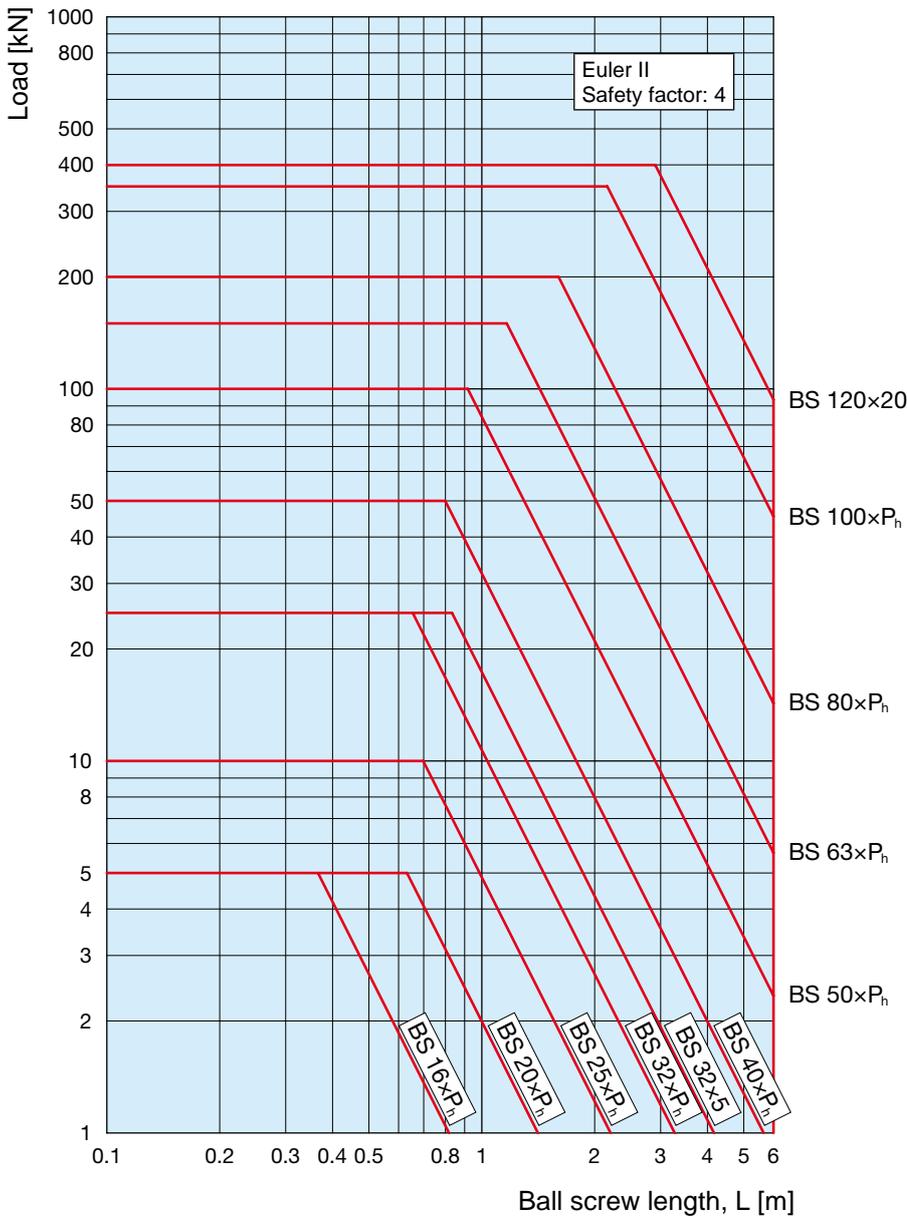


Ball screw jacks

1.9 Ball screw buckling

Euler II: screw jack housing and travelling screw end fixed to pivoting supports
screw jack housing and travelling nut fixed to pivoting supports

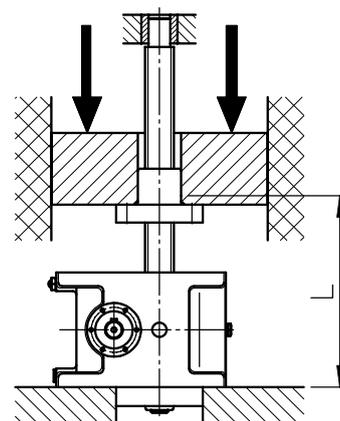
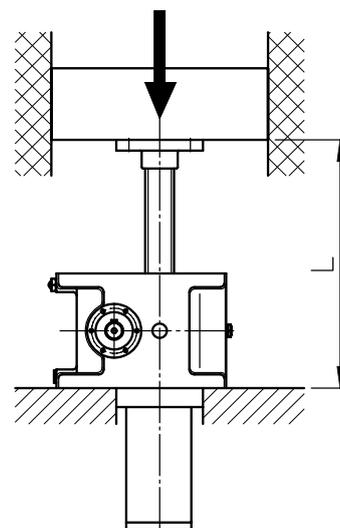
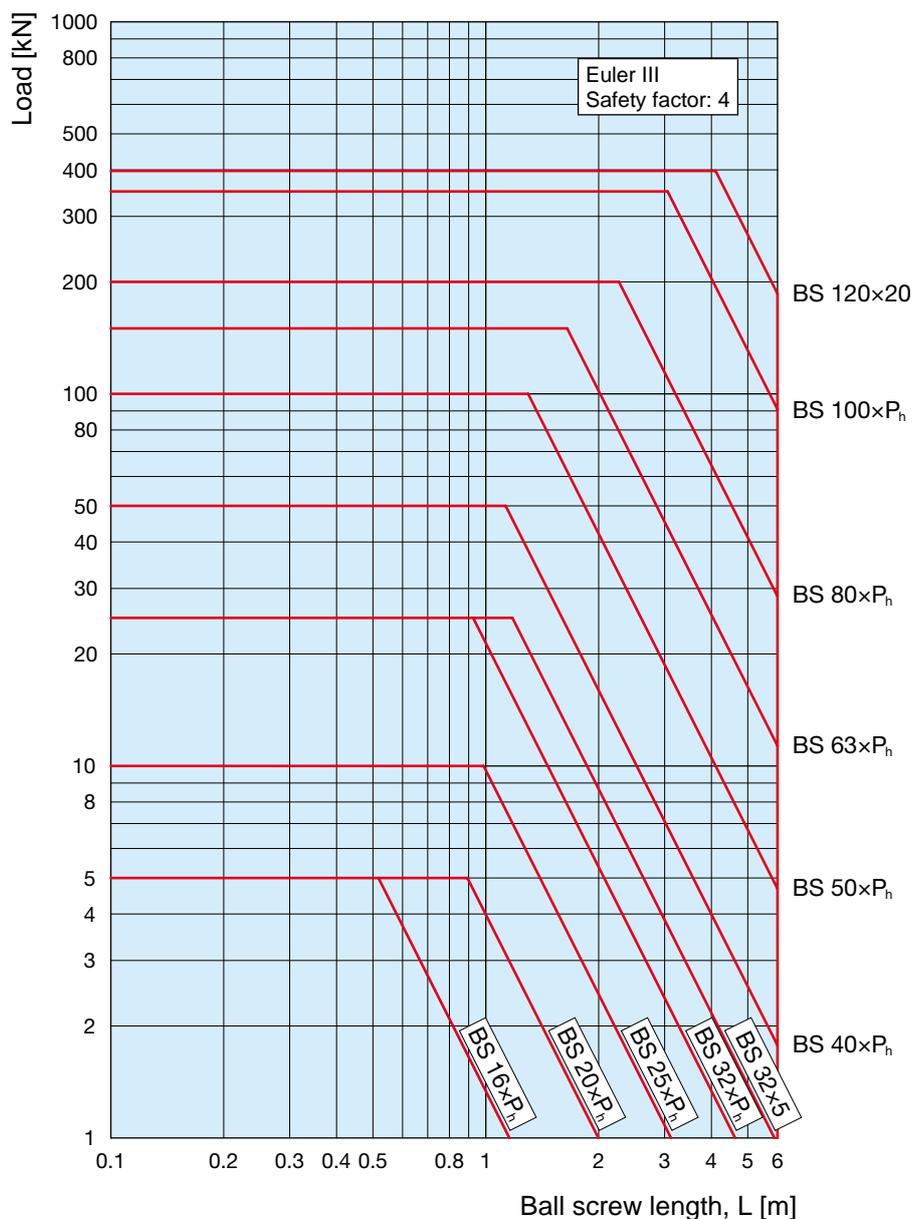
Example: with a push load of 10 kN applied on a screw length of 1 000 mm, the right selection is a screw with nominal diameter 32, mounted on a screw jack MA 25 BS or SJ 25 BS or HS 25.



1.9 Ball screw buckling

Euler III: screw jack housing firmly fixed to the base - guided travelling screw end
screw jack housing firmly fixed to the base - guided travelling nut

Example: with push load of 40 kN applied on a screw length of 4 000 mm, the right selection is a screw with nominal diameter 63, mounted on a screw jack MA 150 BS or SJ 150 BS or HS 150.



Ball screw jacks

1.10 Ball screw critical rotating speed

Following factors limit the ball screw rotating speed:

- 1) external factors (screw length and screw end supports)
- 2) internal factors (ball material, geometry and material of the recirculation elements)

1) External factors

In order to ensure a proper working of a ball screw system and to prevent imbalances which could damage the ball screw, the rotating speed must not reach the critical level. Therefore, this limit exists only for Model B screw jacks with travelling nut and rotating screw.

The critical rotating speed depends on the threaded shaft diameter, the type of screw end and the length of the free ball screw.

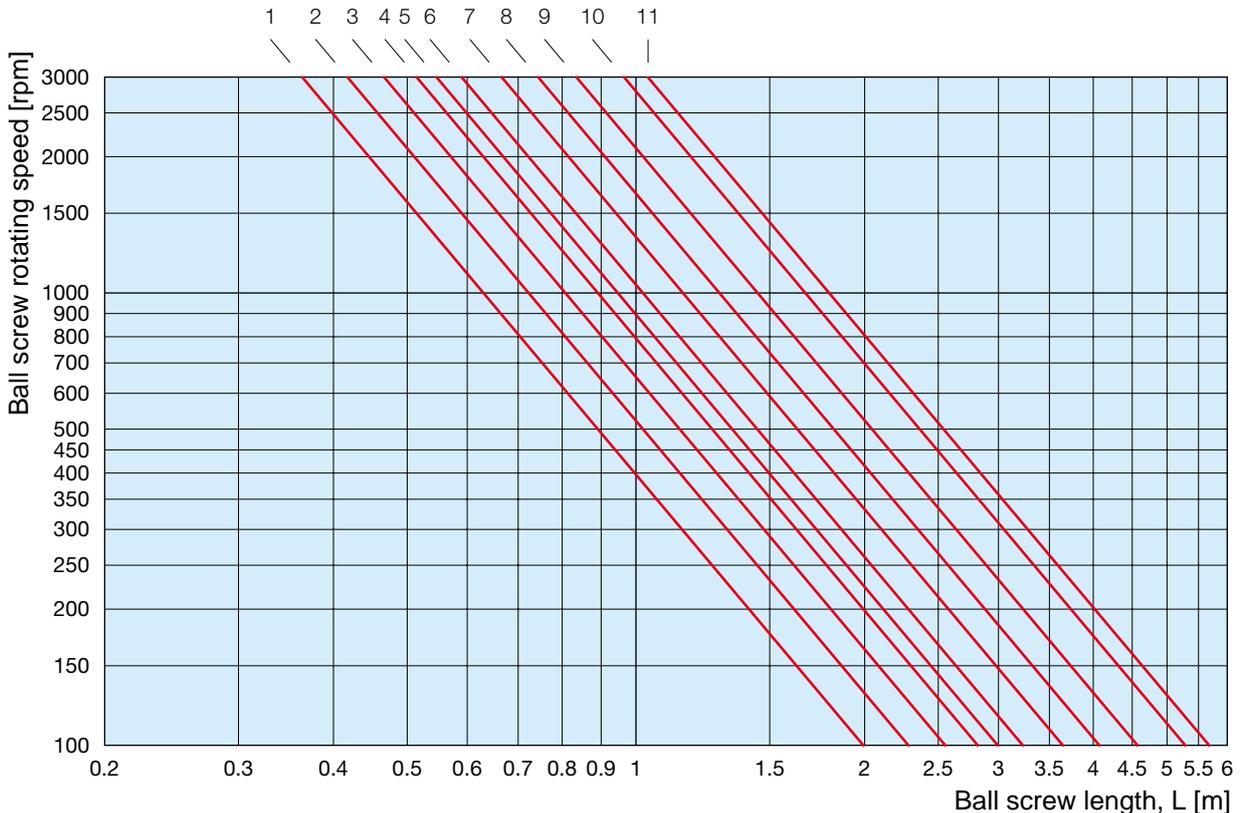
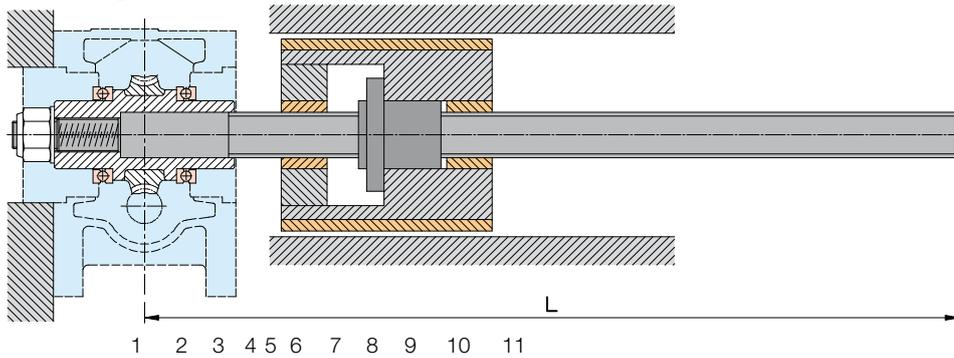
The following formulas are used to calculate the max. allowed rotating speed. They restrict the rotating speed to 80 % of the critical value and they are valid for threaded shafts without an axial through hole:

Free screw end

$$n_{max} = 2.17 \cdot 10^8 \cdot \frac{0.144 \cdot d_2}{L^2}$$

n_{max} [rpm] = max. allowed rotating speed
 d_2 [mm] = ball screw shaft root diameter
 L [mm] = length of screw without end support

Example: For a screw BS 40×10, 1 m long, with not supported end, the max. allowed rotating speed is 1 046 rpm. This rotating speed is equivalent to a linear speed of 175 mm/s.



- | | | | | | |
|-------------------|--------------------|--------------------|-----------------|--------------------|----------------|
| 1 - BS 16×5-10-16 | 3 - BS 25×5-10-25 | 5 - BS 32×5 | 7 - BS 50×10-20 | 9 - BS 80×10-16-20 | 11 - BS 120×20 |
| 2 - BS 20×5-10-20 | 4 - BS 32×10-20-32 | 6 - BS 40×10-20-40 | 8 - BS 63×10-20 | 10 - BS 100×16-20 | |

ATTENTION! By horizontal mounting a ball screw static deflection, caused by its weight and possibly aggravated by the presence of the push load, should always be considered. Therefore, we recommend an accurate evaluation and use of a screw supporting system on both nut sides, integral and travelling with the nut itself; this will ensure the correct alignment and concentricity between the screw and the nut. In case of doubts, please contact SERVOMECH.

Supported screw end

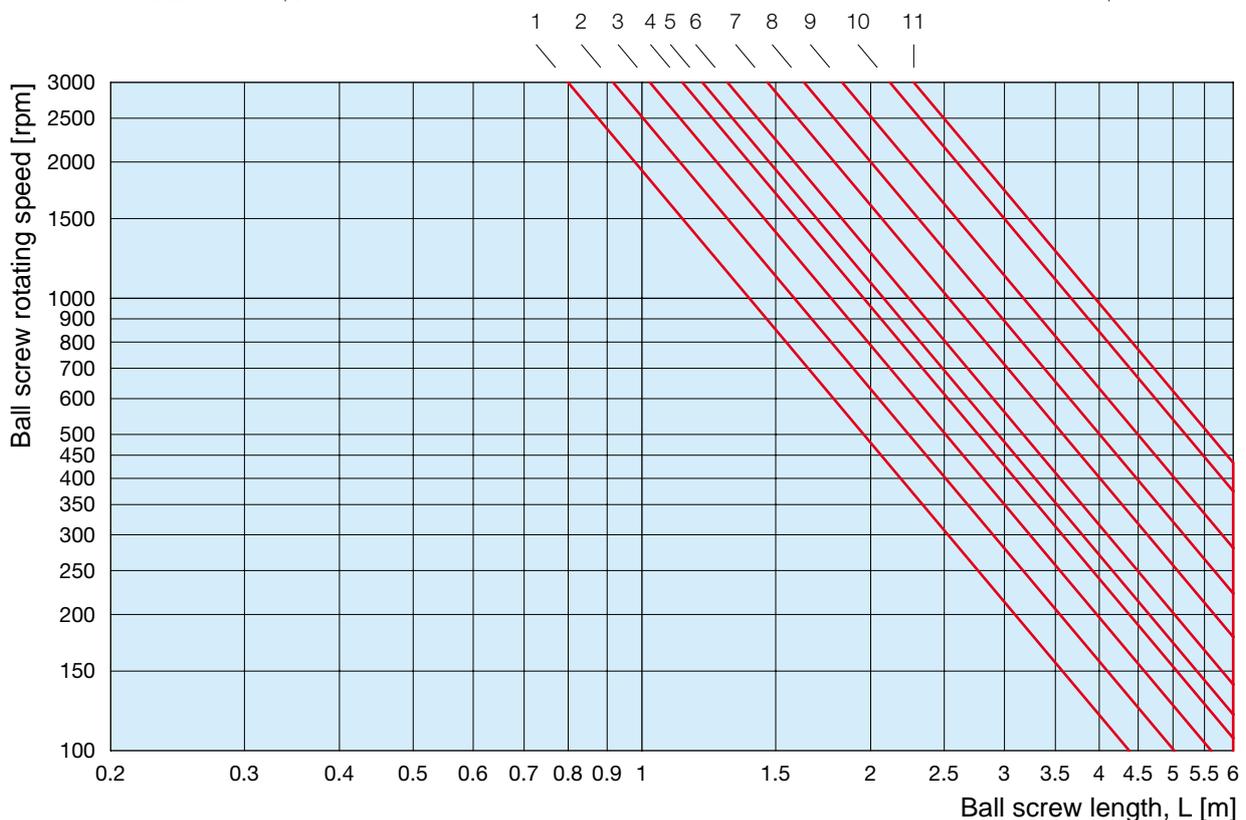
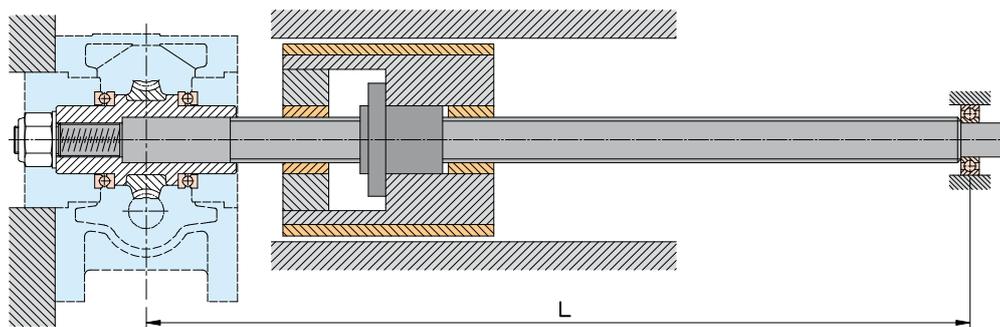
$$n_{max} = 2.17 \cdot 10^8 \cdot \frac{0.694 \cdot d_2}{L^2}$$

n_{max} [rpm] = max. allowed rotating speed

d_2 [mm] = ball screw shaft root diameter

L [mm] = length of screw with end support

Example: For a screw BS 40×10, 3 m long, with end support, the max. allowed rotating speed is 560 rpm. This rotating speed is equivalent to a linear speed of 93 mm/s



1 - BS 16×5-10-16	3 - BS 25×5-10-25	5 - BS 32×5	7 - BS 50×10-20	9 - BS 80×10-16-20	11 - BS 120×20
2 - BS 20×5-10-20	4 - BS 32×10-20-32	6 - BS 40×10-20-40	8 - BS 63×10-20	10 - BS 100×16-20	

Ball screw jacks

1.10 Ball screw critical rotating speed

2) Internal Factors

Depending on screw material, geometry and material of the recirculation elements and screw diameter, there is a specific limit of the max. rotating speed. For ball screws used in screw jacks, SERVOMECH considers following max. rotating speed values:

Ball screw nominal diameter [mm]	Max. rotating speed [rpm]
16	5625
20	4500
25	3600
32	2810
40	2250
50	1800
63	1430
80	1125
100	875
120	730

NOTE: by travelling screw jack (Mod.A), only the limit due to internal factors (2) is effective; by screw jack with travelling nut (Mod.B), the max. allowed rotating speed is the lower speed value calculated using both criteria (1) and (2).

1.11 Ball screw life calculation

Ball screws life corresponds to the number of revolutions that the screw can perform with regard to its nut before any sign of fatigue appears on the material of screw, nut and rolling elements.

The **nominal ball screw life** (L_{10}) is calculated with the following formula:

$$L_{10} = \left(\frac{C_a}{F_m \cdot f_{sh}} \right)^3 \cdot 10^6$$

where:

L_{10} [revolutions] = ball screw nominal life

C_a [N] = ball screw dynamic load

F_m [N] = equivalent dynamic load

f_{sh} = shocks factor

- $f_{sh} = 1$: load without shocks
- $1 < f_{sh} \leq 1.3$: load with light shocks
- $1.3 < f_{sh} \leq 1.8$: load with medium shocks
- $1.8 < f_{sh} \leq 3$: load with heavy shocks

The result of the calculation corresponds to the number of revolutions of the screw with regard to the nut, reached by the 90 % of the ball screw, seemingly identical, subject to the same load conditions, motion laws and environment conditions.

The **equivalent dynamic load** (F_m) is defined as an hypothetical load concentric to the screw, axial only, with constant width and direction that, if applied, would have the same effects on the ball screw life as the real applied load. To determine it, the working cycle is divided in distinct and separate phases, each of them characterized by its load level, the specific rotating speed and the relevant time of load application.

$$F_m = \sqrt[3]{\sum_{i=1}^n F_i^3 \cdot \frac{n_i}{n_m} \cdot \frac{t_i}{t_{tot}}}$$

where:

t_i = duration of each single phase

F_i = load level for each single phase

n_i = rotating speed for each single phase

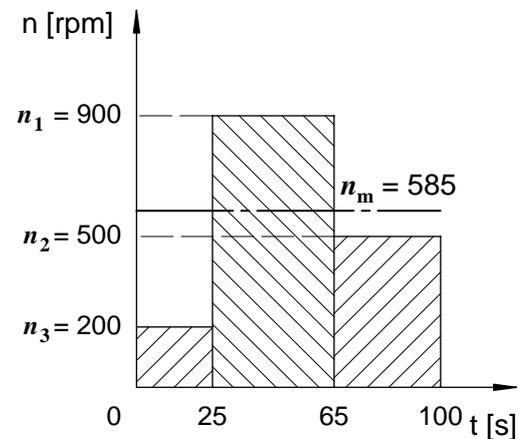
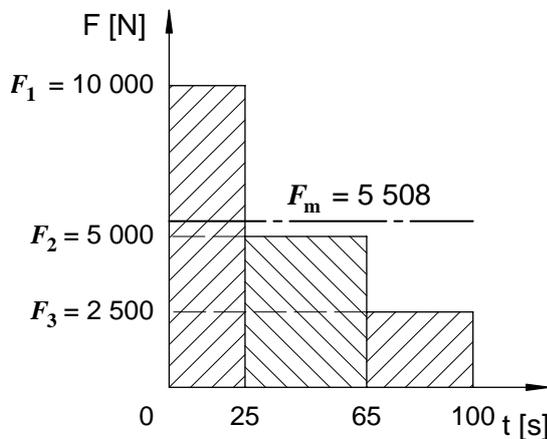
$$n_m = \sum_{i=1}^n n_i \cdot \frac{t_i}{t_{tot}}$$

$$t_{tot} = \sum_{i=1}^n t_i$$

If a preloaded nut is used, the equivalent dynamic load is determined taking into consideration also the pre-load force, adding it to the load level of each single phase of the working cycle.

Example:

i	t_i [s]	n_i [rpm]	F_i [N]	n_m [rpm]	F_m [N]
1	25	200	10 000	585	5 508
2	40	900	5 000		
3	35	500	2 500		



The ball screw life expressed in hours (L_{10h}) is calculated as follows:

$$L_{10h} = \frac{L_{10}}{60 \cdot n_m}$$

where:

n_m [rpm] = equivalent rotating speed

The previous formulas regarding the life refer to a ball screw reliability of 90 %. If a higher life reliability is required (**modified ball screw life**, L_{10m}), the corrective factor f_a must be applied:

$$L_{10m} = L_{10} \cdot f_a$$

Reliability [%]	90	95	96	97	98	99
Factor f_a	1	0.62	0.53	0.44	0.33	0.21