Plastic Nuts sizing

In applications where silence is important or where lubrication is not allowed (grease or oil), self lubricating plastic nuts are recommended. The use of plastics is very constrained by the actual working conditions, therefore we do suggest studying the problem together with our technical office and not relying on a choice based only on intuition. This is because plastic materials have sometimes great features such as low friction and self-lubrication, but at the same time limitations caused by operating temperatures, hygroscopic problems, or some mechanical features that may not be suitable for the intended use. An advanced study of the application in this case is therefore required in order to obtain positive and satisfying results.

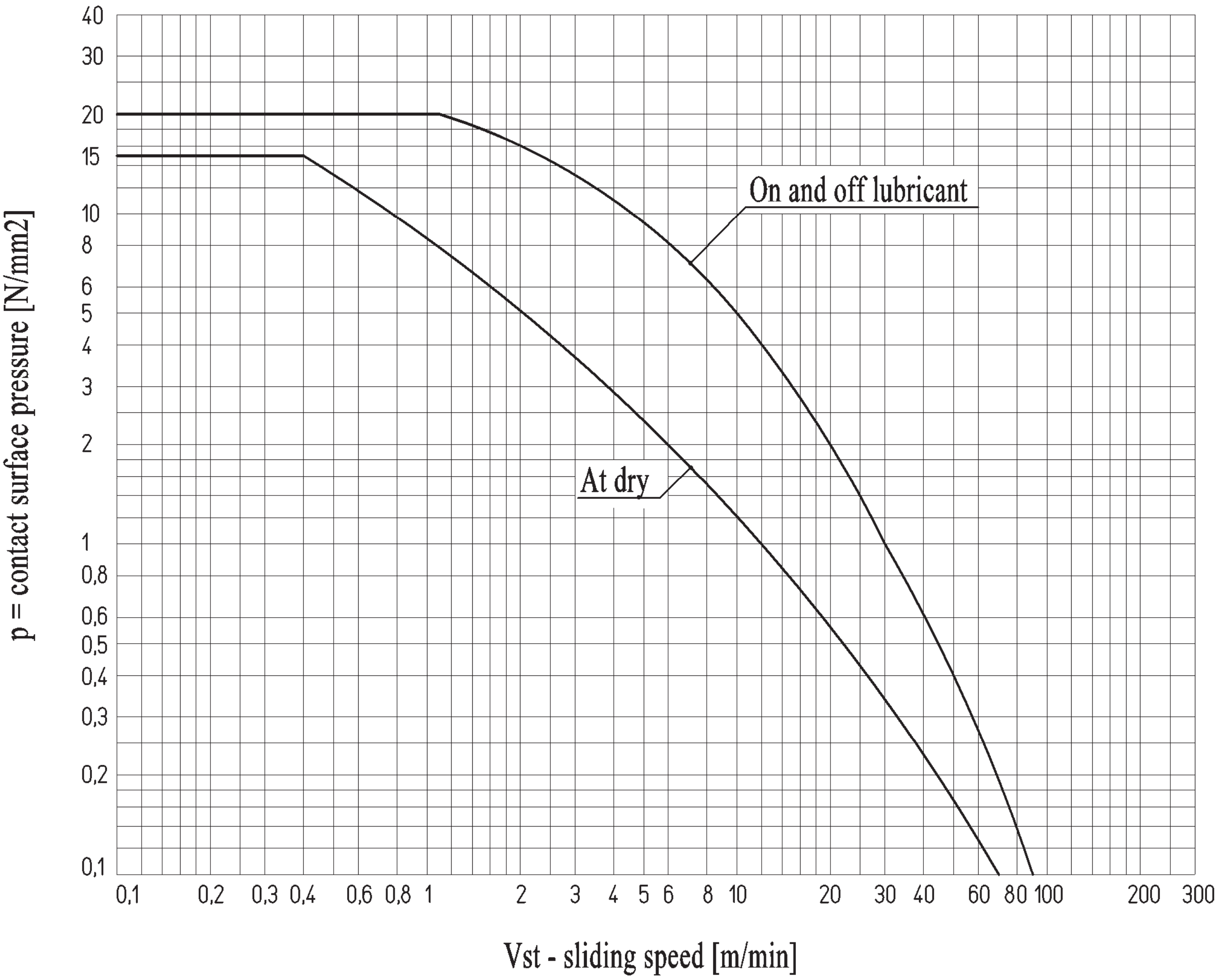
Regarding the plastic nuts, the study of the product p•Vst allows you to draw a chart which describes a curve that limits the values of p•Vst within which we have a gentle flow of the surfaces in contact with limited wearing of the nut and constant in time. Operating outside the limit drawn on the chart is not possible as in this case we would have a quick wearing of the nut following the surface erosion caused by the contact with the screw.

Cylindrical nut MPH

Graph N° 2 shows the limit of the product p•Vst of the cylindrical nut MPH. As this plastic is resistant to wear but not self-lubricant, drawing the limit curve relating to material used in dry conditions and material lubricated intermittently has been necessary.

Graph N° 2 – Sliding condition for nuts MPH

Test condition: - continuous operation - temperature 23°C – relative humidity approx 50%



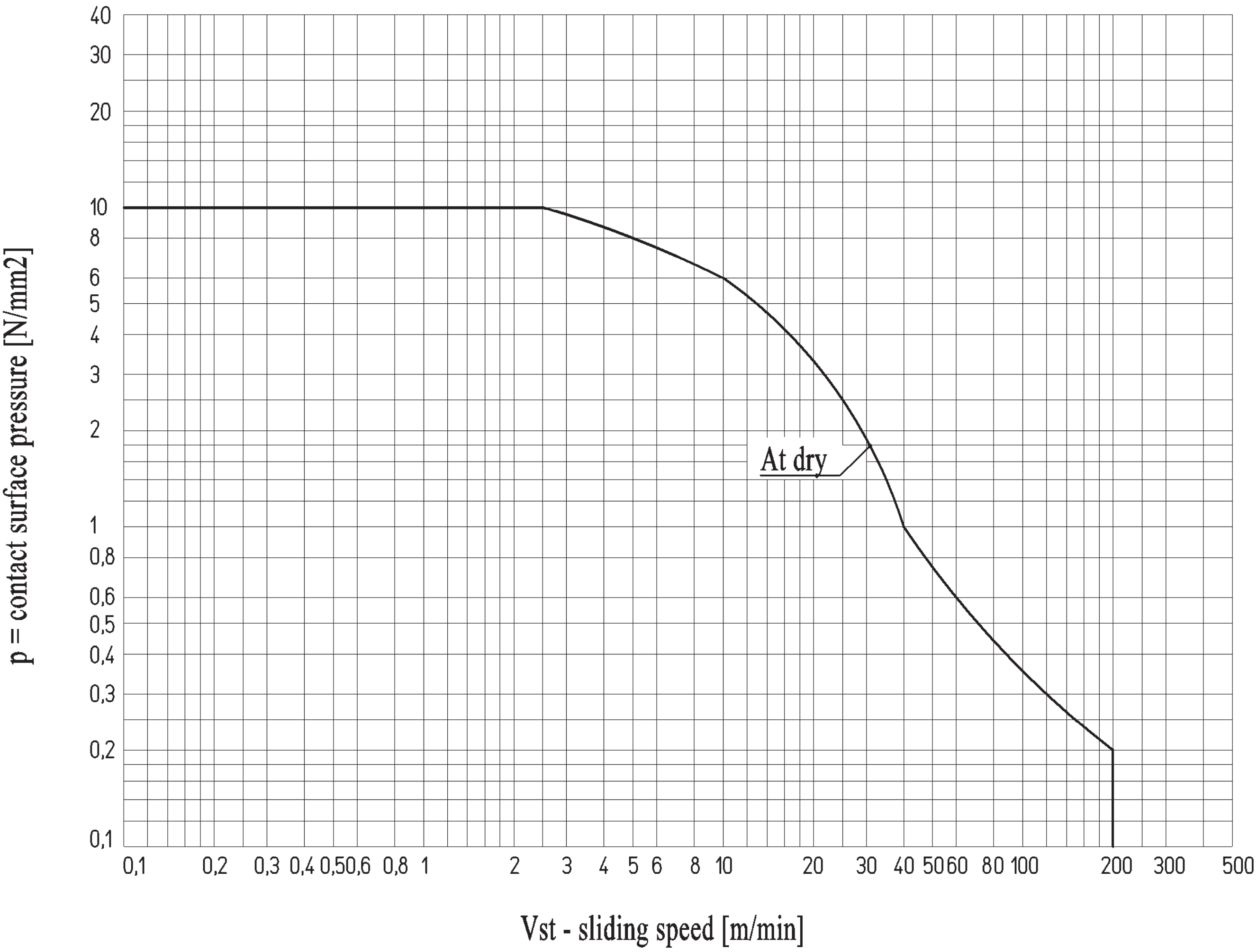
Self-lubricating plastic flanged nut with 3xTr length FCS

Graph N° 3 shows the limit of the product p•Vst of the nut FCS. The plastic used for the FCS features a strong resistance to wear and a complete self-lubricating property.

Prior using the FCS, please read what stated on page 50.

Graph N° 3
Sliding conditions for nuts in self-lubricating plastic FCS

Test conditions: - continuous operation - temperature 23°C – relative humidity approx 50% with no lubrication



 We riserve the right to change sizes and features without notice.

General considerations for plastic nuts

The use of plastics is very constrained by the actual working conditions, therefore you may need to study the problem together with our technical department, and not rely on a choice based on intuition only. This is because plastics have sometimes excellent self-lubrication features, but have, at the same time, restrictions on the working temperature or moisture absorption problems as well as some mechanical properties that may not be suitable for the intended use. The preliminary study of the application, in such cases, is therefore required to achieve positive and satisfying results.

Safety factor for the forces of inertia "*f i*"

During the sizing process we must also check that the inertia forces present during acceleration and deceleration are relatively low so that the value of p●Vst remains within the controlled limits. Whereas this calculation is difficult, in the presence of a non-uniform movement or under great variations, safety factors reported in Chart. N°2 must be considered.

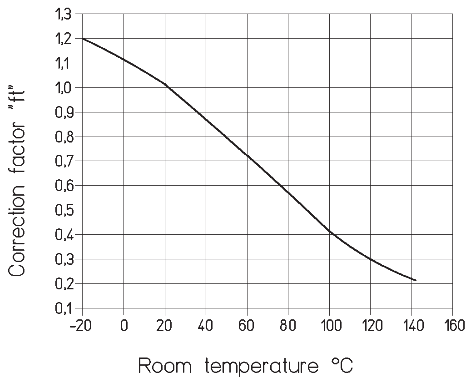
Chart. n° 2 : Safety factors with respect to the forces of inertia

Load type	*f i*
Loads with constant ramps of acc. / dec. controlled	from 1 to 0,5
Loads with constant start and stop at tear	from 0,5 to 0,33
Loads and speed greatly variable	from 0,33 to 0,25
Loads in presence of shocks and vibrations	from 0,25 to 0,17

Correction factor for working environment temperature

Using plastic nuts MPH o FCS, the value of p•Vst admissible must be corrected in function of the working environment temperature. Plastic becomes softer at higher temperature and withstands minor load. At lower temperatures, it becomes harder and bears heavier loads. Correction factor "*f* t" is shown in graph n° 4.

Graph N°4 - Correction factor "ft" for nuts MPH and FCS



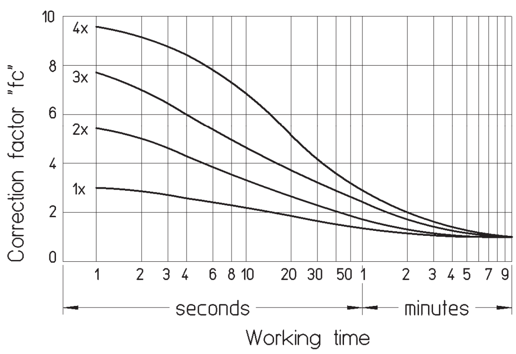
Correction factor dependent on intermittent use

Plastic nuts operating in on and off cycles for relatively short periods of time do not reach the limit of the maximum permissible temperature of the surface in contact with the screw. This temperature is a constraint that mainly contributes to limit the values of the product p•Vst in graphs N° 2 and N° 3 for the nuts MPH e FCS in continuous operation. The value of p•Vst admissible when operating in on and off cycles is higher than the value in continuous cycles. Deduce from graph N° 5 the value of the factor "*f* c". The curves of "x" represent the relationship between the downtime and the working time of the nut.

- l x represents downtime same as working time.
- 2 x represents downtime twice as much of the working time.
- 3 x represents downtime three times the working time.
- 4 x represents downtime four times the working time.

Find the working time value on the horizontal axis the working time value for the case in exam, climb vertically until intersecting the line of the relationship between the downtime and work time, then move horizontally and read the value of "*f* c".

Graph N°5 - Correction factor "fc" for nuts MPH and FCS



The values of the three coefficients *"fi", "ft", "fc"* are used to correct the value of the product "(p•Vst)" max read from graph N° 2 (for nut MPH) or graph N° 3 (for nut FCS), considering the maximum admissible sliding speed in "test conditions" relating to the contact surface pressure value of the real case in exam.

To calculate the admissible p•Vst of the case in exam we shall use **(7) :** $p \bullet Vst\ am = (p \bullet Vst)_{max} \bullet fi \bullet ft \bullet fc$

Example of calculation with self-lubricating plastic nut

Size to wear a nut FCS flanged in self-lubricating plastic with 3xTr length which operate in the following conditions:
- Constant axial load with forces of inertia limited by controlled ramps of acceleration/deceleration of F = 1750 N
- Moving speed = 10 m / min
- Working time = 20 sec. With downtime = 60 sec.
- Working environment temperature = 50°C
- No lubricant

The nut FCS is perfectly self-lubricating and therefore suitable to operate in the considered conditions.
We choose a nut which is available among those that may be compatible with the dimensions of the motion system to be realized. Then we verify that the value of the product p•Vst is lower than the admissible value of p•Vst as per the graph N° 3 and then correct it with the coefficients "*fi*", "*ft*" and "*fc*" from the chart N° 2 and graphs N° 4 and 5.

We choose the FCS40AR (flanged nut in self-lubricating plastic with 3xTr length, Tr 40x7 right threaded)
We calculate the contact surface pressure with **(1)**

$$p = \frac{F}{At} = \frac{1750\,[N]}{6880\,[mm^2]}$$

F = Axial Force [N]
At = Total bearing surface between the teeth of the screws and the nuts in the plane perpendicular to the axis [mm^2]

$$p = 0{,}25 \left[\frac{N}{mm^2}\right]$$

The sliding speed is calculated with **(4)**

$$Vst = \frac{Vtr}{sen\ \alpha} = \frac{10\left[\dfrac{m}{min}\right]}{sen\ 3°30'}$$

Vtr = Motion Speed $\left[\frac{m}{min}\right]$
α = thread helix angle

$$Vst \cong 164 \left[\frac{m}{min}\right]$$

The value of the product p•Vst is:

$$p \bullet Vst = 0{,}25\,[N/mm^2] \bullet 164 \left[\frac{m}{min}\right] \cong 41 \left[\frac{N}{mm^2} \bullet \frac{m}{min}\right]$$

Now we calculate the admissible value of the product p•Vst in the conditions in exam.
From the graph N° 3 we see that in continuous working conditions at 23°C with p = 0,25 [N/mm^2] the admissible value of Vst is ≅ 140 [m/min]

i.e. $(p \bullet Vst)_{max} = 0{,}25 \bullet 140 = 35 \left[\frac{N}{mm^2} \bullet \frac{m}{min}\right]$

- From graph N° 2 we read the value of the coefficient "*fi*". In our case "*fi*" may be = 0,75.
- From graph N° 4 we read the value of the coefficient "*ft*". In our case, in the working environment temperature of 50°C we may assume "*ft*" = 0,8
- From graph N° 5 we read the value of the coefficient "*fc*". In our case with working time of 20 sec. and downtime of 60 sec., therefore

$$\frac{downtime}{working\ time} = 3\ (curve\ 3x)$$

we assume "*fc*" = 3,7

The maximum admissible value of the product p•Vst in our case is **(7):**

$$p \bullet Vst\ am = (p \bullet Vst)_{max} \bullet fi \bullet ft \bullet fc = 35 \left[\frac{N}{mm^2} \bullet \frac{m}{min}\right] \bullet 0{,}75 \bullet 0{,}8 \bullet 3{,}7 = 77{,}7 \left[\frac{N}{mm^2} \bullet \frac{m}{min}\right]$$

As the value of the product p•Vst in this case is lower than the admissible value, the nut FCS 40 AR may be used for this motion.

Lifetime of the plastic nut

Using the experimental values it is possible to give an indication of the lifetime a plastic nut may have. The parameters that affect the life of a plastic nut are as follows:
- Value of the contact surface pressure p [N/mm^2]
- Value of the sliding speed Vst [m/min]
- Constant of the resistance to the wear of the plastic in exam derived from experimental tests k $\left[\frac{mm3 \bullet min}{N \bullet m \bullet hrs}\right]$
- Correction factor *f*c of the on and off cycle.

All data shown below are for coupling of plastic nuts with our precision rolled screws as we guarantee a surface roughness less than 1 μm Ra.
Coupling plastic nuts with lathed screws is not possible.
The following calculations and considerations are for screws working at a temperature of approx 20/25°C with relative humidity from 30% to 70%.
For working environment at a different temperature and humidity, you should contact our Technical Office directly.

To calculate the lifetime we use the following formula:

$$t = \frac{m \bullet fc}{p \bullet Vst \bullet k} \quad (8)$$

m = increase in the axial play between screw and nut in respect of the initial value [mm]
*f*c = correction factor from graph N° 5
p = contact surface pressure (see page 53 onward) [N/mm^2]
Vst = sliding speed (see page 53 onward) [m/min]
k = constant of resistance to wear $\left[\frac{mm3 \bullet min}{N \bullet m \bullet hrs}\right]$

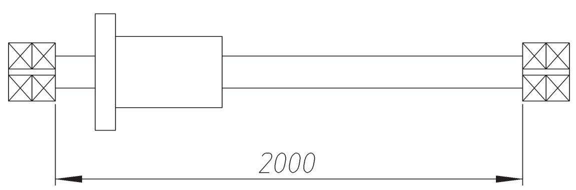
Value of the constant k for plastic nuts.

nuts MPH	$k = 10,5 \bullet 10^{-5}$
nuts FCS	$k = 2,5 \bullet 10^{-5}$

Example of lifetime calculation of a plastic nut

Size to wear and calculate the lifetime of the nut FCS operating in the following conditions:
- Constant axial load forces of inertia limited by controlled ramps of acceleration/deceleration of F = 450 N
- Motion speed = 10 m/min
- Working time = 12 sec. with downtime = 12 sec.
- Distance covered in 12 sec. at 10 m/min ≅ 2000 mm
- Working environment temperature ≅ 22°C
- Working environment mean relative humidity ≅ 40% : 60%
- No lubrication
- Minimum lifetime requested: the coupling screw/nut must work for 200.000 cycles (i.e. approx 1.330 hrs at the above conditions) increasing the axial play in respect of the initial value of 0,1 mm.

V motion =10 m/min



Nuts type FCS are perfectly self-lubricant and therefore suitable to work in the considered conditions.
Seen the good motion speed requested (10 m/min) we verify to wear the nut FCS 28 BR, with pitch 10 (2 starts at pitch 5).
To verify the product p•Vst see example on page 60.

Contact surface pressure is calculated with **(1)**.

$$p = \frac{F}{At} = \frac{450\,[N]}{3600\,[mm^2]} = 0{,}125\left[\frac{N}{mm^2}\right]$$

The sliding speed is calculated with **(4)**.

$$Vst = \frac{Vtr}{\text{sen}\ \alpha} = \frac{10\left[\frac{m}{min}\right]}{\text{sen}\ 7°07'} = 80{,}7\left[\frac{m}{min}\right]$$

The value p•Vst is:

$$p \bullet Vst = 0{,}125\,[N/mm^2] \bullet 80{,}7\left[\frac{m}{min}\right] \cong 10\left[\frac{N}{mm^2} \bullet \frac{m}{min}\right]$$

Now we calculate the admissible value of the product p•Vst at the considered conditions.
From graph N° 3 we see that in continuous working conditions at 23°C with p = 0,125 [N/mm^2] the admissible value of Vst is $\cong$ 180 [m/min]

$$\text{i.e. } (p \bullet Vst)\ max = 0{,}125 \bullet 180 = 22{,}5\left[\frac{N}{mm^2} \bullet \frac{m}{min}\right]$$

- from chart N° 2 *"fi"* = 0,75
- form graph N° 4 " *ft"* = 1
- from graph N° 5 *"fc"* = 3

- the maximum admissible value of p•Vst, in this case, with **(7) :**

$$p \bullet Vst\ amm = p \bullet Vst \bullet fi \bullet ft \bullet fc = 22{,}5\left[\frac{N}{mm^2} \bullet \frac{m}{min}\right] \bullet 0{,}75 \bullet 1 \bullet 2 = 33{,}75\left[\frac{N}{mm^2} \bullet \frac{m}{min}\right]$$

As the value of p•Vst is here less than the admissible one, the nut FCS 28 BR may be use for this motion.

Verify to wear:

Now we calculate in how long we would face wear in continuous working conditions and therefore an increase of the axial play of 0,2 mm with **(8)**

$$t = \frac{m \bullet fc}{p \bullet Vst \bullet k} = \frac{0{,}1 \bullet 2}{10 \bullet 2{,}5 \bullet 10^{-5}} = 800\ hrs$$

Therefore 800 working hrs, at the speed of 10 m/min, correspond to the following distance:

800 • 60 • 10 = 480.000 m

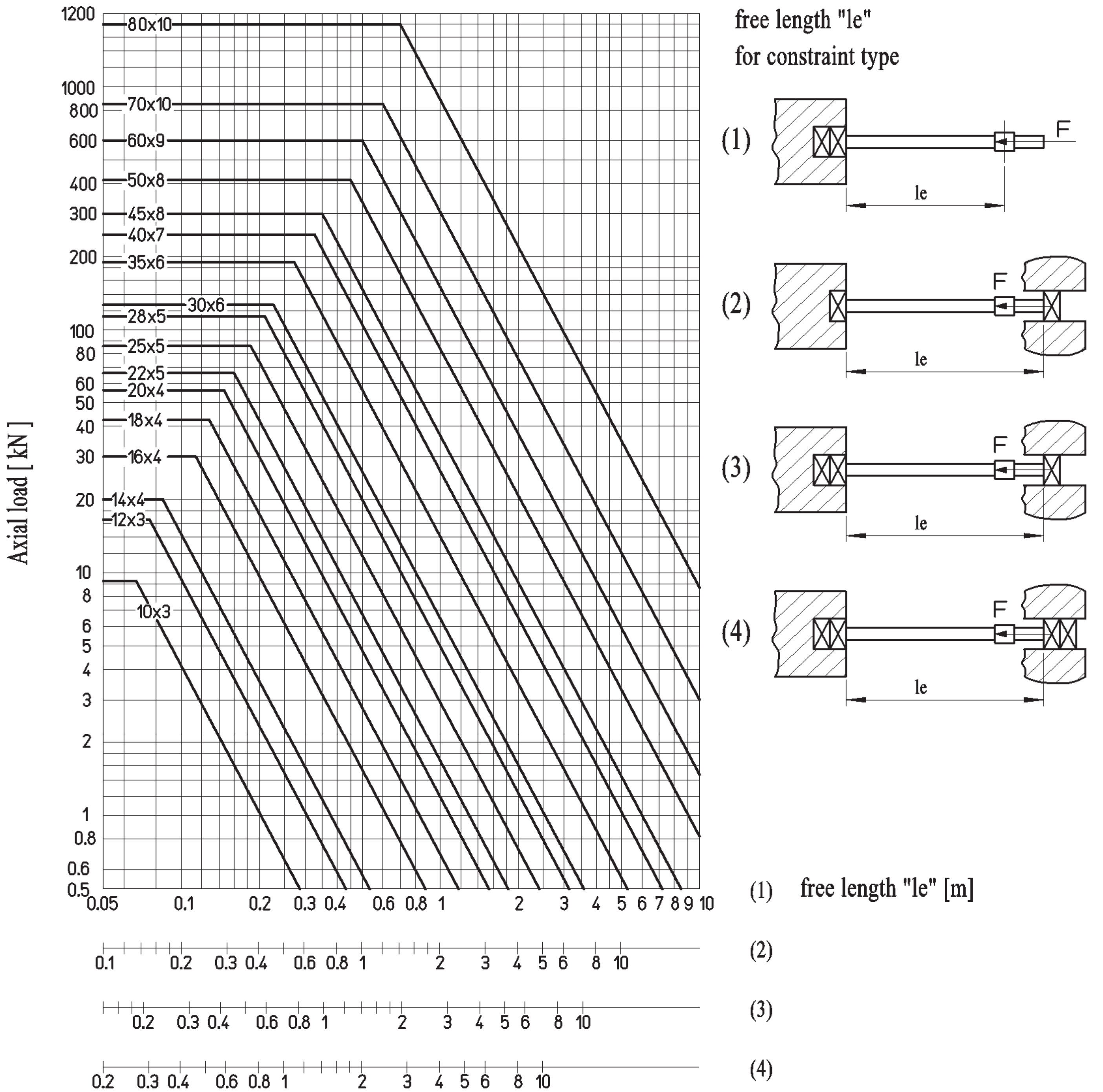
Number of cycles: $\frac{480.000}{2} = 240.000$ cycles

We have a lifetime of 1.600 hrs. at the considered conditions.

Critical Axial Load (Peak Load)

When there are compression loaded screws allowance must be made for limitations due to peak load to avoid screw bending due to excessive axial compression load. Admissible axial load depends on the core diameter (d3) of the screw, end constraints (bearings) and free length 'le'.
Regarding the values given in graph no. 6, allow a minimum safety factor ≥ 2.

Graph no. 6 - Peak Load



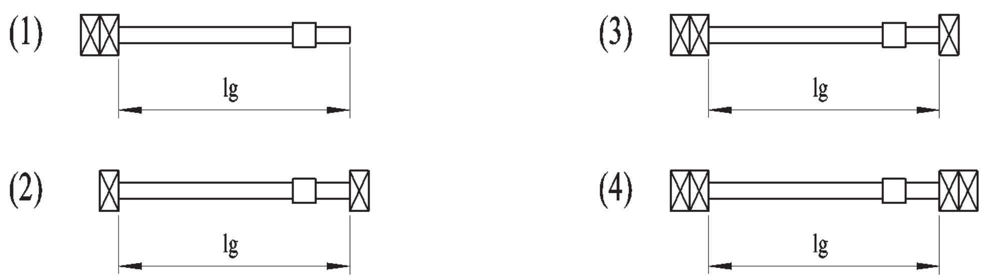
Example: find the admissible axial load of a Tr 30x6 screw 3000 mm long with constraint conditions as in drawing 4.
From graph 6 Take Fmax = 11 kN with safety factor of 2 and assume Fadm = 11/2 = 5.5 kN.

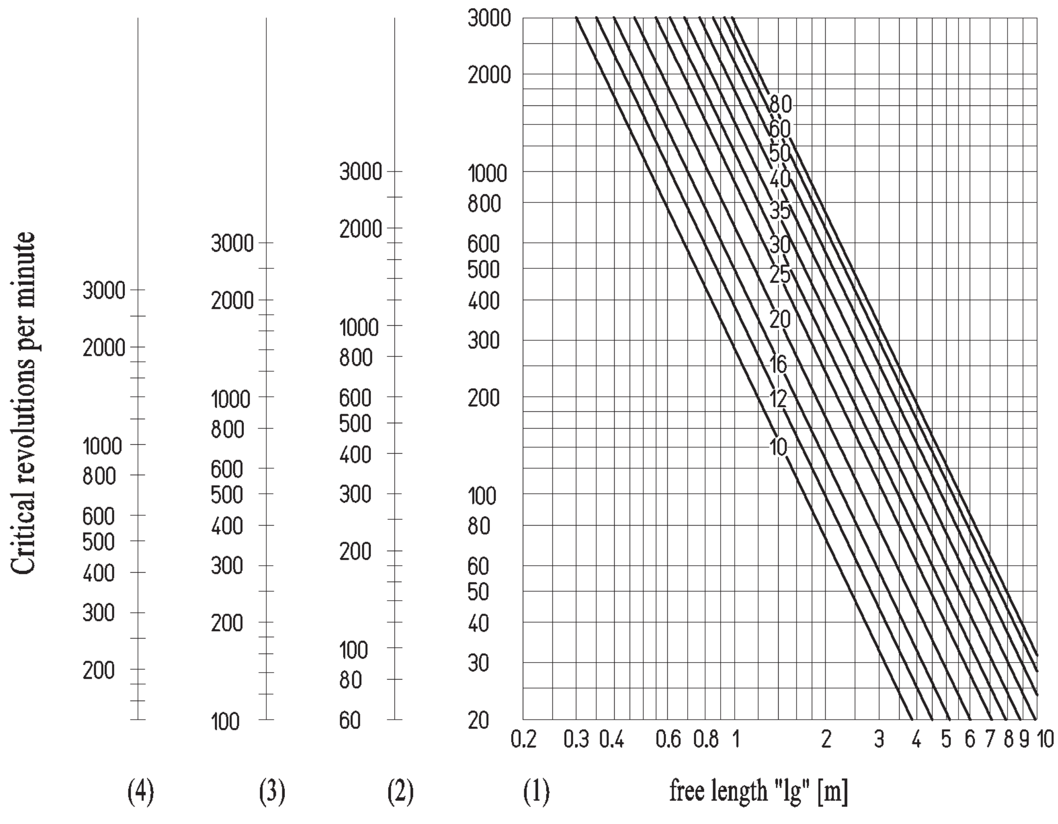
Critical revolutions per minute

The critical revolutions per minute is the rotating speed at which screw vibrations appear. This rotation speed must never be reached because the vibrations cause serious operating irregularities. Critical rpm depend on screw diameter, end constraints (bearings), free length "lg" and from the assembly accuracy.
For values shown in Graph 7 assume a minimum safety factor related to the assembly accuracy as per the following chart:

Chart n°3 Assembly accuracy coefficient:		
Assembly accuracy	**Conditions**	**Safety coefficient**
Good assembly accuracy: - Nut alignment to screw within 0.05mm	Bearing and nut seats obtained from CNC lathe onto an already finished structure.	1.3 – 1.6
Average assembly accuracy: - Nut alignment to screw within 0.10mm	Bearing and nut seats processed on parts which are then assembled together. Alignments are checked by comparators with estreme care after mounting.	1.7 – 2.5
Low assembly accuracy: - Nut alignment to screw within 0.25mm	Bearing and nut seats processed on parts which are then assembled or welded together. Alignments are checked by comparators after mounting.	2.6 – 4.5

Graph no. 7 – Critical rpm





Example: find the critical rpm of a screw Tr 40x7 length 3000 mm with constraint conditions as in drawing 3 with average assembly accuracy. Graph 7 gives critical rotation speed ≅ 1000 rpm
From chart n°3 we calcolate the Safety coefficient = 2.2.
We can reach the working speed at a maximum round speed of: n. max = 1000/2.2 = 454 rpm.

Efficiency

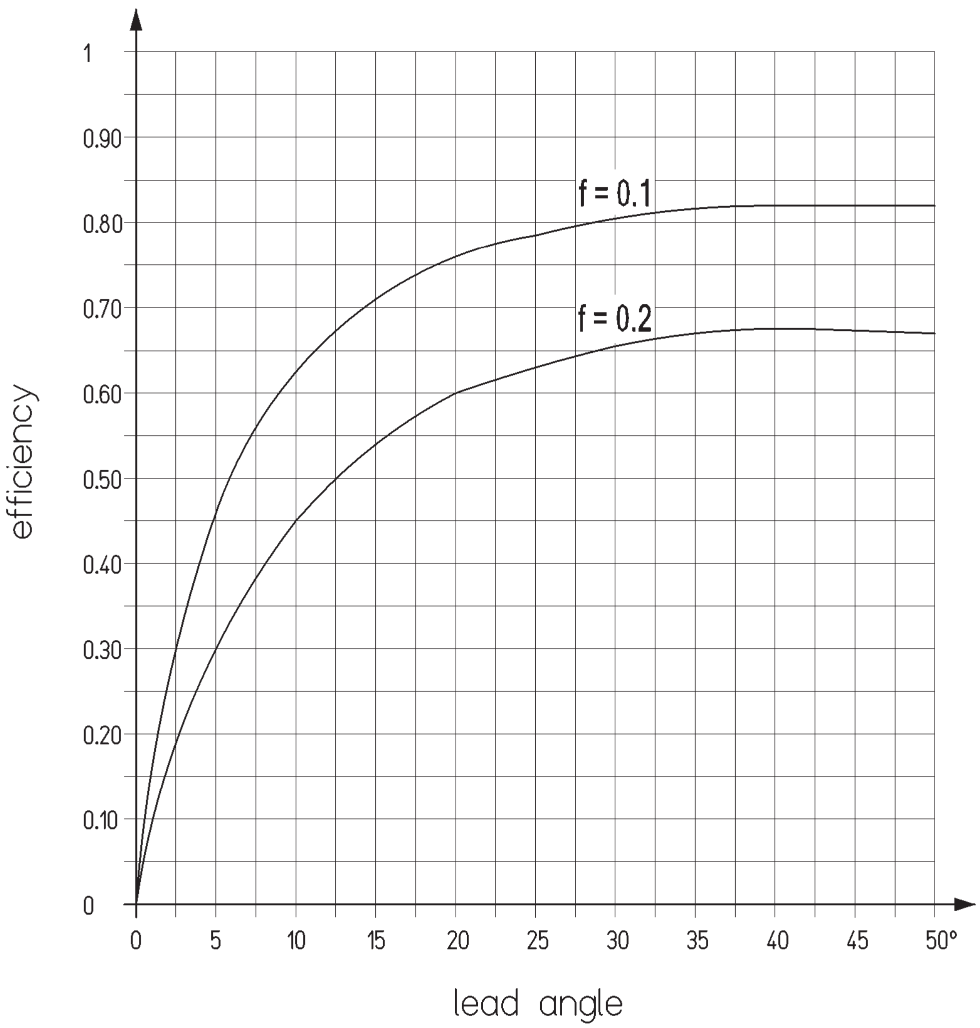
By efficiency is meant the ability of a screw & nut system to convert rotary motion into rectilinear motion. This parameter allows appraisal of how much rotation energy is converted into useful energy for linear movement, hence how much energy is dissipated as heat.
The following formula can be used for calculation.

$$(9) \quad \eta = \frac{1 - f \bullet \mathrm{tg}\alpha}{1 + \dfrac{f}{\mathrm{tg}\alpha}}$$

η = efficiency
f = dynamic friction factor between scew and nut materials
α = lead angle of threads

The numerical efficiency values of each limit are shown in the table 'Screw Specifications' on page 52.

Graph no. 8 – Efficiency



Graph no. 8 shows that efficiency is greater if the lead angle of the screw thread is greater, hence to dissipate less energy as heat, it is recommended to use screws with lead angle as high as possible for the type of work (Pay attention if irreversibility of the system is needed). Efficiency is inversely proportionate to the dynamic friction factor, i.e. using material with a lower friction factor there is less waste of energy. For this reason we make precision rolled trapezoidal screws with minimal roughness on the side of the tooth and always less than 1 µm Ra (usually 0.2 to 0.7 µm). We also make wear-resistant self-lubricating plastic flanged nuts which ensure very low friction factors with no need for lubrication. Dynamic friction factor $f \cong 0.1$, first breakaway $\cong 0.15$.

Torque

The Torque necessary for moving a screw & nut system is calculated by the following equation.

$$(10) \quad C = \frac{F \bullet P}{2\,\pi\,\eta\,1000}$$

C = torque (input) [N•m]
F = axial force on nut [N]
P = true lead of screw [mm]
η = efficiency (assume effeciency with first breakaway friction factor *f*= 0.2, Table on page 52)

Example of calculation :

Find torque necessary for movement of a screw Tr 30x6 coupled with a nut HCL Tr 30x6.

Resistant axial force = 10.000 N
Screw lead = 6 mm
$\eta = 0.26$

$$\text{Torque} = \frac{F \bullet P}{2 \bullet \pi \bullet \eta \bullet 1000} = \frac{10.000\,[N] \bullet 6\,[mm]}{2 \bullet \pi \bullet 0.26 \bullet 1000} = 36.7\ N \bullet m$$

The torque value does not consider the efficiency of mechanical parts moving together with the screw system, such as bearings, belts or other transmission components. In project phase, an increase between the 20 and 30% of the theoretical value is recommended. If electric motors with low static torque are used assume another increase of 50% to find nominal torque.

$C = 36.7\ [N \bullet m] \bullet 1.3 \bullet 1.5 \cong 71.6\ [N \bullet m]$

Power

The power necessary for moving a trapezoidal screw & nut system is calculated with the following equation.

$$(11) \quad P = \frac{C \bullet n}{9550}$$

P = power [kW]
C = torque [N•m]
n = rpm

Example of calculation :

Calculate the power necessary for moving the screw Tr 30x6 of the above example at 600 rpm.

$$P = \frac{C \bullet n}{9550} = \frac{71.6\,[N \bullet m] \bullet 600\,[round/min]}{9550} \cong 4.5\ kW$$

This is the minimum useful power necessary.