Metal cutting manufacturing processes, as well as robotic applications, face the challenge of obtaining ever better precision and finishes.

To foster this vision, Servotak provides the **world most advanced rack&pinion system**, and we mean every word. No competitor can even match our performance.

This catalog is targeted at industrial equipment manufacturers that have both the freedom to select the best product, and the resources to be market leaders, by producing industry leading machines.

Thanks to Servotak SL Linear Systems, you **will** be able to create more precise machines and obtain **better** finishes.

For your every need, our engineers are at your service to study your requirements and offer expert advice.

—P. Bertomeu, Technical Director

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SL 20250131-1300   SL-5

Why Select Servotak

For Our Core Values

A customer's first order is the beginning of a long fruitful professional relationship. Our customers enjoy the benefits of a wide product range and of an experienced engineering team.

For Our Quality

We offer a new standard in linear first class precision transmissions, offering more reliable, smoother and more silent operation, thanks to it's innovative tooth profile.

For Our Innovation

Our products are made using cutting edge and often exclusive machines.

The contents of this catalogue form the foundation for modular translation and/or elevation systems that offer reliable and repeatable positioning, ideal for innovative machine tool solutions, robotics, etc.

For Our Experience

Present in a wide range of industries, including many global leaders in their sector, Servotak products have been used in the most diverse and unique projects, ranging from the ALMA project for the ESA (European Space Agency), to a new 90 meter Gantry machining centre for Alstom, to a PKM (Parallel Kinematics Machine) machining centre for Boeing, to many others…

For Our High Value Offerings

Global marketplaces require excellent supply chain management. We strive not only to offer technical excellence but also high value.

For Our End to End Approach

From motor selection, to rack, pinion, and gearbox, we model, calculate and optimize all the elements of the transmission system. Only with a holistic view can excellence be reached.

For Our Customer Service

From analysis to delivery, we work closely with our customers as our teams analyse each project's issues and requirements.

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SL-6   SL 20250131-1300

What precision does your machine require?

A careful selection of the gearbox-pinion-rack system is vital to obtain the expected results. Each machine type, expected repeatability, error measurement system, etc. has it's particular needs that result in different configurations. Servotak is able to offer improved performance in every case, from cost sensitive solutions to cutting edge solutions for the most demanding machines. For Gantry machining centers, please inquire.
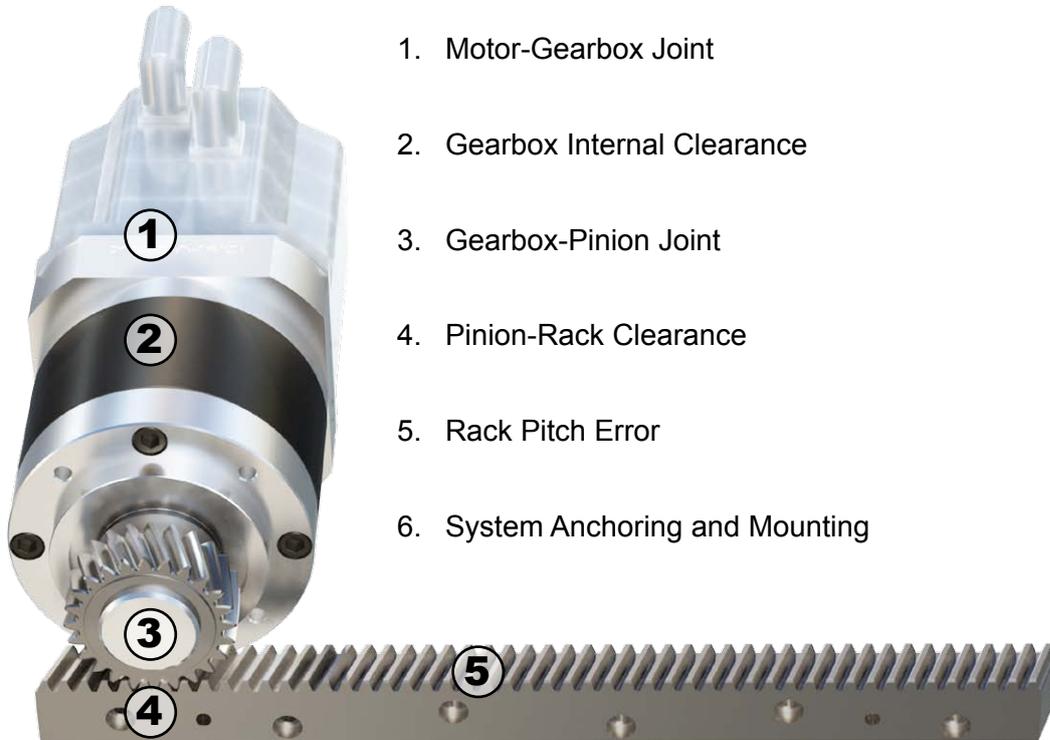
Gearbox-Pinion-Rack System

Linear Precision[1]	Module	Rack Series	Pinion Connection	Recommended Gearbox
±4 µm	0,79577 a 8	Classic Professional Advanced Master	Shrink Disk Integral Pinion	Preloaded System
±6 µm	10 y 12	Classic Professional Advanced Master	Shrink Disk Integral Pinion	Preloaded System
±16 µm	0,79577 a 8	Classic Professional Advanced Master	Shrink Disk ISO 9409-1-A	SG, SGM, SGH, or MQ FG
±19 µm	0,79577 a 12	Basic	Shrink Disk Integral Pinion	Preloaded System
±20 µm	10 y 12	Classic Professional Advanced Master	Shrink Disk ISO 9409-1-A	SG, SGM, SGH, or MQ FG
±30 µm	0,79577 a 12	Basic	Shrink Disk ISO 9409-1-A	SG, SGM, SGH, or MQ FG
±57 µm	0,79577 a 8	Classic Professional Advanced Master	DIN5480 Splined Joint	SG, SGM, or SGH
±60 µm	10 y 12	Classic Professional Advanced Master	DIN5480 Splined Joint	SG, SGM, or SGH
±72 µm	0,79577 a 12	Basic	DIN5480 Splined Joint	SG, SGM, or SGH
±140 µm	0,79577 a 8	Classic Professional Advanced Master	DIN 6885.1 Keyed Joint	SG, SGM, SGH, or MQ
±140 µm	10 y 12	Classic Professional Advanced Master	DIN 6885.1 Keyed Joint	SG, SGM, SGH, or MQ
±155 µm	0,79577 a 12	Basic	DIN 6885.1 Keyed Joint	SG, SGM, SGH, or MQ

[1] Approximate values. Actual values require a full system study. Our engineers are at your disposal.

Typical machines: Machining centers, milling machines, travelling columns, Gantry machines, boring machines, broaching machines, laser machines, punching machines, metal sheet procesing, track motion for robotics, multi-axis manipulators, etc.

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Positioning Error Sources in Rack&Pinion Systems

Conventional linear transmission systems are composed of a motor, a gearbox, a pinion and a rack. The following sources can introduce transmission errors in them:

1. Motor-Gearbox Joint

2. Gearbox Internal Clearance

3. Gearbox-Pinion Joint

4. Pinion-Rack Clearance

5. Rack Pitch Error

6. System Anchoring and Mounting

Ignorable Factors

Modern systems' motor-gearbox joints can be ignored for rigid couplings only, it must be considered for flexible couplings though.

Appropriate mounting and anchoring, as well as a proper anchor point machining, will serve to minimize this error source.

Inevitable factors

The rack's pitch error can only be reduced by using higher quality racks, but it can never be completely eliminated.

Key factors

Reduced backlash gearboxes can be used to avoid internal gearbox clearance related errors.

An appropriate selection of the pinion-gearbox joint system is essential. Servotak recommends shrink disks, ISO 9409-1-A flanges, or integral pinions for high precision systems

Rack-Pinion clearance can only be avoided by the use of preloaded systems.

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SL-8   SL 20250131-1300

Preload

What is it?

Single drive systems, even those that use zero-backlash gearboxes, will have to contend with the pinion-rack backlash. In order to eliminate it, it is necessary to employ dual pinions engaging opposite teeth flanks of the rack's teeth. This is what constitutes the preload, and it can be obtained by either mechanical or electronic means.

How to obtain it?

Mechanical preload is obtained via either a single gearbox with two pinions, or via a gearbox assembly featuring dual output shafts, with two pinions. It must be manually set up and adjusted, and requires only one motor.

Electronic preload uses twin gearbox-pinion-motor systems, and is software controlled, using one motor as a brake for the other.

What are it's advantages and disadvantages?

Electronically preloaded systems require two servomotors, two drives, and a larger distribution panel, on top of a more complex software suite.

Mechanically preloaded systems do not requite any external element to control the preload.

Both systems eliminate both the gearboxes internal backlashes, and the pinion-rack backlashes, with the only error source remaining being the rack's pitch error.

These systems also represent larger investments, and can thus only be justified in projects that require the increased precision.
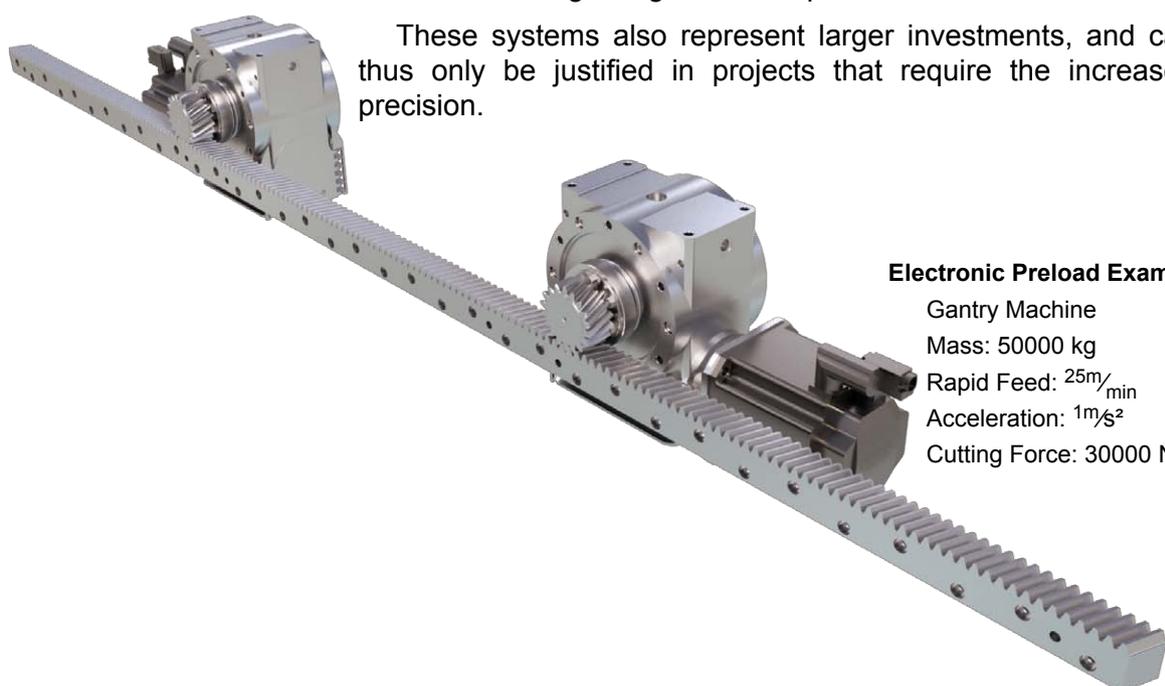
Electronic Preload Example
Gantry Machine
Mass: 50000 kg
Rapid Feed: $25m/min$
Acceleration: $1m/s^2$
Cutting Force: 30000 N

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High performance tooth profile

Professional, **Advanced** and **Master** series racks, and all pinions, have optimized teeth, offering the following advantages:

- Reduced sliding speed

- Greater tooth safety factors

- Cooler and quieter operation

- Better load distribution, reducing surface stress (Hertzian pressure)

- Greater torque transmission due to a larger contact surface and a higher contact ratio

- Mesh misalignments compensation

- Longer service life
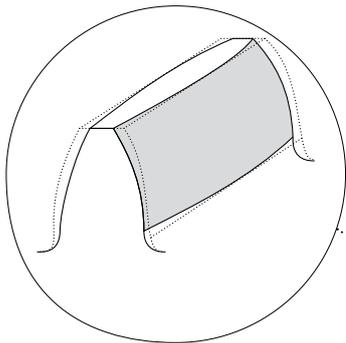
Pinion detail,
highlighting crowning
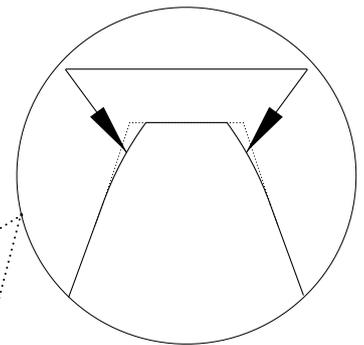
Tooth profile detail,
highlighting tip-relief
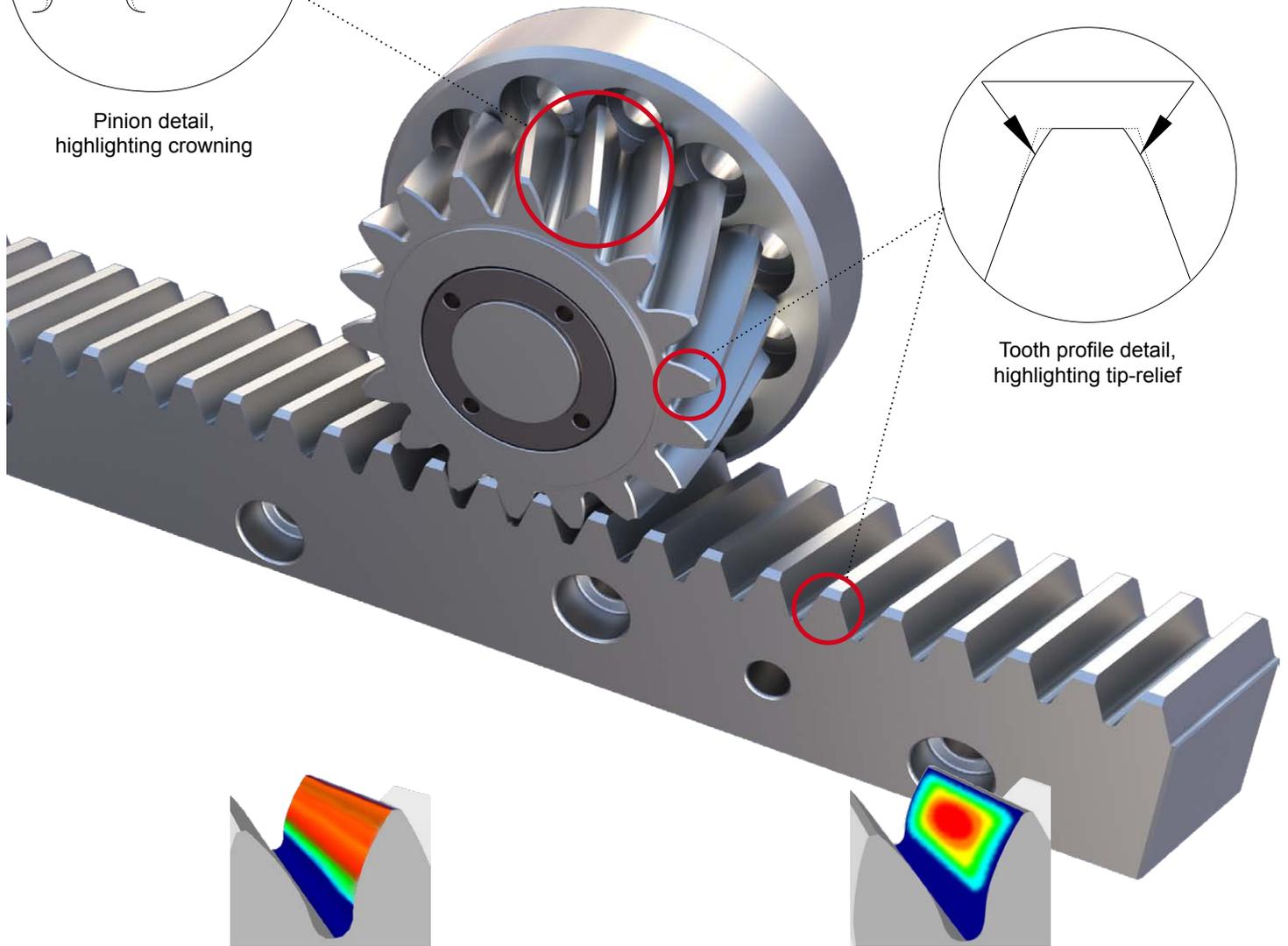
Unoptimized
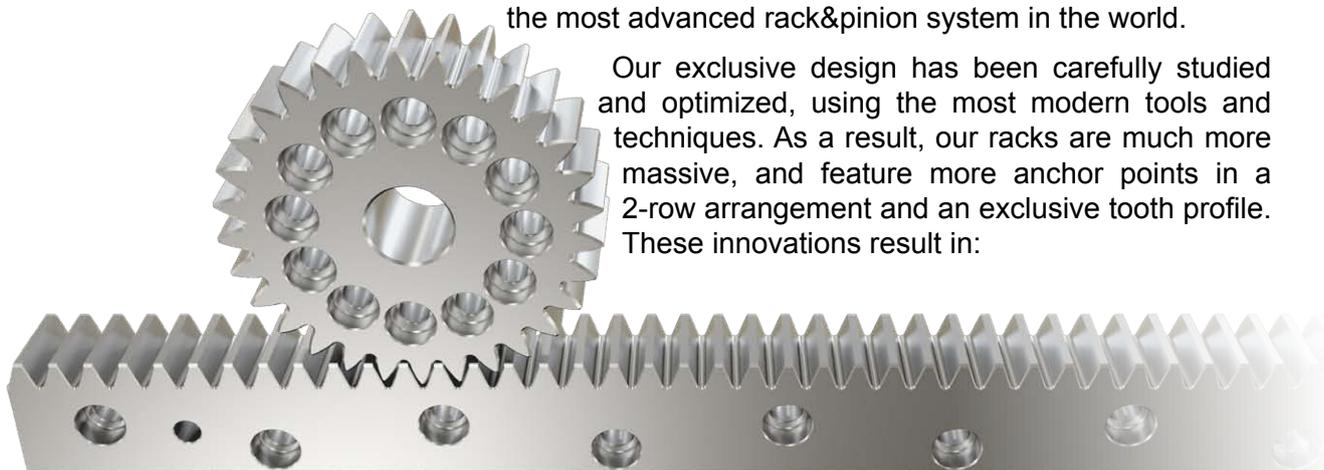Normal force distribution in a
conventional rack&pinion system

Optimized
Normal force distribution in a Servotak
Advanced or Master series system

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SL-10   SL 20250131-1300

For the Most Exacting Machines

State-of-the-art Rack&Pinion Systems

Modern machining processes, such as drilling, milling, grinding and lathing face ever increasing requirements of precision and finishing quality. That was the drive behind Servotak's design of the most advanced rack&pinion system in the world.

Our exclusive design has been carefully studied and optimized, using the most modern tools and techniques. As a result, our racks are much more massive, and feature more anchor points in a 2-row arrangement and an exclusive tooth profile. These innovations result in:

- **Sturdier machines.** The 2-row V-shaped hole pattern optimizes distance between the contact point and the anchor points, resulting in a better force distribution, dampening bending stress (even during starts and stops) and thus reducing failure risk.

- **Better finishes**. Thanks to a significant vibration reduction, our system features a much smoother operation. This translates in finer machining for machine tools, and cleaner trajectories in robots.

- **Greater Load Capacity.** Thanks to it's increased stiffness, our systems exhibit much higher natural and resonance frequencies, consequently allowing for higher accelerations and greater speeds on more massive loads.

- **Easier installation:** Our exclusive tooth profile allows for greater tolerance to mounting distance variations, reducing installation costs and times.

Servotak SL Linear Systems are thus the best option for the most demanding applications

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SL 20250131-1300   SL-11

Servotak High Precision Linear Systems

Description and characteristics

Servotak offers four rack&pinion system series, **Basic**, **Professional**, **Advanced** and **Master**. With 15 metric modules for straight teeth systems, and 12 for helical teeth systems, they cover all the industry requirements.

The series vary in materials, heat treatments, quality levels and surface finishes; and can withstand up to 380000N. Advanced and Master series systems have been designed from the ground up with machine tools in mind, where repeatability, stiffness and reliability requirements are paramount.

Servotak racks are taller and more massive than conventional ones. This added mass imparts greater stiffness to the system, to better dissipate overloads. Racks with holes for continuous mounting include two pin holes, and a greater number of anchor points, on a 2-row V-shaped pattern, for added safety in emergency situations.

The angle of the helical tooth is 19º31'42", designed to allow the use of these systems without resorting to linear encoders.

In addition to the contents of this catalogue, it is possible to deliver rack&pinion systems to customer specifications.

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SL-12   SL 20250131-1300

Materials and Heat Treatments

Basic Series (Racks)

C45 steel, quenched and tempered

Basic series racks are made of C45 steel, quenched and tempered, for a final tensile strength of 700 N/mm^2. Teeth are milled to DIN 3962 class 8 precision, and receive no further heat treatment. Flat surfaces are ground.

Classic Series (Racks)

C45 steel, induction hardened and tempered

Classic series racks, made of C45 steel. receive a high frequency induction heat treatment, followed by tempering, for a final surface hardness of 55-57 HRC. Teeth are ground to DIN 3962 class 6 precision. Teeth are given tip-relief. Flat surfaces are ground.

Professional Series (Racks)

C45 steel, induction hardened and tempered

Advanced series racks, made of C45 steel. receive a high frequency induction heat treatment, followed by tempering, for a final surface hardness of 58-60 HRC. Teeth are ground to DIN 3962 class 5 precision for modules up to 8, and to DIN 3962 class 6 precision for module 10. Teeth are given tip-relief. Flat surfaces are ground.

Advanced Series (Racks)

C45 steel, induction hardened and tempered

Advanced series racks, made of C45 steel. receive a high frequency induction heat treatment, followed by tempering, for a final surface hardness of 58-60 HRC. Teeth are ground to DIN 3962 class 5 precision for modules up to 8, and to DIN 3962 class 6 precision for modules greater than 8. Teeth profiles are optimized, with tip-relief, for longer service life, smoother and quieter operation even under heavy loads, and reduced tooth base stress. Flat surfaces are ground.

Master Series (Racks and Pinions)

### 18CrNiMo5 steel, case hardened and tempered

Master series racks and pinions are made of 18CrNiMo5 steel, case hardened and tempered, for a final surface hardness of 60-62 HRC. Teeth are ground to DIN 3962 class 5 precision for modules up to 8, and to DIN 3962 class 6 precision for modules greater than 8. Teeth profiles are optimized, with tip-relief, for longer service life, smoother and quieter operation even under heavy loads, and reduced tooth base stress. Flat surfaces are ground.

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Rack&Pinion Selection

Follow the steps below to properly select the correct linear system for your project:

1. Based on load type, work cycle duration and starts/hour, determine the safety factor.[1], ranging from 1.5 to 3.

2. Multiply the actual tangential force by the safety factor to obtain the adjusted tangential force.

3. Select the tooth type (straight or helical) based on the application.

4. Using the adjusted tangential force, the linear translation speed, the precission and repeatibility required, and the selected tooth type, obtain the rack series and module using the corresponding rack selection charts.

5. On the basis of the torque to transmit, the gearbox used, its rotational speed, etc, select the most appropriate pinion.

In addition to the contents of this catalogue Servotak offers a wide range of precision gearboxes, ideally suited for your every need. Our engineers can assist you in selecting the proper system for your application, as a holistic vision of the rack-pinion-gearbox system results in more coherent systems that offer improved reliability and optimizes costs.

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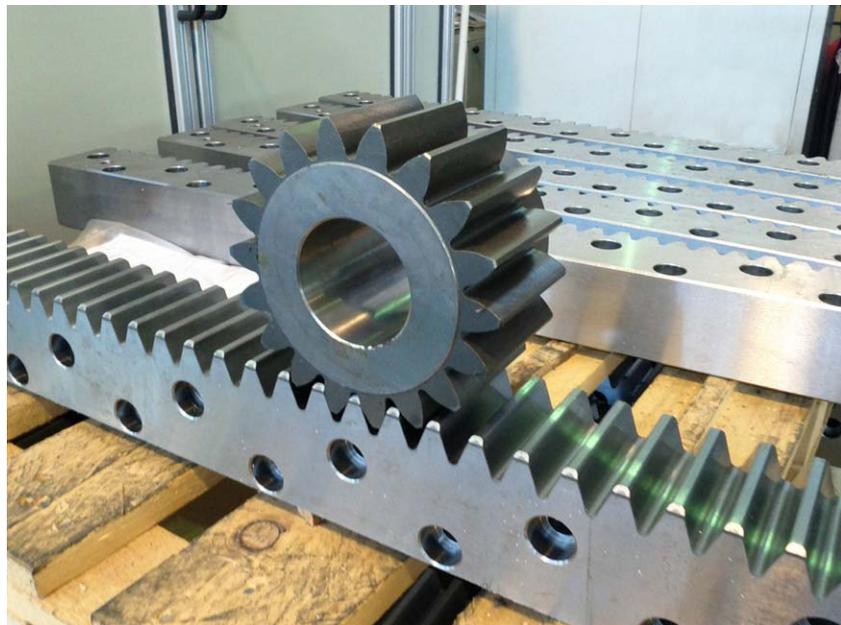
1   ISO6336, DIN3690 and DIN3991 norms recommend using a safety coefficient from 1 to 2.25. Depending on the application, our experience has lead us to recommend even greater safety factors. Our engineers can provide assistance for the proper selection of this safety coefficient. As the charts represent theoretical performance in ideal conditions, and thus do not include shocks or structural distortion, and assume permanent lubrication, appripriate asembly, and a pinion bearing adjacent to the teeth, this coeficient is necessary to ensure proper operation

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SL-14   SL 20250131-1300

Examples

Calculation Example Nr. 1: Elevator

Data:

Load m = 750 kg

Acceleration a = 2 $\frac{m}{s}$

Linear Speed V = 1 $\frac{m}{s}$

System Efficiency η = 95%

Safety Factor C_s = 3

Gravity Acceleration g = 9.81 $\frac{m}{s^2}$

Calculations:

Actual Vertical Tangential Force

$$F_{vr} = \frac{m \cdot (g+a)}{\eta} = \frac{750 \cdot (9.81+2)}{0.95} = 9324 \text{ N}$$

Adjusted Vertical Tangential Force

$$F_{vc} = F_{vr} \cdot C_s = 8858 \cdot 3 = 27972 \text{ N}$$

Using the appropriate "Rack Selection Charts", find the type, module and series of the rack to employ.

Selected Rack Series: Advanced

Teeth Type: Straight

Selected Module m_n = 5

Rack Tangential Force ≥F_{vc} = 28000 N

Constraint: Maximum pinion diameter d_a = 120mm

Nr of Teeth Z = 20

External Diameter d_a = 116.5 mm

Internal Diameter d = 105.5 mm

Actual Torque on Pinion

$$M_r = \frac{d \cdot F_{vr}}{2 \cdot 1000} = \frac{105.5 \cdot 9324}{2000} = 462 \text{ Nm}$$

Rotational Speed on Pinion

$$n = \frac{V \cdot 60 \cdot 1000}{Z \cdot m_n \cdot \pi} = \frac{1 \cdot 60000}{20 \cdot 5 \cdot \pi} = 191 \text{ rpm}$$

Recommended Gearboxes (Assuming 2000 rpm motor):

Coaxial:

SERVOTAK-SG-800-M1-P-XX-10-Motor Type
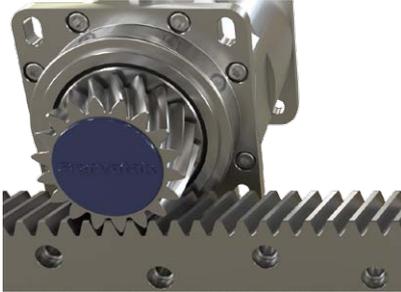
Specs: i = 10, T_{2N} = 600 Nm, T_{2not} = 1800 Nm

Orthogonal:

SERVOTAK-MQ-100-X-H-XX-10-SK-Motor Type

Specs: i = 10, T_{2N} = 555 Nm, T_{2not} = 1700 Nm

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SL 20250131-1300   SL-15

Calculation Example Nr. 2: Conveyor

Data:

Load m = 750 kg

Acceleration a = 2 $\frac{m}{s^2}$

Linear Speed V = 1 $\frac{m}{s}$

System Efficiency η = 95%

Friction Coefficient μ = 0.05

Safety Factor C_s = 3

Gravity Acceleration g = 9.81 $\frac{m}{s^2}$

Calculations:

Actual Horizontal Tangential Force

$$F_{hr} = \frac{P \cdot (g \cdot \mu + a)}{\eta} = \frac{750 \cdot (9.81 \cdot 0.05 + 2)}{0.95} = 1966 \text{ Nm}$$

Adjusted Horizontal Tangential Force

$$F_h = F_{hr} \cdot C_s = 1966 \cdot 3 = 5898 \text{ N}$$

Using the appropriate "Rack Selection Charts", find the type, module and series of the rack to employ.

Chosen Rack Series: Basic

Teeth Type: Helical

Selected Module: 4

Rack Tangential Force ≥F_{hc} = 8100 N

Constraint: Must use a 2000 rpm motor and the following gearbox:
Ref.: SERVOTAK-SG-300-M1-G-10-10-Motor Type

Ratio i = 10

Nominal Output Torque T_{2N} = 160 Nm

Emergency Stop Torque T_{2not} = 480 Nm

Pinion Sizing Calculation:

Maximum Number of Teeth:

$$Z_{max} = \frac{V \cdot 60 \cdot 1000}{\frac{n_1}{i} \cdot m \cdot \pi} = \frac{1 \cdot 60000}{200 \cdot 4 \cdot \pi} = 23.9$$

Z_{max} = 23 teeth

Available Values:
Z: 18, 20, 21 and 22

We select **Z=20**

Pinion Pitch Diameter d = 89.28 mm

Actual Torque on Pinion

$$M_r = \frac{d \cdot F_{hr}}{2 \cdot 1000} = \frac{89.28 \cdot 1966}{2000} = 88 \text{ Nm}$$

As $M_r < T_{2B}$, this pinion meets the desired specifications.

Servotak offers an online tool to assist you.
Visit http://www.servotak.com/tools/engineering_calculator..

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SL-16   SL 20250131-1300

Practical Example

Rack Series Influence in Module Determination

Rack series	Basic, Advanced y Master
Required Tangential Force:	7500 N
Safety Factor C_S:	3
Adjusted Tangential Force:	22500 N
Speed:	1 $^m/_s$
Teeth:	Straight
Nr. of Pinion Teeth:	Z=20
Acceleration:	3 $^m/_{s^2}$
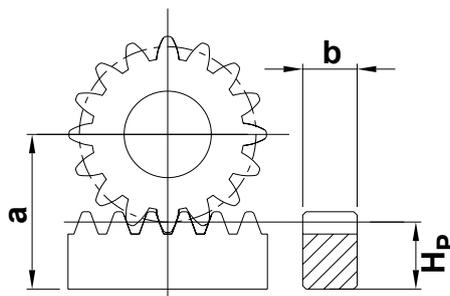
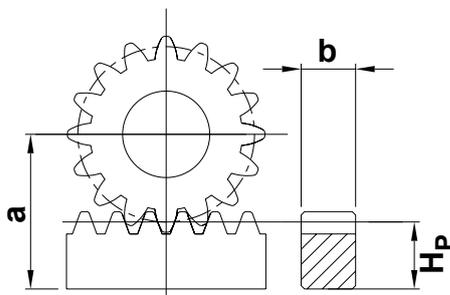| m [mm]	b [mm]	H_P [mm]	a [mm]	n_p [rpm]	M_p [Nm]	F_{Tp} [N]	Rack series and profile [Approximate Teeth Size]
8	80	85,90	170,74	240	2230	27900	**Basic** — Quenched and Tempered
5	50	59,28	112,32	380	1400	28000	**Advanced** — Induction Hardened and Tempered
4	36	45,45	87,87	480	1080	27000	**Master** — Case Hardened and Tempered
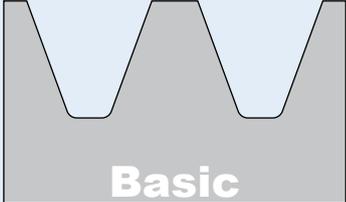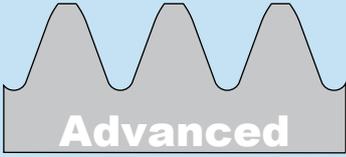
m: Module
n_p: Pinion Rotational Speed
M_p: Torque on Pinion
F_{Tp}: Maximum Allowable Tangential Force on Pinion, according to charts

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SL 20250131-1300   SL-17

Performance Sumary Table

For Pinion Z=20 and Speed=1 $^m/_s$

Teeth	Module	b	H_P	a	n_p	Basic		Advanced		Master	
						M_p	F_{Tp}	M_p	F_{Tp}	M_p	F_{Tp}
	[mm]	[mm]	[mm]	[mm]	[rpm]	[Nm]	[N]	[Nm]	[N]	[Nm]	[N]
Straight	0,79577	10	24,20	32,63	1200	2,8	350	6,5	800	11	1400
	1	10	24,00	34,57	960	4,4	450	10,5	1050	17,5	1750
	1,25	10	23,75	36,95	760	7	550	16,5	1300	27,5	2200
	1,5	15	23,50	39,32	640	15	1000	35	2300	59	3900
	1,59155	15	23,41	40,19	600	17	1100	40	2500	67	4200
	2	20	28,00	49,10	480	35	1750	83	4150	140	7000
	2,5	20	27,50	53,90	380	55	2200	130	5200	220	8800
	3	30	37,00	68,72	320	118	3900	280	9300	470	15700
	3,18310	30	36,82	70,46	300	130	4100	315	9900	530	16700
	4	36	45,45	87,87	240	250	6300	640	16000	1080	27000
	5	50	59,28	112,32	190	550	11000	1400	28000	2360	47200
	6	55	68,15	131,82	160	865	14400	2210	36800	3730	62200
	8	80	85,90	170,74	120	2230	27900	5730	71600	9680	121000
	10	100	93,60	199,68	95	4360	43600	11200	112000	18900	189000
	12	120	111,35	238,68	80	7200	60000	18800	157000	31800	265000
Helical	1	10	24,00	35,18	900	6	550	14	1300	24	2300
	1,25	10	23,75	37,71	720	9	700	21	1600	36	2700
	1,5	15	23,50	40,24	600	20,5	1300	49	3100	82,5	5200
	2	20	28,00	50,32	450	49	2300	115	5400	195	9200
	2,5	20	27,50	55,42	360	73	2750	170	6400	290	10900
	3	30	37,00	70,55	300	163	5100	385	12100	650	20400
	4	36	45,45	90,31	230	345	8100	900	21200	1520	35800
	5	50	59,28	115,37	180	760	14300	2010	37900	3400	64000
	6	55	68,15	135,48	150	1180	18500	3110	48900	5260	82600
	8	80	85,90	175,62	110	3100	36500	8270	97400	13980	164700
	10	100	93,60	205,79	90	6020	56700	16150	152000	27300	257000
	12	120	111,35	246,00	75	10800	85000	27400	215000	46500	365000

m: Module
n_p: Pinion Rotational Speed
M_p: Torque on Pinion
F_{Tp}: Maximum Allowable Tangential Force on Pinion, according to charts

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SL-18   SL 20250131-1300

Rack Profiles Shown at Actual Size

Module 0.79577

Module 1

Module 1.25

Module 1.5

Module 1.59155

Module 2

Module 2.5

Module 3

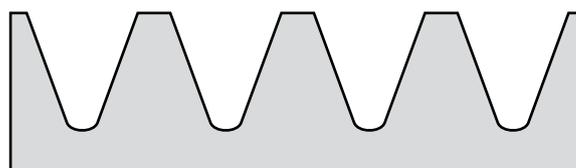**Module 3.18310**
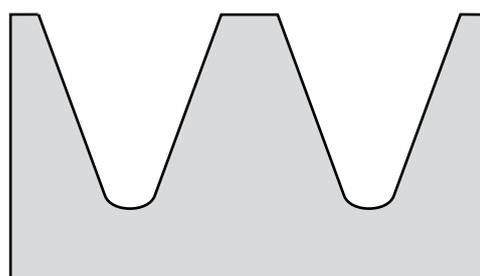
Module 4
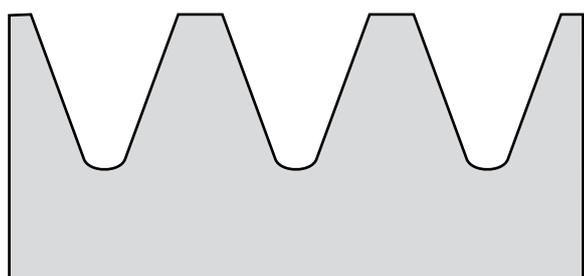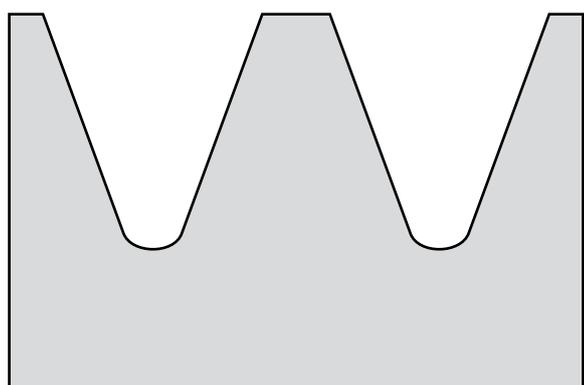
Module 5

Module 6

Module 8

Module 10

Module 12

Notes:

- Outer tooth profiles are approximate.

- In order to fit all profiles on this page, rack sections have been cropped at the bottom.

- Aproximate size. Final print size may vary slightly due to the printing process.