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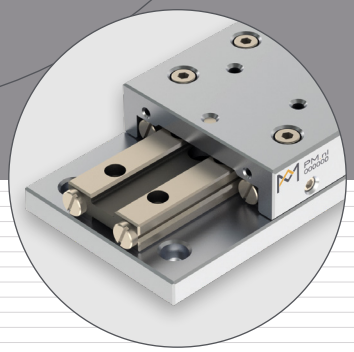
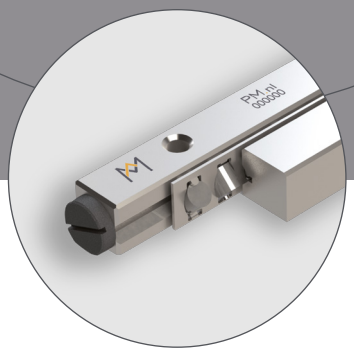
THE 7 KEY CAUSES OF LINEAR GUIDES FAILURE – AND HOW TO AVOID THEM





A MUST-READ FOR ENGINEERS

INTRODUCTION

Precision linear guides offer great advantages in terms of high stiffness, high accuracy and low friction. But as with any other mechanical component: if they are not installed and operated properly, failures may occur, often with disastrous consequences for the equipment and high costs for the user. These failures can even result in reputational damage.

Our experts analysed the most common causes of unexpected failure of precision linear guides. They did so to help users make the right choices, thus reducing failure costs and improving customer trust. They noticed that many of the failures can be retraced to a few main causes. Seven of these are discussed in this e-book.

This publication stands out from other documents because of its focus on the causes, not the issues. By addressing the reasons for failure before offering a solution, we aim to prevent the various problems. Consequently, this booklet provides practical advise for maximum linear guide performance and maximum operational life.

Do you have additional information to share about linear bearings? Please do let us know by sending an e-mail to info@PM.nl. We will consider your input for a future edition of this e-book.

We hope to be of service to you with this publication. Would you like to learn more? Feel free to contact our experts. They are happy to help you.

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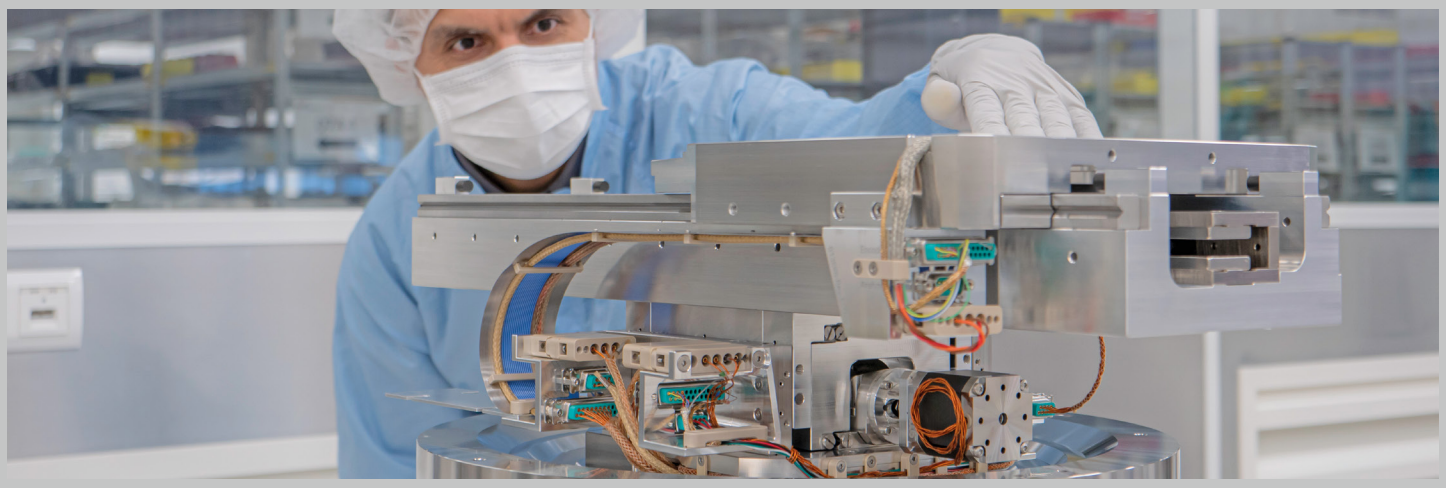
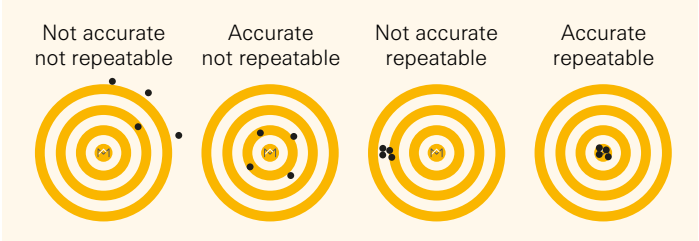


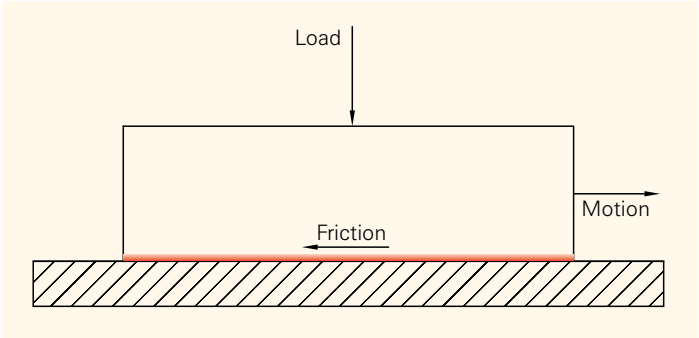
TERMINOLOGY

- **Accuracy:** How close a certain output is to the value it should be. For example: the accuracy of a measurement reflects how close the measured value is to the actual value. For a linear system, this means the degree to which the final position matches the commanded position.



- **Cage:** A metal or plastic strip used between a pair of guide ways that contains the rolling elements. It keeps these elements seperated to avoid mutual contact between the rolling elements and to reduce friction and wear.

- **Friction:** The force (mechanical resistance) created between two moving surfaces, or surfaces that are trying to move.



- **Linear bearing / linear guide:** Mechanical component which enables accurate, low-friction linear motion at high stiffness values for all directions except for its movement direction.

- **Play:** The amount of displacement a component can freely make, sometimes also called backlash. Precision linear guides are normally, in assembled condition, preloaded, to make sure all components are pressed together and no play exists.

- **Preload:** The force applied to the inside of the linear guides to make sure all components are fully into contact, and all play is eliminated. Preload may be force-driven (for example, by adjusting torque on a set screw) or geometrical (for example, by fitting rollers into slides which are slightly larger than the internal space, so that the rollers are prestressed). This makes the linear guide stiffer and its movement more accurate and smooth.

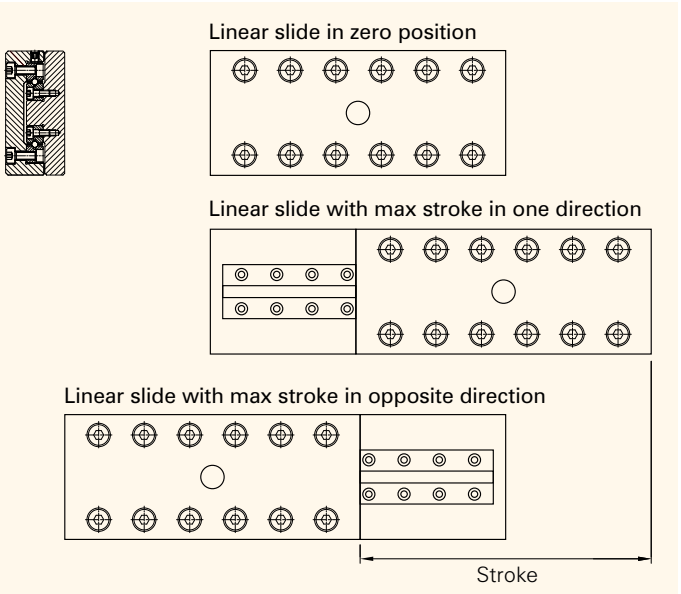
- **Raceway:** In a linear guide, this is the V-groove machined in the inside of the rail. When a pair of rails is aligned, these grooves form the tracks (points of contact) on which the rolling elements move.

- **Repeatability:** A system's ability to return to the same position multiple times under identical conditions. This is an absolute value.

- **Rolling element pitch:** The distance between each rolling element in a cage.

- **Stiffness:** To what extent an object deforms when you apply a force to it.

- **Stroke:** The maximum extent of movement.



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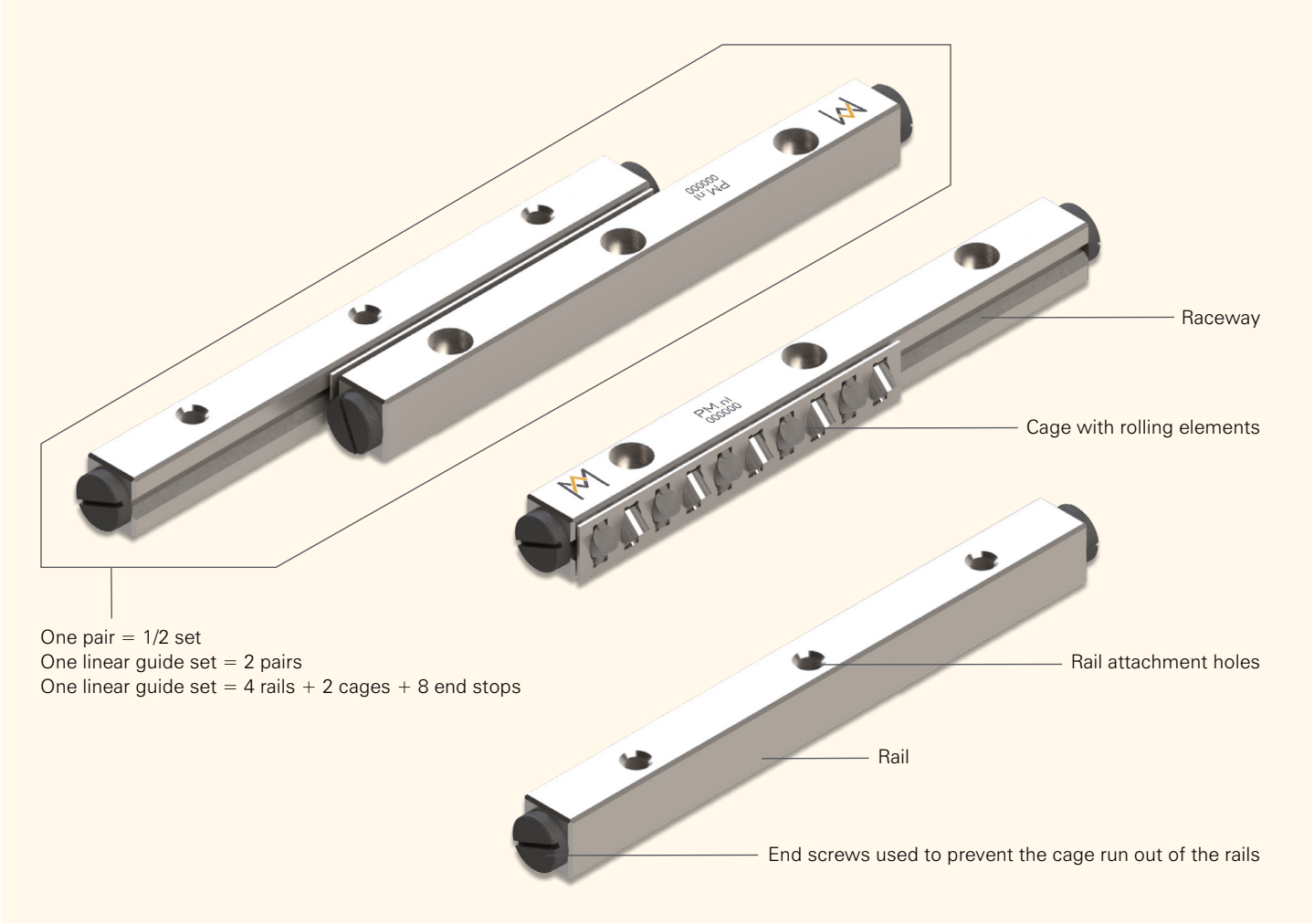
The parts of a precision linear guide set



One pair = 1/2 set
One linear guide set = 2 pairs
One linear guide set = 4 rails + 2 cages + 8 end stops

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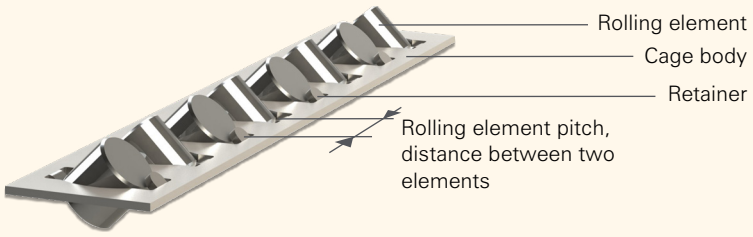
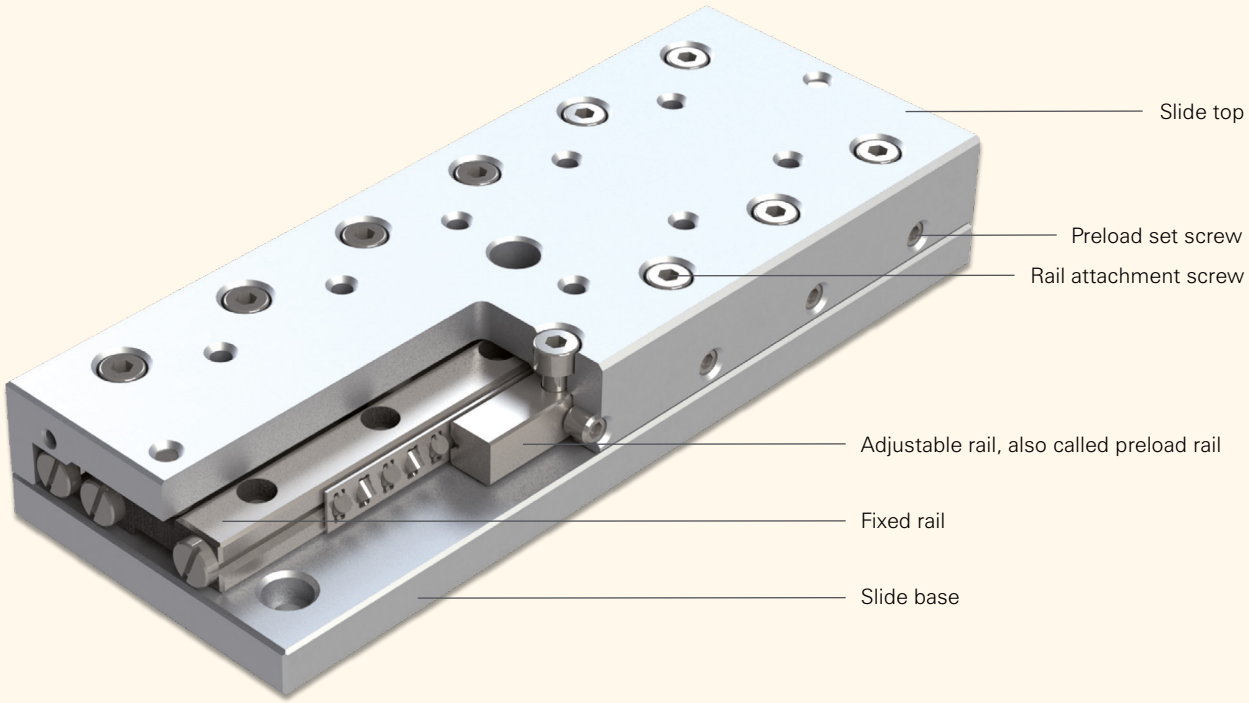
The parts of a cage



The parts of a frictionless linear slide



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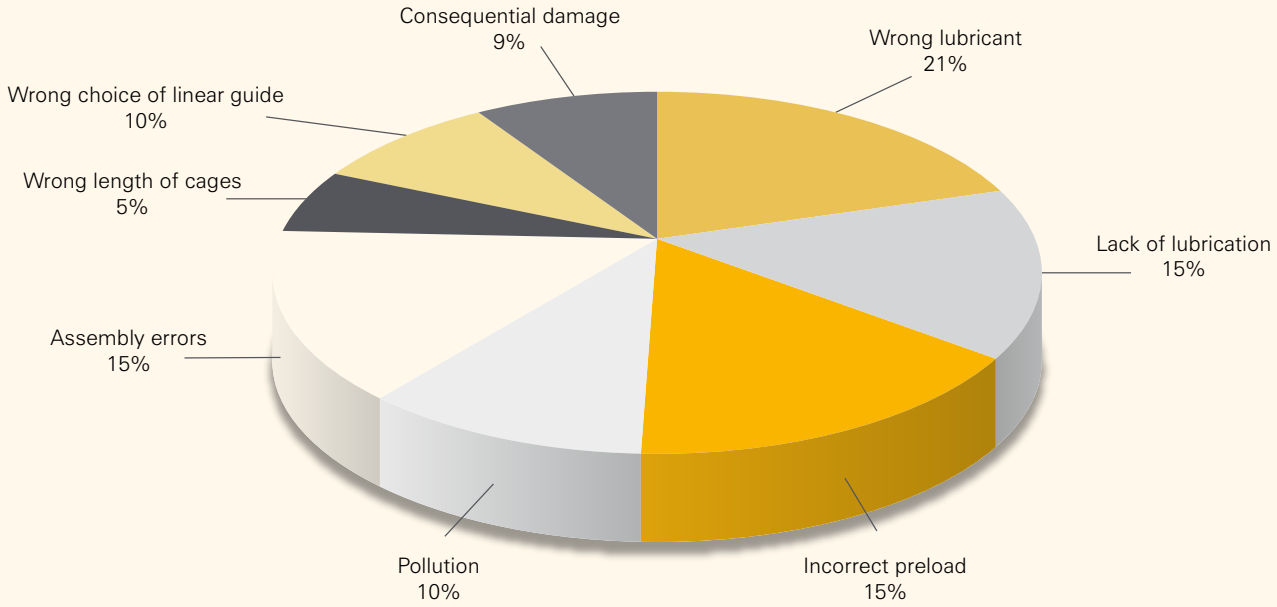
THE 7 KEY CAUSES OF LINEAR GUIDES FAILURE – AND HOW TO AVOID THEM

Main causes of linear guides failure



In the chart above, our experts have listed a total of eight causes of premature failure of precision linear guides. On the next pages, we will discuss the seven most common ones and provide possible solutions.

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CAUSE 1. WRONG CHOICE OF LUBRICANT

Lubrication significantly reduces the friction between parts that move relative to each other and reduces peak stress in the material. When the cage does not move smoothly along with the rails' movement, a disruption in the movement occurs, resulting in internal friction and, in some cases, vibrations.

Under normal conditions, a thin film of lubricant is present between the rolling element and the raceway. When the lubricating film is no longer intact, metal-to-metal contact between the rolling elements and the raceways occurs. Over time, the metal-to-metal contact causes wear. In case of long-stroke applications, this often expresses itself as abrasive wear or pitting. Short stroke applications, in which the roller typically makes a movement smaller than its circumference, tend to show false brinelling.

Improper lubrication may result in:

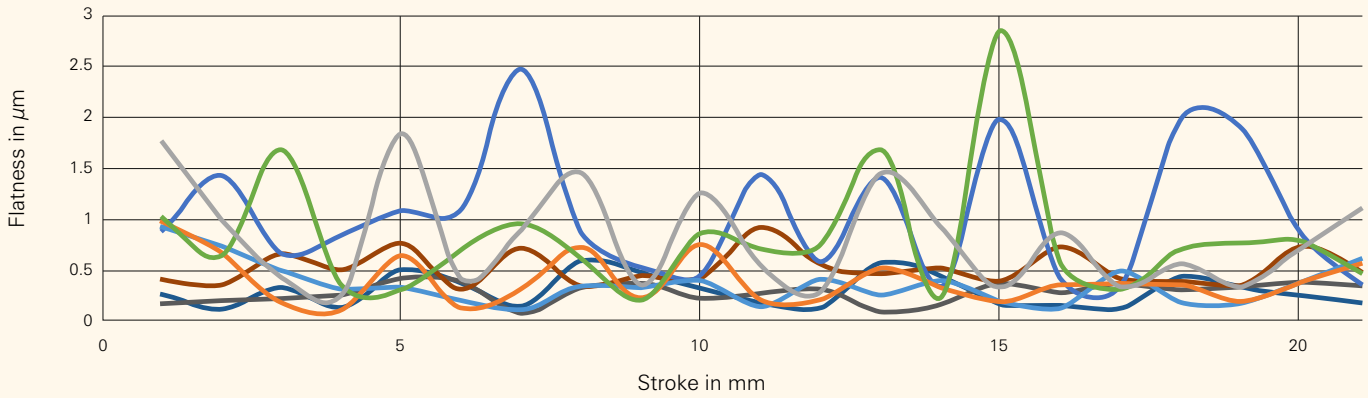
- Premature failure of the linear guide.
- Irregular and/or excessive friction, deteriorating settling times and thus throughput.
- Reduced precision/repeatability.

Lubrication also has an impact on the accuracy and repeatability of linear bearings. The diagram below shows the impact on the performance of a linear stage equipped with cross-roller linear guides that use various lubricants. Each colour represents a measurement with a different lubricant.

POSSIBLE SOLUTIONS

The requirements for lubricants are determined by the application. Please keep the following in mind:

1. Sustaining a lubricating film with a short stroke and at high-frequency oscillating movements is challenging. Therefore, we recommend regular lubrication strokes in the application. The minimum lubrication stroke equals the roller circumference. As a result, the lubrication will be distributed evenly among the raceways, and a lubricant film will be maintained.
2. Always use the oils and greases advised by the manufacturer. At PM, we recommend the type of lubricant that during internal validation of our products. This way, you can be sure that the risk of failure is minimised and performance is guaranteed.
3. Never blend the lubricant with other types or brands: one may counteract the other, and mixing may cause lubricant degradation.
4. Shelf life: make sure the applied lubricant is not expired. Over time, greases may dry out when in storage, and ingredients may lose their effectiveness.



Each colour represents a measurement with a different lubricant

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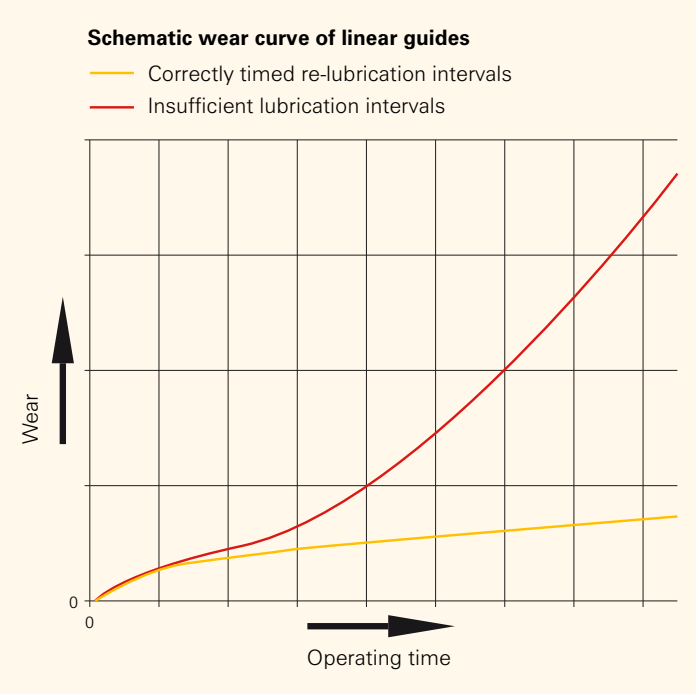
CAUSE 2. LACK OF LUBRICATION

Periodic maintenance is essential but often underestimated. After commissioning, a regular check on lubrication levels is sufficient. Precision linear guides generally use very little lubrication, while ensuring low friction and a long life span.

However, dry-running of the linear guide may result in:

- A shorter lifetime, due to excessive wear.
- Heat generation, due to high friction.
- Degradation of accuracy.



POSSIBLE SOLUTIONS

With regard to lubrication, observe:

1. Usage. Lubricant may vanish when the linear guides are in use. Metal-to-metal contact may occur, resulting in wear. In addition, more aggressive speeds, loads and accelerations will require shorter lubrication intervals.
2. Deviation of environmental conditions. Temperature, oxidation of the lubricant, pollution and other circumstances may reduce the functioning of the lubricant.
3. Type of cage: plastic cages are often capable of storing more grease internally than sheet metal cages.

Add regular monitoring of the linear guides to the maintenance plan. Monitoring should include careful inspection of lubrication, play and wear. Also, make sure to check that the environmental conditions correspond with the lubricant.

In case of doubt, feel free to contact our experts at any time.

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CAUSE 3. INCORRECT PRELOAD

Incorrectly applied preload may lead to:

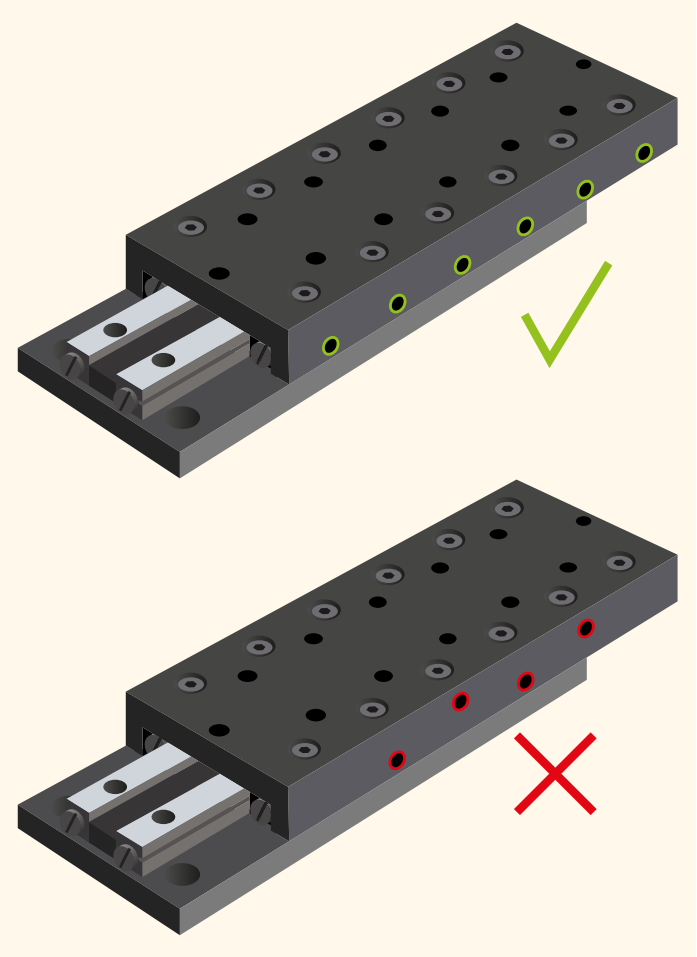
- An incorrect amount of friction or fluctuating friction over the complete stroke of the guide.
- A mild form of bearing play and (consequently) inaccuracy.
- Cage creep.
- The absence of repeatable position accuracy.
- Slipping of rolling elements, leading to excessive wear.
- Reduction in stiffness.

POSSIBLE SOLUTIONS

There are various reasons why preload can be set incorrectly.

The preload set screws

First of all, a person might opt for the wrong type of preload set screws; he/she may place them in a wrong location or use an incorrect number of screws.



The set screws should be aligned and positioned on the rails' centreline to distribute the preload evenly. The set screws should be at the location of the attachment holes in the rails, so that by applying preload, the rail is moving correctly.

The tools

Furthermore, sometimes the wrong tools are used to adjust the preload. We advise the use of torque screw drivers, as these allow fine-tuning of the preload resulting in a uniform motion. Make sure the set screws are free of grease and dirt.

PM offers the service to make the final adjustments of the linear slides at the PM production facilities.

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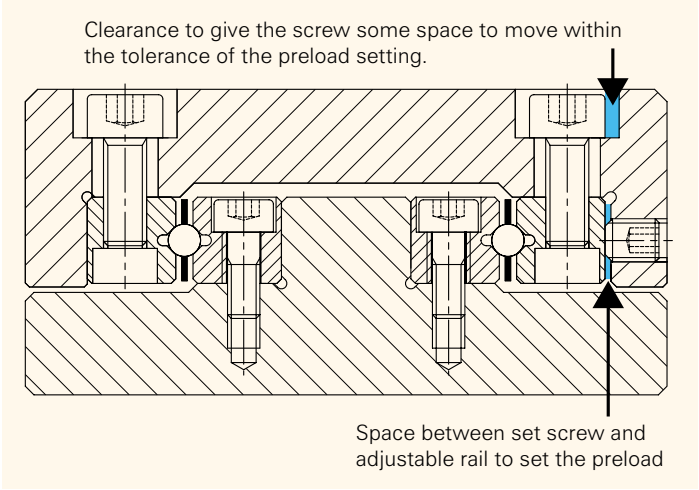
The dimensions

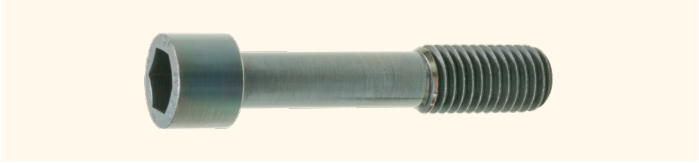
The third cause of incorrect preload adjustment has to do with the use of faulty mounting materials.

Rail attachment screws should be used to secure the adjustable rails. However, these screws often lack sufficient clearance in the holes, making it impossible to adjust the linear guides without play.



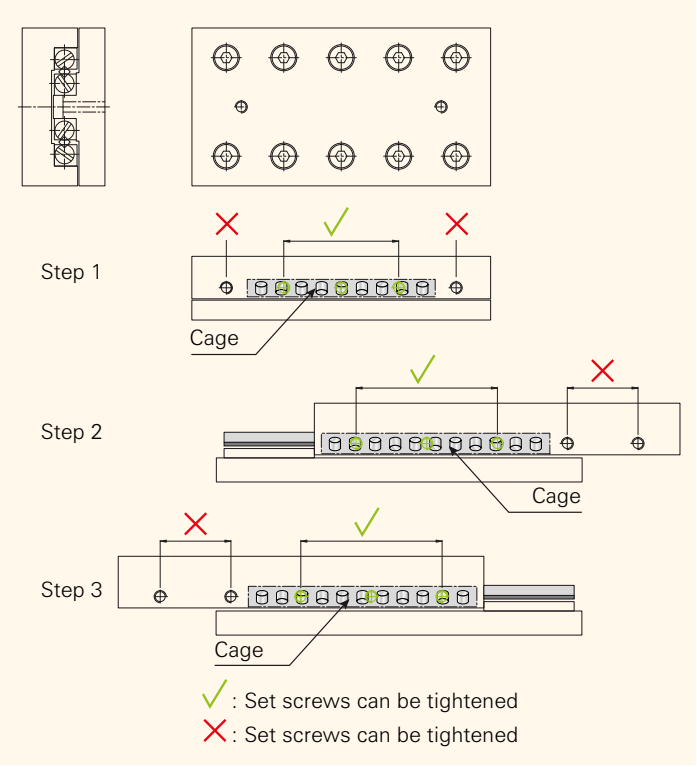
To ensure sufficient clearance, enlarge the fixing holes. This will give the screw head and the screw shaft more clearance to move in the hole.

PM offers special rail attachment screws: type GD (see below image). These screws have a thin shaft, offering more clearance in the hole.



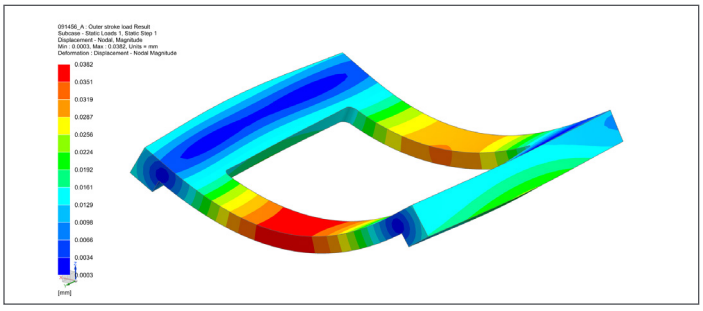
The order of preload adjustment

A fourth cause resulting in an incorrect adjustment, is the order in which the preload is applied. It is essential to adjust the preload at the place where the cage is at that moment. For assembly instructions and preload settings for linear guides, please refer to our catalogue.



Design errors

Lastly, we sometimes come across design errors, in which the counterparts possess insufficient stiffness. As a result, attachment surfaces may deform under prestress or load, and the linear guide no longer operates in a straight line.



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CAUSE 4. POLLUTION

Linear guides and frictionless linear slides are sensitive to pollution, such as fine dust and chips. These may enter the guides when stored without protective packaging or when unpacked in a dusty environment.

Contamination may also occur when components aren't cleaned sufficiently before starting the assembly or when the installation occurs in a 'polluted' environment.

Pollution may result in:

- An non-smooth and inaccurate movement.
- Increased friction.
- Excessive wear.

POSSIBLE SOLUTIONS

Inform your technician

Pollution often occurs due to unfamiliarity of, for example, the one who receives and checks the product, or the one who uses it. Be alert of this and ensure clear instructions. We advise the unpacking of products at the place of assembly, shortly before they are installed.

Examples of possible solutions:

1. The use of wipers

As long as linear guides and slides are properly sealed, they can be used hassle-free in polluted areas. Various options are available, including wipers for the linear guides and seals for the slides.

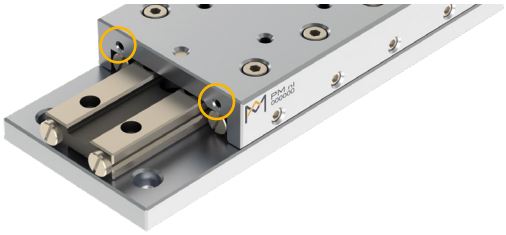
This linear guide is fitted with felt wipers at its ends, which wipe the raceways clean with each movement.

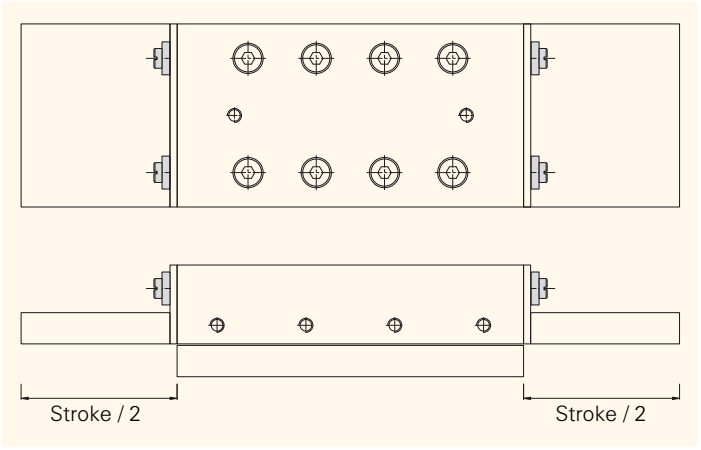
2. The use of seals

This linear slide has a tight gap between the slide top and slide base. Both ends are fitted with cover plates, preventing contamination from entering. In case of extreme pollution, the frictionless slide can be provided with complete seals on all sides – slightly pressurised within, if requested. This results in slightly higher friction.

3. The use of covers

Linear slides have threaded holes on the front of the slide top. These holes can be used to mount a basic cover to protect the linear guides against pollution.





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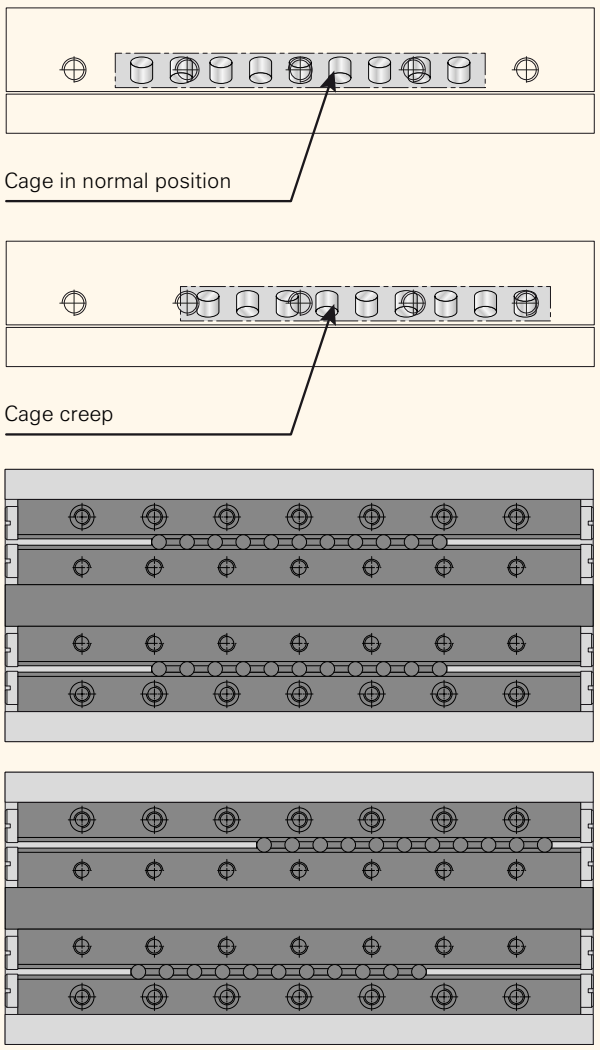
CAUSE 5. INCORRECT ALIGNMENT OF THE LINEAR GUIDES

When in motion, the friction of a linear guide may be higher on one side than on the other. This difference can be caused by a deviation in the parallelism, or flatness, between the linear guides.

As a result of this deviation:

- The friction may vary over the stroke.
- Cage creep may occur.
- The linear slide may slowly move away from its position.
- Slip of the rolling elements occurs, causing excessive wear.

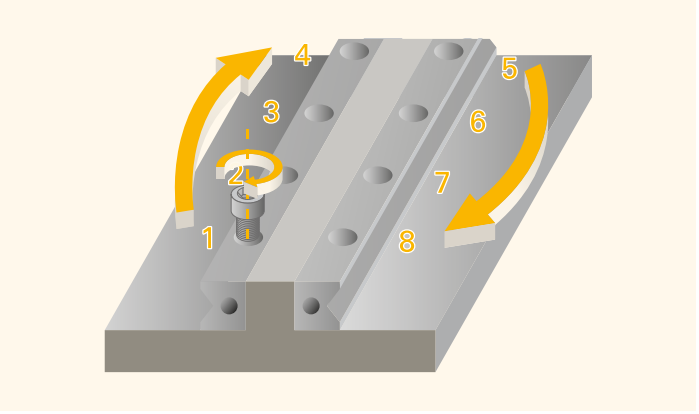
Creeping of the cage (slide in zero position)



POSSIBLE SOLUTIONS

The mounting sequence of the rails

Faulty assembly order of the guide rails may cause them to move out of parallelism.



Mounting surface quality

Mounting surfaces must meet high standards. If modifications to the support and bearing surfaces don't meet these standards, alignment errors will occur. Hence, we advise adequate surface finishing to meet the required tolerances.

Observe the following roughness measurements for mounting surfaces:

- For standard applications (quality grade Q8): Ra 1.4
- For quality grade Q4: Ra 0.8
- For quality grade Q2: Ra 0.2

During assembly, the guide rails must be pushed against the reference shoulder and mounting surface to help achieve system precision.

For optimal performance, mount the linear guides on rigid and fine-machined flat surfaces. Preferably, these surfaces are ground. Also, ensure that the linear bearings are supported over their entire length.

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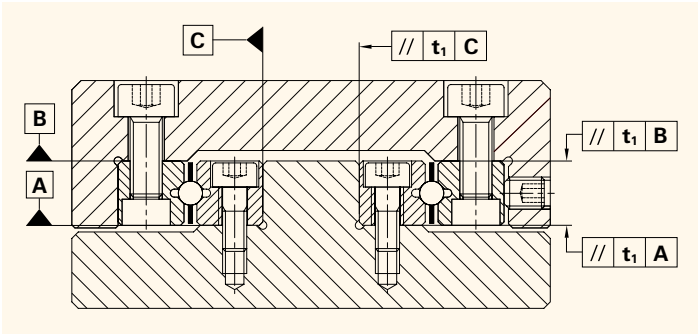
Check the parallelism of the rails

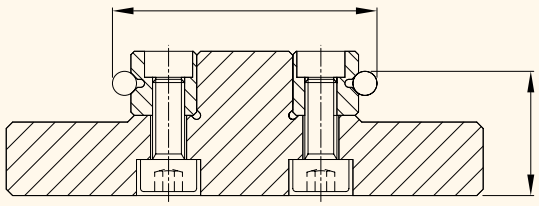
The final assembly accuracy of a linear slide depends on the accuracy and the quality of the rails' supporting structure. The parallelism of the mounting and reference surfaces must not exceed the tolerances as illustrated below. Also, the quality grade of the linear guide must be taken into account.

The quality grades of the linear bearings indicate their maximum permissible tolerance. Please comply with these.

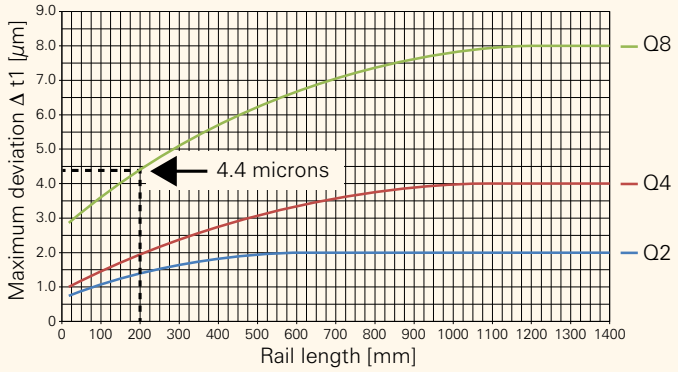
For example, a rail length of 200 mm and a grade Q8, the maximum permissible tolerance is approx. 4.4 microns.



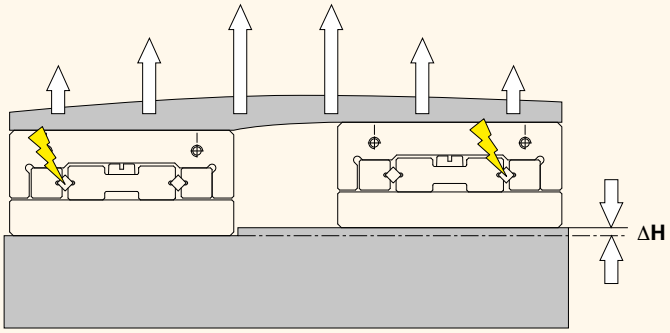
Parallelism of rails V-groove



Mounting surface tolerances



Two connected and parallel-mounted slides may be different in height. This difference will lead to misalignment problems.



When parallel-mounted slides are used, please keep the following in mind:

- When parallel mounting is required, slides can be supplied that are matched on a tight height tolerance of C ± 0.01 mm.
- Alternatively, you could make the distance between two slides as large as possible, limiting the impact of height offset on the linear guides.
- Another solution is to connect the slide with an element that allows for small movements, for example, a connection with limited stiffness in certain directions.

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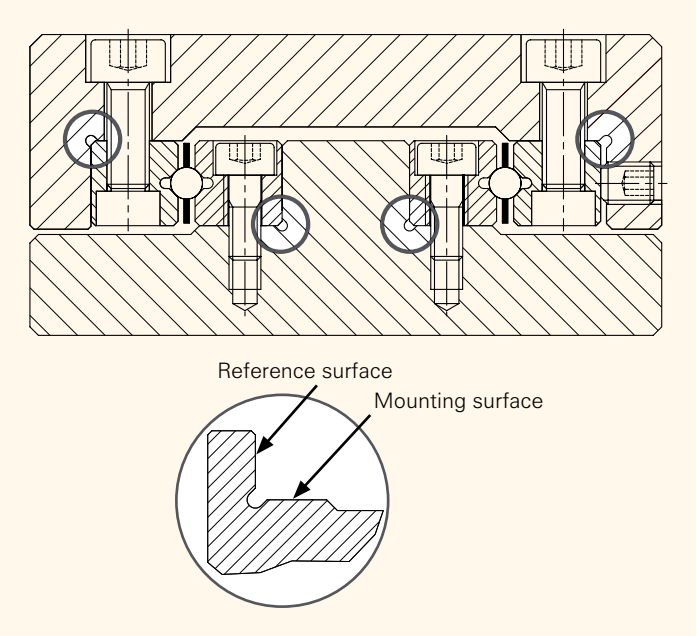
Placement of the linear guide on the mounting surface

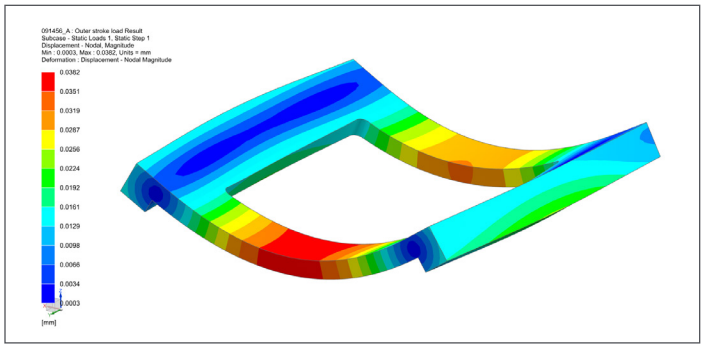
The linear guide may not adhere to the mounting and reference surface – possibly due to leftover material that is stuck between the reference and mounting surfaces. Insufficient contact is another possible cause of faulty linear guide alignment.

Typically a small groove is machined between the mounting and reference surface, as indicated in the figure below. This groove will allow better placement of the guide.



The stiffness of the table elements

A final cause of incorrect alignment might have to do with insufficient stiffness of the interface parts. Lack of rigidity may deform these parts when stressed. As a result, the guides can no longer move in a straight line, misaligning the rails and causing an angle error between the contact and mounting surface.



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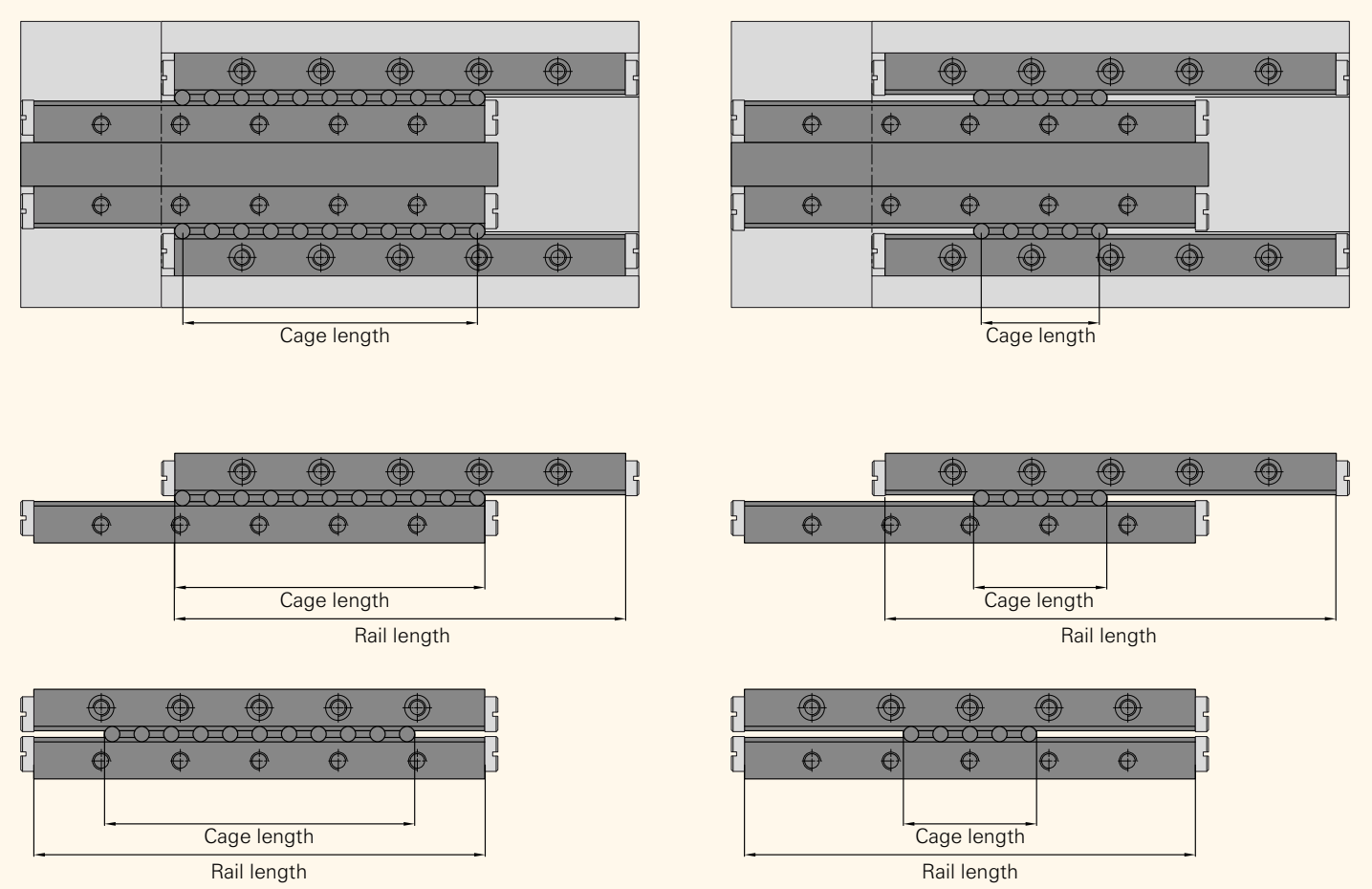
CAUSE 6. WRONG LENGTH OF CAGES



Precision linear guides are widely used in compact installation spaces. Rail length and cage length both impact the length of the stroke. To realise maximum stroke length, sometimes cages are used that are too short. If this is the case, the load will be spread over just a few rolling elements, reducing stiffness and loadcarrying capacity.

Reduced stiffness may lead to:

- Instable behaviour.
- Inaccurate positioning under load.
- Reduced lifetime.

Overload may cause unexpected failure and shorter life span, as excessive stresses act on the linear guide.

POSSIBLE SOLUTIONS

When linear guides are shorter than 400 mm, we advise a maximum stroke length of 70% of the guide rails' length.

For example: if guide rails are 100 mm in length, the stroke length should be a maximum of 70 mm. This will result in a minimum cage length of 65 mm (cage length= rail length - half of the max. stroke -> cage length= 100-70/2).

Part selection

Select a linear guide type or size that offers sufficient carrying capacity. Or select one with a shorter distance between the cage's rolling elements, as shorter distances allow for more rolling elements in the cage.

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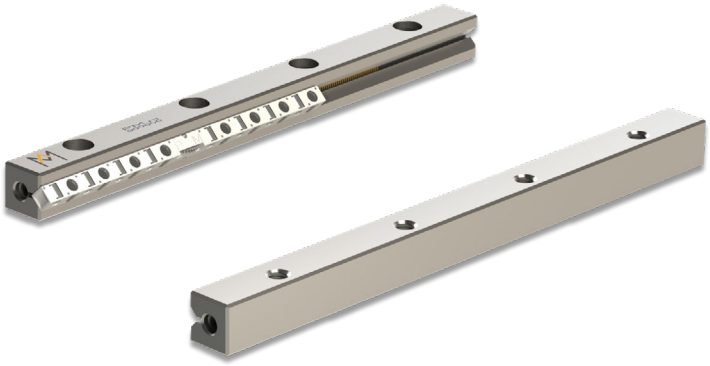
For example: If a steel cage type AA is used in a cross-roller linear guide type RSD-3, the pitch (distance) between the rolling elements is 5 mm.

Alternatively, in a plastic cage type KRE, used in the linear guide type RSDE-3, the pitch between the rolling elements is 3.3 mm. This cage contains more rollers than the type AA. Furthermore, these rollers have more prolonged linear contact on the rail.

The smaller pitch, combined with more prolonged linear contact, results in an increase in load ratings of approximately 50%. The stiffness of type RSDE is almost doubled compared to RSD.

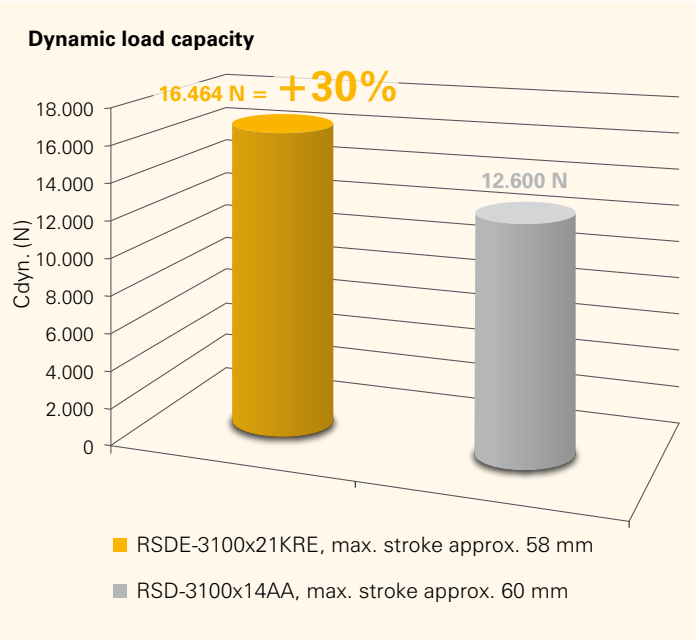


Cage R6x10AA, pitch t=9mm (length 100mm with 10 rollers)

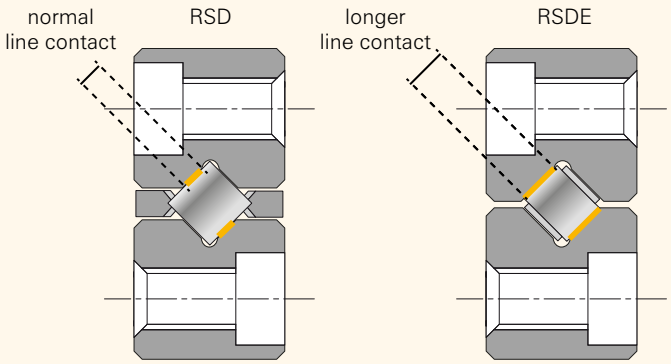
Cage R6x16KRE, pitch t=6.6mm (length 100mm with 16 rollers)

The difference between roller cages

We have illustrated these results in the graph below.



The difference between RSD and RSDE



RSDE linear guides are almost twice as stiff as RSD linear guides.

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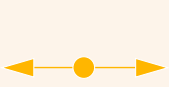
CAUSE 7. WRONG CHOICE OF LINEAR GUIDE

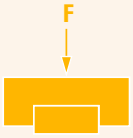
It is hard to select the most suitable linear guide for your equipment. After all, many factors affect the functioning of a linear guide. For instance, you will have to calculate the impact of external forces and moment loads on the guide's life span. Also, safety factors and environmental conditions need to be taken into consideration.

Wrong choices may negatively influence linear guide life span, positioning accuracy, construction robustness and degree of wear.

Below are essential design specifications listed:
All these specifications affect accuracy, life span and correct functioning of a machine or system.

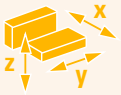
PM has a wide range of linear guides, and every type has its specific characteristics. Within linear guides, various accessories are available. Hence, we advise you to contact us to assist you in choosing the right bearing solution for your linear motion application.


Stroke length



Applied load


Speed and acceleration



Mounting orientation


Cage creep prevention


Installation dimensions


Duty cycle


Environmental conditions

Temperature


Vacuum


Cleanroom


Non-magnetic


Accuracy

Stiffness


Lifetime


Lubricant

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IN CONCLUSION

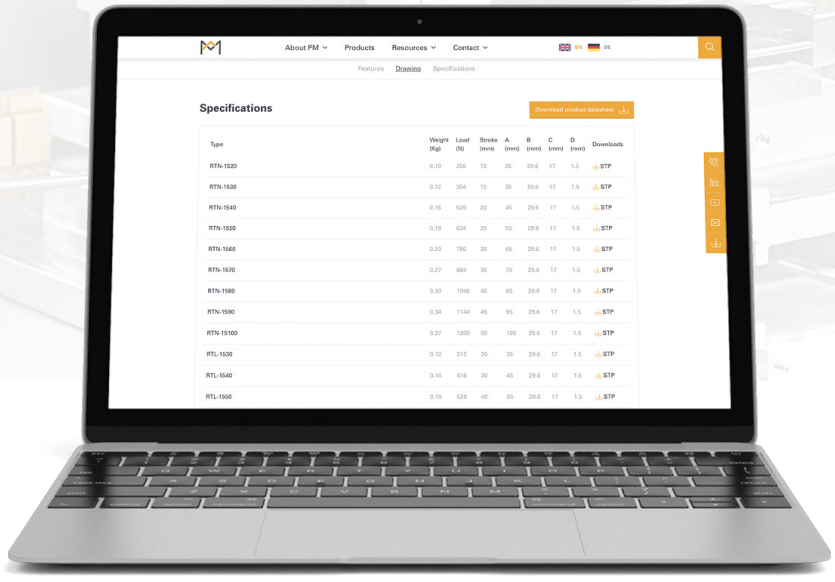
With this ebook, we hope we have been able to help you make machines, devices and instruments that use precision linear guides better and more reliable.

Are you looking for advise or additional information? Feel free to contact us or send an e-mail to info@PM.nl

You can reach us by phone at +31 523 61 22 58.

SAVE TIME!

Direct acces to the 3D CAD models of our standard products



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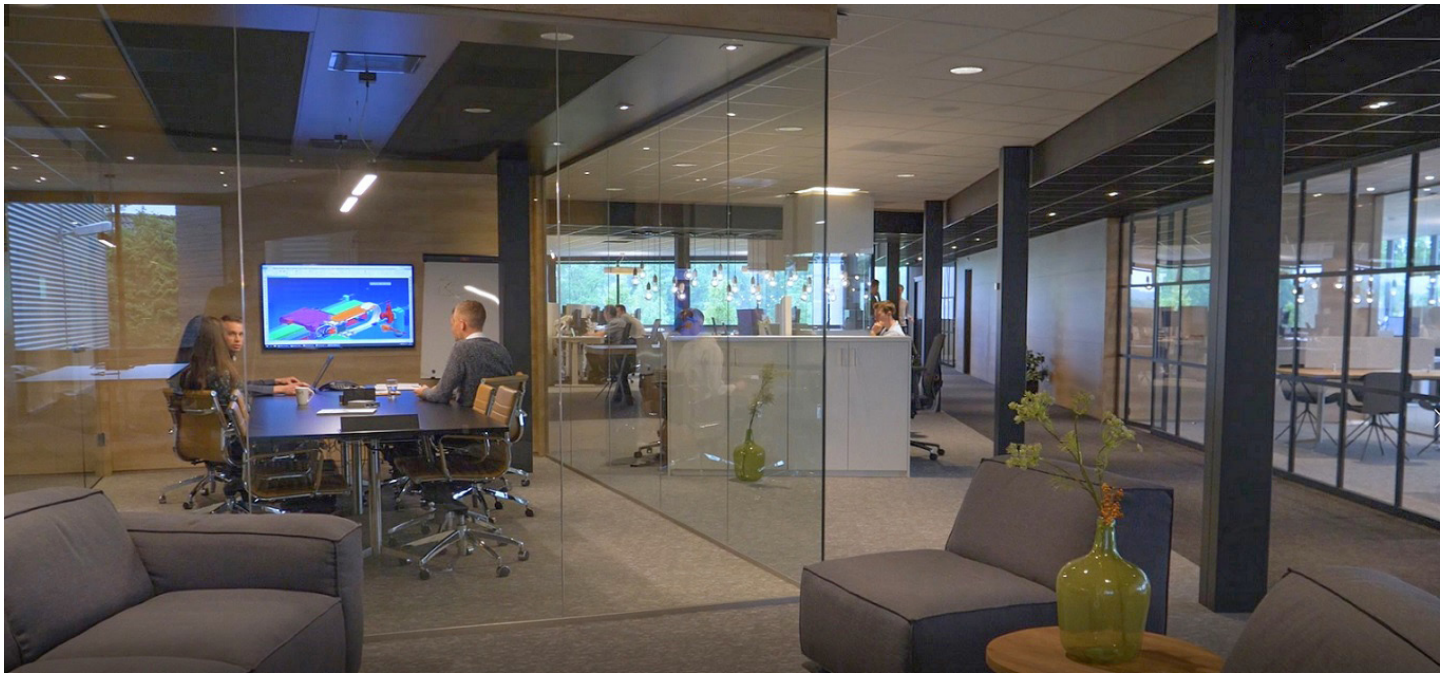
FREE ASSESSMENT OF YOUR DESIGN



With over 50 years of experience in the design and manufacturing of linear guides, PM is the go-to expert. Linear guide assembly and use come naturally to us, but we realise the proper application of all the information available isn't straightforward.

That is why we offer a free assessment of your design by our experts. If you want a valuable advise which ensure a longer lifetime of your linear guides please contact us today to discuss your application.

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