



ROLLON[®]
BY TIMKEN

ROLLON PLAYBOOK

Avoiding Linear Bearing Failure



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AVOIDING LINEAR BEARING FAILURE

When linear bearing systems fail prematurely, the reason almost always involves an overlooked application error. These errors fall into just five different categories and when left unchecked, can reduce the life of a bearing by 50 percent or more:

- Misalignment of the bearing rails and moving elements.
- Inadequate lubrication of the bearing's unsealed components.
- Contamination of the bearing rails and raceways.
- Crash on start-up.
- Excess speed and acceleration.

Rollon has now made it easier than ever to avoid the application mistakes that threaten bearing life.

Our technical service team has published a new playbook explaining the five causes of bearing failure in detail and offering advice on how to steer clear of them.



DISCOVER A SMARTER WAY



TO REDUCE LINEAR BEARING WEAR

*Contamination and poor lubrication practices can shorten the life of linear bearings.
Here is how to avoid both problems.*

DISCOVER A SMARTER WAY TO REDUCE LINEAR BEARING WEAR

To get the longest working life out of a linear bearing, keep it clean and well lubricated. This common-sense advice may sound easy enough to follow. Yet in the real world of round-the-clock, high-cycle manufacturing operations, bearings do get dirty and dry.

And when either of these conditions happens, linear bearings will wear prematurely. In the worst-case scenarios, contamination and inadequate lubrication can create metal-on-metal contact between the bearing's rolling elements and raceway. This can cause excessive wear in the form of denting, pitting or galling.

This warning about contaminants and the importance of lubrication will not come as news to anyone who has designed or worked around industrial machines. When using linear guides on medical, food, packaging, semiconductor or other sensitive equipment, machine builders often take extraordinary measures to keep the contaminants out and the oil in. They may add expensive bellows to cover the guides, or they may opt for a pricey automatic greasing system.

But extraordinary wear-reduction measures aren't just limited to sensitive applications. Often, machine designers turn to high-precision bearings expecting optimum protection against wear. After all, if profiled rail is used in high-end equipment like machine tools, it will certainly have the best reliability and wear-resistance out of all the bearing options for automated systems with less-demanding precision requirements. And it should easily handle typically less-severe contamination of those same applications.

Yet in their zeal to keep linear motion systems running smoothly, machine builders can overlook less expensive design solutions to contamination and lubrication issues.

DISCOVER A SMARTER WAY TO REDUCE LINEAR BEARING WEAR

COMBATING CONTAMINATION

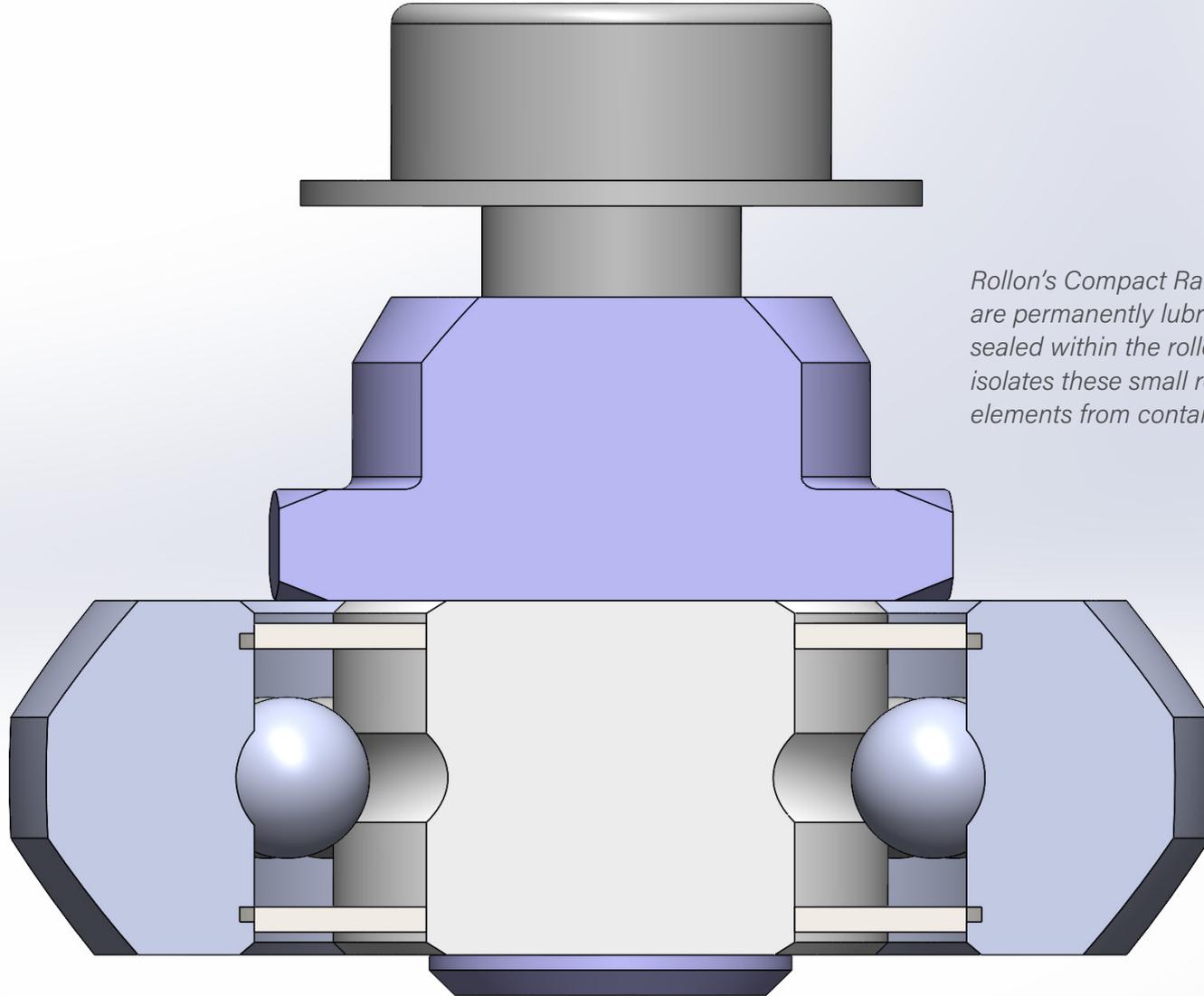
Contamination comes in many forms, some more aggressive than others. Metal chips from machining operations, for example, qualify as one of the biggest offenders from a wear perspective. Silicon dust produced during semiconductor manufacturing can also be tough on linear bearing surfaces. Modern manufacturing processes can throw off a long list of other abrasive, wear-inducing contaminants.

Less-aggressive contaminants can pose problems, too. Even soft contaminants — such as those found in food processing — can gum up linear bearings. This kind of debris is not necessarily a wear issue, but it can keep the linear motion systems from functioning smoothly. Consequently, this can have a negative impact on positioning accuracy and product quality. If a linear bearing gets gummed up to the point it stops working, there are possible potential maintenance and downtime costs.

Keep in mind, too, that contamination is a two-way street. In addition to worrying about contamination from the product interfering with the linear motion system, machine builders also worry about stray lubrication or particulates from the linear bearing contaminating the product. This type of machine-to-product contamination is a cause for concern in contamination-sensitive industries such as medical, semiconductor and electronics.

To combat contamination, machine builders will often supplement the linear bearing's built-in seals with bellows or other types of covers. Though these can substantially add cost to a machine and add to the maintenance burden, they do have their place. Some clean room environments, for example, may require some physical barrier between the product and the machine elements. And inside machining centers, it is crucial to physically protect any motion systems from metal chips.

However, in most medium-precision applications contamination prevention is another example of why using an ultra-precision bearing for jobs with more moderate precision requirements can actually introduce more difficulty for the implementation. Even the most precise bearing isn't totally impervious to dust and particles. In fact, those extra covers and bellows meant to protect profiled rail can still be defeated by high concentrations of contaminants and constant use in certain environments.



Rollon's Compact Rail bearings are permanently lubricated and sealed within the rollers, which isolates these small rolling elements from contaminants.

DISCOVER A SMARTER WAY TO REDUCE LINEAR BEARING WEAR

CHOOSE PRECISION BEARINGS THAT ARE LESS AFFECTED BY CONTAMINATION

Thankfully, many medium-precision applications like automated motion systems encounter milder contamination scenarios. And in those cases, machine builders should consider bearing styles that are less affected by contamination and not as capable of generating any of their own. Bearings with large, sealed rolling elements fall into this category.

With conventional linear guides, the tiny recirculating balls in a raceway have very little clearance. So even a relatively small piece of debris can interfere with the balls. Bearings based on larger-diameter rollers, by contrast, can roll right over even relatively large contaminants. Think of it as the difference between a skateboard and monster truck hitting a speed bump in the road.

Rollon's Compact Rail system, for example, is built around rollers that are an inch in diameter. These linear bearings can roll over all kinds of contaminants that can stop smaller rolling elements dead in their tracks — including metal chips, plastic particulate, paper, dust and more.

Large rollers are also more damage tolerant than smaller rolling elements. Even if a contaminant does happen to mar the roller or the rail surfaces, the large rolling element can usually keep on running.



The Compact Rail slider incorporates an integrated wiper (see inset) that automatically satisfies the system's minimal lubrication requirements.



DISCOVER A SMARTER WAY TO REDUCE LINEAR BEARING WEAR

WELL-OILED MACHINES

Lubrication problems are often described in terms of not enough grease or oil. And sometimes that is the case as lubrication leaches out or is squeezed out of linear bearings, leaving them susceptible to metal-on-metal wear.

There is a flip side to the lubrication issue, too. Maintenance workers, with grease guns in hand, often over-lubricate linear bearings, potentially blowing out seals and introducing oil into the environment.

And keep in mind that lubrication also qualifies as a contaminant. So over-lubed bearings can also worsen contamination problems or force machine builders to opt for bellows or physical covers.

Getting just the right amount of lube into a linear bearing at the right interval can be tricky because it depends on application-specific factors such as the type of bearing and the duty cycle. The application's sensitivity to oil contamination comes into play, too — with sensitive industries demanding lighter lubrication schedules.

There are ways to make sure linear bearings stay properly lubricated throughout with little intervention on the part of maintenance workers. On the expensive end of the spectrum are automatic greasing systems. These systems are a legacy of the linear way systems used in the machine tool industry. The auto-greaser was crucial for maintaining the film of oil that separates a linear way's bearing surfaces.

Some of these expensive auto-lubrication systems have made their way into applications that employ more modern linear guides, and they can be a valid way to get the lube levels right while reducing

the maintenance burden. But aside from their cost, auto-greasing systems can introduce unacceptable levels of contamination into the factory environment — which, again, is an issue in clean-room and other sensitive manufacturing operations.

A lower-cost, cleaner alternative to automated lubrication exists in the form of self-lubricating wipers that integrate into the linear bearing's carriage. Rollon, for example, has optional self-lubricating wipers on its Compact Rail system. These provide lubrication for two million cycles before they need to be refreshed, and they cost a fraction of a PLC-controlled auto-greasing system.

The very idea that automatic lubrication is the only way to achieve optimal lubrication is somewhat outdated. Some linear guides, such as those based on recirculating balls, do require lubrication in all applications. But bearings based on sealed rolling elements may not need much, or any, external lubrication in many applications.

With Compact Rail, the roller acts as a true sealed bearing. Its ball bearings, raceway, and their lubricant are contained inside the outside housing of the roller. The need to add lubricant between the roller and the profiled rail thus becomes less important — or even unnecessary in light-duty or medium-precision applications. This capability makes a big difference in contamination-sensitive operations that would normally resort to expensive bellows or covers to keep stray oil off their shop floors, out of the air and off their products.

DISCOVER A SMARTER WAY TO REDUCE LINEAR BEARING WEAR

COMPACT RAIL FOR MEDIUM-PRECISION APPLICATIONS

Using precision bearings such as Rollon's Compact Rail for medium-precision applications is simply the smarter choice compared to the extraordinary measures some designers formulate to prevent failure from wear and contamination. Not only can designers avoid adding bellows and seals and minimize lubrication headaches, they can skip the costly and time-consuming grinding and machining that comes with preventing misalignment when implementing high-precision guides. In fact, Compact Rail can compensate for misalignment up to four millimeters. They also feature induction-hardened raceways to help ensure long lifetimes and quiet operation. The linear guides are affordable and easy to install on all types of surfaces, including non-machined surfaces.

Machine designers have many tools on their tool belt to optimize the operating life of their linear bearings. Profiled guides, expensive add-ons and lubrication strategies can make sense for some applications, but designers of automated systems with less-stringent accuracy requirements would do well to ask themselves if all the added expense and effort is even necessary. Because bearings with large, sealed rolling elements are not susceptible to small particles, can compensate for misalignment and need less lubrication attention, Compact Rail can be the only safeguard you'll ever need.

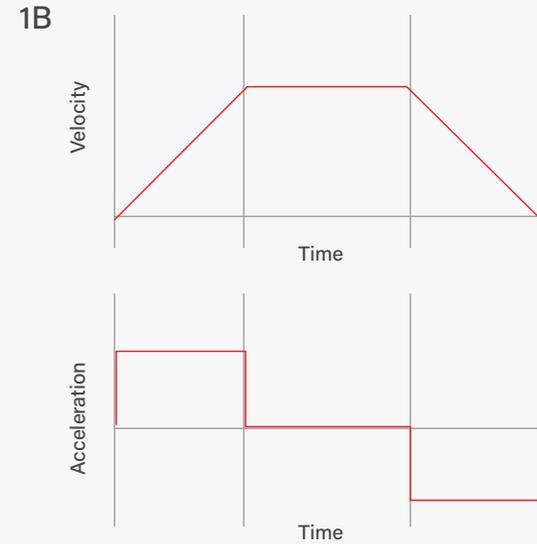
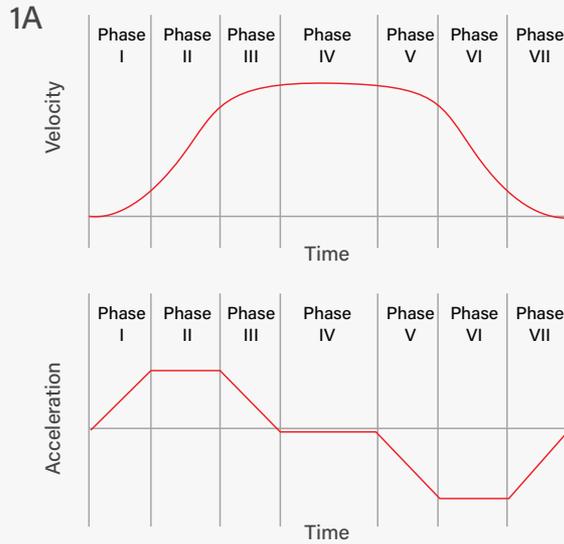
LINEAR BEARING

SPEED AND ACCELERATION:

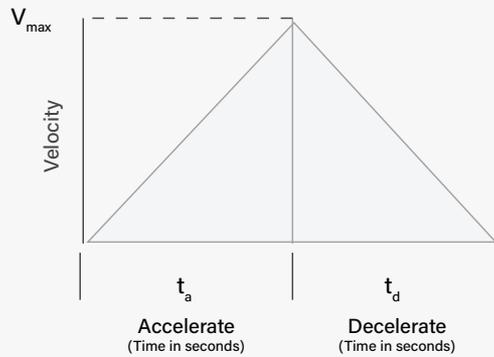
**WHICH SPEC MATTERS MOST
IN AUTOMATED SYSTEMS?**



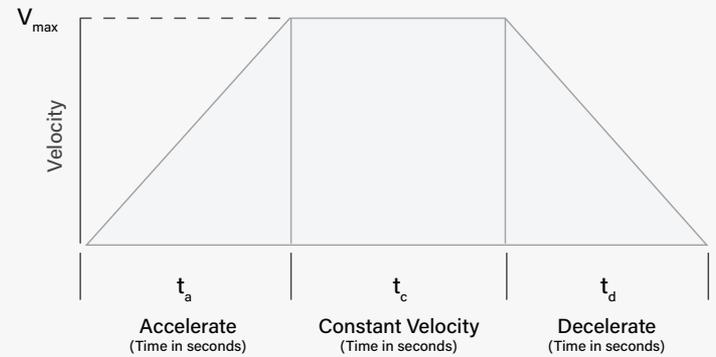
Engineers focused on medium-precision applications like fast, light automation systems may pay too much attention to speed specs when acceleration is what really counts.



TRIANGULAR MOTION PROFILE



TRAPEZOIDAL MOTION PROFILE



The right preload level will help to achieve the desired motion profile without sacrificing load capacity or reducing life expectancy.

LINEAR BEARING SPEED AND ACCELERATION: WHICH SPEC MATTERS MOST IN AUTOMATED SYSTEMS?

Look through the specifications of any linear bearing, and you'll come across a maximum speed. It's an important spec, but not nearly as important as many engineers think.

Speed does play a role in bearing life. Consistently moving loads above a bearing's speed limit can result in premature wear. It is also possible, usually through a control error, to drive a bearing so fast that it will fail. For example, recirculating ball linear guides can experience end cap failure when driven at high speeds or accelerations. And roller bearings can freeze up at extremely high speeds. Yet these over-speed conditions are rare in well-designed motion systems.

What's more, bearing speed is rarely the limiting performance factor in today's motion applications. Standard linear bearings can handle speeds of three meters per second without any difficulty, while high-performance models can reach five meters per second. Some bearings are even faster, with top speeds approaching nine meters per second. The majority of automation applications, meanwhile, run at top speeds well under five meters per second and can be easily accommodated with precision bearings designed for medium-precision applications.

So if today's bearings have speed to spare and over-speed conditions are rare, what good are speed specifications? The answer is that speed doesn't tell us all that much as a stand-alone value. Only when considered in the context of acceleration and the overall motion profile does speed become important.

LINEAR BEARING SPEED AND ACCELERATION: WHICH SPEC MATTERS MOST IN AUTOMATED SYSTEMS?

ACCELERATION CONSIDERATIONS

There is a connection between speed and acceleration beyond their mathematical relationship. Bearings that are engineered to withstand high speeds also tend to be robust enough to withstand high acceleration and vibration forces.

These are the forces that make or break most real-world motion applications. Acceleration and its rate of change (or “jerk”) are the chief determinants of a motion system’s stability and ability to hit position targets.

When control engineers do overtax a linear bearing, excess velocity is rarely the culprit. More typically, the engineer has pushed the system past its ability to handle acceleration, deceleration or vibration forces. In mild cases, this condition can manifest itself as skidding, which can increase wear and shorten bearing life. In extreme cases, excessive acceleration may result in catastrophic bearing failures.

$$L_{km} = 100 \cdot \left(\frac{C}{P} \cdot f_c \cdot f_i \cdot f_h \right)^3$$

Where:

L_{km} is the theoretical life in kilometer

C is the dynamic load rating in Newtons

P is the equivalent external load in Newtons

f_c is the contact factor

f_i is the service factor

f_h is the stroke factor

Dynamic loads obviously play a role in how long linear guides will last. But so does their operating speed. In the lifecycle calculation (below), the service factor term (f_i) captures the influence of operating speed, shock and vibration loads, reverse frequency and the cleanliness of the working environment. Speed, in particular, has a strong influence on service factor.

- Low-speed applications (less than 1 m/s) have a service factor of 1 to 1.5
- Medium-speed applications (1 and 2.5 m/s) have a service factor from 1.5 to 2
- High speed-applications, those above 2.5 m/s, have a service factor ranging from 2 to 3.5

All else being equal, a bearing in a high speed application could conceivably have a lifespan that is 50 to 70% shorter than the same bearing in a low-speed application.

LINEAR BEARING SPEED AND ACCELERATION: WHICH SPEC MATTERS MOST IN AUTOMATED SYSTEMS?

WORKING WITH THE MECHANICS

Control engineers can obviously limit these forces when they program a motion profile, but only if the profile realistically relates to the bearing's mechanical limitations. All too often, it does not. Motion profiles are routinely created around speed targets without reference to the fundamental limitation of the mechanical components. When this disconnect between the motion profile and the mechanical components happens, no amount of drive tuning will help.

And keep in mind that not all the remedies for acceleration difficulties involve the motion programming. Preloading the bearing, which is purely a mechanical process, can help, too.

Some amount of preloading is often desirable because it removes excess clearance between the rolling elements and the rail surfaces, eliminating uneven contact conditions and minimizing wear. As acceleration rises and skidding becomes a risk, keeping the rolling elements in contact with the rail at all times becomes even more important. Increasing the preload also makes the system stiffer, which helps improve positioning accuracy when acceleration, jerk and vibration forces are high.

In general, high acceleration applications demand a higher preload. But there are a couple of trade-offs in that preloading reduces the bearing's load carrying capacity and increases wear. These trade-offs can be kept to a minimum by experimenting to optimize the preload

levels. There is usually a level at which the needs of an aggressive motion profile can be met without sacrificing much load carrying capacity or life expectancy.

Experimenting with different preload levels will require some physical adjustments to the bearings. And not all bearing systems make this task all that easy. Some systems have their preloads determined by their factory setup. The preload on recirculating ball guides, for instance, relates to the size of the ball bearings in relation to raceways. Changing the preload on these systems typically requires changes to the slider, the rails or both.

Other bearing styles allow simple preload adjustments in the field. Rollon's Compact Rail system can be adjusted from outside the rail by turning screws that compress the rail flanges. Aside from allowing adjustments without removing the slider from the rail, this system allows localized fine-tuning. Preloads can be set higher in areas where high dynamic loads occur, such as where the carriage reverses direction. Minimizing the amount of the rail subjected to higher preloads reduces the wear effect accordingly. Most automation applications operate within the speed requirements of Compact Rail, and many also do not require the accuracy of profiled rails. In fact, applications with accuracy requirements above 50- μ are classified as "medium precision," and are well-suited for Compact Rail.

LINEAR BEARING SPEED AND ACCELERATION: WHICH SPEC MATTERS MOST IN AUTOMATED SYSTEMS?

BENEFITS OF COMPACT RAIL FOR AUTOMATED SYSTEMS

Not only is preload adjustment easy and convenient with Compact Rail guides, installation is also hassle-free. Compact Rail can be installed on all surfaces, even if rough, thanks to its ability to deal with misalignment up to four millimeters. Unlike profiled rail guides that cause machine builders to spend significant time and money on surface preparation and machining to make sure bearing rails can go on perfectly, Rollon's Compact Rail's unique rail geometry compensates for alignment errors in one or two axes so it can align itself to less than perfect mounting surfaces. The guide's combination of self-alignment and easy preload adjustment makes it easier to implement than profiled guides, thereby helping designers save time and money.

It may always be tempting to look at a linear bearings' maximum speed to see if it will do the trick in a fast motion system. But focusing solely on speed without regard for the underlying mechanics of the linear bearing system will only slow you down. Rollon's Compact Rail system checks all the boxes for medium-precision applications like automated systems, giving your motion application the proper operating speed, mechanical stability and accuracy without the delays and expense for preloading and avoiding misalignment. The quicker setup and minimal downtime make Compact Rail an exceptionally efficient and cost-effective linear guide for your automation system.



CRASH RESISTANCE **STRATEGIES FOR** **LINEAR MOTION SYSTEMS**



In medium-precision applications, the right precision bearing can solve the greatest threats to a linear motion system's lifetime.

CRASH RESISTANCE STRATEGIES FOR LINEAR MOTION SYSTEMS

How do you know when a linear bearing has reached its end of travel? When the carriage hits the wall. At least that is how the old engineering joke goes. But in reality, crashes are no laughing matter.

Also known euphemistically as “hard stops,” crashes occur when an out-of-control pillow block slams into the bearing’s end stop or some other intermediate target. They most often occur when a linear axis is started up for the first time. Even a single crash on that very first stroke can ruin a bearing, triggering expensive repair or replacement costs.

GET ON THE SAME PAGE

All too often, there is little communication between the engineer who designs a mechanical system and the engineer who ultimately runs it. This lack of communication can make crashes more likely because it increases the likelihood that the linear axis may be run with a motion profile it was not designed to handle.

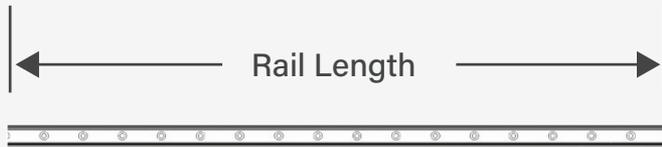
For example, a linear axis may have adequate space for over-travel based on the design inputs — loads, speeds, accelerations and inertia mismatch. Yet if it runs under different conditions, that over-travel space can shrink or disappear.

The reason why bearings crash on start-up mostly comes down to human factors. A control engineer can do a great job calculating the perfect motion profile for a given application, only to overlook some installation details during start-up. Small errors like entering an incorrect motion parameter or failing to connect a limit switch are common and can be catastrophic for the linear bearing.

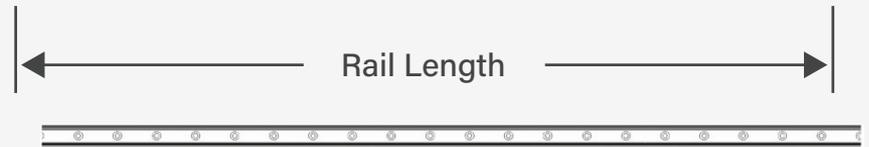
Fortunately, it is not that difficult to minimize crashes and give your bearings a longer lease on life without spending a lot of money. Here’s how:

To avoid this kind of problem, it is important for both design and control engineers to have a sense of whether the design values leave enough flexibility to accommodate changes in real-world operating parameters. If not, a less aggressive motion profile may be the only way to avoid crashes.

CRASH



NO CRASH



— Motion Profile

Crashes most commonly occur on start-up due to an incorrect motion profile.

CRASH RESISTANCE STRATEGIES FOR LINEAR MOTION SYSTEMS

OVER-ENGINEERING

Other than busted bearings, one of the negative consequences of crashes is over-engineering. Instead of trying to avoid crashes, the engineer will accept them as inevitable and try to design systems that will survive them.

To do so, engineers may end up specifying bumpers or gas shocks. Depending on the type of shock absorber, these can cost as little as a few bucks and as much as \$100 each. But install them on multiple axes, and those costs can add up — even before you factor in the labor and spare part costs.

As popular as they are, bumpers and other shock absorbers are a bit like training wheels on a bike. Once someone knows how to ride, they come off. Likewise, linear motion systems that are properly designed and controlled can run safely without the expense of additional protection.

Another crash-prevention strategy involves “sizing up” by choosing a heavy-duty linear component to survive a crash even when a standard-duty precision guide is perfectly suited for the job. By going up a rail guide size, as the thinking goes, the designer can achieve a great, crash-tolerant system. But the high cost of upsizing becomes

apparent pretty quickly: This strategy can cost as much as 15 percent more than the previous size guide. That’s before the machine builder starts to make some accommodations. For example, a larger-size guide will need:

- A larger drive mechanism, either ball screw- or belt-driven.
- A larger motor.
- A change in gearbox.
- A larger steel box frame requiring more welding, more machining to ensure the surfaces are parallel and more mounting time and effort.

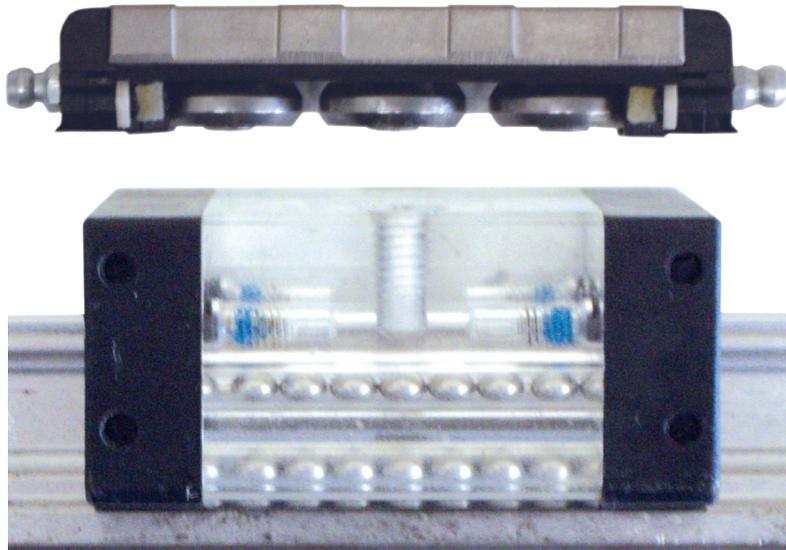
The resulting elaborate system can end up costing tens of thousands of dollars more than transporting that same load with a system using a more-compliant linear guide designed for medium-precision applications. Not only does that great system result in additional design, machining and installation time and effort, those costs get added onto the total cost of the system. When a system costs significantly more than necessary, the resulting competitive disadvantage will mean lost sales.

CRASH RESISTANCE STRATEGIES FOR LINEAR MOTION SYSTEMS

FAVOR CRASH-WORTHY BEARING DESIGNS

While most crashes do occur on start-up, it is true that they occasionally occur well after a machine has been commissioned. Sometimes a loss of power can trigger a crash, or someone might inadvertently change a control setting. And truth be told, some machines are not run all that carefully.

For these reasons, it can make sense for engineers to design with some crash-worthiness in mind. But what is the best way to do that? Engineers can choose to go with shock absorbers and over-engineered components, accepting those costs as the price of crash protection.



The end caps on Rollon's Compact Rail (top) are cosmetic and, even if broken in a crash, will not interfere with the operation of the slider. End caps on recirculating ball linear bearings (bottom) house the crucial rolling elements and are a potential point of failure if shattered in a crash.

CRASH RESISTANCE STRATEGIES FOR LINEAR MOTION SYSTEMS

Or they can favor linear bearings that inherently have crash-worthy construction. Not all bearings are created equal when it comes to surviving a crash. Recirculating ball systems with plastic end caps are notoriously susceptible to crash damage because the plastic tends to shatter. Should a single crash with this type of pillow block occur, you may find its ball bearings all over the floor.

Bearings based on larger roller elements lack this particular Achilles heel. Their ball bearings and their raceway are contained within the roller element, not within a plastic cap. Rollon's Compact Rail is a prime example of this type of bearing, and it will run just fine with a shattered end cap. And if it ever does experience any crash damage, its interchangeable rollers and pillow blocks allow it to be easily repaired without changing the rails. Another benefit that the large rolling elements of a precision guide like Compact Rail can offer is resistance to contamination, which can otherwise stop the rolling elements of high-precision systems in their tracks. Even if a contaminant does happen to mar the roller or the rail surfaces of the bearing, the large rolling element can keep on running. Plus, Compact Rail also features induction-hardened raceways to ensure reliable operation and long life for medium-precision applications.

And when designers choose a high-precision guide to accomplish linear motion as part of a crash-mitigation strategy in their medium-precision applications, they're likely creating much more work, delay and expense than necessary. That's because profiled rail installation will require additional machining to create flat, straight and parallel mounting surfaces in order to prevent misalignment. Rollon's Compact Rail eliminates this additional work. This system tolerates misalignment because its rail geometry can absorb alignment errors in one or two axes.

Given the choice between crash avoidance and crash protection, engineers can save the most money by avoiding crashes in the first place. And it is true that carefully designed motion systems with room for unexpected over-travel are unlikely to crash.

Yet in the real world, it pays to be prepared for the occasional hard stop. With the availability of crash-resistant roller bearings, crash protection does not necessarily require the expense of adding shock absorbers and over-sized components. Compact Rail's crash-worthiness and contamination resistance, together with its induction-hardened raceways, make it an exceptionally reliable bearing for medium-precision applications.

MANAGING MISALIGNMENT IN **LINEAR MOTION SYSTEMS:**

HOW MUCH TOLERANCE DO YOU REALLY NEED?



Of all the factors that contribute to the premature failure of linear bearings, misalignment ranks near the top of the list. When automated system designers choose a more compliant precision guide, they can cope without breaking the bank.

MANAGING MISALIGNMENT IN LINEAR MOTION SYSTEMS: HOW MUCH TOLERANCE DO YOU REALLY NEED?

When design engineers evaluate linear bearings for their automated, assembly-oriented machines with medium-precision positioning accuracy requirements, they always ask about performance attributes such as speed, load capacity and lifecycle. Then, they want to know the price. It's rare, however, that they ask about the bearing's sensitivity to misalignment. And that's a big mistake, because misalignment represents one of the leading causes of premature linear bearing wear and failure.

Linear bearings that should last for years based on expected life calculations can quit after just a few months if they are not aligned to the geometric tolerances they require to run smoothly. Usually, alignment problems begin with the design and preparation of the machine frame itself. It may not be flat, straight or parallel enough for a bearing to be mounted properly. For example, mounting surfaces may have one or more high spots that will read through to the installed bearing rails. Or the frame design may make it difficult to mount bearing rails parallel to one another in the horizontal axis, vertical axis or both.

Whatever the type of misalignment, the result is uneven loading of the bearing's rolling elements and raceway surfaces — including excessive point loads. These uneven loads typically cause wear in the form of pitting. Just as a pothole in the road starts small and then grows as more cars drive over it, pits on the rolling element and raceway surfaces grow with each pass of the carriage. At some point, even before it fails catastrophically, the pitting can cause the bearing to become noisy and sluggish.

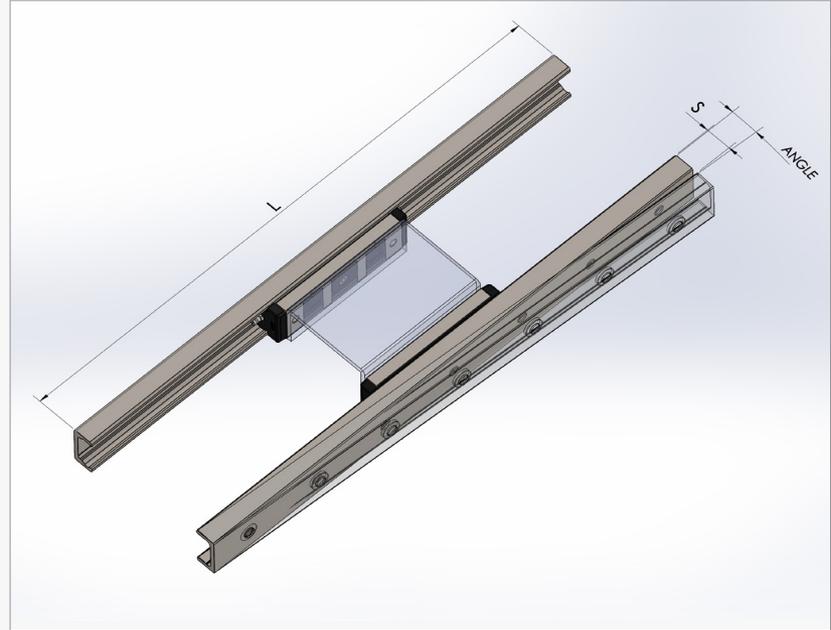
By shortening the working life of linear bearings, misalignment can be a significant cost driver for both the machine builder and owner. Machine builders suffer from higher warranty costs when bearings fail prematurely — not to mention the less tangible cost of a damaged reputation for quality. Machine owners, meanwhile, have to contend not just with the cost of buying and installing new bearings but also any downtime costs.

Rather than incur these costs once the machine has gone into service, it's far better to deal with misalignment up front. In general, there are two ways to do so. The hard way involves design and manufacturing procedures that attempt to eliminate misalignment altogether. These procedures are typically necessary because designers often choose profiled rail linear guides designed for high precision. This painstaking work can prevent misalignment issues from happening at all, but it may not even be necessary depending on the level of precision the application needs. For applications with accuracy requirements above 50 μ , which is common in medium-precision applications like automated systems, there's an easier way: accept misalignment as a fact of life and employ precision linear bearings that inherently have a wide alignment tolerance. Both of these strategies have their place, but they also have drastically different cost implications.

AXIAL PARALLELISM ERROR

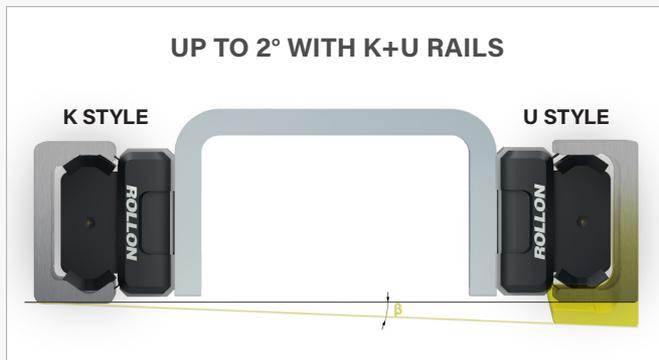
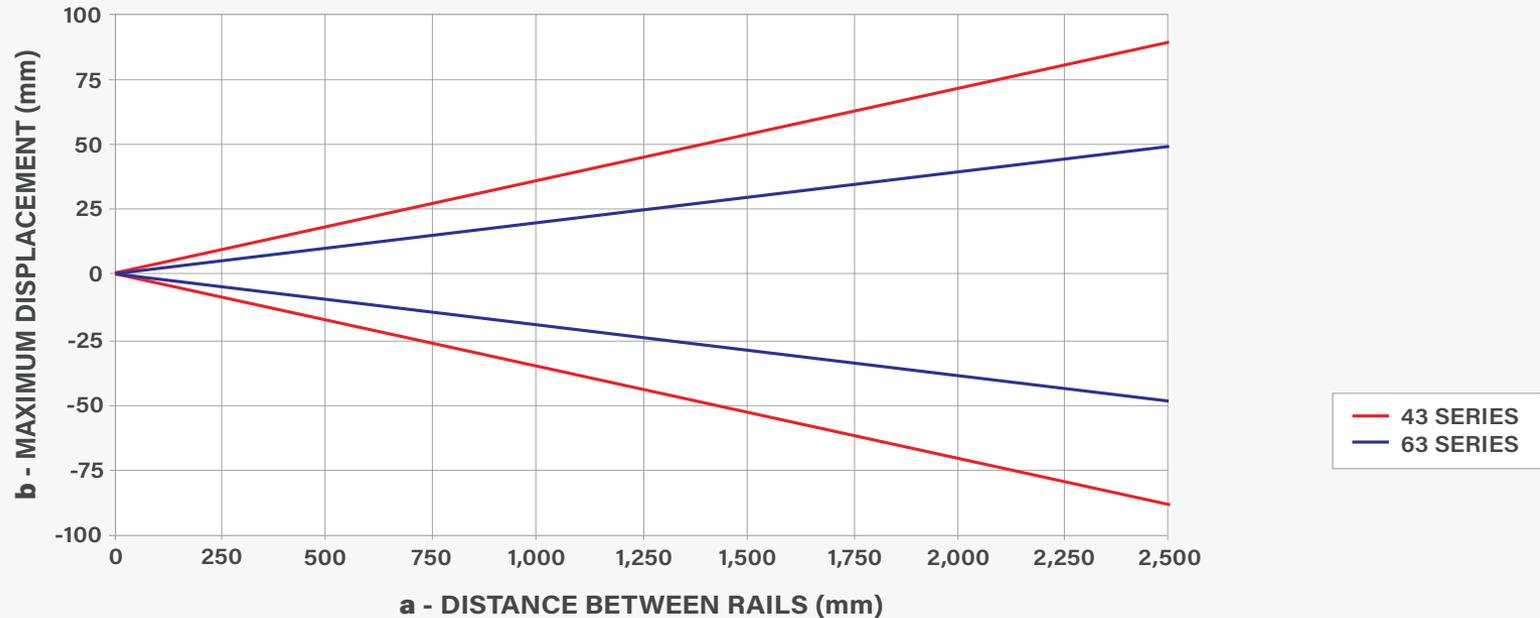


By combining Rollon's T and U Rails, machine builders can stop worrying about rail parallelism in the horizontal plane. The shape of the U Rail features a flat raceway that gives the roller enough lateral freedom to absorb large deviations (see table) from parallel.



RAIL TYPE	RAIL LENGTH (mm)	DISPLACEMENT S (mm)	ANGLE α (°)
18 Series	2,000	1.4	0.040
28 Series	4,080	1.9	0.026
43 Series	4,080	3.9	0.054
63 Series	4,080	3.9	0.054

ALIGNMENT ERRORS IN TWO PLANES



Rollon's K and U Rails work together to absorb alignment errors in two planes. The K Rail geometry gives the roller a rotational freedom that offsets differences in rail height, while the U Rail's flat raceways allow lateral freedom to offset parallelism.

MANAGING MISALIGNMENT IN LINEAR MOTION SYSTEMS: HOW MUCH TOLERANCE DO YOU REALLY NEED?

THE HARD WAY

Linear guides that use recirculating balls are well-established in high-precision motion applications for good reason. When properly installed and maintained, these linear guides are designed to meet the stringent positioning accuracy requirements of machine tools and assembly-oriented industrial machines. In fact, the best of these guides can be found on motion axes that offer repeatability at the micron scale.

But this kind of precision doesn't come cheap. It requires machine builders to take expensive steps to create nearly perfect mounting surfaces for linear guides. Some ultra-high precision guides, for example, call for mounting surfaces that are straight, flat and parallel within a few ten-thousandths of an inch.

This process of eliminating misalignment starts when the machine is still on the drawing board. To accommodate exceedingly precise guides, design engineers will often have to specify pricey frame materials and fabrication methods necessary to create flat, straight, parallel mounting surfaces. Typically the required geometric tolerances will call for precision grinding and lapping operations whose cost rises exponentially with the length of the linear axis.

What's more, misalignment can also result from deflections of the mounting surface when loaded. So ultra-high precision guides may also need engineers to beef up parts of the machine frame in order to provide linear guides with a mounting surface that is rigid enough to prevent deflection.

Steps to combat misalignment also take place on the assembly floor. Assemblers often have to pull linear guides into alignment inch by inch, using custom fixtures, finicky bolt adjustments and shims. This process is nothing new for many machine builders, but it is time-consuming and expensive. And like machining, costs rise with the length of the axis.

MANAGING MISALIGNMENT IN LINEAR MOTION SYSTEMS: HOW MUCH TOLERANCE DO YOU REALLY NEED?

THE EASY WAY

The other broad strategy for dealing with misalignment is to live with it by choosing precision linear bearings that can self-align. In contrast to recirculating ball systems, this type of linear bearing features large rolling elements, rail profiles that give the rolling elements some wiggle room and a simple preload adjustment that enables equal loading of all rolling elements.

The Compact Rail system from Rollon is a prime example of this misalignment-tolerant design. Its rollers have enough rotational and lateral freedom within the raceways to offset even large misalignments in all axes. Whereas ultra-high precision guides measure acceptable misalignment in arc minutes and microns, the Compact Rail system measures it in degrees and millimeters, making it well-suited for automated systems and other medium-precision applications.

For example, Compact Rail rollers can rotate up to two degrees relative to the rail without affecting functionality or increasing wear. This rotational freedom allows the system to accommodate a 20-millimeter difference in rail height when the distance between rails is 500 millimeters. Likewise, the roller's ability to translate laterally allows it to adjust to parallelism problems in the horizontal axis — that is, when rails toe in or toe out. The largest Compact Rail size, for example, can adjust to displacements up to 3.9 millimeters over a 4,080-millimeter rail length. Finally, because the elements are so large and can move within the raceway, they can also adjust to localized variations caused by high spots in mounting surfaces or by a less-than-exacting assembly process.

For machine builders, the benefits of a self-aligning system come down to design freedom and cost reduction. Compact Rail offers more compliance for medium-precision applications than possible with profiled rail. Because it aligns itself to less-than-perfect mounting surfaces, it does not induce the damaging internal forces that cause misalignment. And when the condition of the bearing mounting surface becomes less critical, it is easier to design all or part of a machine frame using lower-cost materials and fabrication methods. Compact Rail, for instance, has been directly mounted to sheet metal, a surface that would be too compliant for conventional linear guides. Gone too are the expensive grinding of mounting surfaces and the fussy assembly methods. That gives builders a more competitively priced machine to satisfy their medium-precision motion needs.

Plus, medium-precision guides offer additional benefits that are not possible with high-precision, profiled guides:

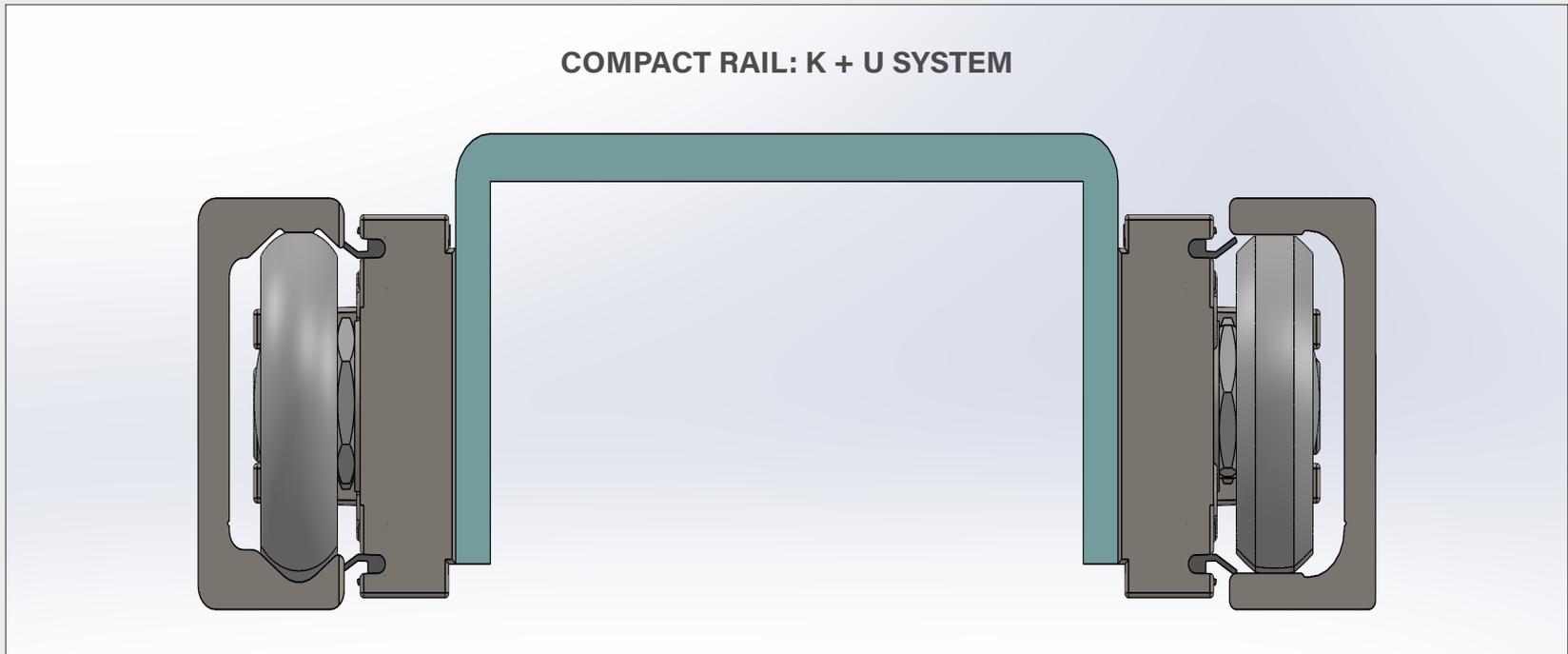
- **Low noise.** Thanks to its ground raceways, Compact Rail operates silently. Recirculating ball-style guides require specific spacers to reduce noise and cannot stand up to dirt.
- **Easy to maintain.** Compact Rail can manage lubricants in low and high temperatures, without derailing in freezing temperatures or incurring reductions in sliding performance.

Precision guides that are designed with a wide alignment tolerance for medium-precision applications can serve many machines in automated environments. When compared to the drawbacks of using profiled guides, Rollon's Compact Rail guides offer cost-savings and eliminate many of the burdens of dealing with misalignment.

CONSIDER PROFILED RAIL FOR HIGH PRECISION

Profiled rail, also known as monorail or ball rail, is a traditional linear guide system that incorporates small recirculating balls to satisfy demanding positioning accuracy requirements. Often used in high-precision motion applications such as machine tools, these guides can achieve repeatability at the micron scale if correctly specified, installed and maintained. However, this level of precision can be both costly and unnecessary depending on the application.

Ensuring that the machine frame is flat, straight and parallel enough for profiled rails to be correctly mounted is a time-consuming and complex task. In addition, the frame geometry can also make it challenging to mount bearing rails parallel to one another in either the horizontal or vertical axis, or both. This results in rolling elements and raceway surfaces that are unevenly loaded, leading to pitting, noise issues and premature bearing failure. To avoid this, machine builders often spend significant time and money on surface preparation and



machining to make sure bearing rails can be installed perfectly straight and flat. Although certain high-end motion applications may require exceptionally flat, straight and parallel mounting surfaces, most do not.

Many automated systems have less-demanding accuracy requirements, which allow them to benefit from another approach to managing misalignment and its associated problems: using a self-aligning linear guide such as Rollon's Compact Rail. This precision system is well-suited for medium-precision applications because it is inherently forgiving of misalignment due to a unique rail geometry that compensates for alignment errors in one or two axes. In contrast to the demanding installation requirements for profiled rail, Compact Rail features large rolling elements, rail profiles that allow some play and a simple preload adjustment that enables equal loading of all elements. This results in a more compliant guide than a profiled rail — one that can align itself to less-than-perfect mounting surfaces in medium-precision applications.

It is important to realize that these two approaches — using high-precision profiled rail or a less-complex, self-aligning precision system — may find application in the same machine. For example, a machine tool spindle may demand a perfectly accurate linear motion system whereas a tool changer does not. Specifying the correct linear guide for each axis based on individual requirements for precision and accuracy can save costs and achieve smooth, reliable linear motion at the same time.

One final point to keep in mind involves contamination. With profiled rail, the small recirculating balls in the raceway have extremely limited clearance, meaning that even tiny pieces of dirt can interfere with motion. Bearings with larger-diameter rollers such as those in Compact Rail can simply roll over much larger pieces of debris with no detrimental effects.

UP TO 1° WITH K+U RAILS



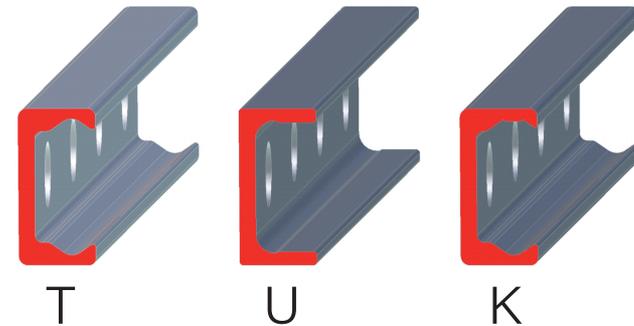
MANAGING MISALIGNMENT IN LINEAR MOTION SYSTEMS: HOW MUCH TOLERANCE DO YOU REALLY NEED?

WHICH WAY?

When comparing the two approaches to misalignment — eliminating it or adjusting to it — keep in mind that both have their place. Some linear axes truly do need a rigid bearing with the best possible precision. In these cases, there is little choice but to spend the money on machine frame upgrades, precision grinding and careful assembly. Other axes — ones with slightly lower precision and accuracy requirements — will be better served by a more compliant precision guide that can align itself to imperfect mounting surfaces. Costs in these cases will be lower.

What machine builders sometimes fail to realize is that these two approaches are complementary. Many machines have linear axes with different accuracy and precision requirements. Consider machine tools, for example. The spindle may need the most accurate linear motion system money can buy, while the tool changer and door do not. All too often, however, the same type of high-precision bearing that is required for one part of the machine will, by default, be used throughout all or most of the machine, driving up costs unnecessarily.

A better way to go is to pick the best linear bearing for each axis individually. And whenever a precision, self-aligning style will meet the accuracy requirements for a given axis, it will save money.



The Compact Rail system offers three different rail profiles, which can be combined to compensate for different types of misalignment.



WANT TO LEARN MORE?

Visit www.rollon.com or call an Applications Engineer today at 1-877-976-5566

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