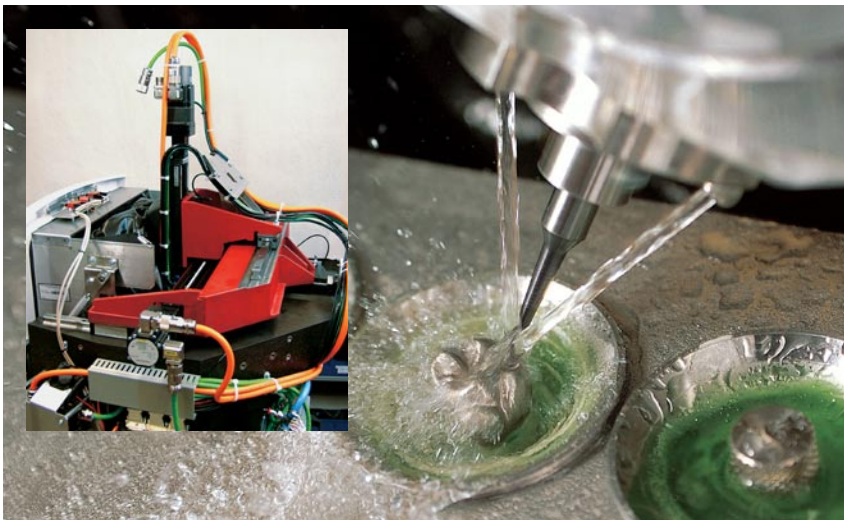
Drive & Control profile

Miniatures in Medical: Mechanical Design Considerations for Using Miniature Linear Guides



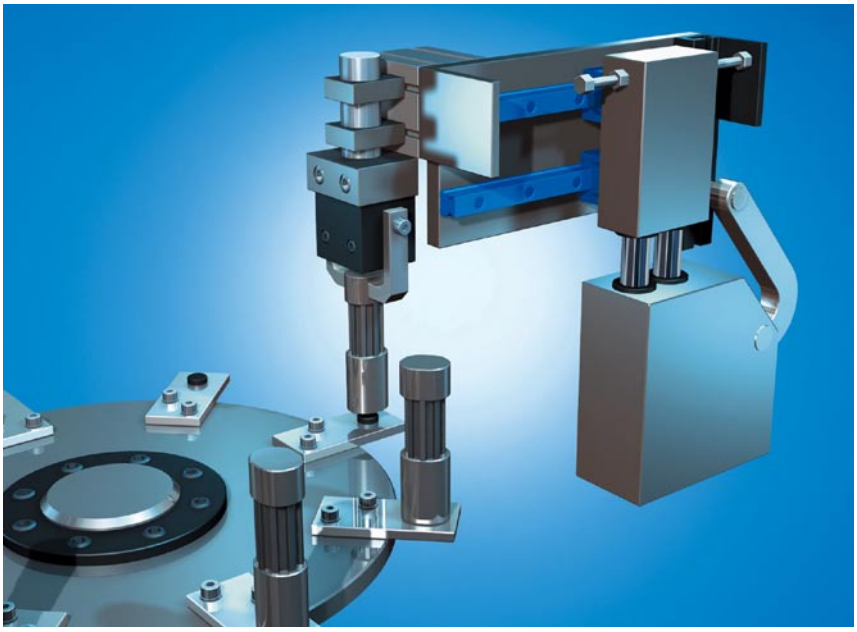
The machine above is used to mill the occlusal surface of a titanium dental crown. The Y axis of this machining equipment for dental laboratories is supported by a ball rail system.

With the wide range of linear motion components available from so many different vendors, designing an appropriate system can seem daunting. In actuality, keeping just a few key concepts in mind, along with the right application data, can help cut through the fog.

Linear motion components in general are used to carry a load in a straight line. The load, the required speed and any size or weight limitations of the application will determine which type of linear guide mechanism is best suited for the job. Linear motion components range from bushing and shaft arrangements (also called round rail) to fully automated linear modules, which combine such components as linear guides / profiled rail, a drive mechanism, motors and controls.

Miniature Linear Guides in Medical Applications

- Miniature ball rail systems or equivalent linear guides are an ideal solution for tabletop medical equipment.
- With miniature components, accuracy is critical.
- Follow guidelines for mounting a profiled rail system to ensure accuracy.
- Factor in the integrity of the mounting surface.
- Make sure your current runner block can be replaced for accuracy upgrades in the future on your pre-installed rails.
- Ask whether the linear motion provider can provide interchangeable rail and runner block combinations across the entire product series.
- Consider whether your components must be certified for cleanroom needs.
- Partner with a company you trust; Rely on their applications engineers to find the right product for a given application.



With miniature linear ball rail components, accuracy is far and away the most critical factor in tabletop lab equipment.

The medical device industry in particular places unique requirements on manufacturers of linear motion technology. Anti-corrosion materials, cleanroom certifications, and the need to fit within smaller and smaller work envelopes are just some of the requirements driving the development of miniature linear motion component products found today. Because of this drive toward miniaturization, this article focuses on design engineering considerations when using miniature linear motion guides.

In the past, the ability to machine small linear guides precisely and accurately was a limiting factor for linear motion manufacturers. Advancements in manufacturing processes, however, have now brought miniature rails and ball screws into the same precision classes as their standard-sized counterparts, thus allowing the downsizing trend in the medical device industry to continue.

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Typical applications for which miniature linear motion components are so well-suited include liquid handling, automated lab equipment, and microscope and imaging equipment, because they are so-called "tabletop" applications. They often need to fit in a small footprint, such as a lab countertop or workbench. They have small work envelopes and low load requirements. As a result, miniature ball rail systems or equivalent linear guides are an ideal solution.

But to fully understand how miniature linear motion components work in medical applications, key motion concepts for applications of any size must first be explored.

Interchangeability

With linear guides, interchangeability can be defined in one of two ways:

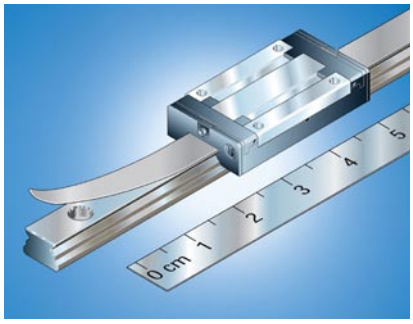
1) Can the current runner block/rail assembly be interchanged with that of an alternate manufacturer, or 2) Can the current runner block be replaced with one that has a higher preload level, accuracy class, seal type, or ball chain option from the same manufacturer?

In both cases, interchangeability gives designers flexibility. In case number one, the issue is simply replacing an entire rail and block assembly with one from another manufacturer. Even in miniature versions, most reputable manufacturers make this possible,

even publishing interchange lists that are cross-referenced by make and model. If the supplier company offers 3D CAD models for any design software a designer might use, it's even quite easy to swap out brands in the design phase.

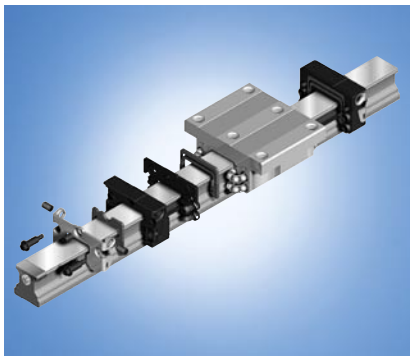
Performing this kind of interchange in the field, however, is an entirely different matter. Because you normally need to exchange the components with a matched set of rail and runner blocks, it means unbolting the entire assembly and any associated mounted components from the machine, then reassembling the whole contraption with the new parts — a time-consuming operation that might take an entire day. Since miniature components are often installed in laboratories or in hospital equipment, the disruption to research or treatment is unacceptable — possibly causing additional investment in duplicate machines.

This is why definition number two is so important: The ability to exchange runner blocks of various accuracy classes on any given rail. This is difficult to achieve even with standard size rails and runner blocks, and only manufacturers with highly refined manufacturing processes are able to provide the precision necessary. But the benefits are substantial, turning our previous one-day replacement of the entire rail assembly into a much simpler one-hour block-only affair.



Easy-to-mount cover strips hide the mounting holes where dirt and contamination can build up. The strips are a cleaner, faster and smoother alternative to plugging individual mounting holes.

Dramatically shorter time to market is another substantial benefit, especially for new generations of existing machines. Medical capabilities improve rapidly and constantly, with new generations of cameras, measuring devices and material handling devices commanding premium prices. If introducing a new generation requires only the replacement of runner blocks with



The smallest size available in standard ball rail components may often work in an application, while offering a few more options in preload, accuracy, seal types, and lubrication features.

higher accuracy versions, different seals or pre-load, then it's much easier to bring the new machine to market quickly.

This type of interchangeability also enables the designer to design in a form factor and to concentrate on performance and cost considerations later for prototypes and design / build phases. To maintain the most design flexibility, it is important to ascertain whether the linear motion provider can provide interchangeable rail and runner block combinations across the entire product series range and product options (i.e. preload, accuracy, ball chain, seals).

For some manufacturers, the rail and runner block ship as matched sets to ensure compliance to specific preload and accuracy class requirements. In other words, the blocks are not interchangeable on pre-installed rails. Others offer interchangeability across only a limited product offering and don't include all accuracy classes or preload levels. And finally, a small group of manufacturers can ship blocks and rails separately across their product offering and still comply with all required preload and accuracy class standards for the application.

With miniature components, accuracy is far and away the most critical factor, so it is important to make sure that runner blocks of the highest accuracy classes

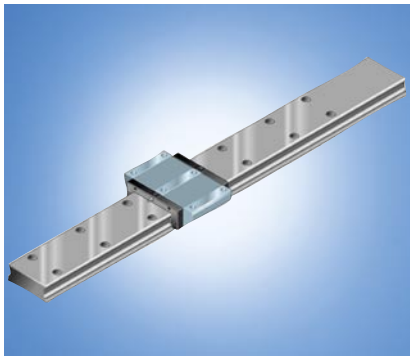
can be installed on the same rails, thereby allowing an easier switch to accommodate future needs.

Mounting Surface Integrity

When designing around miniature ball rail systems, engineers need to consider the same criteria as they do when designing with standard rail. Rail manufacturers assume the rail will be supported along its entire length, and that the base to which it is mounted will be more rigid than the rail itself, thus forcing the rail to conform to the mounting surface. Further, it is assumed that the surface has been properly machined, so that the rail, once bolted down, will have a flatness and straightness that complies to the vertical offset limitations when the runner block is assembled. This cannot be emphasized enough.

Designs that result in vertical offsets outside the manufacturer's specification will induce additional loads on the runner blocks, reduce the overall travel life of the rail and block assembly, and induce a potential for binding. In medical and laboratory applications, where accuracy is now frequently measured in nanometers, it's critical to factor in the integrity of the mounting surface.

As simple as it seems, another key assumption is that all mounting holes for the rail will be used and that the rail will be bolted down to the manufacturer's recommended torque settings. Not occupying all mounting holes, or over- or under-tightening the mounting bolts can introduce excessive deflection into the system beyond the application's original requirements. Mini profiled rail products in particular are susceptible to excess construction tolerances resulting from improper mounting surface preparation or improper assembly.



It's important to make sure that runner blocks of the highest accuracy classes can be installed on the same rails, allowing an easier change-out to accommodate future needs.

If the system requires a mounting surface with less stiffness or rigidity, it may be wise to use clearance blocks (i.e. blocks without preload) to accommodate the reduced integrity of the mounting surface. Mostly, engineers should strive to design within the guidelines of their preferred rail manufacturer.

Beyond the machine base, the mounting surface of the carriage assembly that attaches to the runner block must also be machined properly. Due to the small size and typically softer material (i.e. stainless steel rather than standard steel), miniature runner blocks are more susceptible to imperfections in the mounting surface. A block that is mounted to a convex surface will tend to open up as it is bolted down. The following result is induced clearance and less stiffness. In some equipment, this may not matter. In others, it can give the appearance that the block was not properly sized for the application.

Rail Straightness or Flatness

A common misconception about profiled rail is that it must be perfectly straight or flat out-of-the-box. Often, when longer lengths of rail are received, they do not appear to be perfectly straight—or flat. That's because they probably aren't, nor do they need to be to function properly. Especially in applications requiring miniature rail, the rail is not intended to be the main structural member in the system.

All manufacturers of profiled rail machine their rail to be straight within a certain tolerance range for the bottom reference mounting surface and along the side reference edge. This tolerance is usually specified as a maximum allowable deviation over a specific rail length as it is measured in the free state (i.e. unmounted condition). The true measure of rail straightness and flatness is primarily a function of the surface to which it is mounted, the mounting method, and seating against the reference edge—in other words, its installed state.

Because it is difficult to machine and grind long, slender spans to perfect straightness, miniature profiled rail in particular is susceptible to large tolerances for both flatness and straightness, and is very costly for long single piece lengths. Typically the tolerance band defined for rail flatness and straightness is wider for miniature rail than standard ball rail, which is also the reason that some manufactures limit their single piece lengths to under one meter. Longer single piece lengths are available from some manufacturers, typically topping out at 2m. As with standard size rails, mini ball rails can be butt-jointed to achieve longer stroke lengths, if necessary.

Cleanroom Certification May be Critical

Medical or laboratory applications may require that machines operate in a clean environment. By looking for components that have been certified for cleanroom use, engineers who need those capabilities can save themselves some nasty surprises later.

Reputable linear motion companies do not hesitate to subject relevant products to rigorous independent testing to establish the precise cleanliness rating. Rexroth's miniature Ball Rail Systems, for example, have been tested and certified for use in Class 10 cleanrooms by Germany's prestigious Fraunhofer Institute.

By examining linear motion component cleanroom specifications on the front end, designers can feel confident they are meeting any specific regulatory requirements for the end product—which also helps reduce their time to market. Certifications typically correspond to a range of cleanroom classifications for DIN EN ISO 14644-1, EG-GMP / EU-GMP, and U.S. Federal Standard 209E SI.

Rapid innovation requires constant research

Design engineers in the medical field must stay up to date with the latest linear motion technologies. Unlike some applications, in which more precision and higher performance simply add cost with no substantial benefit, medical design innovation benefits everyone. Medical machine designers must keep asking for more from their linear motion suppliers. The need for innovation in high-tech industries is what keeps suppliers sharp. Partner with a company you trust. Let them know what you need. Rely on their knowledgeable application engineers to help find the right products for a given application. As products get smaller while the demand continues for higher performance, it's these engineering partnerships that will further drive innovation.

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